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ABSTRACT

Mathematical Modeling of Chemical Vapor Deposition Processes and its Application to Thin Film Technology

by
Norman W. Loney

A number of workers in the field of Chemical vapor deposition (CVD) have presented mathematical models in the literature. Some workers were able to produce analytical expressions for the interwafer concentration profile. These analytical expressions were based entirely on zero or first order chemical reaction rates. Until now, it appears that a chemical reaction rate expression that is not zero or first order directly, must be handled by a numerical scheme.

Presented herein is a mathematical model with an analytical interwafer concentration profile. This concentration profile is neither zero nor first order but shifts from zero to first order as the reactor is axially traversed.

The approach used avoids the sometimes cumbersome numerical schemes, while dealing effectively with non-integer order rate expressions characteristic to CVD kinetics. This approach is also amenable to higher order rate expressions such as kC^n, $n > 1$.

We employ a boundary perturbation technique to reduce a nonlinear system of partial differential equations that was otherwise non-tractable analytically. Essentially, analytical expressions are derivable for the concentration profile in the interwafer region regardless of the kinetic expression's non-linearity.

The proposed model was tested with independently published experimental data. In each case the model predictions compare favorable with the experimental data.

Results show that deposition rates of: silicon nitride from dichlorosilane and ammonia, silicon from silane and silicon dioxide from tetraethylorthosilicate can be explained using a shifting order reaction. Further, the neglect of gas phase reactions did not affect the predicted deposition rates.

Concurrence with experimental results on thickness uniformity (radial) is achieved using this model. Control of nonuniformity on the wafers during a CVD process depends on the magnitude of the Sherwood number. Both experimental data and the proposed model show that surface uniformity improves with diminishing Sherwood numbers.

In this work, it is demonstrated (at least qualitatively) that surface chemical reaction provides the controlling resistance. For the range of concentrations and low pressures used in CVD the interwafer Damköhler number is smaller than unity. If the ratio of reaction velocity to diffusion velocity is larger than unity, uniform surface deposition cannot be expected. This implies the surface process is controlling.

MATHEMATICAL MODELING OF CHEMICAL VAPOR DEPOSITION PROCESSES AND ITS APPLICATION TO THIN FILM TECHNOLOGY

by

Norman W. Loney

A Dissertation
Submitted to the Faculty of the Graduate Division of the
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APPROVAL PAGE

Mathematical Modeling of Chemical Vapor Deposition Processes and Its Application to Thin Film Technology

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PE registered in the state of Texas.

DEDICATION

To My Mother, Ella E. Loney,
and in Loving Memory of My Father, David Alexander
who passed away April 1991.

Norman Washington Loney

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CHAPTER 1

INRODUCTION

Chemical vapor deposition (CVD) of solid materials onto a particular substrate is becoming the method of choice for the production of thin film with high purity and good uniformity. CVD phenomena include the disciplines of transport phenomena and chemical reaction kinetics. As such, most of the nonlinearities encountered in each discipline is transferred to CVD processing. Currently, neither the kinetics nor transport processes in CVD is well understood as is evidenced in the literature (44,45).Therefore, pertinent relationships between parameters and their effects are established through experimentation.

There are many CVD processes and they are usually classified according to the type of energy that drives the chemical reactions. Deposited films are mostly used in VLSI device fabrication and frequently, final device application will dictate the upstream CVD processing technique.

Development in CVD processes lie in the economic operation of reactor systems through automation. Obviously, processing a large quantity of wafers in one run implies great savings in the per wafer production cost. In addition, product quality such as deposition uniformity is important. Desired deposition uniformity on a particular wafer and axial uniformity improve with the use of sub-atmospheric pressures (12, 13, 18, 29). These low pressure chemical vapor deposition (LPCVD) processes form the basis for this work.

LPCVD processes are usually conducted in a heated vessel into which substrates are supported vertically and a gas is allowed to flow past the substrates.

Achieving homogeneity and uniformity in the final properties depend (to a large extent) on transport and kinetic parameters.

One way to minimize expenditure while establishing parameters and their effects is to combine an experimental program with mathematical modeling.

Literature search reveals two classes of models : those that are analytical or semianalytical (19,21,29) but which are often limited in their application due to oversimplification during derivation; and those that require complex numerical solutions demanding a large number of experimentally determined or estimated parameters (20,22, 23). For example, Coltrin *et al.*(22) use 20 chemical reactions. At least 20 rate coefficients and activation energies are to be fitted. Further, they considered a nonisothermal system so that entropies, specific heats and enthalpies have to be determined as well. Other fitted parameters include transport properties that are pressure and /or temperature dependent. Another example is that of Roenigk and Jensen (20, 23). They considered an isothermal system, but the number of fitted or estimated parameters are substantial. Multiple chemical reactions considered in both the gas phase and on the surface increase the number of parameters to be estimated.

In this work a mathematical model is described for a CVD process which neglects gas phase chemical reactions . This model contains at most three fitted parameters. The focus is on the typical heterogeneous reaction rate expression commonly encountered in LPCVD (19, 20, 21, 23). Most models attempt to treat multicomponent systems,but the uncertainty in kinetic data and chemistry does not justify such an approach.

A binary system with the primary specie (precursor) treated analogous to a limited reactant is the approach adapted herein. The assumptions used are based on the physics of the problem and are realistic. The resulting system of differential equations were solved analytically with some linearization as provided by Taylor series expansion and regular perturbation approximation.

Model geometry consists of a horizontal vessel (jacket heated) with multiple wafer (thin circular disk) capacity. All wafers are vertically mounted (normal to gas flow) and are supported along the cylinder axis. This vessel is subdivided into three regions. Region I (entrance region) includes the incident side of the first wafer together with a length L prior to the first wafer. Region II is the annulus region bounded by the vessel walls and the axial line of sight along the wafer edges (series of mixed flow reactors). Region III is the interwafer region, which includes the two wafers bounding the region. Connection of all regions is achieved through material balance. Regions II and III will be the focus of attention throughout this work.

Following the model derivation, published experimental data from different chemical systems served as test cases.

CHAPTER 2

LITERATURE SURVEY

Chemical vapor deposition (CVD) has received a substantial amount of attention on the modification of base material to produce microelectronic devices. A large quantity of studies are exploratory experiments. Here the investigator(s) conduct deposition experiments on a set of chemicals (precursors) using a small number of wafers on which to obtain a film. Characterization studies of the deposited film is conducted to determine its microelectronic device technology application. Mathematical modeling however, require an appreciation of the physicochemical hydrodynamics a priori. As such, mathematical modeling of CVD processes is far behind the experimental studies. Further, the published literature on mathematical modeling of CVD phenomena is scarce.

The surveyed literature in this work can be divided into two categories. The first category contain general discussions surrounding physicochemical phenomena. While the second category contain specific CVD modeling cases.

Bird *et al.* (1) and Brodkey and Hirshey (2) as well as Probstein (32) and Frank-Kamenetskii (33) belong to the first category. Basis from which any mathematical modeling study can begin are provided in these books. Of particular importance to CVD modeling are the discussions on the continuum approach and the conditions under which such an approach is justifiable.

Hougen and Watson (9,10), Yang and Hougen (30), Butt (38), Levenspiel (11), Froment and Bischoff (4) and Froment (34) provide substantial discussions surrounding the chemical kinetics. Of particular importance in these, are their discussions on surface chemical reactions. While all of these focus on particulate catalyst systems, their discussions are general enough to be applicable (with some restrictions) to CVD surfaces.

Essential to the discussion of surface reactions is the idea of an adsorption isotherm. The simplest adsorption isotherm is due to Langmuir. The implicit assumption of uniform surface in the Langmuir isotherm derivation is a point of controversy for many years (3). Smith (40) and deBoer (38) oppose the use of Langmuir isotherm in developing intrinsic kinetic relationships. As such they view the development by Hougen and Watson (9) as very approximate. However, Hayward and Trapnell (37), Castellan (41), Froment (34) and Boudart (35, 36) support the use of the isotherm to explain macroscopic kinetics. Further, they subscribe to a phenomenon called structure - insensitivity.

Following Boudart (35), structure-insensitive reactions proceed at a fixed turnover rate that is independent of surface (exposed plane and crystal size). Turnover rate being defined as :

$$\int_{t_0(\theta=0)}^{t_1(\theta=1)} R(t,T,C)\; dt$$

where R is the reaction rate and θ is a measure of surface saturation. Also, a structure-insensitive reaction is unaffected by modifiers and exibit relatively small (≤ few orders of magnitude) changes with the nature of the substrate.

If a system is structure - insensitive, it is expected to rigorously obey clasical kinetics such as in Hougen and Watson (9). Boudart (35) further explained that structure-insensitive reactions proceed needing only one or two adjacent surface atoms. A salient point in (35) is the idea that a structure sensitive reaction at low pressure and high temperature can become structure insensitive at high pressure and low temperature. We believe this behaviour could exist at fixed temperatures as well. In the end both sides of the discussion imply that, unless there is extreme structure sensitivity, Langmuir isotherm is reasonable. Further, the structured approach to obtain kinetic parameters in (9, 10 and 30) is a distinct advantage in initiating any kinetic study. The results so obtained are to be interpreted within those experimental error bounds (accuracy = f*(expt.error)*).

Hess and Jensen (12), Levy (18) and Lee (13) provide general discussions on microelectronics processing (including CVD). The books by Hess and Jensen (12) and Lee (13) present a chemical engineering aspect while Levy (18) espouse the material science and device applications aspects. The most detailed discussions surrounding mathematical modeling of CVD phenomena are in (13).

Specific CVD modeling cases are published for the deposition of silicon, silicon dioxide and silicon nitride systems. Silicon deposition is a widely studied system (experimentally and model). As such there is a fair amount of literature on this (sometimes redundant) system. The most comprehensive mathematical model of silicon deposition is given by Coltrin *et al.* (22).

The full multicomponent, non-isothermal momentum, energy and species equations are employed. Also included is a mechanism containing 20 chemical reactions. This model was solved using numerical analysis techniques on their inhouse computer facility. The predicted results were then compared with a set of independently published experimental data. A most significant conclusion resulting from the comparison is that gas phase reactions are not very significant in CVD. However, the authors failed to make this conclusion.

Jensen and Graves (19) and Roenigk and Jensen (20) did use the surface rate controlling idea in their modeling studies of silicon deposition. However, various averaging schemes were introduced inorder to simplify the computation. Their proposed model results were compared with experimental data from Claassen *et al.* (28). The comparison revealed a good prediction of the experimental trend, but specific deposition rates were not close.

Van den Brekel and Bollen (27) studied low pressure deposition of silicon from silane experimentally. They also provided a reaction mechanism to explain some of their data. One important finding is that surface reaction provide the controlling resistance. Another finding is the verification of the strong Langmuir isotherm behaviour present in the growth rate relationship. This latter finding was also present in the work of Kuiper *et al.* (26).

Collingham and Zollars (21) showed that axial uniformity can be improved with the use of recycle. Their experimental work on silicon deposition included a model which was adopted from Jensen and Graves (19). This adopted model was only able to predict the trend of the experimental data.

Published works on silicon dioxide deposition using low pressure CVD is not as widely studied as silicon deposition. Huppertz and Engl (25) and Desu (42) have studied silicon dioxide deposition from tetraethylorthosilicate. However, Desu believes that gas phase reactions are controlling the deposition.

Huppertz and Engl (25) proposed a two dimensional mathematical model that verified their experimental findings. Among the findings were : surface reaction provides the controlling resistance and the Langmuir isotherm behaviour has a strong influence on the surface reaction rate. Further, their experimental data and model verified the effect of small Sherwood number on the radial uniformity.

Desu and Kalidindi (43) developed a mathematical model to explain some of the experimental results obtained by Desu (42). This model employed a surface reaction rate similar to Huppertz and Engl (25), but gas phase reaction was concluded to be the dominant resistance.

Roenigk and Jensen (23) published a complete set of silicon nitride deposition data from their experimental and modeling study. The system is ammonia (NH_3) and dichlorosilane (DCS) reacting to silicon nitride. This data set include 17 different runs at five temperatures and four total pressures. Seven different NH_3/DCS ratios were also employed. They also reported on the regression technique that was used to generate some of their kinetic parameters. Their modeling approach is quite similar to their previous work (20). This set of experimental data was better predicted by the proposed model than in their previous study (20). However, they did note that for NH_3/DCS ratios greater than 10, the model failed.

Qualitative discussions on the parameters influencing radial uniformity are presented in Hong and Lee (29) and in Middleman and Yeckel (24). The investigators assumed a linear reaction rate (zero or first order) inorder to derive an analytical model. However no attempt was made to compare their predictions with experimental data. Middleman and Yeckel (24) did show that convective effects caused by the wafer edges are negligible.

In mathematical modeling efforts, one challenge is to find a source that is accessible to the potential audience. This can be a stimulus to an interested audience. Usually, no such single source exist. More often the information sought is found in several different sources. Following are sources of some of the applied mathematical concepts used in our work: Thomas and Finney (5) and Churchill and Brown (6) on infinite series multiplication. Boyce and DiPrima (8), O'Neil (7) and Zauderer (17) on Sturm Liouville theory and stability. Schlicting (15), Carrier and Peterson (16) and Zauderer (17) on perturbation theory. Burden and Faires (31) on interpolating polynomials.

In estimating Physical properties such as binary diffusivity coefficient, we found Reid *et al.* (14) to be sufficient.

CHAPTER 3

OBJECTIVE

The general objective of the present work is to derive a mathematical model expected to predict CVD performance within the reliability of experimental data. Specifically, we seek a model that uses realistic assumtions to predict deposition rates.

A predictive model that can forecast economically, the appropriate process variables and desired film properties is not yet available. The difficulty in producing such a comprehensive model is evident from the diverse principles encountered in CVD phenomena.

Some workers in CVD attempt to derive mathematical models with as few simplifying assumptions as is possible. To obtain a solution from such a model requires a full numerical scheme and large blocks of computation facility and time. Further, non mathematical audiences have difficulty interpreting the final results from such a comprehensive effort.

We would like to avoid this complication by producing an analytical model with fewer fitted parameters. Such a model could be used in optimizing CVD processes while generating kinetic parameters based on experimental data.

Results from the proposed model will be compared with experimental data.

CHAPTER 4

MODEL DEVELOPMENT

In this work, we consider dilute gases with no gas phase chemical reaction. A cross section of the CVD reactor is shown in Figure 4.1. As is evidenced, the reactor is divided into three regions. Regions I and II will be discussed later.

Region III

Figure 4.2 is a thin cylindrical shell representing the interwafer region (III) over which, the mass balance for chemical species A will be derived. Following is the mass (moles) balance for the system $2\pi\Delta r\Delta z$.:

$-(2\pi\Delta r\Delta zN_{Ar})|_{r+\Delta r}$ is the molar rate in of species A across the cylindrical surface at $r+\Delta r$, while $-(2\pi r\Delta zN_{Ar})|_{r}$ is the molar rate out of species A across the cylindrical surface at r. Similarly, the rate of input of moles across the surface at z is $2\pi r\Delta rN_{AZ}|_{z}$. The rate of output of moles across the surface at $z+\Delta z$ is $2\pi r\Delta rN_{AZ}|_{z+\Delta z}$. Since gas phase chemical reactions are not under consideration here, the law of conservation reduces to :

$$\text{Rate of mass(moles) in} - \text{Rate of mass(moles) out} = 0 \qquad 4.1.$$

Thus, the above quantities when substituted into equation 4.1 become

$$-2\pi r\Delta zN_{Ar}|_{r+\Delta r} -(-2\pi r\Delta zN_{Ar})|_{r} +2\pi r\Delta rN_{AZ}|_{z} -2\pi r\Delta rN_{AZ}|_{z+\Delta z} =0 \quad 4.2.$$

Upon dividing equation 4.2 by $2\pi\Delta r\Delta z$ and allow Δr and Δz to individually approach zero in the limit, we get :

$$\lim_{\Delta r\to 0}\frac{-rN_{Ar}|_{r+\Delta r}+rN_{Ar}|_{r}}{\Delta r}+\lim_{\Delta z\to 0}\frac{rN_{AZ}|_{z}-rN_{AZ}|_{z+\Delta z}}{\Delta z}=0 \quad 4.3.$$

Further, since each term is the definition of a derivative, we have:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(rN_{Ar}\right)+\frac{\partial}{\partial z}N_{AZ}=0 \qquad 4.4.$$

Since the molar flux (N_{Ar}) in the r-direction is defined to be:

$$N_{Ar}=-D_{AB}\frac{\partial}{\partial r}C_{A}+x_{A}\left(N_{Ar}+N_{Br}\right) \qquad 4.5$$

which consist of a diffusion part and a bulk flow part (1), then a simplification can be effected if mass transfer by diffusion only is considered (13, 24, 29). Mass transfer exclusively by diffusion suggest that the molar average velocity $\underline{V}$ (1) is zero. If $\underline{V}$ is zero then :

$$\underline{\mathcal{N}_A}+\underline{\mathcal{N}_B}=\underline{0}\Rightarrow N_{Ar}+N_{Br}=0\,, \quad 4.6$$

thus equation 4.5 reduces to :

$$N_{Ar}=-D_{AB}\frac{\partial}{\partial r}C_{A} \qquad 4.7$$

where D_{AB} is the binary mass diffusivity (constant).

Further, if r is replaced by z in equations 4.5, 4.6 and 4.7 we get:

$$N_{AZ} = - D_{AB}\frac{\partial C_A}{\partial Z} \qquad 4.8.$$

Then substitution of equations 4.7 and 4.8 into equation 4.4 gives:

$$\frac{1}{r}\frac{\partial}{\partial r}\left[r\frac{\partial C_A}{\partial r}\right] + \frac{\partial^2 C_A}{\partial^2 z^2} = 0 \qquad 4.9.$$

Equation 4.9 is expected to give a unique solution when subjected to the following boundary conditions :

$$N_{AZ} = 0 \text{ at } z = 0, \forall\ r \Leftrightarrow \frac{\partial C_A}{\partial z}\bigg|_{z = 0} \qquad 4.10.$$

$$N_{Ar} = 0 \text{ at } r = 0, \forall\ z \Leftrightarrow \frac{\partial C_A}{\partial r}\bigg|_{r = 0} \qquad 4.11.$$

$$C_A(R_W,z) = C_{Ab_i}\ ;\ 0 < z < \delta \qquad 4.12$$

and

$$N_{AZ}\big|_{z = \delta} = \text{Reaction Rate} \Leftrightarrow -D_{AB}\frac{\partial C_A}{\partial z}\bigg|_{z=\delta} = \text{Rxn.Rate} \qquad 4.13.$$

Equations 4.9, 10, 11, 12 and 13 provide the necessary and sufficient mathematical description of the interwafer region. The concentration profile on a typical wafer is readily available upon solution of the above system of differential equations.

Equations 4.10 and 4.11 are deduced from the symmetry of the chosen coordinate system. Equation 4.12 describes the concentration of species A at the edge of a wafer to be the same as the bulk concentration at that interwafer region. Equation 4.13 states that the flux of species A to a wafer surface is balanced by the surface reaction there.

Region I

This region include the first wafer and a length L prior to the first wafer. It is convenient for material balance computational ease, to also consider the exit region of the reactor (Figure 4.3) here.

The entrance region to the reactor is reffered to in this work as subregion I_0 while the exit region is I_N (Figure 4.3). The appropriate form of the conservation law for these subregions is :

$$\text{Input - Output} = \text{Disappearance by Chemical Reaction.} \qquad 4.14$$

Here, chemical reaction is anticipated on the heated reactor wall as well as on the wafer surfaces.

Subregion I_0

If we let V_0C_{A0}(mol/time) be the input of species A and V_1C_{A1} be the output, then substitution into equation 4.14 gives :

$$V_1C_{A1} = V_0C_{A0} - k_Wf_W(c_A)\pi R_W^2 \; -2k_Tf_T(c_A)\pi R_TL \qquad 4.15$$

where $k_W \pi f_W(c_A) R_W^2$ and $2\pi R_T L k_T f_T(c_A)$ account for chemical reactions on the wafer and reactor surfaces respectively. Further, if knowledge of the chemical reactions on the two surfaces is assumed then equation 4.15 reduces to one equation with two unknowns V_1 and C_{A1}. However, the volumetric flow rate V_1 can be determined from a volume balance in the region thus :

$$V_0 - V_1 = \pi \left[\left(R_W^2 + 2R_T L \right) k_1 f_1(c_A) \right] \frac{R\ T}{P} \qquad 4.16$$

where

$$P\ V\ = n\ R\ T \qquad 4.17$$

is the equation of state applicable to LPCVD systems, and

$$\frac{dV}{dt} = \frac{dn}{dt} \frac{R\ T}{P} \qquad 4.18$$

$$\ni \quad \frac{dn}{dt} = \pi \left[\left(R_W^2 + 2R_T L \right) k_1 f_1(c_A) \right] \qquad 4.19$$

where $k_1 f_1(c_A)$ is an appropriate combination of $k_W f_W(c_A)$ and $k_T f_T(c_A)$. Once V_1 is known, then the unreacted species A concentration can be determined from equation 4.15 and the material balance for subregion I_0 is complete.

Subregion I_N

For this subregion, $V_{N-1}C_{A,N-1}$ (mol / time) is the input of species A and $V_NC_{A,N}$ is the output (Figure 4.3). Following substitution into equation 4.14 we get :

$$V_{N-1}C_{A,N-1} - V_NC_{A,N} - \pi\, k_Nf_N(c_A) \left[R_W^2 + R_T^2 \right] = 0 \qquad 4.20$$

where $\pi k_Nf_N(c_A)\left[R_W^2 + R_T^2\right]$ accounts for chemical reactions on the backface of the last wafer (wafer N) and on the reactor wall. No special length L is considered in computing the surface area for chemical reaction on the reactor wall here. We believe that for a large number of wafers, the supply of species A will be almost exhausted at wafer N (21, 23). As such two simplifications are :

i) The reactor cross sectional area πR_T^2 is a good enough estimate of the surface for chemical reaction, eventhough most reactors have elliptical type heads.

ii) First order reaction rate is a good estimate of $k_Nf_N(c_A)$. Equation 4.20 can then be simplified to :

$$V_{N-1}C_{A,N-1} - V_NC_{A,N} - kC_{A,N}\pi \left[R_W^2 + R_T^2\right] = 0 \qquad 4.21$$

and a volumetric balance similar to that carried out in subregion I_0 gives :

$$V_{N-1} - V_N = \left[k\, C_{A,N}\pi \left[R_W^2 + R_T^2\right]\right]\frac{R\ T}{P} . \qquad 4.22$$

Combining equations 4.21 and 4.22 to eliminate V_N we get :

$$k\pi\left[R_W^2+R_T^2\right]\frac{RTC^2_{A,N}}{P} - \left[V_{N-1}+k\pi\left[R_W^2+R_T^2\right]\right]C_{A,N}+V_{N-1}C_{A,n-1} = 0 \; ; \quad 4.23$$

$$\ni$$

$$C_{A,N}=\frac{V_{N-1}+k\pi\left[R_W^2+R_T^2\right] \pm \left[\left(V_{N-1}+k\pi\left[R_W^2+R_T^2\right]\right)^2-4k\pi\left[R_W^2+R_T^2\right]\frac{RT}{P}V_{N-1}C_{A,N-1}\right]^{1/2}}{2k\pi\left[R_W^2+R_T^2\right]\frac{R\ T}{P}} \quad 4.24$$

and the choice of signs is to be determined on physical grounds. Substitution of equation 4.24 into equation 4.22 give the volumetric flow rate leaving the reactor.

Region II

This annulus region can be treated analogous to a mixed flow reactor (13).Since there will be n such flow reactors (Figure 4.3) where n $\in$ [1,N-1], we will develope the material balance for the n^{th} case.

A volumetric balance on the subregion II_n (Figure 4.3) gives :

$$V_N = V_{N-1}-\left[4\pi\left[\delta R_T k_T f_T(c_A)-R_W\int_0^{\delta} N_{Ar,N-1}\Big|_{r=R_W} dz_{N-1}\right]\right]\frac{R\ T}{P} \qquad 4.25$$

The material balance gives :

$$V_N C_{A,N}=V_{N-1}C_{A,N-1}^{-}\left[4\pi\left[\delta R_T k_T f_T(c_A)-R_W\int_0^{\delta} N_{Ar,N-1}\Big|_{r=R_W} dz_{N-1}\right]\right]\frac{RT}{P} \qquad 4.26$$

where N_{Ar} is as defined in equation 4.7. A procedure to solve equations 4.25 and 4.26 follows :

1.Find $N_{Ar,N-1}\Big|_{r=R_W}$ from the solution of equations 4.9 - 4.13 .

2.Determine V_N from equation 4.25.

3.Determine $C_{A,N}$ from equation 4.26.

4.Repeat step 1 but use $C_{Ab_i} = \frac{1}{2}\left[C_{A,N-1} + C_{A,N}\right]$.

5.Repeat steps 2 and 3 and use the latest values as the final results.

In order to use N_{Ar} in the above procedure , we need a more explicit form of equation 4.13. Since most useful surface reaction rates are highly nonlinear, we will discuss an approach that is novel to CVD modeling.

KINETIC EXPRESSION

The typical reaction rate expression (18,21,23,26) has the form :

$$\text{Rate} = \frac{k_1 C_A C_B}{1 + k_2 C_A + k_3 C_B} \quad (\text{gmol/cm}^2\text{sec.}) \tag{4.27}$$

then if

$$C_{tot} = C_A + C_B \ ; \quad \ni C_B = C_{tot} - C_A \tag{4.28}$$

equation 4.27 becomes :

$$\text{Rate} = \frac{k_1 C_A C_{tot}}{1 + k_2 C_A + k_3 (C_{tot} - C_A)} - \frac{k_1 C_A^2}{(1 + k_3 C_{tot}) + (k_2 + k_3) C_A} \tag{4.29}$$

If we assume that :

$$C_A << C_{tot} \text{ and } C_{tot} \text{ is small}$$

then the second term in equation 4.29 may be neglected and we get :

$$\text{Rate} \simeq \frac{k_1 C_A C_{tot}}{1 + k_2 C_A + k_3 (C_{tot} - C_A)} \ . \tag{4.30}$$

Expansion of the denominator and collecting like terms simplify equation 4.30 to :

$$\text{Rate} \simeq \frac{k_1 C_A C_{tot}}{K + K' C_A} \tag{4.31}$$

where

$$K = 1 + k_3 C_{tot} \text{ and } K' = k_2 - k_3. \tag{4.31A \& 4.31B}$$

Equation 4.31 can now be conveniently expanded in a Taylor series :

$$\frac{k_1 C_A C_{tot} / K' C_A}{1 + \frac{K}{K' C_A}} = k_0^* - k_0^* \left[\frac{K' C_A}{K}\right]^{-1} + k_0^* \left[\frac{K' C_A}{K}\right]^{-2} - \ldots \quad 4.32$$

valid for $\frac{K' C_A}{K} > 1$ with

$$k_0^* = \frac{k_1 C_{tot}}{k_2 - k_3} . \qquad 4.33$$

Thus a zero-order reaction with rate k_0^* defined as in equation 4.33 may be a suitable approximation when :

(i) $k_1 < k_3 < k_2$

(ii) $\frac{(k_2 - k_3) C_A}{1 + k_3 C_{tot}} > 1$

and (iii) $C_A / C_{tot} < 1$.

If however

$\frac{K' C_A}{K} < 1$,then equation 4.31 can be expanded thus :

$$\frac{k_1 C_A C_{tot} / K}{1 + \frac{K' C_A}{K}} = \frac{k_1 C_A C_{tot}}{K}\left[1 - \frac{K' C_A}{K} + \left(\frac{K' C_A}{K} \right)^2 - \ldots \right] \quad 4.34$$

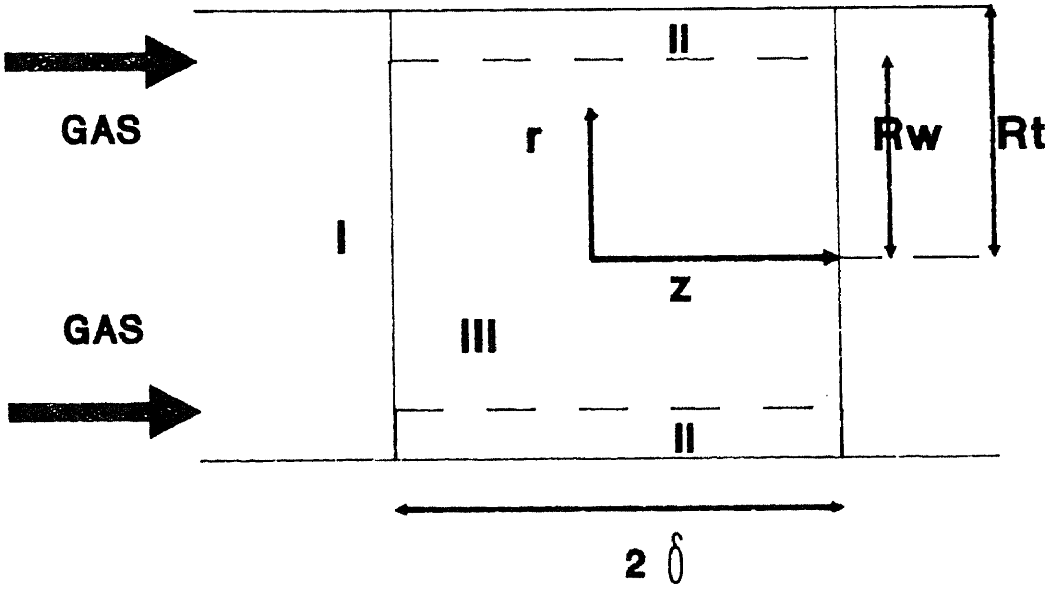
Here a first-order reaction rate approximation may be assumed when

$$\text{(iv)} \quad 0 \le \frac{(k_2 - k_3)C_A}{1 + k_3 C_{tot}} < 1 .$$

Further, if all the conditions (i), (ii), (iii) and (iv) hold during the course of a run, then we have a chemical reaction of shifting order (11). In light of the above discussion on the typical reaction rate expression in CVD (18,21,23,26), we will consider a general rate expression in the next chapter.

Reactor Cross Section

Figure 4.1



Thin Cylindrical Shell (derivation)
Figure 4.2

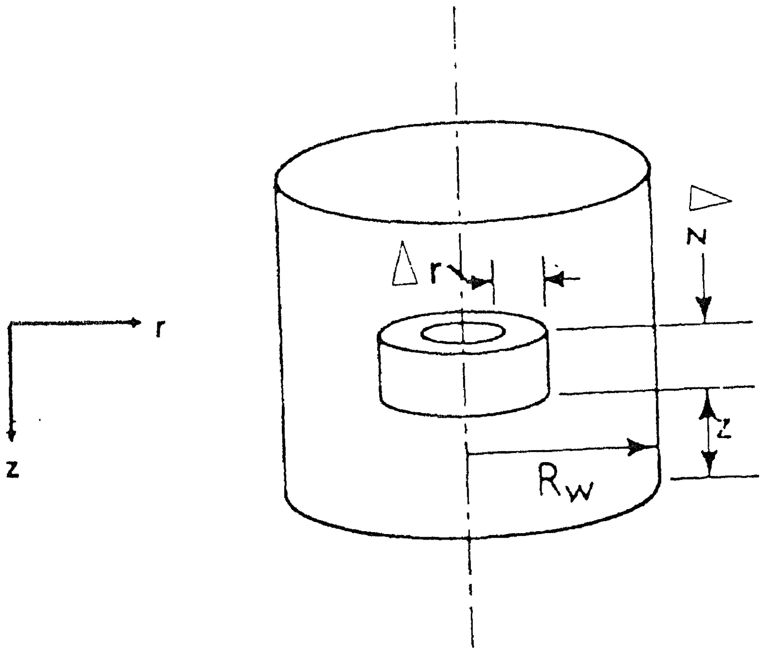
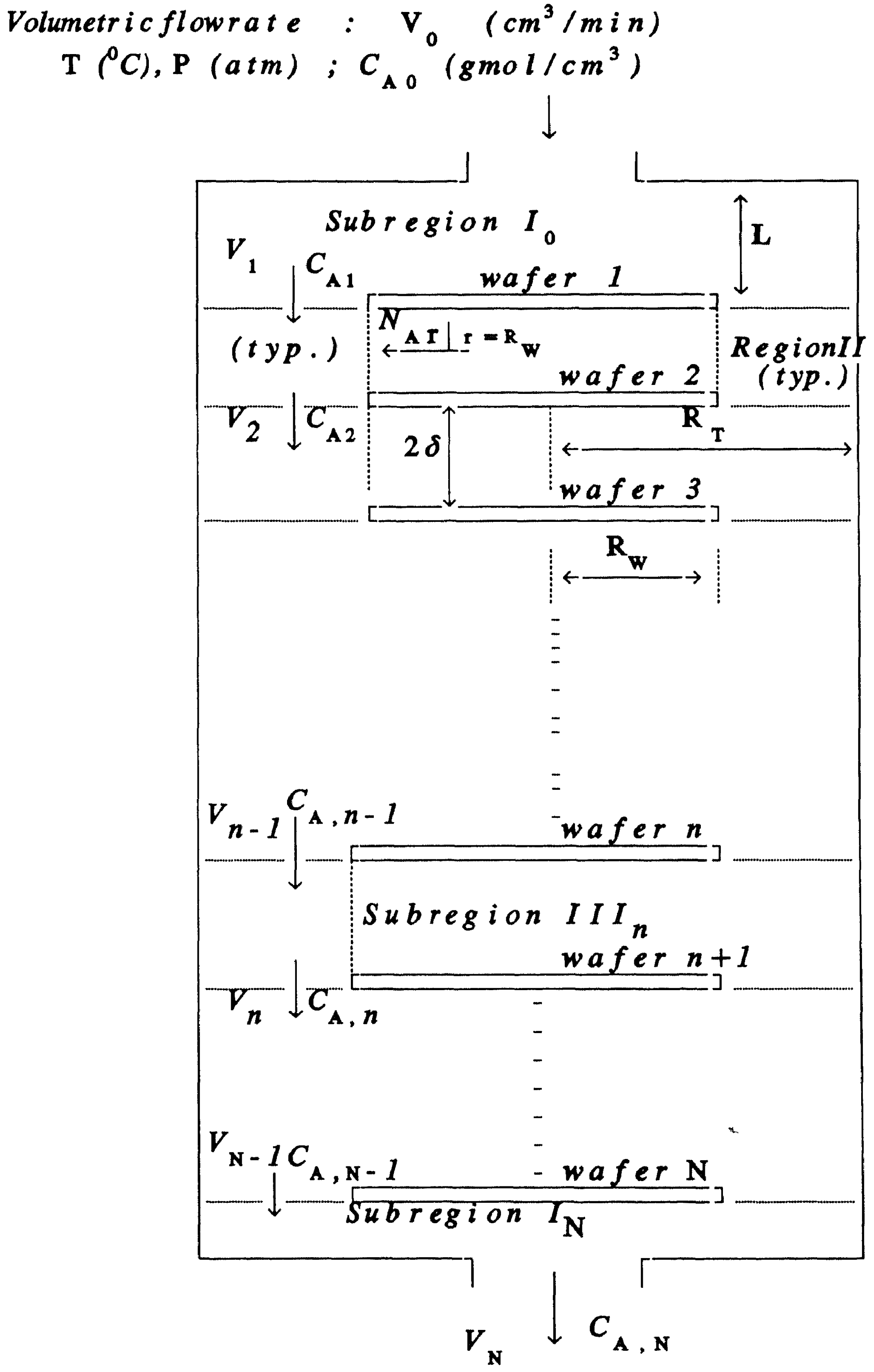


Figure 4.3 Overall Reactor Configuration



CHAPTER 5

INTERWAFER CONCENTRATION PROFILE

It is customary and convenient to recast the problem defined by equations 4.9, 10, 11, 12 and 13 in dimensionless form. In so doing, we will make use of the following :

Let
$$\frac{C_A(r,z)}{C_{Ab_i}} = F(\xi,\zeta) \qquad 5.1$$

with
$$\xi = \frac{r}{R_W} \; ; \; \zeta = \frac{z}{\delta} \qquad 5.2\&5.3$$

then equations 4.9, 10, 11, 12 and 13 become :

$$-\frac{1}{a^2}\frac{\partial^2 F}{\partial \zeta^2} = \frac{\partial^2 F}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F}{\partial \xi} \qquad 5.4$$

$$\frac{\partial F}{\partial \zeta} = 0 \text{ at } \zeta = 0 \qquad 5.5$$

$$\frac{\partial F}{\partial \xi} = 0 \text{ at } \xi = 0 \qquad 5.6$$

$$F(1,\zeta) = 1 \qquad 5.7$$

and

$$-\frac{D_{AB}\, C_{Ab_i}}{\delta}\frac{\partial F(\xi,1)}{\partial \zeta} = \text{Rxn. rate} \qquad 5.8$$

respectively, where

$$a = \frac{\delta}{R_W} \qquad 5.9$$

Further, if we consider a heterogeneous reaction rate expression to be :

$$\text{Rate} \;=\; k_0 C_{Ab_i}\left[\, 1 - \varepsilon F + \varepsilon^2 F^2 - \varepsilon^3 F^3 + \ldots\right] \qquad 5.10$$

where $\varepsilon < 1$ and

$$F \;=\; F_0 + \varepsilon F_1 + \varepsilon^2 F_2 + \ldots \qquad 5.11$$

Substitution of equations 5.10 and 5.11 into equations 5.4 thru 5.8 gives :

$$- \frac{1}{a^2}\frac{\partial^2 F_0}{\partial \zeta^2} = \frac{\partial^2 F_0}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_0}{\partial \xi} \qquad 5.12$$

$$\frac{\partial F_0(0,\xi)}{\partial \zeta} = 0 \qquad 5.13$$

$$\frac{\partial F_0(\zeta,0)}{\partial \xi} = 0 \qquad 5.14$$

$$F_0(\zeta,1) = 1 \qquad 5.15$$

$$- \frac{D_{AB}\, C_{Ab_i}}{\delta}\frac{\partial F_0}{\partial \zeta} = k_0 C_{Ab_i} \quad \text{at } \zeta = 1 \qquad 5.16$$

$$-\frac{1}{a^2}\frac{\partial^2 F_1}{\partial \zeta^2} = \frac{\partial^2 F_1}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_1}{\partial \xi} \qquad 5.17$$

$$\frac{\partial F_1(0,\xi)}{\partial \zeta} = 0 \qquad 5.18$$

$$\frac{\partial F_1(\zeta,0)}{\partial \xi} = 0 \qquad 5.19$$

$$F_1(\zeta,1) = 0 \qquad 5.20$$

$$-\frac{D_{AB}}{\delta} C_{Ab_i} \frac{\partial F_1}{\partial \zeta} = -k_0 C_{Ab_i} F_0 \qquad 5.21$$

$$-\frac{1}{a^2}\frac{\partial^2 F_2}{\partial \zeta^2} = \frac{\partial^2 F_2}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_2}{\partial \xi} \qquad 5.22$$

$$\frac{\partial F_2(0,\xi)}{\partial \zeta} = 0 \qquad 5.23$$

$$\frac{\partial F_2(\zeta,0)}{\partial \xi} = 0 \qquad 5.24$$

$$F_2(\zeta,1) = 0 \qquad 5.25$$

$$-\frac{D_{AB}}{\delta} C_{Ab_i} \frac{\partial F_2}{\partial \zeta} = k_0 C_{Ab_i} (F_0^2 - F_1). \qquad 5.26$$

Equations 5.12 thru 5.16 represent coefficient of the zeroth power of ε. Equations 5.17 thru 5.21 represent coefficient of the first power of ε. Equations 5.22 thru 5.26 represent coefficient of ε raised to the second power. The continuation of this process is possible up to any desired power of ε.

In this derivation, the rate equation is comparable to equation 4.32 and a value of ε can be deduced. A similar approach may be taken with equation 4.34 if necessary.

Appendix A contain the details of the separation of variables method used to obtain the following :

$$F_0 = 1 - \frac{2w}{a} \sum_{n=0}^{\infty} \frac{J_0(\alpha_n \xi)\mathrm{Cosh}(a\alpha_n \zeta)}{\alpha_n^2 \,\mathrm{Sinh}(a\alpha_n) J_1(\alpha_n)} \qquad 5.27$$

with

$$J_0(\alpha_n) = 0 \qquad 5.28$$

$$F_1 = \sum_{n=0}^{\infty} \left[\frac{2wa\alpha_n \mathrm{Sinh}(a\alpha_n) - 2w^2 \mathrm{Cosh}(a\alpha_n)}{a^2 \alpha_n^3 \,\mathrm{Sinh}^2(a\alpha_n) J_1(\alpha_n)} \right] J_0(\alpha_n \xi)\mathrm{Cosh}(a\alpha_n \zeta) \qquad 5.29$$

$$F_2 = \sum_{n=0}^{\infty} \left[Q_n J_0(\alpha_n \xi)\mathrm{Cosh}(a\alpha_n \zeta) \right] \qquad 5.30$$

with

$$Q_n = \frac{-w \int_0^1 \left[F_0^2 - F_1 \right] \xi J_0(\alpha_n \xi) d\xi}{a \alpha_n \mathrm{Sinh}(a\alpha_n) \int_0^1 \xi J_0^2(\alpha_n \xi)\ d\xi} \qquad 5.31$$

where

$$w = \frac{k_0 \delta}{D_{AB}} \qquad 5.32$$

a dimensionless quantity (Sherwood number). J_0 and J_1 are Bessel functions of the first kind of order zero and one respectively.

Continuum Justification

From the Kinetic theory, the mean free path (1, 13) λ, is given by :

$$\lambda = \frac{1}{\sqrt{2}\ \pi\ d^2 C} \qquad 5.33$$

where d is molecular diameter and C is the concentration of molecules (mol / vol). In LPCVD systems ideal gas behaviour is a good enough assumption from which C may be defined.

Thus :

$$C = \frac{P}{R\ T} \qquad 5.34$$

The mean free path of one molecule can be estimated from :

$$\lambda = \frac{k\ T}{\sqrt{2}\ \pi\ d^2 P} \qquad 5.35$$

where k is Boltzmann's constant and P is total pressure.

Without loss of generality, it is quite reasonable to expect the interwafer region to experience the same total pressure as the annulus region. If we consider a viscous pressure flow rate Q_v (13), thus :

$$Q_v = \frac{\pi \; r^4 P'}{8\mu L} (P_1 - P_2) \qquad 5.36$$

where P' is the average of P_1 and P_2.

Then a comparison with molecular flow (13) Q derived by Knudsen can reveal a necessary condition for molecular flow to occur. This necessary condition is still applicable in the interwafer region since only the length of the interwafer region is needed to compare with the mean free path. We thus have :

$$Q_m = \frac{2 \; \pi \; r^3}{3 \; L} \left(\frac{8 \; k \; T}{\pi \; M} \right)^{1/2} \Delta P \qquad 5.37$$

$\ni$

$$\frac{Q_v}{Q_m} = \frac{\pi^2 \; r \; P' \; d^2}{8 \; \sqrt{8} \; k \; T} \qquad 5.38$$

where the hard sphere viscosity (1) μ given by :

$$\mu = \frac{2}{3} \left[\frac{M \; k \; T}{\pi^3 \; d^4} \right]^{1/2} \qquad 5.39$$

is used in Q_v. Substitution of equation 5.35 into 5.38 gives :

$$\frac{Q_v}{Q_m} = \frac{9\pi \; r}{128 \; \lambda} \qquad 5.40$$

in which the average pressure and total pressure are considered equal. Equation 5.40 is a necessary condition for molecular flow to control. A reasonable conclusion from this is, as total pressure decrease, the mean free path increases which promotes molecular flow. The transition from molecular flow to viscous flow can be computed using Knudsen's formulation (13). For our consideration however, it is sufficient to ensure that the mean free path is smaller than 2δ, the length of the interwafer region (III), such that the Knudsen number $(N_k) < 1$.

Mass Transfer Effects

It can be shown that the conservation of mass equation can be written as :

$$(\underline{V}\cdot\underline{\nabla}C)_A = \frac{1}{Sc}\nabla^2 C_A \qquad 5.41$$

where

$$Sc = \frac{\nu}{D_{AB}} = \frac{\mu}{\rho D_{AB}} \qquad 5.42$$

is the dimensionless group (Schmidt number) physically representing the ratio of momentum diffusivity to mass diffusivity.

In our consideration,

$$\frac{1}{Sc}\nabla^2 C_A = 0 \qquad 5.43$$

and 1/Sc is arbitrary. Since μ and ρ are properties of the gas under consideration, then only D_{AB} (mass diffusivity) can be treated as arbitrary.

Figures 1, 2 and 3 of Appendix B show the effect of D_{AB} on deposition uniformity. Essentially any improvement to be gained thru D_{AB} adjustments can just as well be achieved by adjustment of the interwafer spacing (providing $N_k < 1$ still holds).

In our model we assume that mass transfer in the interwafer region is by diffusion only. A mass transfer Peclet number (Pe) can be defined to be the ratio of convective mass transfer to molecular mass transfer (1,2). Thus

$$Pe = \frac{v^* L^*}{D_{AB}} \qquad 5.44$$

where v^* and L^* represent appropriate characteristic velocity and length respectively. We also know that the Reynolds number (N_{re}) can be considered as the ratio of the inertial to viscous forces; or the ratio of the convection to molecular momentum transport (1, 2). In symbols then, we have :

$$N_{re} = \frac{L^* v^* \rho}{\mu} \qquad 5.45$$

where ρ is the density. If we divide equation 5.44 by equation 5.45, we get equation 5.42. It is obvious that Sc is nonzero, therefore there must be some convection. We believe a small Peclet number is the applicable condition in light of the diffusion only assumption. Some typical order of magnitude for Pe, Sc, and N_{re} (CVD systems) are given in Microelectronics Processing (12).

Regardless of this discussion we still need an estimate of the diffusivity, for this we use Reid *et al* (14) :

$$D_{AB} = \frac{1.858E\text{-}03 \; T^{3/2} \left[\frac{M_A + M_B}{M_A M_B}\right]^{1/2}}{P \, \sigma^2_{AB} \, \Omega_D} \qquad 5.46$$

where P is pressure (Atm), Ω_D is diffusion collision integral and σ is characteristic length (Ang). Equation 5.46 is chosen because it has a strong and verifiable theoretical background. Some empirical correlations may be more accurate but they are also more system specific. Whenever a system under consideration has available experimental data then an empirical correlation is the obvious choice.

CHAPTER 6

TESTING THE MODEL

Silicon Nitride Deposition

In this chapter, we will attempt to predict deposition rates on the wafer surfaces. The system under consideration is Dichlorosilane (DCS) and ammonia (NH_3). The experimental data that will be used for comparison is from Roenigk and Jensen (23).

In the reported experiments 110 wafers were used. Ten wafers were removed for deposition measurements starting at wafer number 10. Subsequent samples were taken at every 10th wafer upto wafer number 100. Other variables that were monitored include DCS/NH_3 ratios, Temperature and Pressure.

The expected overall chemical reaction is :

$$SiH_2Cl_2 + 4/3NH_3 \longrightarrow 1/3Si_3N_4 + 2HCl + 2H_2 \qquad 6.1$$

forming amorphous silicon nitride on the wafer surfaces and reactor wall. In all of the computations to follow, DCS is species A.

Roenigk and Jensen (23) reported kinetic parameters determined by regression analysis of their experimental data in concert with their own modeling studies.

Before any computation can be done, we must decide on the specific reaction rate expressions to be used in the various regions of the reactor. In Chapter 5, the concentration profile (5.27, 5.29 and 5.30) for the interwafer region was derived on the basis of a linearized version of a typical nonlinear surface rate expression.

The surface reaction rate expressions for Regions I and II (5.15 5.16 and 5.20) however, were left in general forms.

For Region I, we assume first order kinetics. That is :

$$k_W f_W(c_A) = k_W C_A \qquad \text{(incident side of wafer \#1)} \qquad 6.2$$

and

$$k_T f_T(c_A) = k_T C_A \qquad \text{(reactor wall of length L).} \qquad 6.3$$

Due to the lack of experimental data on this region (I) of an LPCVD reactor system we will pospone a detail study of Region I (future studies). Further, for ease of computation we assume :

$$k_W = k_T \qquad 6.4$$

and treat them as an adjustable parameter to facilitate the closure of the material balance in the region. By adjustable parameter, we mean a k-value is assumed and we compute the deposition rate on the wafers. If the deposition rate on the second wafer is larger than deposition on the first wafer, an adjustment is made to the assumed k-value. Following satisfactory computation of Regions II and III, extrapolation of the deposition profile (27) to wafer #1 should yield a more reliable k-value. The length L is specified as 50cm for all runs reported by Roenigk and Jensen (23).

For Region II, the surface reaction rate constant is expected to be numerically different in general from the rate constant on a wafer surface. This is usually attributable to the differences in substrates, which may effect the reaction mechanism (3). We find however, that when first order kinetics prevail on both surfaces, numerical equality is a good first approximation.

In our attempt to predict the experimental deposition rates for the NH_3/DCS system, equation 5.27 proved to be sufficient. We also assumed a chemical reaction of shifting order (11). A steep drop in the deposition rate up to about wafer number 30, followed by a mostly flat profile suggested a break in the overall reaction rate (low order to high order). The actual location of the shift however, was not entirely obvious. Of the ten wafers sampled in each run reported, the largest difference occurs at or about wafer number 20 (see Table 6.2). We therefore assume this location in all subsequent prediction of the deposition rates. Table 6.3 and Figures 6.1, 6.2 and 6.3 display the results of these choices. Table 6.4 show results of assuming the shift-in-order at different locations.

Results and Discussion

Table 6.4 contain the first five runs that we attempt to predict. In addition to wafer number 20, we considered other possible locations for the shift in order to occur. However, we did not find convincing evidence to change location . Good comparison was not achieved with all experimental runs at other locations chosen. Table 6.4 also show that all the experimental runs would not be satisfied by either a zero-order or a first-order only type reaction on the wafers.

Table 6.3 gives the results of the models prediction along with the experimental results reported by Roenigk and Jensen (23).The run numbers are those used in Roenigk and Jensen (23) and are repeated here.

To further maintain consistency with the experimental data, five thickness measurements were taken at the identical locations on the wafer as mentioned in Roenigk and Jensen (23). The runs reported herein were chosen to display the models' capability to handle different NH_3/DCS ratios.

From Table 6.3 and Figures 6.1, 2 and 3, it is clear that this model reproduces experimental data remarkably well. Further, this model was not affected by the wide range of NH_3/DCS ratios (2-15).

The three runs in Figure 6.1 show excelent agreement with the experimental data it attempted to predict. Except for a slightly flatter than predicted deposition profile at wafers 80 thru 100, run 7 is identical to the experimental result for each wafer reported.

The runs displayed in Figure 6.2 also show excelent agreement between experimental data and prediction. Run 4 does show some disparity between the experimental and predicted data. However, this disparity may not be significant when the reported experimental deposition rates for wafers 80, 90 and 100 are different from their expected tendency. Inspection of Table 6.3 reveal that wafer 90 has a lower deposition rate than wafer 100. This sudden increase in deposition rate at the back end of the reactor is highly unlikely.

Run 12 (experiment) in Figure 6.3 also show the same type of disparity at wafer 90 but with less severity. Here wafers 90 and 100 (experiment) have identical deposition rates which is again unlikely under normal conditions.

Qualitatively, this model's prediction of runs 3, 5 and 10 are at least as good as Roenigk and Jensen's (23), while our run 12 appears to be better. This comparison was made from the Figures provided in Roenigk and Jensen (23), by observing the relative positions of their predicted curves to the experimental data. It is also interesting to note that Roenigk and Jensen's model was not able to predict experimental runs with NH_3/DCS > 10. Experimental runs 4 and 7 with respective NH_3/DCS ratios of 12 and 15 are displayed in Figures 6.2 and 6.1 respectively. It is clear from these Figures that good agreement with the experimental data is achieved by this model. Further, a statistical comparison of predicted and experimental data for runs 4 and 7, reveal no significant difference between predicted and experiment with confidence > 95% . Further, the reported errors are 12 and 9.6 % respectively.

Figure 6.4 show some measure of radial uniformity as achieved in each run predicted by the model. In concurrence with Hong and Lee (29), the increase in mol fraction of DCS together with lower total pressure appears to provide better radial uniformity as evidenced by run 8. Run 4 indicates that increasing the total pressure, together with lowering the mol fraction of DCS, is not the desirable direction to improve radial uniformity.

It appears that the difference in radial uniformity between runs 3 and 5 can be accounted for by the significant difference in total pressure ($P_3/P_5 \approx 2.7$) more so than the difference in mol fraction ($y_3/y_5 \approx 2/3$). This total pressure effect is also evident in Figure 6.5 where deposition rates for runs 5, 6 and 7 are displayed.

Runs 7 and 12 provide a good indication of the mol fraction effect taken without the total pressure consideration. Even though expectation may require the two curves for runs 7 and 12 to be in the order opposite to that displayed in Figure 6.4, the effect of temperature on the reaction rate cannot be ignored here. The mildness of the mol fraction effect can be seen in Figure 6.6. Here temperature and total pressure were held constant, while the mol fraction varied (1/3 - 1/5).

The mol fraction and total pressure of run 6 provide a radial uniformity that places it between runs 5 and 7. However, total pressure effect places it closer to run 5 even though the mol fraction is closer to that of run 7.

The radial uniformity can be improved when total pressure is lowered and the primary species mol fraction is increased as Figure 6.4 shows.

A more quantitative explanation of the behaviour of radial uniformity can be seen through the sherwood number w defined in equation 5.32. Table 6.1 below show the useful parameters w/δ and w for each run displayed in Figure 6.4.

Table 6.1.Sherwood Numbers for NH_3/DCS System

Run #	$w/\delta(cm^{-1})$	w
3	8.14E-04	1.95E-04
4	1.11E-03	2.66E-04
5	1.58E-04	3.79E-05
6	3.47E-04	8.33E-05
7	5.80E-04	1.39E-04
8	9.47E-05	2.27E-05
12	6.16E-04	1.48E-04

It is clear from Table 6.1, that the curves in Figure 6.4 are in order of ascending Sherwood numbers with the smallest on top. That is, the best uniformity correspond to the smallest Sherwood number. This observation is in concurrence with that of Huppertz and Engl (25) and Kuiper *et al* (26). The w/δ parameter is included here for comparison with reported data that may have different interwafer lengths.

For a given interwafer length, small Sherwood numbers suggest small values of w/δ . This further implies low reaction temperature or/and low total pressure. This observation can be explained by the following :

$$k_0 \;\alpha\; e^{-A/T} \qquad 6.5$$

and

$$D_{AB} \;\alpha\; \frac{T^{3/2}}{P} \quad \text{(see equation 5.46)} \qquad 6.6$$

then

$$\frac{k_0}{D_{AB}} \;\alpha\; \frac{P\ e^{-A/T}}{T^{3/2}} = \frac{P}{T^{3/2}}\left[\, 1 - \frac{A}{T} + \frac{A^2}{2T^2} - \ldots\right] \qquad 6.7$$

where A is a constant involving activation energy. From equation 6.7, we can see that small P or/and small T will strongly influence the magnitude of the Sherwood number. It is also evident that for a given temperature , low total pressure will be a dominant influence in deposition uniformity.

Conclusion

The results from our mathematical model compares very well with the reported experimental data. The predicted trends in radial uniformity on a wafer is consistent with the findings of other workers in this field.

Results also show that silicon nitride (amorphous) deposition from the reaction involving dichlorosilane and ammonia can be explained with the use of a shifting order type reaction (zero order to first order). Further, in the range of conditions tested herein, the shift-of-order occurs at about wafer number 20 for a 110 wafered geometry.

Table 6.2 Experimental Deposition Rates and the Axial Differences

	Wafer Number									
Run #	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
3	109.9	96.2	82.5	75.5	72.4	67.1	65.3	61.2	55.7	54.6
	13.7	13.7	7.0	3.1	5.3	1.8	4.1	5.3	1.1	*Δ*
4	114.3	101.8	89.9	79.2	75.6	74.5	68.0	69.4	61.8	63.5
	12.5	11.9	10.7	3.6	1.1	6.5	-1.4	7.6	-1.7	*Δ*
5	37.6	35.3	33.4	32.0	30.8	29.5	28.5	27.4	26.1	26.0
	2.3	1.9	1.4	1.2	1.3	1.0	1.1	1.3	0.1	*Δ*
6	53.2	45.4	44.2	41.8	39.5	37.4	36.2	33.1	32.4	32.1
	7.8	1.2	2.4	2.3	2.1	1.2	3.1	0.7	0.3	*Δ*
7	67.2	60.4	52.2	48.8	44.5	43.8	44.1	39.0	37.0	35.6
	6.8	8.2	3.4	4.3	0.7	2.7	2.1	2.0	1.4	*Δ*
8	14.4	13.7	13.2	12.8	12.9	12.6	12.0	12.1	11.5	11.7
	0.7	0.5	0.4	-0.1	0.3	0.6	-0.1	0.6	-0.2	*Δ*
12	61.0	53.4	43.6	42.3	39.7	37.2	35.2	33.9	32.5	32.5
	7.6	9.8	1.3	2.6	2.5	2.0	1.3	1.4	0.0	*Δ*

Δ is the difference between cosecutive listed wafers i.e. 10-20etc.

Table 6.3.Experimental and Predicted Deposition Rates (Ang./min)

					Wafer Number									
					10	20	30	40	50	60	70	80	90	100
Run	**Temp**	**Pres**	**DCS**	**R**										
3	**800**	**.95**	**25**	**8**	**109.9**	**96.2**	**82.5**	**75.5**	**72.4**	**67.1**	**65.3**	**61.2**	**55.7**	**54.6**
Prediction					109.8	94.9	82.1	77.4	73.0	68.9	65.0	61.2	57.7	54.5
4	**800**	**.95**	**25**	**12**	**114.3**	**101.8**	**89.9**	**79.2**	**75.6**	**74.5**	**68.0**	**69.4**	**61.8**	**63.5**
Prediction					114.6	101.1	89.4	83.8	78.7	73.8	69.2	64.9	60.9	57.1
5	**800**	**.35**	**10**	**5**	**37.6**	**35.3**	**33.4**	**32.0**	**30.8**	**29.5**	**28.5**	**27.4**	**26.1**	**26.0**
Prediction					37.6	35.5	33.6	32.2	30.8	29.5	28.3	27.1	25.9	24.8
6	**800**	**.65**	**10**	**10**	**53.2**	**45.4**	**44.2**	**41.8**	**39.5**	**37.4**	**36.2**	**33.1**	**32.4**	**32.1**
Prediction					53.3	48.6	44.4	41.9	39.5	37.2	35.1	33.1	31.2	29.4
7	**800**	**.95**	**10**	**15**	**67.2**	**60.4**	**52.2**	**48.8**	**44.5**	**43.8**	**41.1**	**39.0**	**37.0**	**35.6**
Prediction					67.4	60.2	53.8	50.0	46.5	43.2	40.2	37.4	34.7	32.3
8	**700**	**.55**	**25**	**2**	**14.4**	**13.7**	**13.2**	**12.8**	**12.9**	**12.6**	**12.0**	**12.1**	**11.5**	**11.7**
Prediction					14.5	13.8	13.2	12.9	12.7	12.5	12.2	12.0	11.8	11.5
9	**700**	**.55**	**25**	**3**	**13.5**	**13.0**	**12.6**	**12.4**	**12.4**	**12.3**	**12.3**	**11.6**	**11.4**	**11.5**
Prediction					13.6	13.1	12.6	12.5	12.4	12.2	12.1	12.0	11.8	11.7
10	**700**	**.55**	**25**	**4**	**13.0**	**12.5**	**12.4**	**12.4**	**12.4**	**12.3**	**12.3**	**12.0**	**11.5**	**11.5**
Prediction					13.1	12.8	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9
12	**750**	**.95**	**25**	**4**	**61.0**	**53.4**	**43.6**	**42.3**	**39.7**	**37.2**	**35.2**	**33.9**	**32.5**	**32.5**
Prediction					61.2	52.7	45.4	42.5	39.8	37.2	34.9	32.6	30.5	28.6

R is NH_3/DCS ratio

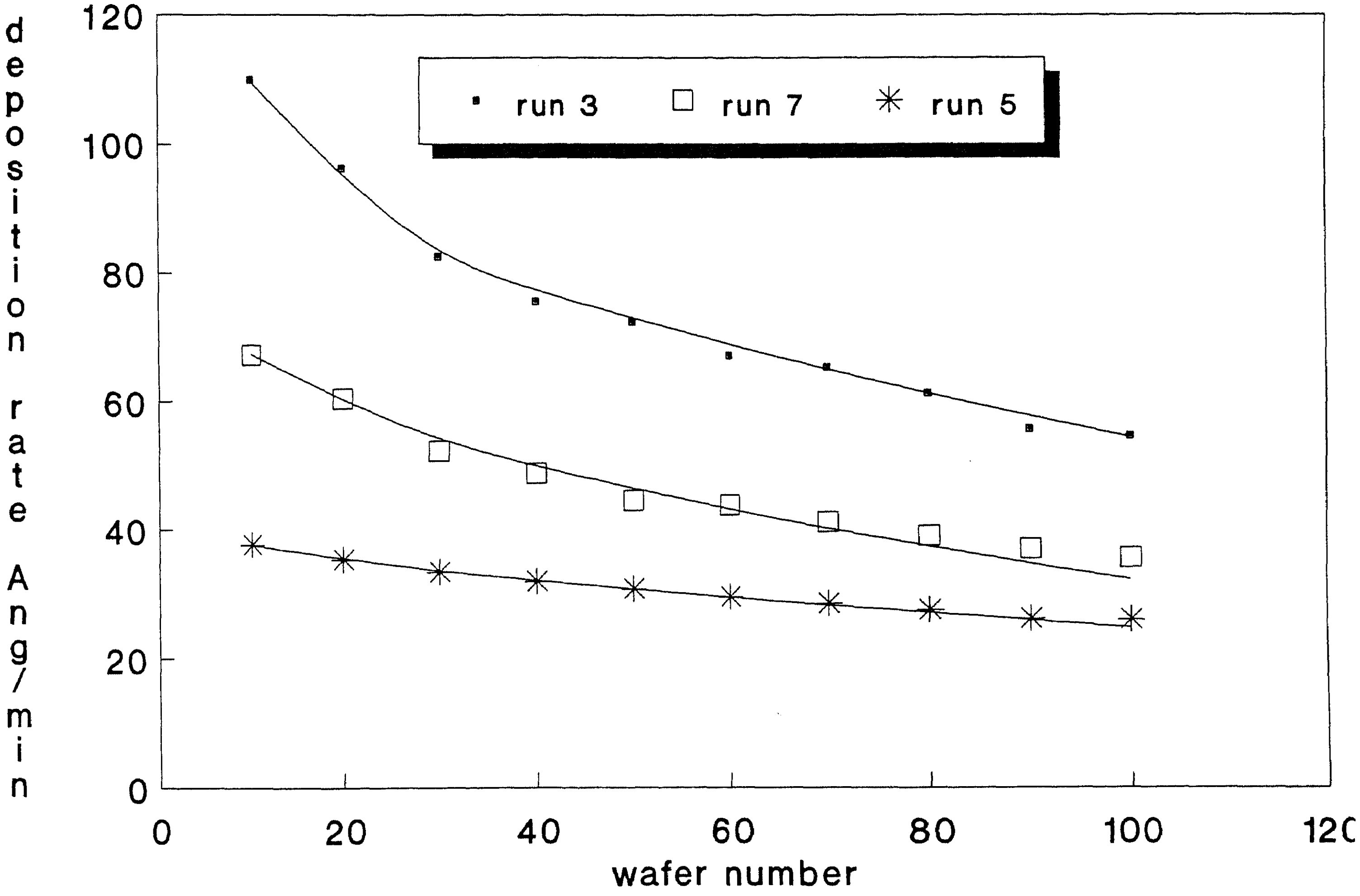
Experimental Data (**bold face**) *from Roenigk & Jensen*-1987

Table 6.4.Trials to Determine Location of Shift.

	Wafer Number									
Run#	10	20	30	40	50	60	70	80	90	100	
3	109.9	96.2	82.5	75.5	72.4	67.1	65.3	61.2	55.7	54.6	Expt
	109.8	94.9	82.1	77.4	73.0	68.9	65.0	61.2	57.7	54.5	20
	109.8	87.3	82.4	77.7	73.3	69.2	65.2	65.2	61.5	58.0	15
	109.8	102.8	81.7	77.1	72.7	68.6	64.7	61.0	57.5	54.3	25
	109.8	102.8	88.9	76.8	72.4	68.3	64.4	60.8	57.3	54.0	30
	109.8	102.8	96.2	76.5	72.2	68.1	64.2	60.5	57.1	53.8	35
4	114.3	101.8	89.9	79.2	75.6	74.5	68.0	69.4	61.8	63.5	Expt
	114.6	101.1	89.4	83.8	78.7	73.8	69.2	64.9	60.9	57.1	20
	114.6	95.5	89.6	84.1	78.9	74.0	69.4	65.1	61.1	57.3	15
	114.6	107.0	89.1	83.6	78.4	73.6	69.0	64.7	60.7	57.0	25
	114.6	107.0	94.4	83.4	78.2	73.4	68.8	64.6	60.6	56.8	30
	114.6	107.0	99.8	83.1	78.0	73.2	68.6	64.4	60.4	56.6	35
5	37.6	35.3	33.4	32.0	30.8	29.5	28.5	27.4	26.1	26.0	Expt
	37.6	35.5	33.6	32.2	30.8	29.5	28.3	27.1	25.9	24.8	20
	37.6	35.1	33.6	32.2	30.8	29.5	28.3	27.1	25.9	24.8	15
	37.6	36.0	33.6	32.2	30.8	29.5	28.3	27.1	25.9	24.8	25
	37.6	36.0	34.0	32.2	30.8	29.5	28.3	27.0	25.9	24.8	30
	37.6	36.0	34.4	32.2	30.8	29.5	28.2	27.0	25.9	24.8	35
6	53.2	45.4	44.2	41.8	39.5	37.4	36.2	33.1	32.4	32.1	Expt
	53.3	48.6	44.4	41.9	39.5	37.2	35.1	33.1	31.2	29.4	20
	53.3	47.1	44.5	41.9	39.5	37.3	35.2	33.1	31.2	29.4	15
	53.3	50.1	44.3	41.8	39.4	37.2	35.1	33.0	31.2	29.4	25
	53.3	50.1	45.7	41.8	39.4	37.1	35.0	33.0	31.1	29.3	30
	53.3	50.1	47.1	41.7	39.3	37.1	34.9	32.9	31.0	29.3	35
7	67.2	60.4	52.2	48.8	44.5	43.8	41.1	39.0	37.0	35.6	Expt
	67.4	60.2	53.8	50.0	46.5	43.2	40.2	37.4	34.7	32.3	20
	67.4	57.9	53.9	50.1	46.6	43.3	40.3	37.5	34.8	32.4	15
	67.4	62.5	53.6	49.9	46.4	43.1	40.1	37.3	34.7	32.2	25
	67.4	62.5	55.7	49.8	46.3	43.1	40.0	37.2	34.6	32.2	30
	67.4	62.5	57.9	49.7	46.2	43.0	40.0	37.1	34.5	32.1	35

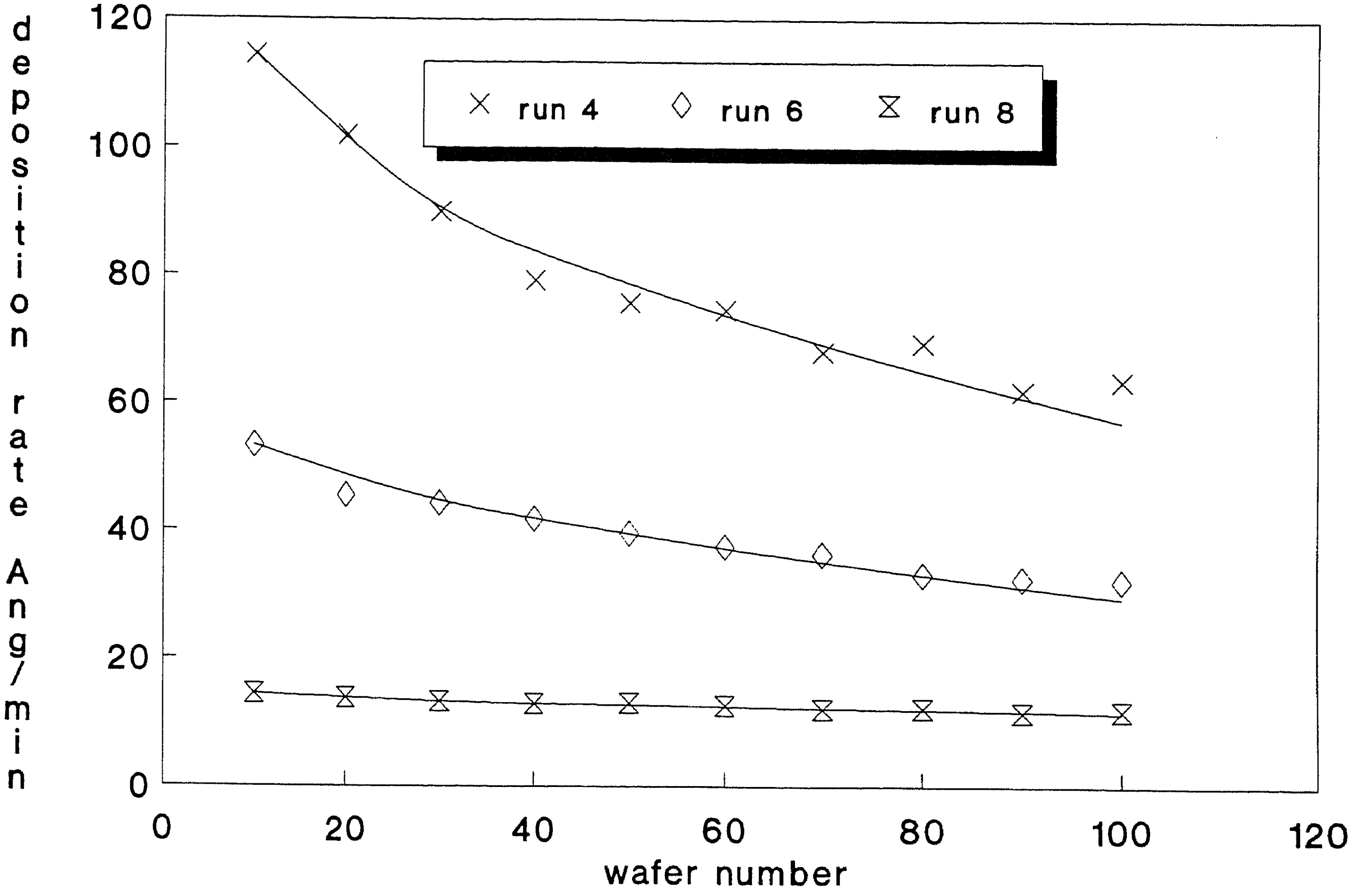
Theoretical Prediction vs Experiment

Figure 6.1 Runs 3, 5 & 7



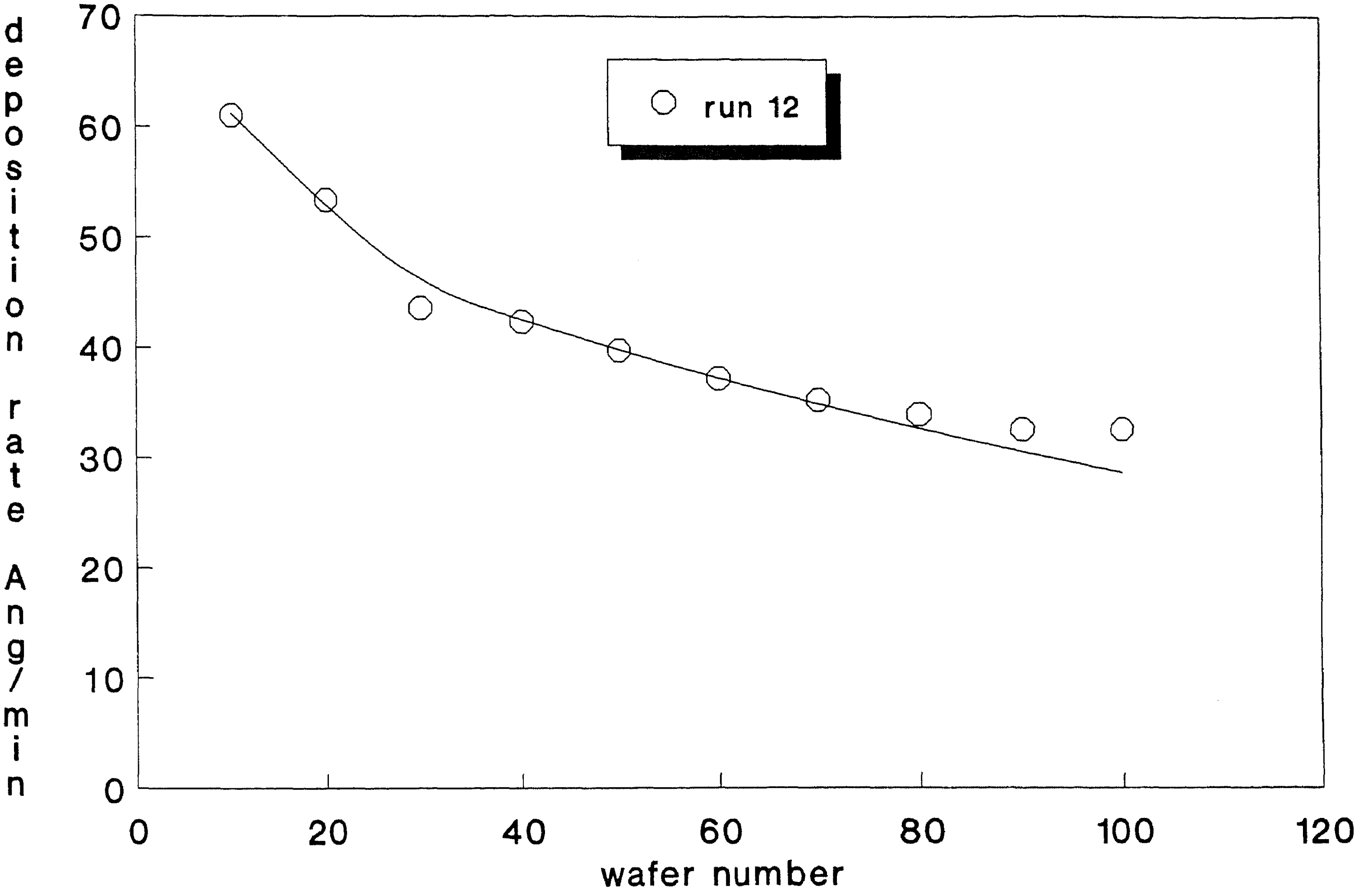
Data of Roenigk &Jensen(1987)

Theoretical Prediction vs Experiment
Figure 6.2 Runs 4,6 &8



Data of Roenigk & Jensen(1987)

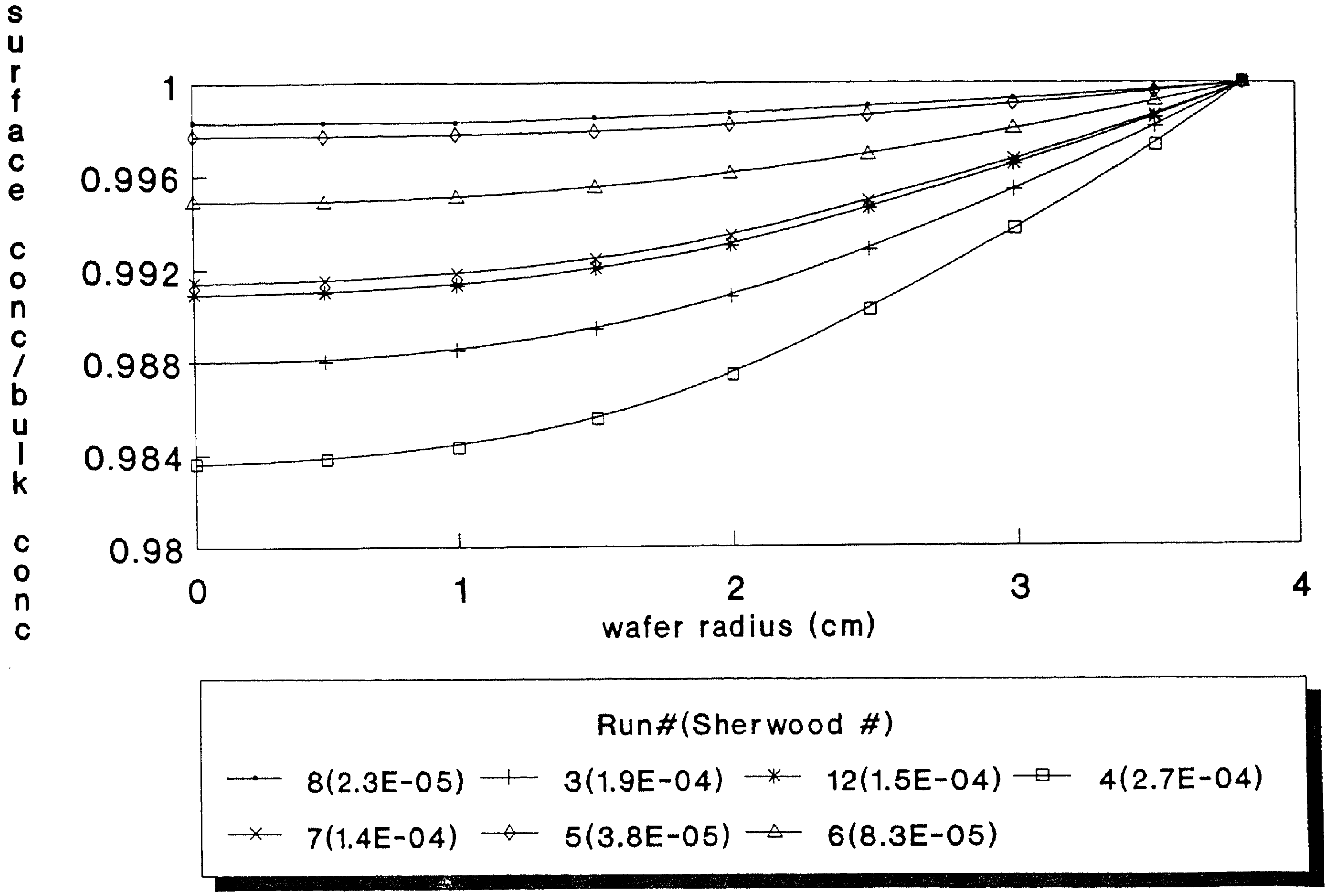
Theoretical Prediction vs Experiment
Figure 6.3 Run 12



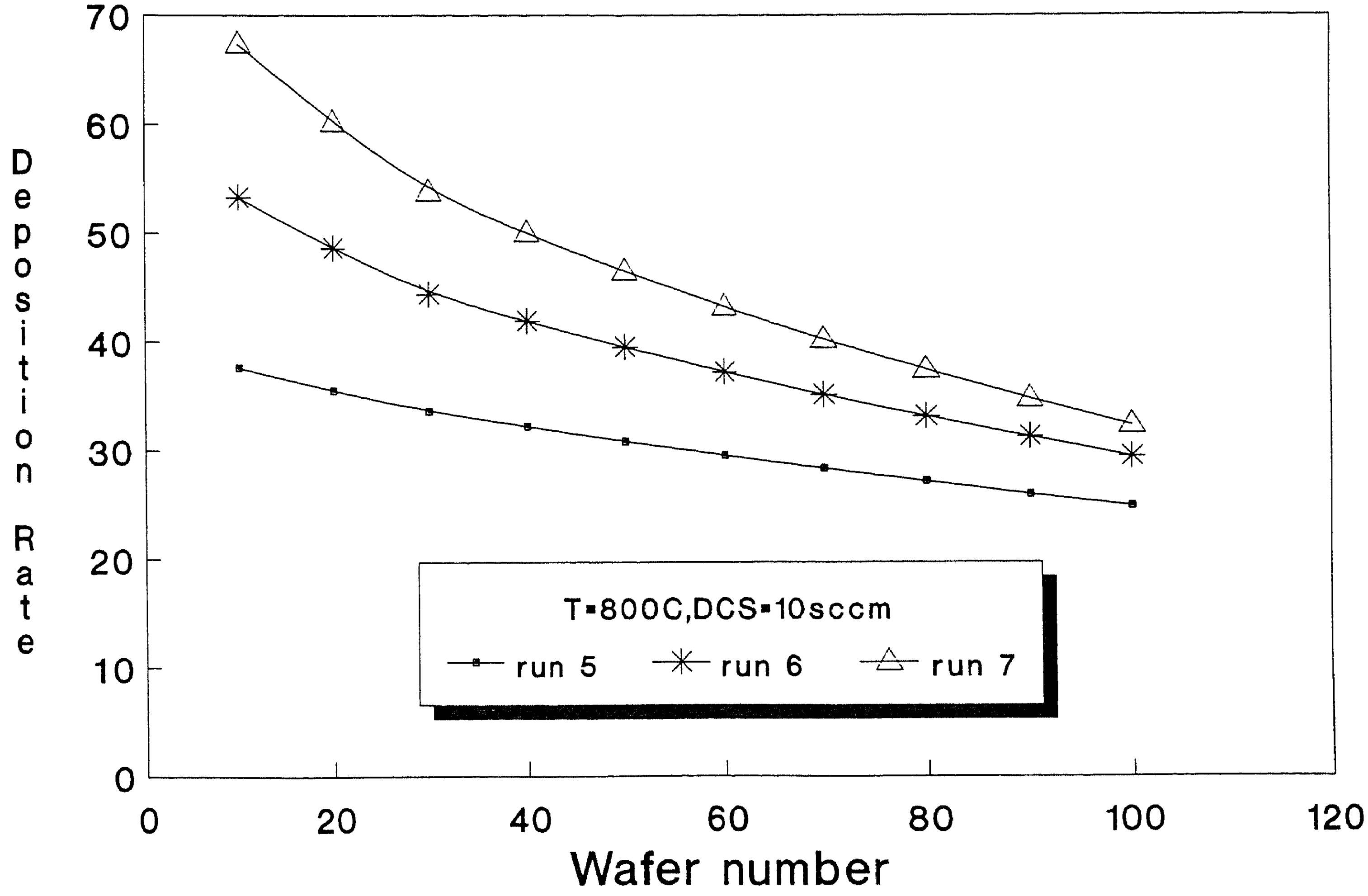
ata of Roenigk & Jensen(1987)

Deposition Uniformity

Figure 6.4

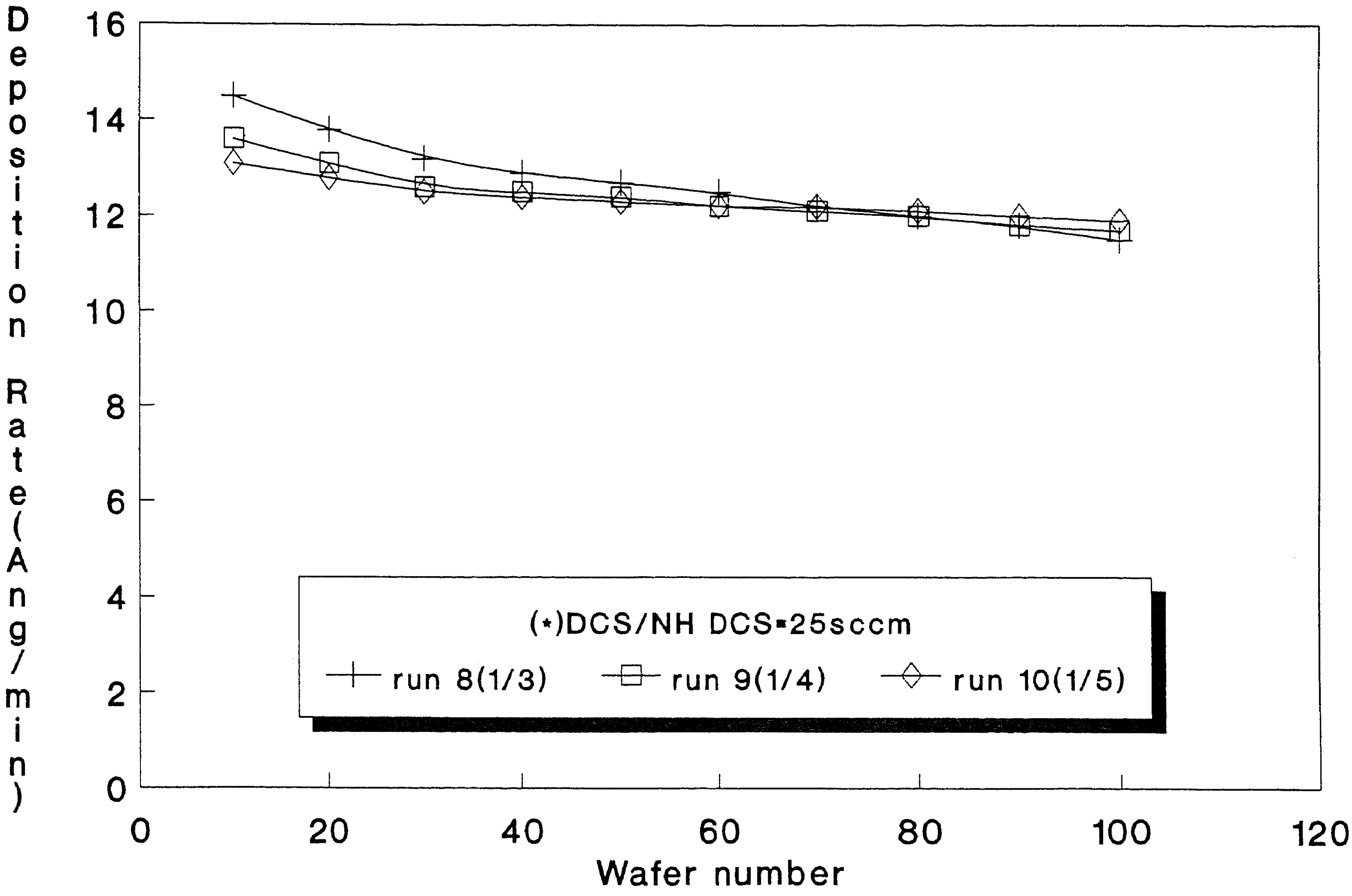


Deposition Rate vs Wafer Number
Figure 6.5 Pressure Effect



Model Predictions (runs 5-7)

Deposition Rate vs Wafer number
Figure 6.6 Feed Ratio Effect



Model Predictions (T=700C,P=.55Torr)

CHAPTER 7

POLYSILICON DEPOSITION

In this chapter we compare our model predictions of silicon deposition rates to two different published sources. The first source is that of Collingham and Zollars (21) (Source A) and the second is Jensen and Graves (19) and Claassen, Bloem, Valkenburg and Van den Breckel (28) and Roenigk and Jensen (20) (Source B). The system under consideration is silane pyrolysis in Nitrogen ambient. The expected overall chemical reaction is:

$$SiH_4 \longrightarrow Si + 2H_2 \qquad 7.1$$

forming silicon deposit on the hot surfaces. In all computations to follow, Silane is species A.

Source A

In the reported experiment, 240 wafers were used. Ten wafers were sampled for deposition measurements starting at wafer number 6. Subsequent samples include wafer numbers 12, 24, 36, 48, 60, 721, 20, 180 and 234. The authors reported objective is recycling effect on axial uniformity in LPCVD. As such, their non-recycle case form the basis for our model comparison.

Since we are no more informed about Region I at this point, we will make the same consideration as in the previous chapter. The length L is specified as 20 cm for all runs reported.

For Region II, the surface reaction rate to be used (at least partially) in the model is:

$$\text{Rate} = \frac{K_S C_A}{K_c + C_{tOt} + K_A C_A} \;(\text{gmol/cm}^2\text{sec}) \tag{7.2}$$

where K_S, K_C and K_A are rate constants with appropriate units. This choice of rate expression reflects a sufficient amount of published experimental evidence (26 -28). In addition, we believe that H_2 effects are significant in this region (II) and should be considered through the rate equation. This belief is further supported by the results achieved by the model (Table 7.2).

For interwafer concentration profile, equation 5.27 is an appropriate choice. The shifting-order reaction (11) assumption is also used here. The actual location of the shift is believed to be at wafer number 35. Table 7.2 and Figures 7.1 and 7.2 show the model results together with the experimental data for Source A.

Source B

This experiment used 50 wafers with wafer spacing four times that used in Source A. Five wafers were sampled for deposition measurements starting at wafer number 6. The remaining four samples were wafer numbers 16, 26, 36 and 46. A value for the length L was not specified for this experiment, as such we used a conservatively estimated value based on the previous geometries. Table 7.1 show reactor conditions and parameters for both sources.

Graves and Jensen and Roenigk and Jensen primary objective was to compare their model with experimental data provided by Claassen *et al* (28).

As such, the data on the wafers are reported in graphs. Claassen *et al* (28) reported their data in graphical form as well. The reported graphs in these references only promote qualitative analysis, a fact that our discussion will reflect.

As in previous cases, a shift in reacting order is assumed in the interwafer region (III). We estimate that the shift occurs on or about wafer number 16. Table 7.3 gives the results for Source B. Figure 7.3 is a comparison between our prediction and the data extracted from Figure 2 of Jensen and Graves (19).

Equation 7.2 is not expected to provide good results in the front end of the reactor. Since the inhibitory effects of H_2 are anticipated only when a substantial amount of this product is present. It is not unreasonable to anticipate substantial pyrolysis of the silane operating conditions not withstanding, prior to the onset of H_2 effects. In anticipation of those events, we reduce equation 7.2 as was done in Chapter 4 to derive 4.34. Using the rate constant data provided in each source, we were able to derive an initial estimate of the first order rate constant. First order reaction rate was used in Region II starting at wafer number 2 upto and including wafer **n**. The full rate expression (equation 7.2) was introduced at wafer **n+1**. In the absence of experimental data (onset of H_2 inhibition), the number **n** is varied until a good match between model predictions and experiment is achieved.

Results and Discussion

Our approach to predicting silicon deposition rates herein, parallels that of Chapter 6. Various locations were investigated in addition to the specific wafer number where the shift-in order is reported (specific results not included). The reported locations are those that give the best representation of all the available experimental data.

For Source B, n is 27. In addition, Table 7.3 show results for n = 2, 16 and 50. On the assumption that extracted deposition rates from a graph are applicable, n = 27 is the best choice. The other choices seem to support our conjecture of the location where H_2 effects are significant during the reaction. More important, our use of equation 7.2 is certainly the right direction toward the prediction of H_2 inhibitory effect in silane pyrolysis. The experiments of Claassen, Bloem, Valkenburg and Van den Breckel (28) already showed that H_2 in the feed lowers the silicon deposition rates significantly.

Qualitatively, Figure 7.3 show that our model's prediction compares favorable to the data in Figures 2 and 2a (zero H_2 in feed) of Jensen and Graves (19) and Roenigk and Jensen (20) respectively.

For Source A, n is 50. Results based on the use of other locations are included in Table 7.2. Figure 7.1 shows the model predictions along with the experimental data. From Table 7.2 and Figure 7.1, it is clear that our model predicts the experimental deposition rates very well.

Again, the use of equation 7.2 in Region II supports our idea as to where inhibitory H_2 effect is significant.

Figure 7.2 gives a measure of radial uniformity. The model predicts nonunifority to be less than 1/2 percent which agrees with the reported observation (21).

Conclusion

Our mathematical model results compares very well (qualitatively and quantitatively) with reported experimental data. The results show that silicon deposition from silane pyrolysis is well explained with the use of a shifting order reaction.

Results also infer H_2 inhibitory effects in silane pyrolysis through a reaction rate expression that includes H_2 concentration as a variable.

Table 7.1.Reactor Geometry and Operating Conditions.

	Source A	**Source B**
# of Wafers	240	50
Length L (cm)	20	10
Wafer Spacing (cm)	0.25	1.0
Wafer Dia. (cm)	3.81	7.62
Reactor Dia. (cm)	5.7	12.0
Press. (torr)	0.91	0.53
Temp. (^{0}C)	600	625
Mol.Frac.	0.1	0.0047
Total Flow (sccm)	52	1000

Table 7.2. Experimental and Predicted Deposition Rates.

	Wafer Number									
Run #	6	12	24	36	48	60	72	120	180	234
1	**41.8**	**40.7**	**39.3**	**30.4**	**27.6**	**22.7**	**20.2**	**10.2**	**2.4**	—
Pred(*n*=50)	42.3	40.9	38.2	29.8	28.1	23.3	19.0	8.1	2.7	1.0
Pred(*n*=36)	42.3	40.9	38.2	29.5	24.2	19.7	16.0	6.8	2.2	0.8
Pred(*n*=2)	40.0	36.2	29.4	19.9	16.1	13.1	10.5	4.4	1.4	0.5
_Zero-order_*	42.3	40.9	38.2	29.8	28.1	26.5	24.9	19.6	14.4	10.9
_First-order_*	35.5	34.5	32.5	30.6	28.8	27.2	25.6	20.1	14.8	11.2

*-indicate reaction rate used on reactor walls

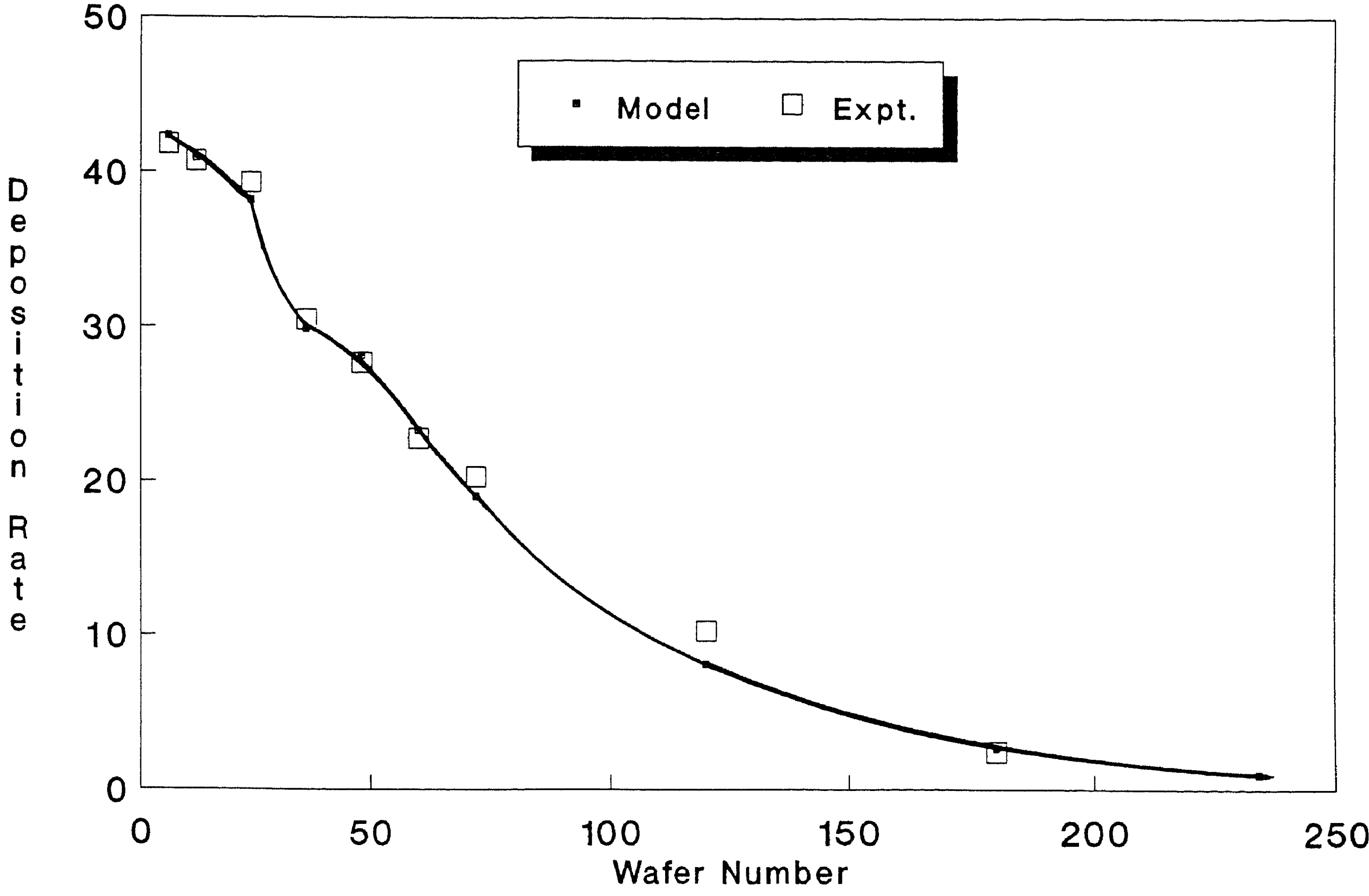
Experimental Data (**bold face**) *from Collingham & Zollars* 1989.

Table 7.3.Results of Model-Source B Data

	Wafer Number					
	6	16	26	36	46	
	27.8	21.6	15.5	12.5	7.7	Source B
n=27	27.9	21.4	15.8	12.0	8.9	
n=2	24.6	14.6	8.3	6.2	4.5	
n=16	27.9	21.3	12.2	9.0	6.7	
n=50	27.9	26.2	24.7	23.2	21.8	
*	17.7	16.7	16.2	15.5	14.8	

*-First Order on Wafers & Wall.

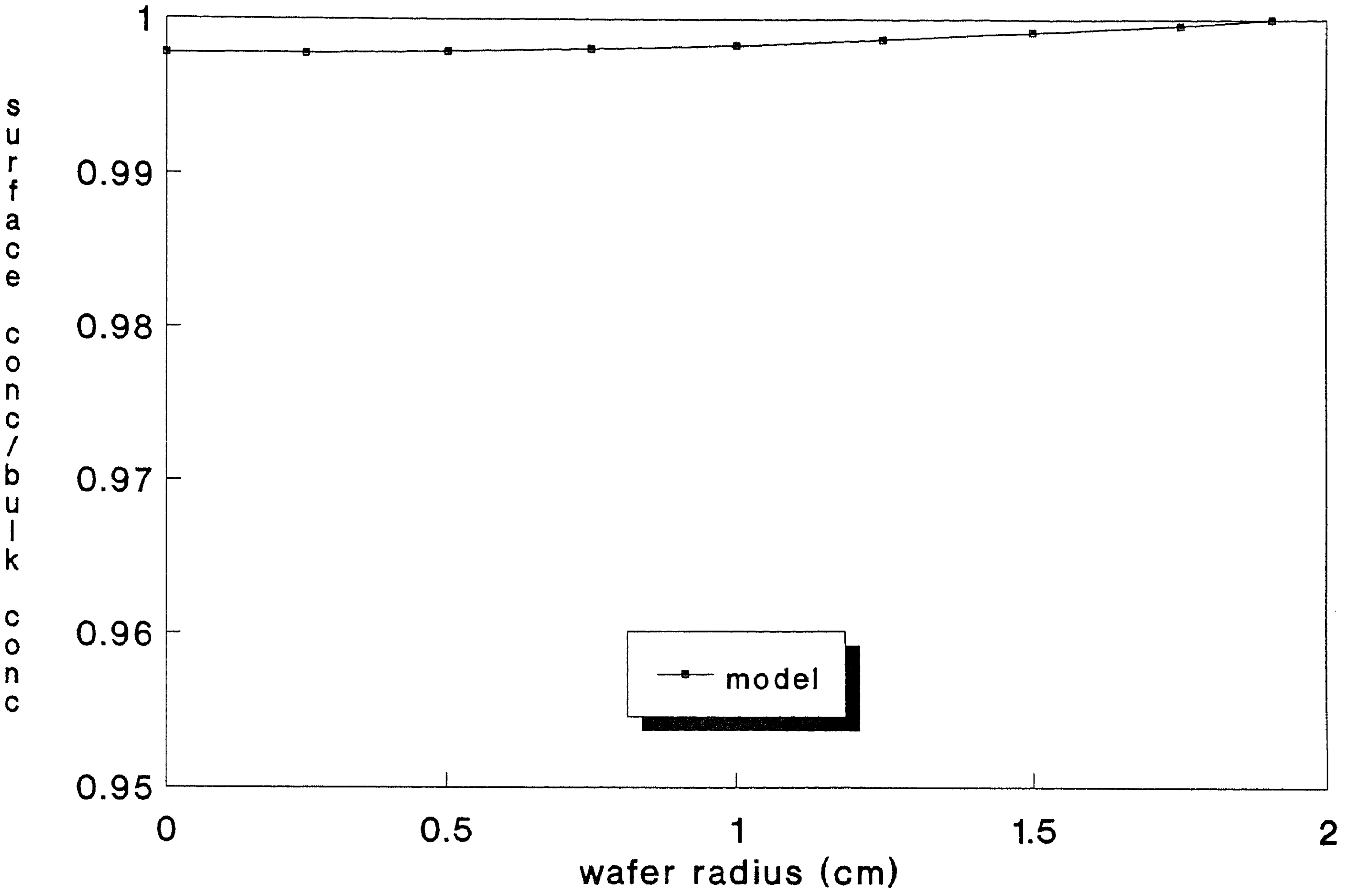
Prediction vs Experiment
Figure 7.1 Si-deposition (Ang/min)



Data from Collingham & Zollars(1989)

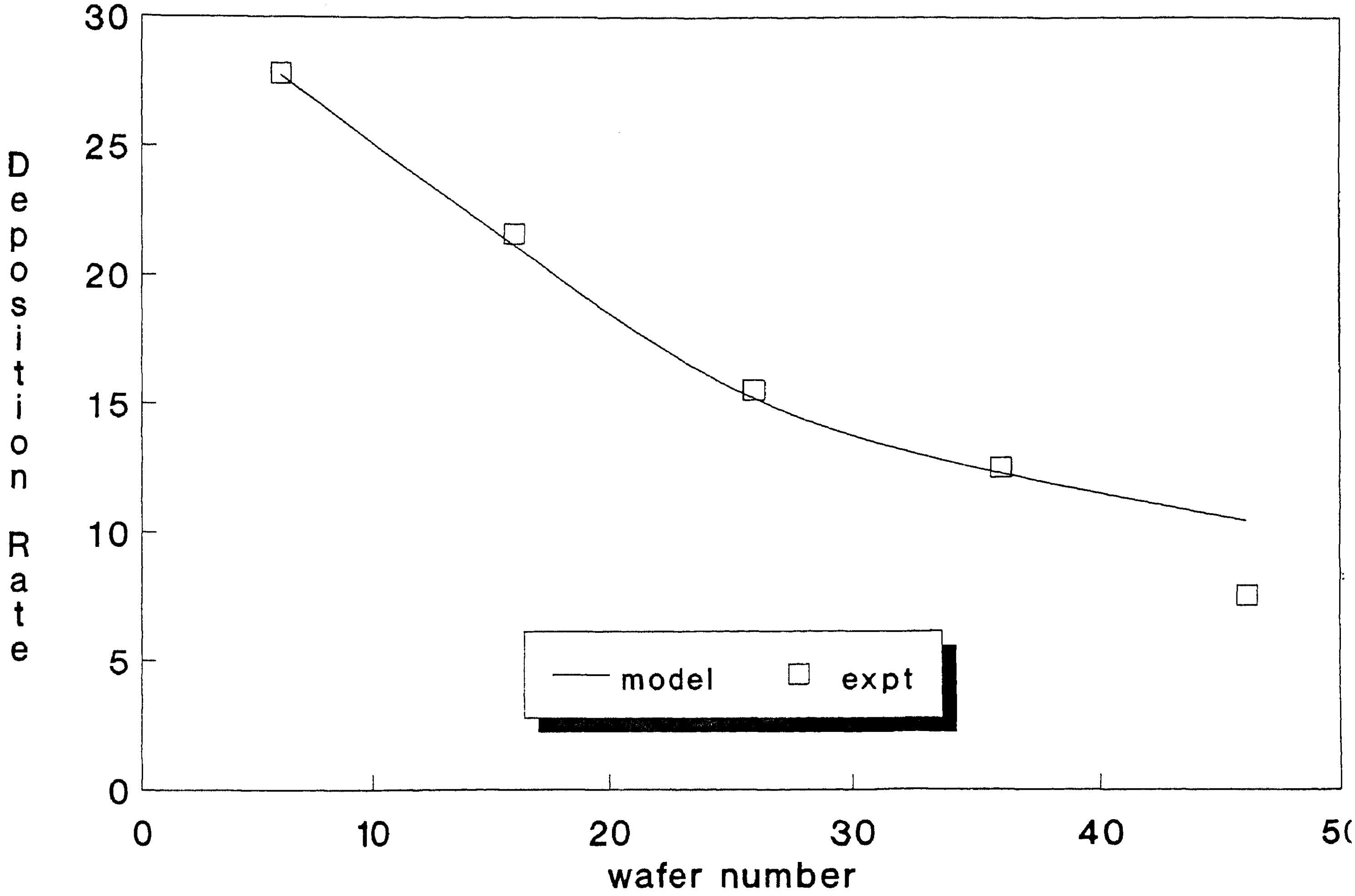
Deposition uniformity

Figure 7.2 Source A



Prediction

Comparison of Model and Experiment.
Figure 7.3 Source B



Jensen/graves

CHAPTER 8

SILICON DIOXIDE DEPOSITION

Herein, we compare our model predictions of silicon dioxide deposition rates to the experimental data of Desu (42) and Desu and Kaldindi (43). The system under consideration is the pyrolysis of Tetraethoxysilane (TEOS) to silicon dioxide (SiO_2). One possible overall reaction scheme is :

$$SiO_4C_8H_{20} \longrightarrow SiO_2 + 4C_2H_4 + 2H_2O \quad 8.1$$

as proposed by Huppertz and Engl (25). TEOS is species A in all subsequent computations.

In the reported experiments, 34 wafers were used. The first and last nine wafers were placed 5mm apart. The remaining wafers were placed 20 mm apart. The length L is specified as 9.5 cm. Deposition rates were measured on alternate wafers, starting at wafer number 11 upto and including wafer number 25. The operating pressure and total flow (N_2 as diluent) were 53.33 pa and 175 sccm as confirmed by Desu (private communication). Two sets of data were reported by Desu and kalidindi (42). The data were obtained at two temperatures and two initial species A concentration. The first set was obtained at 700 ^{0}C and C_{A0}= 3.37E-09 gmol/cm^3. The second set was obtained at 680 ^{0}C and C_{A0}= 3.0E-10 gmol/cm^3. All other conditions were held constant.

In Region II, a first order surface reaction rate is assumed on the reactor wall similar to Chapter 6.

Equation 5.27 was sufficient to predict the interwafer concentration profiles. We also assumed a chemical reaction of shifting order and determined the location of the shift (wafer 13) as was done in previous chapters. Table 8.1 and Figure 8.1 contain the final results of the model predictions. Included in Table 8.1 for each set, are two additional runs. One of complete zero order and one of complete first order on the wafers.

Results and Discussion

The treatment of this experimental data set is quite similar to that of Chapter 6. As such we will try to avoid duplication of details where possible.

The reported claim of gas phase decomposition of TEOS is not supported by the reported model. Our model which uses a surface reaction control (25) approach reproduces the reported experimental data much better. Unfortunately, this is not conclusive evidence of the controlling resistance as the reported model employ enough simplifying assumptions to significantly affect the final results.

Table 8.1 and Figure 8.1 does show that our prediction is remarkably close to the experimental data. This strongly suggest that surface reaction is the controlling resistance. Further, SiO_2 deposition rates can be predicted with the use of a shifting order reaction (zero order to first order). Eventhough the reported deposition profiles are very flat, we believe that a shift in order occurs. This assertion is further supported by the growth rate partial pressure correlation of Huppertz and Engl (25).

Predicted thickness uniformity agrees with previous conclusions, that is, excellent uniformity is expected if the Sherwood number is small. In this case the Sherwood number is 5.654E-05 (see Table 6.1). For the wafer spacing of 2 cm, used here the thickness nonuniformity is predicted to be smaller than run 8 in Chapter 6. At least qualitative agreement with Huppertz and Engl (25) is achieved when our prediction is compared to their experimental thickness uniformity data.

Conclusion

Reported experimental data on silicon dioxide deposition rates were well reproduced by our mathematical model. Results also show that silicon dioxide deposition can be explained by a shifting order surface reaction.

Predicted thickness uniformity concurs with previous results both herein (Chapter 6) as well as in published results (25).

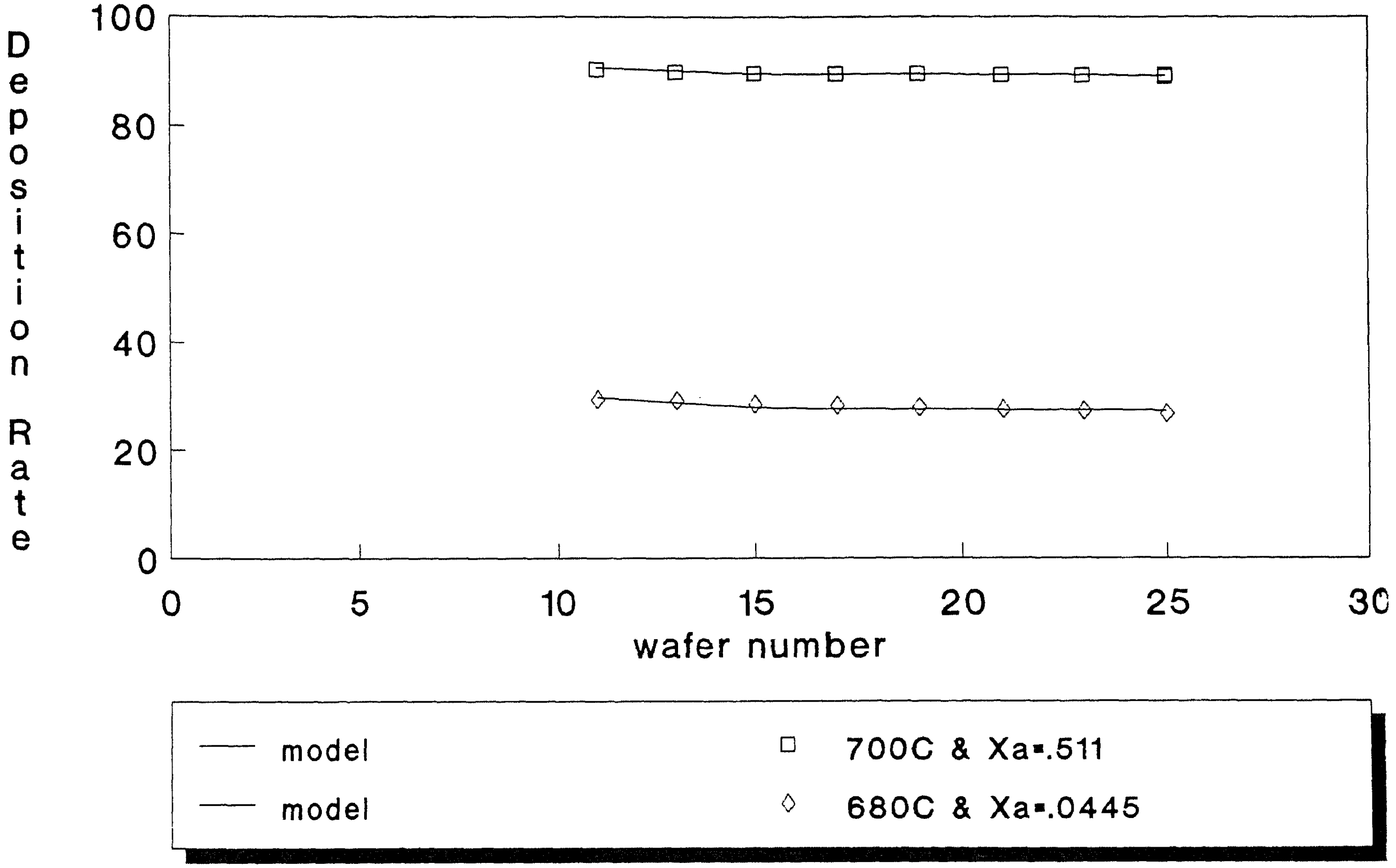
Table 8.1 Experimental and Predicted Deposition Rates.

	Wafer Number								
	11	13	15	17	19	21	23	25	
T=700^{0}C	90.2	89.8	89.6	89.5	89.5	89.3	89.2	89.0	Expt.
data	90.7	90.1	89.5	89.5	89.5	89.4	89.4	89.3	Pred.
	90.7	90.7	90.6	90.6	90.6	90.5	90.5	90.5	*
	89.6	89.6	89.5	89.5	89.5	89.4	89.4	89.4	**
T=680^{0}C	29.4	29.1	28.5	28.2	27.9	27.5	27.2	26.8	Expt.
data	29.8	28.8	27.8	27.7	27.6	27.5	27.5	27.4	Pred.
	29.8	29.8	29.7	29.6	29.5	29.4	29.4	29.3	*
	27.9	27.8	27.8	27.7	27.6	27.5	27.5	27.4	**

** Zero order on wafer throughout*

*** First order on wafer throught*

Comparison of Model and Experiment.
Figure 8.1 Silicon Dioxide



Desu/Kalidindi

CHAPTER 9

MODEL PHILOSOPHY AND OVERALL DISCUSSION

There are several technical points of interest that have been raised during the course of this modeling study. The most critical ones are :controlling resistance, reaction rate expressions, system stability, interwafer concentration profile and surface uniformity. Below we present a discussion on each as we believe they are related to LPCVD processing in a hot wall reactor from the perspective of our model.

In discussions concerning fluid flow and chemical reactions, it is desirable to determine which group exerts the larger influence on the final results. This approach simplifies the problem and yield a clearer path toward forcasting results.

In CVD, a chemical reaction is expected on the surface of a desired substrate. This reaction process is cosidered to be catalyzed by the solid impermeable surface (no pores). To complete the overall deposition process a reactant is expected to experience the following steps (4,9,10,11,41) :

1) mass transfer of reactant(s) to the surface
2) adsorption of reactant(s) on the surface
3) chemical reaction on the surface
4) desorption from the surface (gaseous product)

and 5) mass transfer of products to the bulk fluid.

Since these steps are sequential, they can be estimated individually and grouped to reflect an overall resistance to the successful completion of the process.

Since process rates are expected to vary widely with operating condition changes, very often only one or the other of two steps dominate the variation. This slow step is the so-called rate-controlling step and provides the influential resistance (controlling resistance).

If we consider steps 2, 3 and 4 in the sense of chemical reactions then the five steps can be represented as :

$$-\frac{1}{\text{surface area}}\frac{dN_i}{dt} = \frac{1}{\frac{1}{k_{MT}} + \frac{1}{k_{RXn}}} C^{\upsilon}_{i,Blk} \qquad 9.1$$

where N_i is the moles of species *i*, k_{MT} and k_{RXn} are the rate coefficients for mass transfer and chemical reactions respectively. $C_{i,Blk}$ is the species bulk concentration and υ is the reaction order. It is clear that $1/k_{MT}$ and $1/k_{RXn}$ represent the respective resistance and the larger resistance (smaller rate coefficient) will dominate the process.

A simple relationship called the Damköhler number (Da) is useful in estimating which resistance is controlling. Following Probstein (32), assume for the purpose of demonstration, that the reaction rate is :

$$\text{rate} = k_0 C^{\upsilon} \ (\text{gmol.cm}^{-2}\text{sec}^{-1}) \qquad 9.2$$

where k_0 is the rate coefficient with units $\text{mol}^{1-\upsilon}\text{cm}^{3\upsilon-2}\text{sec}^{-1}$.

At steady state, equation 4.13 can be written as :

$$- D\frac{\partial C}{\partial z} = k_0 \, C^{\upsilon} \text{ at } z=\delta \qquad 9.3$$

and the negative sign can be removed if the rate is considered in terms of disappearance of species (rate = $-r_i$). Then from equations 5.1 and 5.3 we get :

$$\frac{\partial C}{\partial z} = \frac{\partial F}{\partial \zeta} \, (C_{Blk}/\delta) \text{ at } z = \delta \qquad 9.4$$

and equation 9.3 can be written as :

$$\frac{-DC_{Blk}}{\delta} \left.\frac{\partial F}{\partial \zeta}\right|_{\zeta=1} = k_0 \left[F \, C_{Blk}\right]^{\upsilon} \qquad 9.3A$$

or
$$- \left.\frac{\partial F}{\partial \zeta}\right|_{\zeta=1} = \frac{k_0 F^{\upsilon} C_{Blk}^{\upsilon-1}}{D/\delta} = F^{\upsilon} Da \qquad 9.5$$

where:

$$Da = \frac{k_0 C_{Blk}^{\upsilon-1}}{D/\delta} = \frac{\text{reaction velocity}}{\text{diffusion velocity}} \qquad 9.6$$

If υ is 1 and D is D_{AB}, then Da is w in equation 5.32. It is also of interest to point out that a Damköhler number can be defined relative to convection velocity.

If Da » 1, then species rate of disappearance (production) is large relative to mass transfer rate by diffusion and equation 4.13 could be replaced by C(r, δ) equal to zero (very fast reaction).

Further, since species flux to the surface (equation 4.7) is proportional to the concentration difference, then with $C(r,\delta)$ set equal to zero the driving force is maximized and the so-called limiting flux is achieved.

However if $Da \ll 1$, the rate of species disappearance (production) is small relative to mass transfer and equation 4.13 could be replaced with $\partial C(r,\delta)/\partial z$ set equal to zero (const. conc. = bulk conc.).

In CVD, equation 9.2 is not generally true. In particular when simple rate forms analogous to equation 9.2 are applicable throughout the reaction, υ is not an integer. This kind of complication motivates a modification of the boundary condition such as we have in equation 5.10. Further, our approach allows us to take advantage of rate forms such as equation 9.2 with υ as particular integers ($\upsilon = 0,1,\ldots$). Results based on our approach are shown in Figures 6.1 to 6.3 and Figures 7.1 to 7.3 as well as Figure 8.1. These results are strong indirect evidence that surface reaction rate is controlling as opposed to homogeneous reaction rates. Further, Table 9.1 below show that Da smaller than one are anticipated when estimates are made from Roenigk and Jensen's Si_3N_4 data :

Table 9.1 Estimates of rate constants and Diffusion Velocity

First order rate const(cm/sec)	Zero order rate const(gmol/cm^{2}sec)	D/δ(cm/sec)
3.85	1.44E-09	4000
16.2	6.32E-10	2818
75.4	1.48E-10	3880

data from Roenigk and Jensen's (1987) Si_3N_4.

Our modification of the boundary condition is certainly in the right neighborhood and there is no doubt that diffusion to reaction resistance is comparably small (Figure 6.4).

Reaction Rate Expression

In chapter 4, we reduced a complex reaction rate form to a simpler one. The primary objective there, was to obtain the simplest possible right hand side for equation 4.13. We mathematically described the interwafer region using equations 4.9 through 4.13. Observing that such a description provides a linear problem if equation 4.13 is linear, hence the reduction. Following this approach led us to equation 4.31 which is nonlinear, but two distinct Taylor series representations become obvious. The primary objective is now achievable by consideration of the first term of either series. Solution of the linear problem is achievable by the method of separation of variables (appendix A).

Cognizant of the possibility of getting poor results from the linear problem, we seek an approach that can use such results as first approximations. The perturbation methods (16, 17) immidiately come to mind. Specifically, we employ a regular boundary perturbation (appendix A). The central idea is to reduce a complex problem to a series of simpler ones that can be solved by an elementary metod (separation of variables or transforms). This must be acomplished with a minimum loss of the basic features of the original problem. In our case, a nonlinear form (equation 4.31) exibiting shifting order (kinetic) characteristics. Equations 5.10 and 11 combine both the desired mathematical simplcity and kinetic integrity. Equations 5.12 through 5.26 is a partial listing of the series of simpler problems obtained when equations 5.10 and 11 are used (appendix A). Following Levenspiel (11), we assumed the effective rate to be between zero and first order.

The overall model was tested using independently published experimental data generated from three distinct systems(chapter 6-8). In all cases the shifting order assumption (zero to first order) was used to successfully predict deposition rates.

Rearrangement of equation 4.31 produces the Langmuir isotherm form (4,32,33,37,38,39,41) which can be used to explain the shifting order assumption. Following Castellan (41) and Hayward and Trapnell (37), the conditions (i) and (ii) stated in chapter 4 provide the large surface coverage case. While truncation of equation 4.32 after term one gives a concentration independent rate. This means we have a zero order reaction at high concentration of species A.

Condition (iv) implies low surface coverage and truncation of equation 4.34 after term one gives first order rate. Thus we have first order reaction at relatively low concentration. Since species A concentration is higher at the reactor entrance and reduces axially, the Langmuir isotherm supports our claim. It is important to note that a first order reaction rate would be all that is needed to predict deposition rates if adsorption/desorption provided the controlling resistance (37,41).

Experimental data on silicon dioxide deposition (25) and on silicon deposition were correlated with their respective precursor partial pressures. In both cases (at least qualitatively) the Langmuir isotherm behaviour appears very strong.

Regardless of the Langmuir controversy (34-36,38,40), we believe this isotherm provides suitable explanation of macroscopic surface kinetics in CVD.

Surface uniformity appears to be the focal point of the controversy, however all the evidence to date is based on traditional catalysts. While CVD substrates are not completely uniform surfaces, they are polished surfaces. This difference between CVD substrates and traditional catalysts may be very significant.

System Stability

By stability we mean : a disturbed system that will return to the previous steady state after the removal of the disturbance (4, 33, 39). In describing the interwafer region (Region III) mathematically, we assumed steady state.

On this basis alone, there is no reason to expect instability. However, equation 4.13 reintroduces a time dependency through the reaction rate (dN/dt) where N is the number of mols.

Without specific experimental, very few mechanisms can be discounted. One of those few is an autocatalytic reaction. This type of reaction is excludable on the basis of surface reaction controlling arguments. Autocatalytic reactions imply increasing reaction rates over short time intervals. Such rate increases are expected to result in a change in controlling resistance. However, as previously discussed, no change in controlling resistance was determined or observed.

One plausible mechanism is the chain type. This mechanism can result in increased reaction rates also. However, elimination of this mechanism requires more data than is currently available. As such we will discuss stability using a chain type mechanism. Following Frank-Kamenetskii (33), consider a reaction involving C_A, q_0, q_1 and q_2. Here C_A is active product concentration, while q_1 and q_2 represent chain initiation and chain termination rate constants respectively and q_0 is chain generation rate. Then :

$$\frac{dC_A}{dt} = q_0 + q_1C_A - q_2C_A \qquad 9.7$$

is a typical reaction rate involving the active product. Chain propagation is excluded since it does not affect the amount of active product.

If C_A is a constant, say $C_A(0)$ at some time t_0, then equation 9.7 reduces to :

$$C_A(0) = \frac{q_0}{q_2 - q_1} \qquad 9.8$$

a steady state value at t_0 ($q_2 > q_1$). Then $\forall\ t \neq t_0$, C_A is not a constant and equation 9.7 solves to :

$$C_A(t) = \frac{q_0}{q_2 - q_1} + m\ e^{-(q_2-q_1)t} \qquad 9.9$$

where $-(q_2-q_1)$ is the eigenvalue and m is arbitrary. Equation 9.9 reduces to equation 9.8 as $t \longrightarrow \infty$ if $q_2 > q_1$.

$C_A(0)$ is a relatively constant active product which implies a steady reaction rate. Of course q_0, q_1 and q_2 do change as the reaction progresses and there is some dependency on initial concentration. $C_A(0)$ changes also and since the time interval to t_0 is small, the initial reactants are not significantly changed. From equation 9.9 it is clear that instability occurs as $t \longrightarrow \infty$ if $q_1 > q_2$. Further, if the disturbance is such that q_2 eqals q_1 ignition occurs.

If several active products are under consideration, equation 9.7 would be replaced by a system of differential equations. Solution using matrix techniques would produce the necessary eigenvalues. Inspection of these eigenvalues as to their signs would determine stability.

The number of eigenvalues increase in the case of several active products, but basically, stability as defined herein would occur for negative eigenvalues. For a more elaborate discussion on stability and eigenvalues see Boyce and DiPrima (8) and O'Neil (7).

In general, equation 4.9 is linear and holomorphic. As such, the dependent variable C_A has its maximum and minimum inside the domain of definition. This means that C_A is bounded. Except for the condition described by equation 4.13 a bounded solution is expected. This is a somewhat milder requirement than the stability definition stated above but it does guarantee convergence.

Since the annulus region (Region II) treated herein as a series of mixed flow reactor, the necessary and sufficient conditions derived in standard textbooks are applicable. A good discussion can be found in Froment and Bischoff (4) and in Butt (39).

In CVD processes chemical reactions in the annulus region are only important from a material balance perspective. In addition the hot wall reactor system is isothermal with heating provided by a resistance heater.

Interwafer Concentration Profile

In all of the test cases, equation 5.27 proved to be sufficient. Further, it was only necessary to use the first two terms of the infinite series.

With such a truncation we expect some error on the order of :

$$\text{error} \leq \left| \frac{J_0(\alpha_2\zeta)\text{Cosh}(a\alpha_2\zeta)}{a\alpha_0^2\ \text{Sinh}(a\alpha_2)J_1(\alpha_2)} \right| \qquad 9.10$$

for $\zeta \in (0,1)$. Specifically, for the silicon nitride system considered in chapter 6 (wafer surface) :

$$\text{error} \leq \left| 1.573J_0(\alpha_2\zeta) \right|. \qquad 9.11$$

Table 9.2 gives an estimation of the error using two terms of the infinite series in equation 5.27 (Si_3N_4 system). This two term truncation results in an average error ≤ 3 percent. This value compares very well with the reported average of 8.5 percent for the runs considered.

Table 9.2 Estimation of Error Bound on the Concentration Profile

Wafer rad.	2-Terms	Error	%
0	30.581	1.573	5.1
0.5	30.201	1.105	3.6
1.0	29.257	0.112	0.4
1.5	27.123	0.575	2.1
2.0	23.504	0.488	2.1
2.5	18.256	0.074	0.4
3.0	11.657	0.460	3.9
3.5	4.396	0.288	6.5
			avg = 3.0

From these considerations of the interwafer concentration profile we propose an overall reaction rate R (gmol/cm^{2}sec) as :

$$R = k_0 C_{Ab_i} f(\varepsilon F) \qquad 9.12$$

where k_0 has units cm/sec and C_{Ab_i} has units gmol/cm^3 and F is as defined in equations 5.1 and 5.11. The growth rate G (Ang/min) can be estimated from :

$$G = 60\,\frac{M\ R}{\rho}\,E08 \qquad 9.13$$

where M (g/gmol) and ρ (g/cm^3) are respectively the molecular weight and density of the deposited film.

The parameter $\in$ is defined as :

$$\varepsilon = \frac{k_2 - k_3 C_{A0}}{1 + k_3 C_{tot}}. \qquad 9.14$$

Motivation for the definition of ε was provided by the substitution of equation 5.10 into equation 5.8 (equation 5 appendix A), followed by comparison with equation 4.34. Essentially, we have a corrected first order subtracted from a zero order reaction rate as in equation 9.12. Determination of an interwafer concentration profile based on a first order reaction rate produces equation 56 (appndx. A)

$$F = 1\text{-}2w \sum_{n=0}^{\infty} \frac{J_0(\alpha_n \zeta)\,\text{Cosh}(a\alpha_n \zeta)}{\left[a\alpha_n^2\ \text{Sinh}(a\alpha_n) + w\alpha_n \text{Cosh}(a\alpha_n)\right] J_1(\alpha_n)}$$

which has an extra term in the denominator in comparison to equation 5.27. If the first two terms of the infinite series are considered in both equations 5.27 and equation 56 of the appendix A, we get the following :

$$\left|F_0 - F\right| < 1.573 \left|J_0(\alpha_2\zeta)\right| \qquad 9.15$$

This is almost the bound on the error (equation 9.11) on F_0 when two terms are used (at least an upper bound). Some estimates are shown in Table 9.3 below. This is sufficient to motivate equation 9.14 and the concern will be the accuracy with which k_2 and k_3 can be determined (experimentally) based on a suitable reaction mechanism.

Table 9.3 Estimates of $|F_0\text{-}F|$ and the Error Bound.

r	Δ	Error
0	0.104	1.573
0.5	0.102	1.105
1.0	0.096	0.112
1.5	0.086	0.575
2.0	0.072	0.488
2.5	0.054	0.074
3.0	0.053	0.462
3.5	0.013	0.288

$\left|F_0 - F\right| = 2\, w_{avg} \Delta$; $w_{avg} = 1.27E\text{-}04$ for Si_3N_4.

Surface Uniformity

In the production of large quantities of wafers, an implicit assumption is a uniformly deposited film on each wafer. Previous discussions (chapter 6-8) have isolated the Sherwood number (w) as the overall parameter to control.

Figure 6.4 and Huppertz and Engl (25) both show that uniformity (radial) improves with diminishing sherwood number. That is, for a given chemistry, the most uniform deposit will come from the run employing the smallest sherwood number. It is clear from equation 5.32 that the most direct way (mathmatically) to reduce **w** is to increase diffusivity. Practical considerations however, may limit the amount of adjustments that can be made through increasing D_{AB}.

Another parameter that could be used to lower **w** is the reaction rate coefficient (k). However, once the chemistry is established, controllable adjustments through this parameter are not easily achieved. It is interesting to note that increasing k, results in poor radial uniformity as is evident in Figure 2 of appendix B. One implication of this behaviour is : given good surface uniformity ($w < 1$), and fixed physicochemical hydrodynamics the chemical reaction rate is expected to provide the controlling resistance.

An alternative to increasing D_{AB} and or adjusting k, is to increase the wafer spacing. Figures 1 and 3 of appendix B show that (qualitatively) improvements gained through diffusivity is equivalent to that gained through increased wafer spacing.

A routine to execute the repetitive material balance computations is given in appendix C. The computer code is in Basic. The example given in the routine is discussed in chapter 7 (Source A). The data was taken from Collingham and Zollars no-recycle case as stated in chapter 7.

Conclusion

A mathematical model is proposed which was used to predict CVD performance within the reliability of experimental data (chapters 6-8). Experimental data reported in the literature on silicon nitride, silicon (two sources) and silicon dioxide were used to test the proposed model. In all cases the proposed model successfully reproduced the reported deposition rates.

Results show that deposition rates of silicon nitride from dichlorosilane and ammonia, silicon from silane and silicon dioxide from tetraethylorthosilicate can be explained with the use of a shifting order reaction (zero to first order). Further, the neglect of gas phase reactions did not affect the predicted deposition rates herein.

The subdivision of the reactor into three regions improve the flexibility of the proposed model. This flexibility is demonstrated in the successful prediction of silicon deposition including the H_2 inhibitory effects (chapter 7).

Concurrence with experimental results on thickness uniformity (radial) is achieved with the model. Control of nonuniformity on the wafers during a CVD process depends on the magnitude of the sherwood number. Both model predictions and experimental data show that surface uniformity improves with diminishing Sherwood numbers.

In the present work, we demonstrated (at least theoretically) that surface chemical reaction is the controlling resistance. By examining equation 5.32, we observe that, for a given wafer spacing and fixed diffusivity coefficient a small Sherwood number (w) implies a small reaction rate coefficient.

In light of previous discussion (controlling resistance) the chemical reaction is controlling. Herein, we only considered surface chemical reaction. Modification of a typical nonlinear surface rate expression led to simplification of an otherwise analytically intractable boundary value problem. Regardless of the nonlinearity of this problem, the boundedness on the interwafer concentration profile guarantees convergence. As a result a stable analytical reaction rate is producible (growth rate). This growth rate does require experimental kinetic data based on a specific mecanism. However, we have derived an analytical mathematical model that uses realistic physics.

Future Studies

Following are some particular items that can improve the proposed model:

1) Investigate Region I and quantify its effects on downstream profiles

2) Use experimental kinetic parameters (equation 9.14) to independently test the model following the lead of Yang and Hougen (30) as well as others (4,9,10,34).

3) Stress (tensile and compressive) is an important parameter that often dictates the aplicability of deposited films. The proposed model will be more comprehensive when stress computation capability is added.

4) Consider modification to predict in situ doping.

APPENDIX A

PERTURBATION AND SEPARATION OF VARIABLES

Herein, we present the detailed calculations that yield the concentration profiles. First, we present the perturbation details necessary to reduce the given problem to a series of simpler ones (equations A-1 through 5C). The books by Zauderer (17) Carrier and Pearson (16) and Schlichting (15) provide sufficient details on regular perturbation methods.

By regular we mean equations A-1 through A-5 with A-5 linearized, produce a unique solution in the domain of definition.

In the method of separation of variables (7, 8) the occurrence of generalized fourier series are expected. However, we have a singular Sturm-Liouville problem. This bring forward the issue of convergence of the resulting series. Zauderer (pp 136 - 150) and / or Boyce and DiPrima (chapter 11) provide sufficient material to validate equations A-24 through A-26.

Equation A-44 present an elementary question concerning the multiplication of infinite series. Thomas and Finney (5) and Churchill and Brown (6) provide the necessary approach to perform this algebra. Churchill and Brown (6) provide an approach generally firm in theory as compared to Thomas and Finney (5).

The Bessel functions are infinite series and are tabulated in most mathematics handbooks. However, the specific cases under consideration were not conveniently tabulated and interpolation was necessary. The book by Burden, Faires and Reynolds (31) provides general interpolation techniques, in particular Lagrange's formalism.

Given the following system:

$$-\frac{1}{a^2}\frac{\partial^2 F}{\partial \zeta^2} = \frac{\partial^2 F}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F}{\partial \xi} \qquad \text{A-1}$$

$$\frac{\partial F}{\partial \zeta} = 0 \text{ at } \zeta = 0 \qquad \text{A-2}$$

$$\frac{\partial F}{\partial \xi} = 0 \text{ at } \xi = 0 \qquad \text{A-3}$$

$$F(1,\zeta) = 1 \qquad \text{A-4}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\frac{\partial F(\xi,1)}{\partial \zeta} = k_0 C_{Ab_i}\left[1 - \varepsilon F + \varepsilon^2 F^2 - \varepsilon^3 F^3 + \ldots\right] \qquad \text{A-5}$$

where

$$\frac{C_A(r,z)}{C_{Ab_i}} = F(\xi,\zeta) = F_0 + \varepsilon F_1 + \varepsilon^2 F_2 + \ldots \qquad \text{A-6}$$

has been used to transform the equations from dimensional form to dimensionless form. C_A is the concentration profile (gmol / cm^3) and is a function of r and z (as discussed in chapter 4). F is the dimensionless concentration profile with

$$\xi = r/R_W \; ; \qquad \text{A-7}$$

$$\zeta = z/\delta \; ; \qquad \text{A-8}$$

and

$$\varepsilon = \frac{\left[k_2 - k_3\right]C_{A0}}{1 + k_3 C_{tot}} < 1 \qquad \text{A-9}$$

Substitution of equation A-6 into equations A-1 through A-5 gives:

$$-\frac{1}{a^2}\left[\frac{\partial^2 F_0}{\partial\zeta^2}+\varepsilon\frac{\partial^2 F_1}{\partial\zeta^2}+\varepsilon^2\frac{\partial^2 F_2}{\partial\zeta^2}+\ldots\right]=\frac{\partial^2 F_0}{\partial\xi^2}+\varepsilon\frac{\partial^2 F_1}{\partial\xi^2}+\varepsilon^2\frac{\partial^2 F_2}{\partial\xi^2}+$$

$$\ldots+\frac{1}{\xi}\left[\frac{\partial F_0}{\partial\xi}+\varepsilon\frac{\partial F_1}{\partial\xi}+\varepsilon^2\frac{\partial F_2}{\partial\xi}\ldots\right] \qquad \text{I}$$

$$\frac{\partial F_0}{\partial\zeta}+\varepsilon\frac{\partial F_1}{\partial\zeta}+\varepsilon^2\frac{\partial F_2}{\partial\zeta}+\ldots=0 \text{ at } \zeta=0 \qquad \text{II}$$

$$\frac{\partial F_0}{\partial\xi}+\varepsilon\frac{\partial F_1}{\partial\xi}+\varepsilon^2\frac{\partial F_2}{\partial\xi}+\ldots=0 \text{ at } \xi=0 \qquad \text{III}$$

$$F_0+\varepsilon F_1+\varepsilon^2 F_2+\ldots=1 \text{ at } \xi=1 \qquad \text{IV}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\left[\frac{\partial F_0}{\partial\zeta}+\varepsilon\frac{\partial F_1}{\partial\zeta}+\varepsilon^2\frac{\partial F_2}{\partial\zeta}+\ldots=k_0C_{Ab_i}\left[1-\varepsilon(F_0+\varepsilon F_1+\varepsilon^2F_2+\ldots)\right.\right.$$

$$+\varepsilon^2(F_0+\varepsilon F_1+\varepsilon^2F_2+\ldots)^2+O(\varepsilon^3) \qquad \text{V}$$

Equations I through V can be simplified by equating powers of ε:

ε^0:

$$-\frac{1}{a^2}\frac{\partial^2 F_0}{\partial\zeta^2}=\frac{\partial^2 F_0}{\partial\xi^2}+\frac{1}{\xi}\frac{\partial F_0}{\partial\xi} \qquad \text{A-1A}$$

$$\frac{\partial F_0}{\partial\zeta}=0 \text{ at } \zeta=0 \qquad \text{A-2A}$$

$$\frac{\partial F_0}{\partial\xi}=0 \text{ at } \xi=0 \qquad \text{A-3A}$$

$$F_0 = 1 \text{ at } \xi = 1 \tag{A-4A}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\frac{\partial F_0(\xi,1)}{\partial \zeta} = k_0 C_{Ab_i} \tag{A-5A}$$

ε:

$$-\frac{1}{a^2}\frac{\partial^2 F_1}{\partial \zeta^2} = \frac{\partial^2 F_1}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_1}{\partial \xi} \tag{A-1B}$$

$$\frac{\partial F_1}{\partial \zeta} = 0 \text{ at } \zeta = 0 \tag{A-2B}$$

$$\frac{\partial F_1}{\partial \xi} = 0 \text{ at } \xi = 0 \tag{A-3B}$$

$$F_1 = 0 \text{ at } \xi = 1 \tag{A-4B}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\frac{\partial F_1(\xi,1)}{\partial \zeta} = -\, k_0 C_{Ab_i} F_0(\xi,1) \tag{A-5B}$$

ε^2:

$$-\frac{1}{a^2}\frac{\partial^2 F_2}{\partial \zeta^2} = \frac{\partial^2 F_2}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F_2}{\partial \xi} \tag{A-1C}$$

$$\frac{\partial F_2}{\partial \zeta} = 0 \text{ at } \zeta = 0 \tag{A-2C}$$

$$\frac{\partial F_2}{\partial \xi} = 0 \text{ at } \xi = 0 \tag{A-3C}$$

$$F_2 = 0 \text{ at } \xi = 1 \tag{A-4C}$$

$$-\frac{D_{AB}C_{Ab_i}}{\delta}\frac{\partial F_2(\xi,1)}{\partial \zeta} = k_0 C_{Ab_i}\left[F_0^2 - F_1\right] \tag{A-5C}$$

The process can be continued upto any desired power of ε. A detailed discussion of this procedure can be found in Zauderer (17) and Carrier and Pearson (16).

Considering equations A-1A through 5A and introducing the folowing device:

$$F_0 = 1 - F^* \qquad \text{A-10}$$

such that equation A-1A through 5A become:

$$-\frac{1}{a^2}\frac{\partial^2 F^*}{\partial \zeta^2} = \frac{\partial^2 F^*}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F^*}{\partial \xi} \qquad \text{A-11}$$

$$\frac{\partial F^*}{\partial \zeta} = 0 \text{ at } \zeta = 0 \qquad \text{A-12}$$

$$\frac{\partial F^*}{\partial \xi} = 0 \text{ at } \xi = 0 \qquad \text{A-13}$$

$$F^* = 0 \text{ at } \xi = 1 \qquad \text{A-14}$$

$$\frac{\partial F^*(\xi,1)}{\partial \zeta} = \frac{k_0 \delta}{D_{AB}} = w \qquad \text{A-15}$$

where w is the Sherwood number or Damköhler number (equation 5.32). Note that $k_0 C_{Ab_i}$ is the zero order reaction rate k_0^* (equation 4.33).

If we now assume:

$$F^* = f(\xi)g(\zeta) \qquad \text{A-16}$$

then equation A-11 reduces to:

$$g'' + \beta a^2 g = 0 \qquad \text{A-17}$$

subject to:

$$g'(0) = 0 \qquad \text{A-12A}$$

and

$$f'' + \frac{1}{\zeta} f' - \beta f = 0 \qquad \text{A-18}$$

subject to

$$f'(0) = 0 \; ; \qquad \text{A-13A}$$

$$f(1) = 0 \; ; \qquad \text{A-14A}$$

where β is the separation constant. Further there are three distinct cases depending on whether $\beta < 0$, $\beta > 0$ or β is zero (7,8).

Suppose $\beta < 0$; say $\beta = -\alpha^2$ —— **Case I**

then

$$g(\zeta) = A_1 e^{\alpha a \zeta} + A_2 e^{-\alpha a \zeta} \qquad \text{A-19}$$

after applying equation A-12A we get:

$$A_1 = A_2 \ni$$

$$g_1(\zeta) = \bar{A}_1 \operatorname{Cosh}(a\alpha_1\zeta) \qquad \text{A-20}$$

and

$$f(\xi) = B_1 J_0(\alpha\xi) + B_2 Y_0(\alpha\xi). \qquad \text{A-21}$$

Equation A-13A requires B_2 to be chosen as zero since a bounded solution is sought and Y_0 and Y_0' are unbounded at the origin. The remainder of Equation A-21 reduces to :

$$f_1(\xi) = \bar{B}_1 J_0(\alpha_1\xi) \qquad \text{A-23}$$

after application of equation A-14A gives:

$$J_0(\alpha_n) \;=\; 0\ .\ (\text{eq'n.5.28}) \qquad \text{A-22}$$

Application of the superposition principle gives:

$$F^* \;=\; \sum_{n=0}^{\infty} D_n J_0(\alpha_n \xi)\ \text{Cosh}(a\alpha_n \zeta) \qquad \text{A-24}$$

and equation A-15 reduces equation A-24 to:

$$w \;=\; \sum_{n=0}^{\infty} a\alpha_n D_n J_0(\alpha_n \xi)\ \text{Sinh}(a\alpha_n) \qquad \text{A-25}$$

a generalized Fourier series (7,8,17). Using the orthogonal property (weighted) to solve equation A-25 we get:

$$D_n \;=\; \frac{2\ w}{a\ \alpha_n^2\ \text{Sinh}(a\alpha_n)\ J_1(\alpha_n)}\ . \qquad \text{A-26}$$

Substituting equation A-26 into equation A-24 and using equation A-10 gives:

$$F_0 \;=\; 1 - \frac{2\ w}{a} \sum_{n=0}^{\infty} \frac{J_0(\alpha_n \xi)\ \text{Cosh}(a\alpha_n \zeta)}{\alpha_n{}^2\ \text{Sinh}(a\alpha_n)\ J_1(\alpha_n)} \qquad \text{A-24B}$$

and equation 5.27, where J_0 and J_1 are Bessel functions of the first kind of order zero and one respectively.

Suppose β is zero, then as a second case we have:

$$g'' = 0 \qquad \text{A-27}$$

and

$$f'' + \frac{1}{\zeta} f' = 0; \qquad \text{A-28}$$

However the unboundedness of the resulting logarithmic (from eq'n. A-28) forces one arbitrary constant to be chosen as zero and the other is identically zero (condition A-14A). Therefore we get the trivial solution regardless of $g(\zeta)$. This means that there are no zero eigenvalues.

Suppose $\beta > 0$, then as a case three we let β be λ^2 for convenience. Equations A-17 and A-18 become:

$$g(\zeta) = w_1\cos(\lambda a\zeta) + w_2\sin(\lambda a\zeta) \qquad \text{A-29}$$

and

$$f(\xi) = p_1 I_0(\lambda\xi) + p_2 K_0(\lambda\xi) \ . \qquad \text{A-30}$$

Again the unboundedness of K_0 and K_0' at the origin forces the choice of p_2 to be zero. Further, since I_0 is never zero p_1 must also be chosen as zero inorder to satisfy equation A-14A. Therefore we arrive at the trivial solution and we conclude that β is neiher zero nor positive.

Equations A-1B through A-5B can be treated similarly. Neglecting the details we get:

$$F_1 = \sum_{n=0}^{\infty}\left[\frac{2\ w\ a\ \alpha_n\ \mathrm{Sinh}(a\alpha_n)-2w^2\mathrm{Cosh}(a\alpha_n)}{a^2\ \alpha_n^3\ \mathrm{Sinh}^2(a\ \alpha_n)\ J_1(\alpha_n)}\right] J_0(\alpha_n\xi)\mathrm{Cosh}(a\alpha_n\zeta) \qquad \text{A-31}$$

and equation 5.29.

Considering equations A-1C through A-5C similarly gives:

$$F_2 = \sum_{n=0}^{\infty}\left[Q_n J_0(\alpha_n\xi)\ \mathrm{Cosh}(a\alpha_n\zeta)\right] \qquad \text{A-32}$$

and equation 5.30, with Q_n defined by:

$$Q_n = -\frac{w\int_0^1\left[F_0^2 - F_1\right]\xi\ J_0(\alpha_n\xi)\ d\xi}{a\ \alpha_n\ \mathrm{Sinh}(a\alpha_n)\int_0^1 \xi\ J_0^2(\alpha_n\xi)\ d\xi} \qquad \text{A-33}$$

and equation 5.31.

F_0^2 is given by:

$$F_0^2 = \left[1-\frac{2w}{a}\sum_{n=0}^{\infty}\frac{J_0(\alpha_n\xi)\ \mathrm{Cosh}(a\alpha_n\zeta)}{\alpha_n^2\ \mathrm{Sinh}(a\alpha_n)\ J_1(\alpha_n)}\right]^2 \qquad \text{A-34}$$

where

$$\left[\sum_{n=0}^{\infty} D_n J_0(\alpha_n \xi) \operatorname{Cosh}(a\alpha_n \zeta)\right]^2 = \sum_{n=0}^{\infty} H_n(\alpha_n \xi;\zeta) \qquad \text{A-35}$$

defines the squaring of an infinite series (5,6) and H_n is given by:

$$H_n = \sum_{k=0}^{\infty} L_k J_0(\alpha_k \xi) \operatorname{Cosh}(a\alpha_k \zeta) L_{n-k} J_0(\alpha_{n-k}\xi) \operatorname{Cosh}(a\alpha_{n-k}\xi) \qquad \text{A-36}$$

where

$$L_m = \frac{1}{\alpha_m^2 \operatorname{Sinh}(a\alpha_m)\, J_1(\alpha_m)} .$$

Inspection of equation A-5 shows a zero order reaction rate minus a corrected first order reaction rate (truncated after two terms). This motivates determination of the concentration profile for the first order reaction rate. Thus:

$$-\frac{1}{a^2}\frac{\partial^2 F}{\partial \zeta^2} = \frac{\partial^2 F}{\partial \xi^2} + \frac{1}{\xi}\frac{\partial F}{\partial \xi} \qquad \text{A-37}$$

$$\frac{\partial F}{\partial \zeta} = 0 \text{ at } \zeta = 0 \qquad \text{A-38}$$

$$\frac{\partial F}{\partial \xi} = 0 \text{ at } \xi = 0 \qquad \text{A-39}$$

$$F\,(1,\zeta) = 1 \qquad \text{A-40}$$

$$-\frac{D_{AB}}{\delta}\,\frac{\partial F(\xi,1)}{\partial \zeta} = k_0 F(\xi,1) \qquad \text{A-41}$$

Employing the same device as in A-10 and following the procedure used previously, we get:

$$F = 1 - 2w \sum_{n=0}^{\infty} \frac{J_0(\alpha_n \xi)\ \mathrm{Cosh}(a\alpha_n \zeta)}{\left[a\ \alpha_n^2\ \mathrm{Sinh}(a\alpha_n) + w\alpha_n \mathrm{Cosh}(a\alpha_n)\right]\ J_1(\alpha_n)} \qquad \text{.A-42}$$

Comparison of equations A-42 with A-24B shows an extra term in the denominator of equation A-42. To estimate the significance of the extra term we consider two terms of the infinite-series-part of both equations. Further, we compared these with the error bound and found that both series give essentially the same answer. That is: $|F_0 - F| < 1.573|J_0(\alpha_2\xi)|;\quad 0 < \xi < 1$. Inorder to see this result, consider the following :

$$F_0 = 1\text{-}2w\left[35.163J_0(\alpha_0\xi) - 4.582J_0(\alpha_1\xi)\right] \qquad \text{A-43}$$

$$F = 1\text{-}2w\left[35.05J_0(\alpha_0\xi) - 4.576J_0(\alpha_1\xi)\right] \qquad \text{A-44}$$

$$\text{error} \leq |\ 1.573J_0(\alpha_2\xi)| \qquad \text{A-45}$$

Then:

$$|\ F_0 - F| = 2w\ |0.006J_0(\alpha_1\xi) - 0.11J_0(\alpha_0\xi)| = 2w|\Delta| \qquad \text{A-46}$$

and

$| \Delta | <$ error; where Δ is defined by

$$\Delta = 0.006J_0(\alpha_1\xi) - 0.11J_0(\alpha_0\xi). \qquad \text{A-47}$$

Table A-1 below show values for Δ and error as a function of r (cm). Also shown are values that directly compare the full Bessel series (interpolated) with two terms.

Table A-1 Comparison and Estimates of $|F_0\text{-}F|$ with Error(trnct'd.)

r(cm)	$J_0(\alpha_0\xi)^*$	$J_0(\alpha_0\xi)_F$	$J_0(\alpha_1\xi)^*$	$J_0(\alpha_1\xi)_F$	$\lvert\Delta\rvert$	Error
0	1.0	1.0	1.0	1.0	.104	1.573
0.5	0.9752	0.9749	0.8730	0.8727	.102	1.105
1.0	0.9025	0.9024	0.5402	0.5400	.096	0.112
1.5	0.7881	0.7877	0.1253	0.1254	.086	0.575
2.0	0.6396	0.6393	-0.2236	-0.2234	.072	0.488
2.5	0.4679	0.4679	-0.3960	-0.3934	.054	0.074
3.0	0.2856	0.2856	-0.3722	-0.3523	.052	0.462
3.5	0.1053	0.1054	-0.2740	-0.1513	.012	0.288

* *series truncated after two terms*

F *full series (interpolated)*

An average w of 1.27E-04 was used (silicon nitride system).

APPENDIX B

SENSITIVITY OF RADIAL UNIFORMITY

The figures presented herein give some idea of the important parameters affecting radial uniformity. We consider the ratio C_A/C_{Ab_i} on the wafer as a measure of uniformity. These figures were generated using first order reaction rates and a 10.16 cm diameter wafer. The parameter **a** was defined in equation 5.9.

Presented in Figures B-1, B-2 and B-3 are sensitivity of radial uniformity with D_{AB}, k and **a** respectively. Figure B-1 shows radial uniformity is relatively insensitive to changes in diffusion but large diffusion rates will give good uniformity. This finding supports the claim that small Sherwood number or low Damköhler number accompanies good radial uniformity.

Figure B-2 gives uniformity sensitivity relative to reaction rate constan k. It is not surprising that this parameter is the most sensitive of the three considered. Evidently, a fast reaction or when diffusion is controlling, poor radial uniformity can be expected.

Figure B-3 shows that **a** behaves similar to diffusivity but will reach its optimum before diffusivity. This means that adjustments in wafer spacing can be optimized to obtain the diffusion effect and hence improve uniformity.

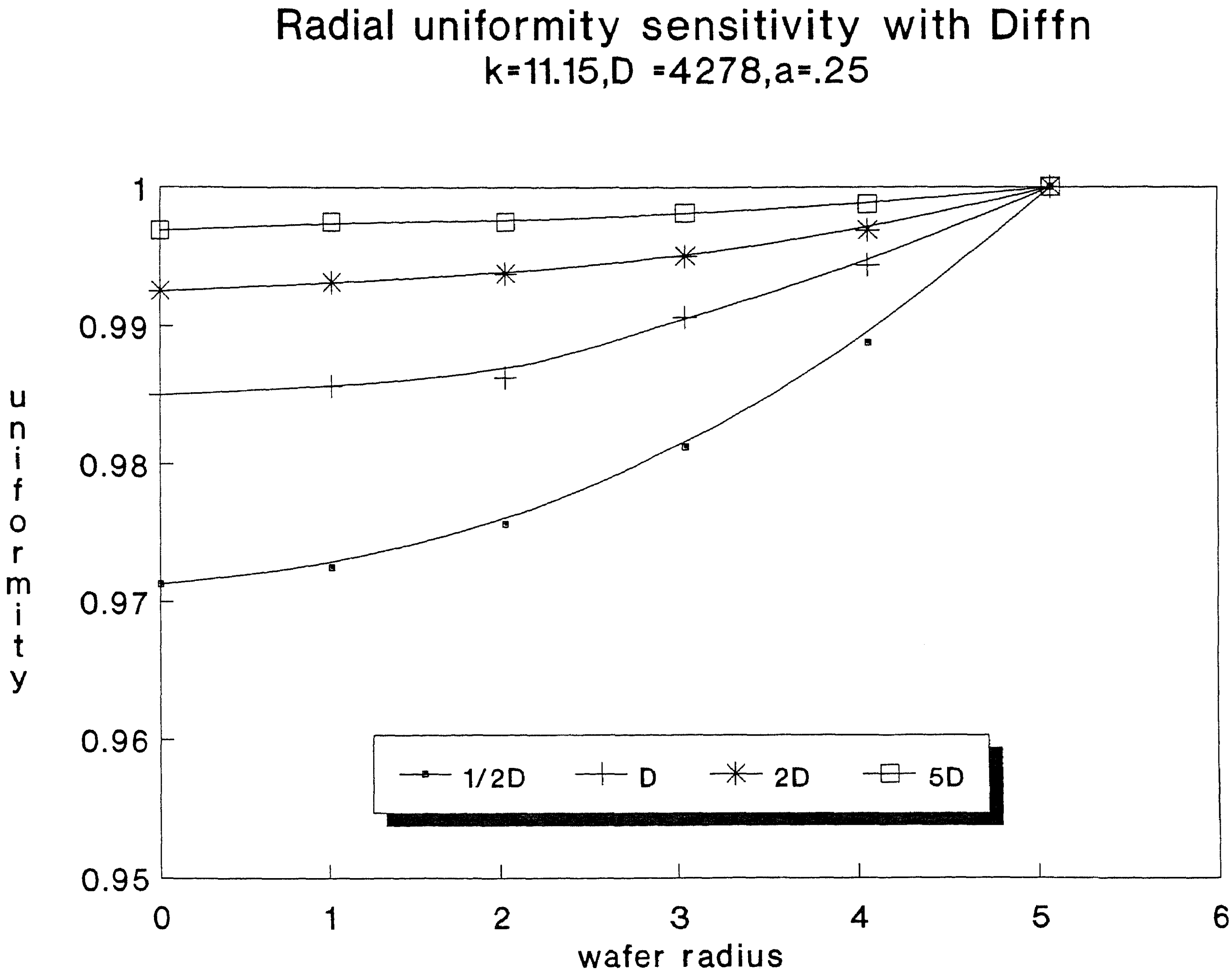
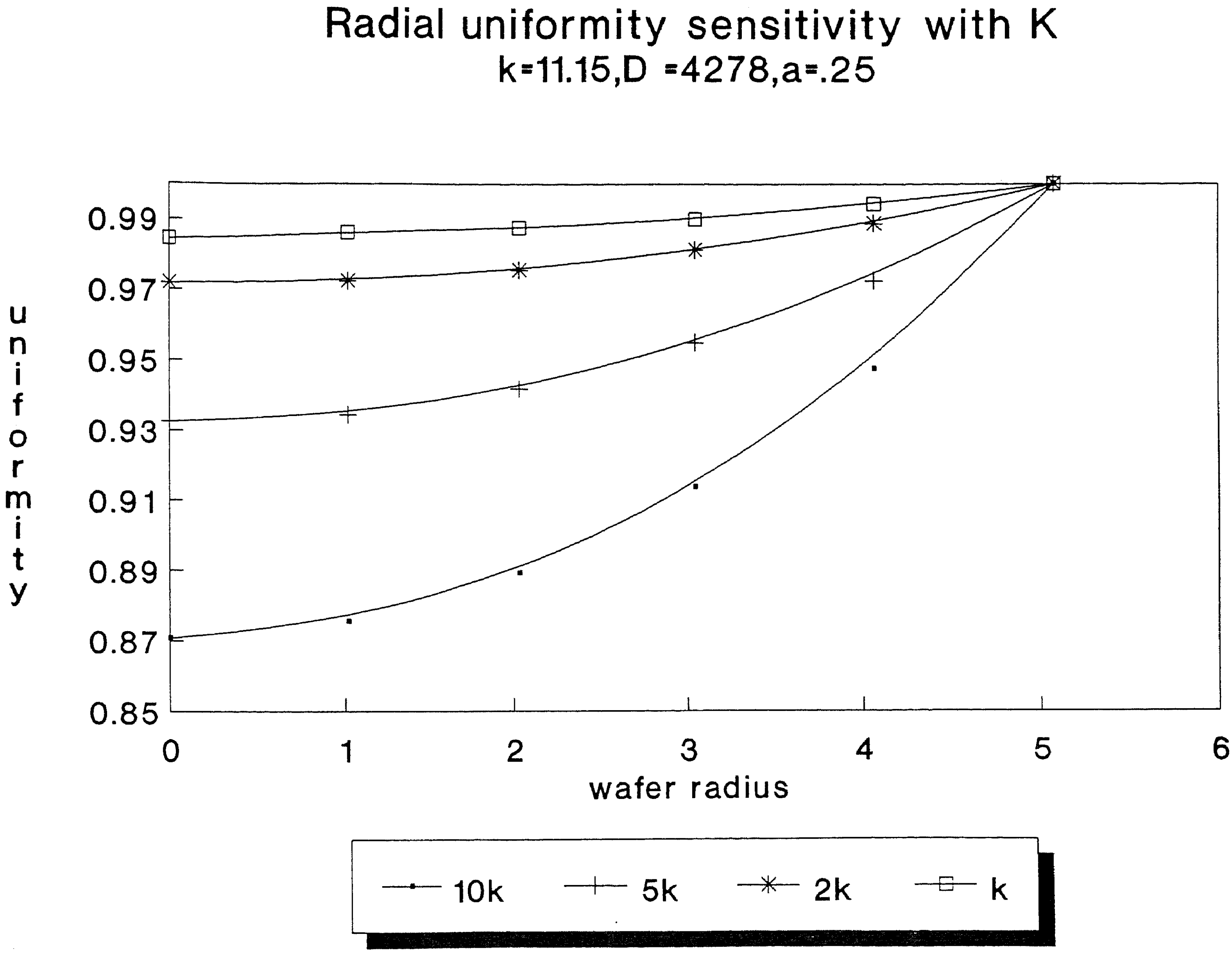

Radial uniformity sensitivity with Diffn
k=11.15,D =4278,a=.25
uniformity
1
0.99
0.98
0.97
0.96
0.95
0
1
2
3
4
5
6
wafer radius
1/2D
D
2D
5D

Figure B-1


Radial uniformity sensitivity with K
k=11.15,D =4278,a=.25
uniformity
0.99
0.97
0.95
0.93
0.91
0.89
0.87
0.85
0
1
2
3
4
5
6
wafer radius
10k
5k
2k
k

igure B-2

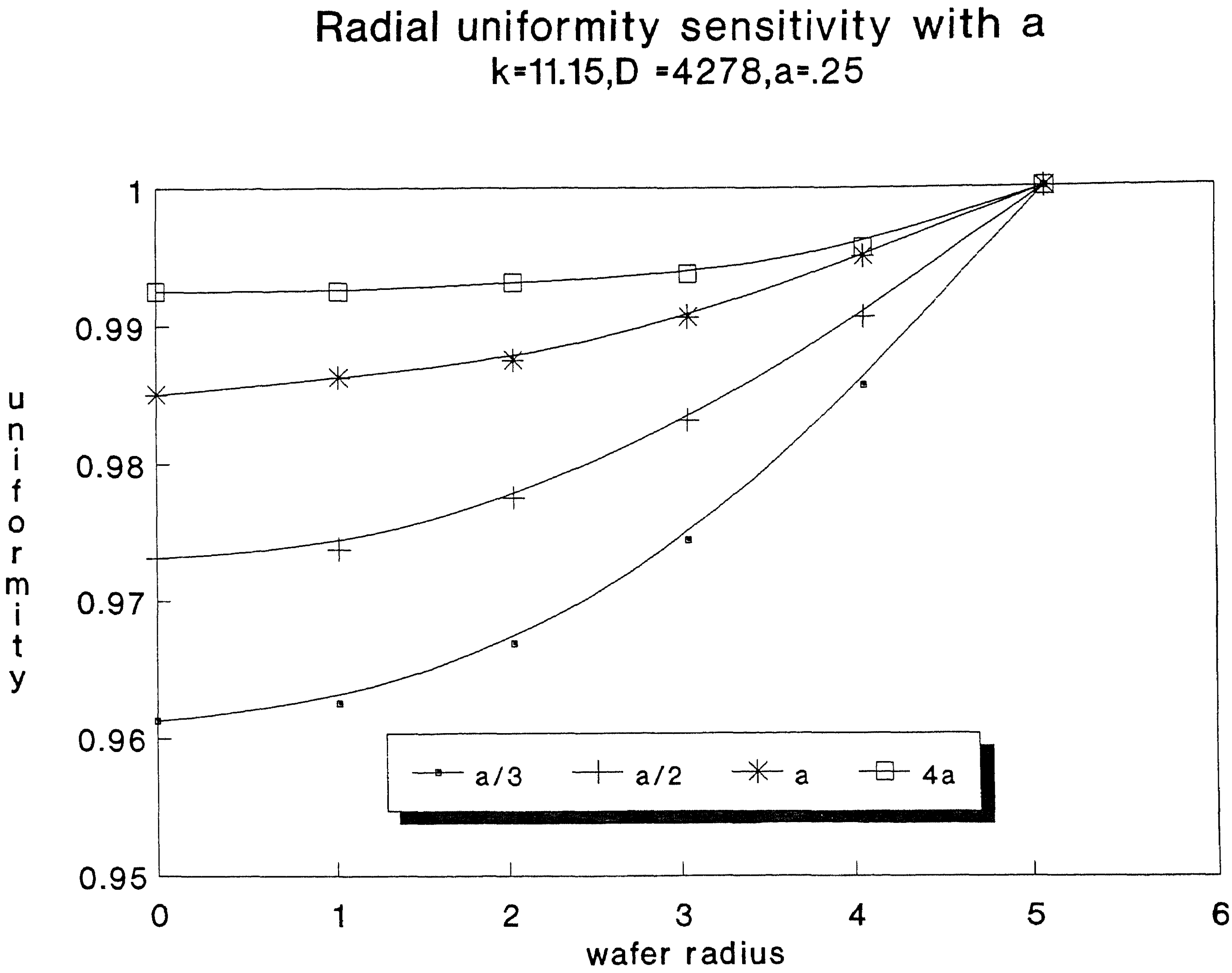

Radial uniformity sensitivity with a
k=11.15,D =4278,a=.25
1
0.99
0.98
0.97
0.96
0.95
uniformity
0
1
2
3
4
5
6
wafer radius
a/3
a/2
a
4a

Figure B-3

APPENDIX C

Following is a listing of the computer code (BASIC) used to execute the repetitive material balance computations. Included is an example of an actual simulation for silicon deposition. This is Source A reported in chapter 7.

Variable Dictionary

K_1	rate constant used in Region I_0
K_2	first order rate constant used (walls and wafer).
YA	precursor mol fraction
A	1/2 wafer space divided by wafer radius
RW	wafer radius (cm)
RT	reactor radius (cm)
T	temperature (Kelvin)
P	pressure (atm.)
V0	initial volumetric flow rate (cm^3/min)
RHO	film density (g/cm^3)
MW	film molecular weight (g/g-mol)
L0mda	first zero of the Bessel function (J_0)
L1mda	second zero of J_0
R	radial coordinate
DAB	binary diffusion coefficient (cm^2/sec)
N	number of wafers
PI	π
X	the length L used in Region I

K0	rate constant used on wafer (eq'n. 5.10)
KS, KC, KA	see equation 7.2 where S, C and A are subscripts.
GI	growth rate (Ang./min.)
CA(I)	concentration (gmol/cm^3)
CAI	bulk concentration at the ith interwafer region
NARI	flux of material into interwafer region (gmol/cm^2-sec)
DELL	δ 1/2 wafer spacing

```
100 CLS
110 DIM V(245),CA(245),A(9,3),B(9,4)
120 REM Collingham & Zolars system
125  REM A and B are tables table A gives Bessel functions versus radius,while t
able B gives Growth rate versus radius on each wafer.
130 READ K1,K2,YA,A,RW,RT,T,P,V0,RHO,MW,L0MDA,L1MDA,R,DAB,N
135 READ DELL, PI,X,K0,KS,KC,KA
140 DATA 4.35,0.472,0.1000,0.066,1.905,2.85,873,1.1942E-03,139244,2.40,28.06,2.4
048,5.5201,0,1816.11,240,0.125,3.141593,20,.564,5.4545E-07,7.873E-08,21.86
145 REM DETERMINE INITIAL COMPONENT CONCENTRATION
147 REM
150 GC = 82.06*T/P
152 REM
155 REM GC = RT/P where R is the gas constant
157 REM
160 CA0 = YA/GC
162 REM
164 REM CA0 is initial concentration (gmol/cubic cm)
165 CSH0 = (EXP(2.4048*A) + EXP(-2.4048*A))/2
170 CSH1 = (EXP(5.5201*A) + EXP(-5.5201*A))/2
172 REM
175 REM CSH0 is hyperbolic cosine evaluated at the first zero of the bessel func
tion
180 REM
190 SH0 =(EXP(2.4048*A) -EXP(-2.4048*A))/2
195 SH1 = (EXP(5.5201*A) -EXP(-5.5201*A))/2
200 REM SUBREGION I (ENTRANCE TO REACTOR INCLUDING THE FIRST WAFER)
210 REM VOLUMETRIC BALANCE DUE TO CHEMICAL REACTION ON THE REACTOR WALL &
215 RA0 = CSH0/SH0
220 RA1 = CSH1/SH1
225 REM MATERIAL BALANCE OF COMPONENT A.
235 DEPOS = K1*CA0*PI*GC*60*(RW^2 + RT*2*X)
237 V(1) = V0-DEPOS
240 CA(1) = (V0*CA0 - (K1*CA0*PI*(RW^2 + RT*2*X)*60))/V(1)
250 REM ESTIMATE GROWTH RATE G(I) IN A/MIN ON THE FIRST WAFER
260 GI = (K1*CA(1)*60*MW)/(RHO*1E-08)
270 LPRINT
280 LPRINT "Growth rate wafer 1 =";GI,"V(1) =";V(1),"CA(1) =";CA(1)
282 REM END OF FIRST REGION.
285 CNST0 = K2*RW/DAB
290 REM SUBREGION II-ANNULUS REGION
295 REM
300 GOSUB 1900
302 REM PRINTING TABLE A BESSEL FUNCTIONS VERSUS R.
306 LPRINT "       R(cm)","   J0(L0MDA*r/RW)       ";"J0(L1MDA*r/RW)"
310      FOR I = 1 TO 9
315 LPRINT USING "     ##.#####^^^^      ";A(I,1),A(I,2),A(I,3)
318 NEXT I
345 CAI = SQR(CA(1)*CA0)
350 NARI = -.4115*CAI*K0*DELL/A
351 REM
355 LPRINT "Quantities out mean Annulus effluent in cubic cm./min & g-mol/cubic
cm respectively"
360 REM NARI IS THE INTEGRATED FLUX BETWEEN 0 AND DELTA AT r =RW.
370 FOR I = 2 TO 35
375  REM RATE = KS*CA(I-1)/(KC+CA0+KA*CA(I-1))
380 V(I) = V(I-1) -(4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60 *GC)
390 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60)/V(I)
400 CAI = (CA(I) + CA(I-1))/2
405 REM
```

```
407 REM Zero order reaction rate on wafers
410 NARI = -.4115*CAI*K0*DELL/A
412 REM
415 REM first order reaction rate on wall
420 V(I) = V(I-1) - (4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60*GC)
430 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*K2*CA(I-1)-RW*NARI)*60)/V(I)
432 REM MAKING SURE THAT THE I-VALUE REMAINS CONSISTENT WITH THE LOOP VALUE.
435 KOUNT = I
440 GOSUB 3000
442 I = KOUNT
445 LPRINT
450 LPRINT "     WAFER";I;"   V(OUT) = ";V(I);"   CA(OUT) = ";CA(I)
455  LPRINT "     R(cm)","   CA(r,dell)     ";" CA/CAI     ";"G(angs./min)"
460 FOR M = 1 TO 9
475 REM THIS TABLE CONTAINS THE GROWTH RATE AS A FUNCTION OF WAFER RADIUS.
480 LPRINT USING "      ##.#####^^^^    ";B(M,1),B(M,2),B(M,3),B(M,4)
500 NEXT M
505 WAVG = (B(1,4) +B(3,4) +B(5,4) +B(7,4) +B(8,4))/5
507 LPRINT "      Average Deposit =";WAVG
510 NEXT I
570 NARI = -.4115*CAI*K2*RW
605 REM Full surface reaction rate expression available for use on wall
610 FOR I = 36 TO 49
620  REM RATE = KS*CA(I-1)/(KC+CA0+KA*CA(I-1))
625 REM
630 V(I) = V(I-1) -(4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60 *GC)
640 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60)/V(I)
650 CAI = (CA(I) + CA(I-1))/2
660 NARI = -.4115*CAI*K2*RW
670 V(I) = V(I-1) - (4*PI*(DELL*RT*K2*CA(I-1) -RW*NARI)*60*GC)
680 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*K2*CA(I-1)-RW*NARI)*60)/V(I)
690 KOUNT = I
700 GOSUB 3000
710 I = KOUNT
720 LPRINT
730 LPRINT "     WAFER";I;"   V(OUT) = ";V(I);"   CA(OUT) = ";CA(I)
740  LPRINT "     R(cm)","   CA(r,dell)     ";" CA/CAI     ";"G(angs./min)"
750 FOR M = 1 TO 9
760 REM THIS TABLE CONTAINS THE GROWTH RATE AS A FUNCTION OF WAFER RADIUS.
770 LPRINT USING "      ##.#####^^^^    ";B(M,1),B(M,2),B(M,3),B(M,4)
780 NEXT M
790 WAVG = (B(1,4) +B(3,4) +B(5,4) +B(7,4) +B(8,4))/5
800 LPRINT "      Average Deposit =";WAVG
810 NEXT I
820    GOTO 5040
1900 REM THIS SUBROUTINE CALCULATES THE FIRST 4 TERMS OF THE BESSEL FUNCTION J0
1910 REM The above line must not be removed -it is a subroutine call
2000 LMDA = L0MDA
2005 A(1,1) = 0
2010 FOR I = 1 TO 8
2020    FOR J = 2 TO 3
2030 LMDR = (LMDA*R)/RW
2040 L2MDR = LMDR*LMDR
2050 L4MDR = L2MDR*L2MDR
2060 L6MDR = L4MDR*L2MDR
2063 L8MDR = L6MDR*L2MDR
2065 L10MDR = L8MDR*L2MDR
2070 J0LMD0 =1-L2MDR/4+L4MDR/64-L6MDR/2304+(L8MDR/147456!)-L10MDR/1.47456E+07
2075 REM A IS A TABLE  OF THE MODIFIED ZERO ORDER BESSEL FUNCTIONS VERSUS WAFE
RADIUS.
```

```
2080  A(I,J) = J0LMD0
2090 LMDA = L1MDA
2100 NEXT J
2110 R = R+.25
2115 A(I+1,1) = R
2120 LMDA = L0MDA
2130 NEXT I
2133 A(9,1) = 1.905
2134 REM The next two lines  are due to J0(x) =0.
2135 A(9,2) =0
2137 A(9,3) =0
2140 RETURN
2999 REM INITIALIZE - R MAY NEED TO BE CHANGED HERE.
3000 REM THIS SUBROUTINE GENERATES A TABLE CONTAINING GROWTHRATE CONC. & CA/C
VERSUS RADIUS ON EACH WAFER.
3002 R = 0
3005 B(1,1) = 0
3008 CNST = K0*RW/DAB
3010 FOR I = 1 TO 8
3013 H1 = .193*A(I,3)*RA1
3016 H0 =.6662*A(I,2)*RA0
3017 REM
3018 CA = CAI*(1-CNST*(H0-H1))
3025 B(I,2) = CA
3030 B(I,3) = CA/CAI
3032        IF KOUNT > 35 GOTO 3040
3035 B(I,4) = K0*CAI*MW*60/(RHO*1E-08)
3037   GOTO 3047
3040 B(I,4) =(K2*CA*MW*60)/(RHO*1E-08)
3045 REM change r for different reactors
3047 R = R + .25
3050 B(I+1,1) = R
3055 B(9,1) = 1.905
3060 NEXT I
3061 REM Special consideration -must be examined before further use.
3075 B(9,2) =CAI
3080 B(9,3) = B(9,2)/CAI
3082     IF KOUNT > 35 GOTO 3090
3085 B(9,4) = K0*B(9,2)*MW*60/(RHO*1E-08)
3087     RETURN
3090 B(9,4) = (K2*B(9,2)*MW*60)/(RHO*1E-08)
4000 RETURN
5040 REM  This line is important-DO NOT ERASE-SEE LINE 570
5045 REM
5050 NARI = -.4115*CAI*K2*RW
5060 FOR I = 50 TO N
5065 RATE = KS*CA(I-1)/(KC+CA0+KA*CA(I-1))
5070 V(I) = V(I-1) -(4*PI*(DELL*RT*RATE -RW*NARI)*60 *GC)
5080 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*RATE -RW*NARI)*60)/V(I)
5090 CAI = (CA(I) + CA(I-1))/2
6000 NARI = -.4115*CAI*K2*RW
6010 V(I) = V(I-1) -(4*PI*(DELL*RT*RATE -RW*NARI)*60 *GC)
6020 CA(I) =(V(I-1)*CA(I-1) -4*PI*(DELL*RT*RATE -RW*NARI)*60)/V(I)
6030 KOUNT = I
6040 GOSUB 3000
6050 I = KOUNT
6060 LPRINT
6065 LPRINT "     WAFER";I;"    V(OUT) = ";V(I);"    CA(OUT) = ";CA(I)
6070 LPRINT "    R(cm)","    CA(r,dell)      ";" CA/CAI      ";"G(angs./min)"
6075 FOR M = 1 TO 9
```

```
6080 REM THIS TABLE CONTAINS THE GROWTH RATE AS A FUNCTION OF WAFER RADIUS.
6085 LPRINT USING "     ##.#####^^^^    ";B(M,1),B(M,2),B(M,3),B(M,4)
6090 NEXT M
6095 WAVG = (B(1,4) +B(3,4) +B(5,4) +B(7,4) +B(8,4))/5
7000 LPRINT "     Average Deposit =";WAVG
7010 NEXT I
7020 REM COMPONENTS LEAVING THE REACTOR SECTION
7030 CROT = SQR((V(N)+K2*PI*(RW^2+RT^2))^2-(4*K2*PI*(RW^2+RT^2)*GC*V(N)*CA(N)))
7035 CA(N+1) =(V(N)+K2*PI*(RW^2+RT^2) - CROT)/(2*K2*PI*(RW^2+RT^2)*GC)
7037 IF CA(N+1) > CA(N) THEN CA(N+1) = CA(N) ELSE CA(N+1) =CA(N+1)
7040 V(N+1) = V(N)-(K2*CA(N+1)*PI*(RW^2+RT^2)*GC)
7050 LPRINT "     These quantities are the Reactor section effluents"
7060 LPRINT "     CA(N+1) =";CA(N+1),"V(N+1) =";V(N+1)
7070 END
```

```
Growth rate wafer 1 = 167.9669             V(1) = 129598.9
CA(1) = 5.504359E-10
    R(cm)             J0(LOMDA*r/RW)      J0(L1MDA*r/RW)
 0.00000E+00           1.00000E+00         1.00000E+00
 2.50000E-01           9.75255E-01         8.73044E-01
 5.00000E-01           9.02855E-01         5.40177E-01
 7.50000E-01           7.88152E-01         1.25269E-01
 1.00000E+00           6.39576E-01        -2.23602E-01
 1.25000E+00           4.67942E-01        -3.96027E-01
 1.50000E+00           2.85571E-01        -3.72162E-01
 1.75000E+00           1.05284E-01        -2.74049E-01
 1.90500E+00           0.00000E+00         0.00000E+00
Quantities out mean Annulus effluent in cubic cm./min & g-mol/cubic cm respect
ely

WAFER 2      V(OUT) =  129574      CA(OUT) =  5.473335E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      5.46726E-10     9.97823E-01      2.16782E+01
 2.50000E-01      5.46737E-10     9.97843E-01      2.16782E+01
 5.00000E-01      5.46777E-10     9.97916E-01      2.16782E+01
 7.50000E-01      5.46860E-10     9.98067E-01      2.16782E+01
 1.00000E+00      5.47001E-10     9.98325E-01      2.16782E+01
 1.25000E+00      5.47206E-10     9.98699E-01      2.16782E+01
 1.50000E+00      5.47460E-10     9.99163E-01      2.16782E+01
 1.75000E+00      5.47725E-10     9.99647E-01      2.16782E+01
 1.90500E+00      5.47919E-10     1.00000E+00      2.16782E+01
       Average Deposit = 21.67818

WAFER 3      V(OUT) =  129549.2     CA(OUT) =  5.44243E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      5.44595E-10     9.97823E-01      2.15937E+01
 2.50000E-01      5.44606E-10     9.97843E-01      2.15937E+01
 5.00000E-01      5.44646E-10     9.97916E-01      2.15937E+01
 7.50000E-01      5.44728E-10     9.98067E-01      2.15937E+01
 1.00000E+00      5.44869E-10     9.98325E-01      2.15937E+01
 1.25000E+00      5.45073E-10     9.98699E-01      2.15937E+01
 1.50000E+00      5.45326E-10     9.99163E-01      2.15937E+01
 1.75000E+00      5.45590E-10     9.99647E-01      2.15937E+01
 1.90500E+00      5.45783E-10     1.00000E+00      2.15937E+01
       Average Deposit = 21.59369

WAFER 4      V(OUT) =  129524.5     CA(OUT) =  5.411686E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      5.41517E-10     9.97823E-01      2.14717E+01
 2.50000E-01      5.41528E-10     9.97844E-01      2.14717E+01
 5.00000E-01      5.41567E-10     9.97916E-01      2.14717E+01
 7.50000E-01      5.41650E-10     9.98067E-01      2.14717E+01
 1.00000E+00      5.41790E-10     9.98325E-01      2.14717E+01
 1.25000E+00      5.41992E-10     9.98699E-01      2.14717E+01
 1.50000E+00      5.42244E-10     9.99163E-01      2.14717E+01
 1.75000E+00      5.42507E-10     9.99647E-01      2.14717E+01
 1.90500E+00      5.42699E-10     1.00000E+00      2.14717E+01
       Average Deposit = 21.47165

WAFER 5      V(OUT) =  129499.9     CA(OUT) =  5.381105E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      5.38458E-10     9.97823E-01      2.13503E+01
 2.50000E-01      5.38469E-10     9.97843E-01      2.13503E+01
 5.00000E-01      5.38508E-10     9.97916E-01      2.13503E+01
```

```
  7.50000E-01      5.38589E-10     9.98067E-01       2.13503E+01
  1.00000E+00      5.38729E-10     9.98325E-01       2.13503E+01
  1.25000E+00      5.38930E-10     9.98699E-01       2.13503E+01
  1.50000E+00      5.39181E-10     9.99163E-01       2.13503E+01
  1.75000E+00      5.39442E-10     9.99647E-01       2.13503E+01
  1.90500E+00      5.39632E-10     1.00000E+00       2.13503E+01
        Average Deposit = 21.35034

WAFER 6      V(OUT) =  129475.5     CA(OUT) =  5.350686E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
  0.00000E+00     5.35414E-10     9.97823E-01       2.12297E+01
  2.50000E-01     5.35425E-10     9.97844E-01       2.12297E+01
  5.00000E-01     5.35464E-10     9.97916E-01       2.12297E+01
  7.50000E-01     5.35545E-10     9.98067E-01       2.12297E+01
  1.00000E+00     5.35684E-10     9.98325E-01       2.12297E+01
  1.25000E+00     5.35884E-10     9.98699E-01       2.12297E+01
  1.50000E+00     5.36133E-10     9.99163E-01       2.12297E+01
  1.75000E+00     5.36393E-10     9.99647E-01       2.12297E+01
  1.90500E+00     5.36582E-10     1.00000E+00       2.12297E+01
        Average Deposit = 21.22967

WAFER 7      V(OUT) =  129451.2     CA(OUT) =  5.320427E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
  0.00000E+00     5.32387E-10     9.97823E-01       2.11096E+01
  2.50000E-01     5.32398E-10     9.97844E-01       2.11096E+01
  5.00000E-01     5.32437E-10     9.97916E-01       2.11096E+01
  7.50000E-01     5.32517E-10     9.98067E-01       2.11096E+01
  1.00000E+00     5.32655E-10     9.98325E-01       2.11096E+01
  1.25000E+00     5.32854E-10     9.98699E-01       2.11096E+01
  1.50000E+00     5.33102E-10     9.99163E-01       2.11096E+01
  1.75000E+00     5.33360E-10     9.99647E-01       2.11096E+01
  1.90500E+00     5.33548E-10     1.00000E+00       2.11096E+01
        Average Deposit = 21.10963

WAFER 8      V(OUT) =  129427.1     CA(OUT) =  5.290328E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
  0.00000E+00     5.29376E-10     9.97823E-01       2.09902E+01
  2.50000E-01     5.29387E-10     9.97844E-01       2.09902E+01
  5.00000E-01     5.29425E-10     9.97916E-01       2.09902E+01
  7.50000E-01     5.29505E-10     9.98067E-01       2.09902E+01
  1.00000E+00     5.29642E-10     9.98325E-01       2.09902E+01
  1.25000E+00     5.29840E-10     9.98699E-01       2.09902E+01
  1.50000E+00     5.30087E-10     9.99163E-01       2.09902E+01
  1.75000E+00     5.30343E-10     9.99647E-01       2.09902E+01
  1.90500E+00     5.30531E-10     1.00000E+00       2.09902E+01
        Average Deposit = 20.99023

WAFER 9      V(OUT) =  129403.1     CA(OUT) =  5.260388E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
  0.00000E+00     5.26380E-10     9.97823E-01       2.08715E+01
  2.50000E-01     5.26391E-10     9.97843E-01       2.08715E+01
  5.00000E-01     5.26429E-10     9.97916E-01       2.08715E+01
  7.50000E-01     5.26509E-10     9.98067E-01       2.08715E+01
  1.00000E+00     5.26645E-10     9.98325E-01       2.08715E+01
  1.25000E+00     5.26842E-10     9.98699E-01       2.08715E+01
  1.50000E+00     5.27087E-10     9.99163E-01       2.08715E+01
  1.75000E+00     5.27342E-10     9.99647E-01       2.08715E+01
  1.90500E+00     5.27529E-10     1.00000E+00       2.08715E+01
        Average Deposit = 20.87146
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WAFER 10      V(OUT) =  129379.2     CA(OUT) =  5.230607E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       5.23401E-10      9.97823E-01      2.07533E+01
 2.50000E-01       5.23411E-10      9.97843E-01      2.07533E+01
 5.00000E-01       5.23449E-10      9.97916E-01      2.07533E+01
 7.50000E-01       5.23529E-10      9.98067E-01      2.07533E+01
 1.00000E+00       5.23664E-10      9.98325E-01      2.07533E+01
 1.25000E+00       5.23860E-10      9.98699E-01      2.07533E+01
 1.50000E+00       5.24104E-10      9.99163E-01      2.07533E+01
 1.75000E+00       5.24357E-10      9.99647E-01      2.07533E+01
 1.90500E+00       5.24543E-10      1.00000E+00      2.07533E+01
        Average Deposit = 20.75332

WAFER 11      V(OUT) =  129355.5     CA(OUT) =  5.200983E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       5.20437E-10      9.97823E-01      2.06358E+01
 2.50000E-01       5.20448E-10      9.97844E-01      2.06358E+01
 5.00000E-01       5.20485E-10      9.97916E-01      2.06358E+01
 7.50000E-01       5.20564E-10      9.98067E-01      2.06358E+01
 1.00000E+00       5.20699E-10      9.98325E-01      2.06358E+01
 1.25000E+00       5.20894E-10      9.98699E-01      2.06358E+01
 1.50000E+00       5.21136E-10      9.99163E-01      2.06358E+01
 1.75000E+00       5.21388E-10      9.99647E-01      2.06358E+01
 1.90500E+00       5.21572E-10      1.00000E+00      2.06358E+01
        Average Deposit = 20.63581

WAFER 12      V(OUT) =  129331.9     CA(OUT) =  5.171517E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       5.17489E-10      9.97823E-01      2.05189E+01
 2.50000E-01       5.17500E-10      9.97844E-01      2.05189E+01
 5.00000E-01       5.17537E-10      9.97916E-01      2.05189E+01
 7.50000E-01       5.17616E-10      9.98067E-01      2.05189E+01
 1.00000E+00       5.17749E-10      9.98325E-01      2.05189E+01
 1.25000E+00       5.17943E-10      9.98699E-01      2.05189E+01
 1.50000E+00       5.18184E-10      9.99163E-01      2.05189E+01
 1.75000E+00       5.18435E-10      9.99647E-01      2.05189E+01
 1.90500E+00       5.18618E-10      1.00000E+00      2.05189E+01
        Average Deposit = 20.51891

WAFER 13      V(OUT) =  129308.4     CA(OUT) =  5.142207E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       5.14557E-10      9.97823E-01      2.04026E+01
 2.50000E-01       5.14567E-10      9.97844E-01      2.04026E+01
 5.00000E-01       5.14604E-10      9.97916E-01      2.04026E+01
 7.50000E-01       5.14683E-10      9.98067E-01      2.04026E+01
 1.00000E+00       5.14816E-10      9.98325E-01      2.04026E+01
 1.25000E+00       5.15008E-10      9.98699E-01      2.04026E+01
 1.50000E+00       5.15248E-10      9.99163E-01      2.04026E+01
 1.75000E+00       5.15497E-10      9.99647E-01      2.04026E+01
 1.90500E+00       5.15679E-10      1.00000E+00      2.04026E+01
        Average Deposit = 20.40264

WAFER 14      V(OUT) =  129285.1     CA(OUT) =  5.113052E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       5.11640E-10      9.97823E-01      2.02870E+01
 2.50000E-01       5.11650E-10      9.97843E-01      2.02870E+01
 5.00000E-01       5.11687E-10      9.97916E-01      2.02870E+01
 7.50000E-01       5.11765E-10      9.98067E-01      2.02870E+01
 1.00000E+00       5.11897E-10      9.98325E-01      2.02870E+01
 1.25000E+00       5.12089E-10      9.98699E-01      2.02870E+01
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 1.50000E+00      5.12327E-10     9.99163E-01     2.02870E+01
 1.75000E+00      5.12575E-10     9.99647E-01     2.02870E+01
 1.90500E+00      5.12756E-10     1.00000E+00     2.02870E+01
       Average Deposit = 20.28699

WAFER 15      V(OUT) =  129261.9     CA(OUT) =   5.084053E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      5.08738E-10     9.97823E-01     2.01719E+01
 2.50000E-01      5.08749E-10     9.97843E-01     2.01719E+01
 5.00000E-01      5.08786E-10     9.97916E-01     2.01719E+01
 7.50000E-01      5.08863E-10     9.98067E-01     2.01719E+01
 1.00000E+00      5.08995E-10     9.98325E-01     2.01719E+01
 1.25000E+00      5.09185E-10     9.98699E-01     2.01719E+01
 1.50000E+00      5.09422E-10     9.99163E-01     2.01719E+01
 1.75000E+00      5.09668E-10     9.99647E-01     2.01719E+01
 1.90500E+00      5.09848E-10     1.00000E+00     2.01719E+01
       Average Deposit = 20.17194

WAFER 16      V(OUT) =  129238.8     CA(OUT) =   5.055207E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      5.05853E-10     9.97823E-01     2.00575E+01
 2.50000E-01      5.05863E-10     9.97844E-01     2.00575E+01
 5.00000E-01      5.05900E-10     9.97916E-01     2.00575E+01
 7.50000E-01      5.05976E-10     9.98067E-01     2.00575E+01
 1.00000E+00      5.06107E-10     9.98325E-01     2.00575E+01
 1.25000E+00      5.06296E-10     9.98699E-01     2.00575E+01
 1.50000E+00      5.06532E-10     9.99163E-01     2.00575E+01
 1.75000E+00      5.06777E-10     9.99647E-01     2.00575E+01
 1.90500E+00      5.06956E-10     1.00000E+00     2.00575E+01
       Average Deposit = 20.05752

WAFER 17      V(OUT) =  129215.9     CA(OUT) =   5.026515E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      5.02982E-10     9.97823E-01     1.99437E+01
 2.50000E-01      5.02992E-10     9.97843E-01     1.99437E+01
 5.00000E-01      5.03029E-10     9.97916E-01     1.99437E+01
 7.50000E-01      5.03105E-10     9.98067E-01     1.99437E+01
 1.00000E+00      5.03235E-10     9.98325E-01     1.99437E+01
 1.25000E+00      5.03423E-10     9.98699E-01     1.99437E+01
 1.50000E+00      5.03657E-10     9.99163E-01     1.99437E+01
 1.75000E+00      5.03901E-10     9.99647E-01     1.99437E+01
 1.90500E+00      5.04079E-10     1.00000E+00     1.99437E+01
       Average Deposit = 19.9437

WAFER 18      V(OUT) =  129193.1     CA(OUT) =   4.997975E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      5.00127E-10     9.97823E-01     1.98305E+01
 2.50000E-01      5.00137E-10     9.97844E-01     1.98305E+01
 5.00000E-01      5.00173E-10     9.97916E-01     1.98305E+01
 7.50000E-01      5.00249E-10     9.98067E-01     1.98305E+01
 1.00000E+00      5.00378E-10     9.98325E-01     1.98305E+01
 1.25000E+00      5.00566E-10     9.98699E-01     1.98305E+01
 1.50000E+00      5.00798E-10     9.99163E-01     1.98305E+01
 1.75000E+00      5.01041E-10     9.99647E-01     1.98305E+01
 1.90500E+00      5.01218E-10     1.00000E+00     1.98305E+01
       Average Deposit = 19.83048

WAFER 19      V(OUT) =  129170.4     CA(OUT) =   4.969588E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.97286E-10     9.97823E-01     1.97179E+01
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 2.50000E-01      4.97297E-10      9.97843E-01      1.97179E+01
 5.00000E-01      4.97333E-10      9.97916E-01      1.97179E+01
 7.50000E-01      4.97408E-10      9.98067E-01      1.97179E+01
 1.00000E+00      4.97537E-10      9.98325E-01      1.97179E+01
 1.25000E+00      4.97723E-10      9.98699E-01      1.97179E+01
 1.50000E+00      4.97954E-10      9.99163E-01      1.97179E+01
 1.75000E+00      4.98195E-10      9.99647E-01      1.97179E+01
 1.90500E+00      4.98371E-10      1.00000E+00      1.97179E+01
       Average Deposit = 19.71786

WAFER 20      V(OUT) =  129147.8      CA(OUT) =  4.941352E-10
R(cm)              CA(r,dell)          CA/CAI       G(angs./min)
 0.00000E+00      4.94462E-10      9.97823E-01      1.96059E+01
 2.50000E-01      4.94472E-10      9.97844E-01      1.96059E+01
 5.00000E-01      4.94508E-10      9.97916E-01      1.96059E+01
 7.50000E-01      4.94583E-10      9.98067E-01      1.96059E+01
 1.00000E+00      4.94710E-10      9.98325E-01      1.96059E+01
 1.25000E+00      4.94895E-10      9.98699E-01      1.96059E+01
 1.50000E+00      4.95126E-10      9.99163E-01      1.96059E+01
 1.75000E+00      4.95365E-10      9.99647E-01      1.96059E+01
 1.90500E+00      4.95540E-10      1.00000E+00      1.96059E+01
       Average Deposit = 19.60585

WAFER 21      V(OUT) =  129125.4      CA(OUT) =  4.913267E-10
R(cm)              CA(r,dell)          CA/CAI       G(angs./min)
 0.00000E+00      4.91652E-10      9.97823E-01      1.94944E+01
 2.50000E-01      4.91662E-10      9.97844E-01      1.94944E+01
 5.00000E-01      4.91697E-10      9.97916E-01      1.94944E+01
 7.50000E-01      4.91772E-10      9.98067E-01      1.94944E+01
 1.00000E+00      4.91899E-10      9.98325E-01      1.94944E+01
 1.25000E+00      4.92083E-10      9.98699E-01      1.94944E+01
 1.50000E+00      4.92312E-10      9.99163E-01      1.94944E+01
 1.75000E+00      4.92550E-10      9.99647E-01      1.94944E+01
 1.90500E+00      4.92724E-10      1.00000E+00      1.94944E+01
       Average Deposit = 19.49443

WAFER 22      V(OUT) =  129103.1      CA(OUT) =  4.885331E-10
R(cm)              CA(r,dell)          CA/CAI       G(angs./min)
 0.00000E+00      4.88857E-10      9.97823E-01      1.93836E+01
 2.50000E-01      4.88867E-10      9.97843E-01      1.93836E+01
 5.00000E-01      4.88902E-10      9.97916E-01      1.93836E+01
 7.50000E-01      4.88976E-10      9.98067E-01      1.93836E+01
 1.00000E+00      4.89103E-10      9.98325E-01      1.93836E+01
 1.25000E+00      4.89286E-10      9.98699E-01      1.93836E+01
 1.50000E+00      4.89513E-10      9.99163E-01      1.93836E+01
 1.75000E+00      4.89750E-10      9.99647E-01      1.93836E+01
 1.90500E+00      4.89923E-10      1.00000E+00      1.93836E+01
       Average Deposit = 19.38362

WAFER 23      V(OUT) =  129081     CA(OUT) =  4.857545E-10
R(cm)              CA(r,dell)          CA/CAI       G(angs./min)
 0.00000E+00      4.86077E-10      9.97823E-01      1.92734E+01
 2.50000E-01      4.86087E-10      9.97844E-01      1.92734E+01
 5.00000E-01      4.86122E-10      9.97916E-01      1.92734E+01
 7.50000E-01      4.86196E-10      9.98067E-01      1.92734E+01
 1.00000E+00      4.86321E-10      9.98325E-01      1.92734E+01
 1.25000E+00      4.86503E-10      9.98699E-01      1.92734E+01
 1.50000E+00      4.86730E-10      9.99163E-01      1.92734E+01
 1.75000E+00      4.86965E-10      9.99647E-01      1.92734E+01
 1.90500E+00      4.87137E-10      1.00000E+00      1.92734E+01
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      Average Deposit = 19.27339

WAFER 24      V(OUT) =  129058.9     CA(OUT) =  4.829908E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.83312E-10     9.97823E-01      1.91637E+01
 2.50000E-01     4.83322E-10     9.97843E-01      1.91637E+01
 5.00000E-01     4.83357E-10     9.97916E-01      1.91637E+01
 7.50000E-01     4.83430E-10     9.98067E-01      1.91637E+01
 1.00000E+00     4.83555E-10     9.98325E-01      1.91637E+01
 1.25000E+00     4.83736E-10     9.98699E-01      1.91637E+01
 1.50000E+00     4.83961E-10     9.99163E-01      1.91637E+01
 1.75000E+00     4.84195E-10     9.99647E-01      1.91637E+01
 1.90500E+00     4.84366E-10     1.00000E+00      1.91637E+01
      Average Deposit = 19.16375

WAFER 25      V(OUT) =  129037     CA(OUT) =  4.802418E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.80561E-10     9.97823E-01      1.90547E+01
 2.50000E-01     4.80571E-10     9.97843E-01      1.90547E+01
 5.00000E-01     4.80606E-10     9.97916E-01      1.90547E+01
 7.50000E-01     4.80679E-10     9.98067E-01      1.90547E+01
 1.00000E+00     4.80803E-10     9.98325E-01      1.90547E+01
 1.25000E+00     4.80983E-10     9.98699E-01      1.90547E+01
 1.50000E+00     4.81207E-10     9.99163E-01      1.90547E+01
 1.75000E+00     4.81440E-10     9.99647E-01      1.90547E+01
 1.90500E+00     4.81610E-10     1.00000E+00      1.90547E+01
      Average Deposit = 19.0547

WAFER 26      V(OUT) =  129015.2     CA(OUT) =  4.775076E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.77826E-10     9.97823E-01      1.89462E+01
 2.50000E-01     4.77836E-10     9.97844E-01      1.89462E+01
 5.00000E-01     4.77870E-10     9.97916E-01      1.89462E+01
 7.50000E-01     4.77943E-10     9.98067E-01      1.89462E+01
 1.00000E+00     4.78066E-10     9.98325E-01      1.89462E+01
 1.25000E+00     4.78245E-10     9.98699E-01      1.89462E+01
 1.50000E+00     4.78467E-10     9.99163E-01      1.89462E+01
 1.75000E+00     4.78699E-10     9.99647E-01      1.89462E+01
 1.90500E+00     4.78868E-10     1.00000E+00      1.89462E+01
      Average Deposit = 18.94623

WAFER 27      V(OUT) =  128993.6     CA(OUT) =  4.74788E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.75105E-10     9.97823E-01      1.88383E+01
 2.50000E-01     4.75115E-10     9.97844E-01      1.88383E+01
 5.00000E-01     4.75149E-10     9.97916E-01      1.88383E+01
 7.50000E-01     4.75221E-10     9.98067E-01      1.88383E+01
 1.00000E+00     4.75344E-10     9.98325E-01      1.88383E+01
 1.25000E+00     4.75522E-10     9.98699E-01      1.88383E+01
 1.50000E+00     4.75743E-10     9.99163E-01      1.88383E+01
 1.75000E+00     4.75973E-10     9.99647E-01      1.88383E+01
 1.90500E+00     4.76141E-10     1.00000E+00      1.88383E+01
      Average Deposit = 18.83834

WAFER 28      V(OUT) =  128972     CA(OUT) =  4.72083E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.72398E-10     9.97823E-01      1.87310E+01
 2.50000E-01     4.72408E-10     9.97844E-01      1.87310E+01
 5.00000E-01     4.72442E-10     9.97916E-01      1.87310E+01
 7.50000E-01     4.72514E-10     9.98067E-01      1.87310E+01
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 1.00000E+00      4.72636E-10      9.98325E-01      1.87310E+01
 1.25000E+00      4.72813E-10      9.98699E-01      1.87310E+01
 1.50000E+00      4.73033E-10      9.99163E-01      1.87310E+01
 1.75000E+00      4.73262E-10      9.99647E-01      1.87310E+01
 1.90500E+00      4.73429E-10      1.00000E+00      1.87310E+01
       Average Deposit = 18.73103

WAFER 29      V(OUT) =  128950.6      CA(OUT) =  4.693925E-10
R(cm)              CA(r,dell)          CA/CAI         G(angs./min)
 0.00000E+00      4.69707E-10      9.97823E-01      1.86243E+01
 2.50000E-01      4.69716E-10      9.97844E-01      1.86243E+01
 5.00000E-01      4.69750E-10      9.97916E-01      1.86243E+01
 7.50000E-01      4.69822E-10      9.98067E-01      1.86243E+01
 1.00000E+00      4.69943E-10      9.98325E-01      1.86243E+01
 1.25000E+00      4.70119E-10      9.98699E-01      1.86243E+01
 1.50000E+00      4.70337E-10      9.99163E-01      1.86243E+01
 1.75000E+00      4.70565E-10      9.99647E-01      1.86243E+01
 1.90500E+00      4.70731E-10      1.00000E+00      1.86243E+01
       Average Deposit = 18.62429

WAFER 30      V(OUT) =  128929.3      CA(OUT) =  4.667165E-10
R(cm)              CA(r,dell)          CA/CAI         G(angs./min)
 0.00000E+00      4.67029E-10      9.97823E-01      1.85181E+01
 2.50000E-01      4.67039E-10      9.97843E-01      1.85181E+01
 5.00000E-01      4.67073E-10      9.97916E-01      1.85181E+01
 7.50000E-01      4.67144E-10      9.98067E-01      1.85181E+01
 1.00000E+00      4.67264E-10      9.98325E-01      1.85181E+01
 1.25000E+00      4.67439E-10      9.98699E-01      1.85181E+01
 1.50000E+00      4.67656E-10      9.99163E-01      1.85181E+01
 1.75000E+00      4.67883E-10      9.99647E-01      1.85181E+01
 1.90500E+00      4.68048E-10      1.00000E+00      1.85181E+01
       Average Deposit = 18.51813

WAFER 31      V(OUT) =  128908.1      CA(OUT) =  4.640548E-10
R(cm)              CA(r,dell)          CA/CAI         G(angs./min)
 0.00000E+00      4.64366E-10      9.97823E-01      1.84125E+01
 2.50000E-01      4.64376E-10      9.97844E-01      1.84125E+01
 5.00000E-01      4.64409E-10      9.97916E-01      1.84125E+01
 7.50000E-01      4.64480E-10      9.98067E-01      1.84125E+01
 1.00000E+00      4.64600E-10      9.98325E-01      1.84125E+01
 1.25000E+00      4.64774E-10      9.98699E-01      1.84125E+01
 1.50000E+00      4.64990E-10      9.99163E-01      1.84125E+01
 1.75000E+00      4.65215E-10      9.99647E-01      1.84125E+01
 1.90500E+00      4.65379E-10      1.00000E+00      1.84125E+01
       Average Deposit = 18.41255

WAFER 32      V(OUT) =  128887.1      CA(OUT) =  4.614074E-10
R(cm)              CA(r,dell)          CA/CAI         G(angs./min)
 0.00000E+00      4.61717E-10      9.97823E-01      1.83075E+01
 2.50000E-01      4.61727E-10      9.97844E-01      1.83075E+01
 5.00000E-01      4.61760E-10      9.97916E-01      1.83075E+01
 7.50000E-01      4.61831E-10      9.98067E-01      1.83075E+01
 1.00000E+00      4.61950E-10      9.98325E-01      1.83075E+01
 1.25000E+00      4.62123E-10      9.98699E-01      1.83075E+01
 1.50000E+00      4.62338E-10      9.99163E-01      1.83075E+01
 1.75000E+00      4.62561E-10      9.99647E-01      1.83075E+01
 1.90500E+00      4.62725E-10      1.00000E+00      1.83075E+01
       Average Deposit = 18.30752

WAFER 33      V(OUT) =  128866.1      CA(OUT) =  4.587744E-10
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R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       4.59083E-10     9.97823E-01      1.82031E+01
 2.50000E-01       4.59092E-10     9.97844E-01      1.82031E+01
 5.00000E-01       4.59126E-10     9.97916E-01      1.82031E+01
 7.50000E-01       4.59195E-10     9.98067E-01      1.82031E+01
 1.00000E+00       4.59314E-10     9.98325E-01      1.82031E+01
 1.25000E+00       4.59486E-10     9.98699E-01      1.82031E+01
 1.50000E+00       4.59700E-10     9.99163E-01      1.82031E+01
 1.75000E+00       4.59922E-10     9.99647E-01      1.82031E+01
 1.90500E+00       4.60085E-10     1.00000E+00      1.82031E+01
       Average Deposit = 18.20306

WAFER 34      V(OUT) =  128845.3     CA(OUT) =  4.561555E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       4.56463E-10     9.97823E-01      1.80992E+01
 2.50000E-01       4.56472E-10     9.97844E-01      1.80992E+01
 5.00000E-01       4.56505E-10     9.97916E-01      1.80992E+01
 7.50000E-01       4.56575E-10     9.98067E-01      1.80992E+01
 1.00000E+00       4.56693E-10     9.98325E-01      1.80992E+01
 1.25000E+00       4.56863E-10     9.98699E-01      1.80992E+01
 1.50000E+00       4.57076E-10     9.99163E-01      1.80992E+01
 1.75000E+00       4.57297E-10     9.99647E-01      1.80992E+01
 1.90500E+00       4.57459E-10     1.00000E+00      1.80992E+01
       Average Deposit = 18.09917

WAFER 35      V(OUT) =  128824.6     CA(OUT) =  4.535507E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       4.53857E-10     9.97823E-01      1.79958E+01
 2.50000E-01       4.53866E-10     9.97844E-01      1.79958E+01
 5.00000E-01       4.53899E-10     9.97916E-01      1.79958E+01
 7.50000E-01       4.53968E-10     9.98067E-01      1.79958E+01
 1.00000E+00       4.54085E-10     9.98325E-01      1.79958E+01
 1.25000E+00       4.54255E-10     9.98699E-01      1.79958E+01
 1.50000E+00       4.54466E-10     9.99163E-01      1.79958E+01
 1.75000E+00       4.54686E-10     9.99647E-01      1.79958E+01
 1.90500E+00       4.54847E-10     1.00000E+00      1.79958E+01
       Average Deposit = 17.99583

WAFER 36      V(OUT) =  128806.7     CA(OUT) =  4.513005E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       4.51436E-10     9.97823E-01      1.49474E+01
 2.50000E-01       4.51445E-10     9.97844E-01      1.49477E+01
 5.00000E-01       4.51478E-10     9.97916E-01      1.49488E+01
 7.50000E-01       4.51546E-10     9.98067E-01      1.49511E+01
 1.00000E+00       4.51663E-10     9.98325E-01      1.49549E+01
 1.25000E+00       4.51832E-10     9.98699E-01      1.49605E+01
 1.50000E+00       4.52042E-10     9.99163E-01      1.49675E+01
 1.75000E+00       4.52261E-10     9.99647E-01      1.49747E+01
 1.90500E+00       4.52421E-10     1.00000E+00      1.49800E+01
       Average Deposit = 14.95866

WAFER 37      V(OUT) =  128789     CA(OUT) =  4.49061E-10
R(cm)               CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00       4.49196E-10     9.97823E-01      1.48732E+01
 2.50000E-01       4.49205E-10     9.97844E-01      1.48736E+01
 5.00000E-01       4.49238E-10     9.97916E-01      1.48746E+01
 7.50000E-01       4.49306E-10     9.98067E-01      1.48769E+01
 1.00000E+00       4.49422E-10     9.98325E-01      1.48807E+01
 1.25000E+00       4.49590E-10     9.98699E-01      1.48863E+01
 1.50000E+00       4.49800E-10     9.99163E-01      1.48932E+01
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 1.75000E+00      4.50017E-10     9.99647E-01      1.49004E+01
 1.90500E+00      4.50176E-10     1.00000E+00      1.49057E+01
      Average Deposit = 14.88445

WAFER 38      V(OUT) =  128771.3     CA(OUT) =   4.468318E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      4.46967E-10     9.97823E-01      1.47994E+01
 2.50000E-01      4.46976E-10     9.97844E-01      1.47997E+01
 5.00000E-01      4.47008E-10     9.97916E-01      1.48008E+01
 7.50000E-01      4.47076E-10     9.98067E-01      1.48030E+01
 1.00000E+00      4.47192E-10     9.98325E-01      1.48069E+01
 1.25000E+00      4.47359E-10     9.98699E-01      1.48124E+01
 1.50000E+00      4.47567E-10     9.99163E-01      1.48193E+01
 1.75000E+00      4.47784E-10     9.99647E-01      1.48265E+01
 1.90500E+00      4.47942E-10     1.00000E+00      1.48317E+01
      Average Deposit = 14.81058

WAFER 39      V(OUT) =  128753.7     CA(OUT) =   4.446132E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      4.44748E-10     9.97823E-01      1.47260E+01
 2.50000E-01      4.44757E-10     9.97844E-01      1.47263E+01
 5.00000E-01      4.44789E-10     9.97916E-01      1.47273E+01
 7.50000E-01      4.44857E-10     9.98067E-01      1.47296E+01
 1.00000E+00      4.44972E-10     9.98325E-01      1.47334E+01
 1.25000E+00      4.45138E-10     9.98699E-01      1.47389E+01
 1.50000E+00      4.45345E-10     9.99163E-01      1.47457E+01
 1.75000E+00      4.45561E-10     9.99647E-01      1.47529E+01
 1.90500E+00      4.45718E-10     1.00000E+00      1.47581E+01
      Average Deposit = 14.73705

WAFER 40      V(OUT) =  128736.1     CA(OUT) =   4.42405E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      4.42539E-10     9.97823E-01      1.46528E+01
 2.50000E-01      4.42548E-10     9.97843E-01      1.46531E+01
 5.00000E-01      4.42580E-10     9.97916E-01      1.46542E+01
 7.50000E-01      4.42648E-10     9.98067E-01      1.46564E+01
 1.00000E+00      4.42762E-10     9.98325E-01      1.46602E+01
 1.25000E+00      4.42928E-10     9.98699E-01      1.46657E+01
 1.50000E+00      4.43133E-10     9.99163E-01      1.46725E+01
 1.75000E+00      4.43348E-10     9.99647E-01      1.46796E+01
 1.90500E+00      4.43505E-10     1.00000E+00      1.46848E+01
      Average Deposit = 14.66387

WAFER 41      V(OUT) =  128718.7     CA(OUT) =   4.402071E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      4.40341E-10     9.97823E-01      1.45800E+01
 2.50000E-01      4.40350E-10     9.97844E-01      1.45803E+01
 5.00000E-01      4.40382E-10     9.97916E-01      1.45814E+01
 7.50000E-01      4.40449E-10     9.98067E-01      1.45836E+01
 1.00000E+00      4.40563E-10     9.98325E-01      1.45874E+01
 1.25000E+00      4.40727E-10     9.98699E-01      1.45928E+01
 1.50000E+00      4.40932E-10     9.99163E-01      1.45996E+01
 1.75000E+00      4.41146E-10     9.99647E-01      1.46067E+01
 1.90500E+00      4.41302E-10     1.00000E+00      1.46118E+01
      Average Deposit = 14.59102

WAFER 42      V(OUT) =  128701.4     CA(OUT) =   4.380195E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      4.38153E-10     9.97823E-01      1.45076E+01
 2.50000E-01      4.38162E-10     9.97844E-01      1.45079E+01
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 5.00000E-01      4.38194E-10      9.97916E-01      1.45089E+01
 7.50000E-01      4.38260E-10      9.98067E-01      1.45111E+01
 1.00000E+00      4.38374E-10      9.98325E-01      1.45149E+01
 1.25000E+00      4.38538E-10      9.98699E-01      1.45203E+01
 1.50000E+00      4.38741E-10      9.99163E-01      1.45271E+01
 1.75000E+00      4.38954E-10      9.99647E-01      1.45341E+01
 1.90500E+00      4.39109E-10      1.00000E+00      1.45392E+01
       Average Deposit = 14.51853

WAFER 43      V(OUT) =  128684.1      CA(OUT) =  4.358423E-10
R(cm)             CA(r,dell)       CA/CAI          G(angs./min)
 0.00000E+00      4.35975E-10      9.97823E-01      1.44355E+01
 2.50000E-01      4.35984E-10      9.97843E-01      1.44358E+01
 5.00000E-01      4.36016E-10      9.97916E-01      1.44368E+01
 7.50000E-01      4.36082E-10      9.98067E-01      1.44390E+01
 1.00000E+00      4.36195E-10      9.98325E-01      1.44428E+01
 1.25000E+00      4.36358E-10      9.98699E-01      1.44482E+01
 1.50000E+00      4.36561E-10      9.99163E-01      1.44549E+01
 1.75000E+00      4.36772E-10      9.99647E-01      1.44619E+01
 1.90500E+00      4.36927E-10      1.00000E+00      1.44670E+01
       Average Deposit = 14.44637

WAFER 44      V(OUT) =  128666.9      CA(OUT) =  4.336753E-10
R(cm)             CA(r,dell)       CA/CAI          G(angs./min)
 0.00000E+00      4.33808E-10      9.97823E-01      1.43637E+01
 2.50000E-01      4.33817E-10      9.97844E-01      1.43640E+01
 5.00000E-01      4.33848E-10      9.97916E-01      1.43651E+01
 7.50000E-01      4.33914E-10      9.98067E-01      1.43672E+01
 1.00000E+00      4.34026E-10      9.98325E-01      1.43710E+01
 1.25000E+00      4.34189E-10      9.98699E-01      1.43763E+01
 1.50000E+00      4.34391E-10      9.99163E-01      1.43830E+01
 1.75000E+00      4.34601E-10      9.99647E-01      1.43900E+01
 1.90500E+00      4.34754E-10      1.00000E+00      1.43951E+01
       Average Deposit = 14.37455

WAFER 45      V(OUT) =  128649.8      CA(OUT) =  4.315184E-10
R(cm)             CA(r,dell)       CA/CAI          G(angs./min)
 0.00000E+00      4.31651E-10      9.97823E-01      1.42923E+01
 2.50000E-01      4.31660E-10      9.97844E-01      1.42926E+01
 5.00000E-01      4.31691E-10      9.97916E-01      1.42936E+01
 7.50000E-01      4.31756E-10      9.98067E-01      1.42958E+01
 1.00000E+00      4.31868E-10      9.98325E-01      1.42995E+01
 1.25000E+00      4.32030E-10      9.98699E-01      1.43048E+01
 1.50000E+00      4.32230E-10      9.99163E-01      1.43115E+01
 1.75000E+00      4.32440E-10      9.99647E-01      1.43184E+01
 1.90500E+00      4.32592E-10      1.00000E+00      1.43235E+01
       Average Deposit = 14.30307

WAFER 46      V(OUT) =  128632.8      CA(OUT) =  4.293718E-10
R(cm)             CA(r,dell)       CA/CAI          G(angs./min)
 0.00000E+00      4.29504E-10      9.97823E-01      1.42212E+01
 2.50000E-01      4.29513E-10      9.97843E-01      1.42215E+01
 5.00000E-01      4.29544E-10      9.97916E-01      1.42225E+01
 7.50000E-01      4.29609E-10      9.98067E-01      1.42247E+01
 1.00000E+00      4.29720E-10      9.98325E-01      1.42284E+01
 1.25000E+00      4.29881E-10      9.98699E-01      1.42337E+01
 1.50000E+00      4.30081E-10      9.99163E-01      1.42403E+01
 1.75000E+00      4.30289E-10      9.99647E-01      1.42472E+01
 1.90500E+00      4.30441E-10      1.00000E+00      1.42522E+01
       Average Deposit = 14.23193
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WAFER 47      V(OUT) =  128615.9     CA(OUT) =  4.272353E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.27367E-10     9.97823E-01      1.41505E+01
 2.50000E-01      4.27376E-10     9.97844E-01      1.41507E+01
 5.00000E-01      4.27407E-10     9.97916E-01      1.41518E+01
 7.50000E-01      4.27472E-10     9.98067E-01      1.41539E+01
 1.00000E+00      4.27582E-10     9.98325E-01      1.41576E+01
 1.25000E+00      4.27742E-10     9.98699E-01      1.41629E+01
 1.50000E+00      4.27941E-10     9.99163E-01      1.41695E+01
 1.75000E+00      4.28148E-10     9.99647E-01      1.41763E+01
 1.90500E+00      4.28299E-10     1.00000E+00      1.41813E+01
        Average Deposit = 14.16112

WAFER 48      V(OUT) =  128599.1     CA(OUT) =  4.251088E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.25240E-10     9.97823E-01      1.40800E+01
 2.50000E-01      4.25249E-10     9.97843E-01      1.40803E+01
 5.00000E-01      4.25280E-10     9.97916E-01      1.40813E+01
 7.50000E-01      4.25344E-10     9.98067E-01      1.40835E+01
 1.00000E+00      4.25454E-10     9.98325E-01      1.40871E+01
 1.25000E+00      4.25613E-10     9.98699E-01      1.40924E+01
 1.50000E+00      4.25811E-10     9.99163E-01      1.40989E+01
 1.75000E+00      4.26017E-10     9.99647E-01      1.41058E+01
 1.90500E+00      4.26168E-10     1.00000E+00      1.41108E+01
        Average Deposit = 14.09064

WAFER 49      V(OUT) =  128582.3     CA(OUT) =  4.229924E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.23123E-10     9.97823E-01      1.40099E+01
 2.50000E-01      4.23132E-10     9.97844E-01      1.40102E+01
 5.00000E-01      4.23163E-10     9.97916E-01      1.40113E+01
 7.50000E-01      4.23227E-10     9.98067E-01      1.40134E+01
 1.00000E+00      4.23336E-10     9.98325E-01      1.40170E+01
 1.25000E+00      4.23495E-10     9.98699E-01      1.40222E+01
 1.50000E+00      4.23691E-10     9.99163E-01      1.40288E+01
 1.75000E+00      4.23896E-10     9.99647E-01      1.40356E+01
 1.90500E+00      4.24046E-10     1.00000E+00      1.40405E+01
        Average Deposit = 14.0205

WAFER 50      V(OUT) =  128527.5     CA(OUT) =  4.160593E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.18603E-10     9.97823E-01      1.38603E+01
 2.50000E-01      4.18612E-10     9.97844E-01      1.38606E+01
 5.00000E-01      4.18642E-10     9.97916E-01      1.38616E+01
 7.50000E-01      4.18706E-10     9.98067E-01      1.38637E+01
 1.00000E+00      4.18814E-10     9.98325E-01      1.38673E+01
 1.25000E+00      4.18971E-10     9.98699E-01      1.38725E+01
 1.50000E+00      4.19166E-10     9.99163E-01      1.38789E+01
 1.75000E+00      4.19368E-10     9.99647E-01      1.38856E+01
 1.90500E+00      4.19517E-10     1.00000E+00      1.38905E+01
        Average Deposit = 13.87074

WAFER 51      V(OUT) =  128473.4     CA(OUT) =  4.092255E-10
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      4.11730E-10     9.97823E-01      1.36327E+01
 2.50000E-01      4.11739E-10     9.97844E-01      1.36330E+01
 5.00000E-01      4.11769E-10     9.97916E-01      1.36340E+01
 7.50000E-01      4.11831E-10     9.98067E-01      1.36361E+01
 1.00000E+00      4.11937E-10     9.98325E-01      1.36396E+01
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 1.25000E+00     4.12092E-10     9.98699E-01      1.36447E+01
 1.50000E+00     4.12283E-10     9.99163E-01     1.36510E+01
 1.75000E+00     4.12483E-10     9.99647E-01      1.36576E+01
 1.90500E+00     4.12628E-10     1.00000E+00      1.36625E+01
       Average Deposit = 13.64299

WAFER 52      V(OUT) =  128420.2      CA(OUT) =   4.024898E-10
R(cm)              CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     4.04960E-10     9.97823E-01      1.34086E+01
 2.50000E-01     4.04969E-10     9.97843E-01      1.34088E+01
 5.00000E-01     4.04998E-10     9.97916E-01      1.34098E+01
 7.50000E-01     4.05060E-10     9.98067E-01      1.34118E+01
 1.00000E+00     4.05164E-10     9.98325E-01      1.34153E+01
 1.25000E+00     4.05316E-10     9.98699E-01      1.34203E+01
 1.50000E+00     4.05504E-10     9.99163E-01      1.34266E+01
 1.75000E+00     4.05701E-10     9.99647E-01      1.34331E+01
 1.90500E+00     4.05844E-10     1.00000E+00      1.34378E+01
       Average Deposit = 13.41867

WAFER 53      V(OUT) =  128367.9      CA(OUT) =   3.958513E-10
R(cm)              CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     3.98288E-10     9.97823E-01      1.31876E+01
 2.50000E-01     3.98296E-10     9.97844E-01      1.31879E+01
 5.00000E-01     3.98325E-10     9.97916E-01      1.31889E+01
 7.50000E-01     3.98386E-10     9.98067E-01      1.31909E+01
 1.00000E+00     3.98489E-10     9.98325E-01      1.31943E+01
 1.25000E+00     3.98638E-10     9.98699E-01      1.31992E+01
 1.50000E+00     3.98823E-10     9.99163E-01      1.32053E+01
 1.75000E+00     3.99016E-10     9.99647E-01      1.32117E+01
 1.90500E+00     3.99157E-10     1.00000E+00      1.32164E+01
       Average Deposit = 13.19757

WAFER 54      V(OUT) =  128316.3      CA(OUT) =   3.893089E-10
R(cm)              CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     3.91712E-10     9.97823E-01      1.29699E+01
 2.50000E-01     3.91720E-10     9.97844E-01      1.29702E+01
 5.00000E-01     3.91749E-10     9.97916E-01      1.29711E+01
 7.50000E-01     3.91808E-10     9.98067E-01      1.29731E+01
 1.00000E+00     3.91909E-10     9.98325E-01      1.29764E+01
 1.25000E+00     3.92056E-10     9.98699E-01      1.29813E+01
 1.50000E+00     3.92238E-10     9.99163E-01      1.29873E+01
 1.75000E+00     3.92428E-10     9.99647E-01      1.29936E+01
 1.90500E+00     3.92567E-10     1.00000E+00      1.29982E+01
       Average Deposit = 12.97967

WAFER 55      V(OUT) =  128265.5      CA(OUT) =   3.828618E-10
R(cm)              CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     3.85232E-10     9.97823E-01      1.27553E+01
 2.50000E-01     3.85240E-10     9.97844E-01      1.27556E+01
 5.00000E-01     3.85268E-10     9.97916E-01      1.27565E+01
 7.50000E-01     3.85326E-10     9.98067E-01      1.27585E+01
 1.00000E+00     3.85426E-10     9.98325E-01      1.27618E+01
 1.25000E+00     3.85570E-10     9.98699E-01      1.27665E+01
 1.50000E+00     3.85749E-10     9.99163E-01      1.27725E+01
 1.75000E+00     3.85936E-10     9.99647E-01      1.27786E+01
 1.90500E+00     3.86072E-10     1.00000E+00      1.27832E+01
       Average Deposit = 12.76494

WAFER 56      V(OUT) =  128215.5      CA(OUT) =   3.765088E-10
R(cm)              CA(r,dell)         CA/CAI       G(angs./min)
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 0.00000E+00       3.78846E-10       9.97823E-01       1.25439E+01
 2.50000E-01       3.78854E-10       9.97844E-01       1.25441E+01
 5.00000E-01       3.78881E-10       9.97916E-01       1.25451E+01
 7.50000E-01       3.78939E-10       9.98067E-01       1.25470E+01
 1.00000E+00       3.79036E-10       9.98325E-01       1.25502E+01
 1.25000E+00       3.79178E-10       9.98699E-01       1.25549E+01
 1.50000E+00       3.79355E-10       9.99163E-01       1.25607E+01
 1.75000E+00       3.79538E-10       9.99647E-01       1.25668E+01
 1.90500E+00       3.79672E-10       1.00000E+00       1.25713E+01
        Average Deposit = 12.55334

WAFER 57      V(OUT) =  128166.2      CA(OUT) =  3.702489E-10
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00       3.72553E-10       9.97823E-01       1.23355E+01
 2.50000E-01       3.72561E-10       9.97844E-01       1.23358E+01
 5.00000E-01       3.72588E-10       9.97916E-01       1.23367E+01
 7.50000E-01       3.72644E-10       9.98067E-01       1.23386E+01
 1.00000E+00       3.72741E-10       9.98325E-01       1.23417E+01
 1.25000E+00       3.72880E-10       9.98699E-01       1.23464E+01
 1.50000E+00       3.73054E-10       9.99163E-01       1.23521E+01
 1.75000E+00       3.73234E-10       9.99647E-01       1.23581E+01
 1.90500E+00       3.73366E-10       1.00000E+00       1.23624E+01
        Average Deposit = 12.34483

WAFER 58      V(OUT) =  128117.7      CA(OUT) =  3.640813E-10
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00       3.66353E-10       9.97823E-01       1.21302E+01
 2.50000E-01       3.66361E-10       9.97844E-01       1.21305E+01
 5.00000E-01       3.66387E-10       9.97916E-01       1.21314E+01
 7.50000E-01       3.66443E-10       9.98067E-01       1.21332E+01
 1.00000E+00       3.66538E-10       9.98325E-01       1.21364E+01
 1.25000E+00       3.66675E-10       9.98699E-01       1.21409E+01
 1.50000E+00       3.66845E-10       9.99163E-01       1.21465E+01
 1.75000E+00       3.67023E-10       9.99647E-01       1.21524E+01
 1.90500E+00       3.67152E-10       1.00000E+00       1.21567E+01
        Average Deposit = 12.13939

WAFER 59      V(OUT) =  128070      CA(OUT) =  3.580048E-10
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00       3.60245E-10       9.97823E-01       1.19280E+01
 2.50000E-01       3.60252E-10       9.97844E-01       1.19282E+01
 5.00000E-01       3.60278E-10       9.97916E-01       1.19291E+01
 7.50000E-01       3.60333E-10       9.98067E-01       1.19309E+01
 1.00000E+00       3.60426E-10       9.98325E-01       1.19340E+01
 1.25000E+00       3.60561E-10       9.98699E-01       1.19385E+01
 1.50000E+00       3.60729E-10       9.99163E-01       1.19440E+01
 1.75000E+00       3.60903E-10       9.99647E-01       1.19498E+01
 1.90500E+00       3.61031E-10       1.00000E+00       1.19540E+01
        Average Deposit = 11.93698

WAFER 60      V(OUT) =  128023      CA(OUT) =  3.520185E-10
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00       3.54227E-10       9.97823E-01       1.17287E+01
 2.50000E-01       3.54234E-10       9.97844E-01       1.17290E+01
 5.00000E-01       3.54260E-10       9.97916E-01       1.17298E+01
 7.50000E-01       3.54313E-10       9.98067E-01       1.17316E+01
 1.00000E+00       3.54405E-10       9.98325E-01       1.17346E+01
 1.25000E+00       3.54537E-10       9.98699E-01       1.17390E+01
 1.50000E+00       3.54702E-10       9.99163E-01       1.17445E+01
 1.75000E+00       3.54874E-10       9.99647E-01       1.17502E+01
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 1.90500E+00     3.54999E-10    1.00000E+00     1.17543E+01
      Average Deposit = 11.73756

WAFER 61     V(OUT) =  127976.8     CA(OUT) =   3.461214E-10
R(cm)            CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00     3.48298E-10    9.97823E-01     1.15324E+01
 2.50000E-01     3.48305E-10    9.97844E-01     1.15327E+01
 5.00000E-01     3.48330E-10    9.97916E-01     1.15335E+01
 7.50000E-01     3.48383E-10    9.98067E-01     1.15352E+01
 1.00000E+00     3.48473E-10    9.98325E-01     1.15382E+01
 1.25000E+00     3.48604E-10    9.98699E-01     1.15425E+01
 1.50000E+00     3.48766E-10    9.99163E-01     1.15479E+01
 1.75000E+00     3.48935E-10    9.99647E-01     1.15535E+01
 1.90500E+00     3.49058E-10    1.00000E+00     1.15576E+01
      Average Deposit = 11.54111

WAFER 62     V(OUT) =  127931.3     CA(OUT) =   3.403125E-10
R(cm)            CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00     3.42458E-10    9.97823E-01     1.13391E+01
 2.50000E-01     3.42465E-10    9.97844E-01     1.13393E+01
 5.00000E-01     3.42490E-10    9.97916E-01     1.13401E+01
 7.50000E-01     3.42542E-10    9.98067E-01     1.13418E+01
 1.00000E+00     3.42630E-10    9.98325E-01     1.13448E+01
 1.25000E+00     3.42758E-10    9.98699E-01     1.13490E+01
 1.50000E+00     3.42918E-10    9.99163E-01     1.13543E+01
 1.75000E+00     3.43084E-10    9.99647E-01     1.13598E+01
 1.90500E+00     3.43205E-10    1.00000E+00     1.13638E+01
      Average Deposit = 11.3476

WAFER 63     V(OUT) =  127886.4     CA(OUT) =   3.345908E-10
R(cm)            CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00     3.36705E-10    9.97823E-01     1.11486E+01
 2.50000E-01     3.36712E-10    9.97844E-01     1.11488E+01
 5.00000E-01     3.36737E-10    9.97916E-01     1.11496E+01
 7.50000E-01     3.36788E-10    9.98067E-01     1.11513E+01
 1.00000E+00     3.36875E-10    9.98325E-01     1.11542E+01
 1.25000E+00     3.37001E-10    9.98699E-01     1.11584E+01
 1.50000E+00     3.37158E-10    9.99163E-01     1.11636E+01
 1.75000E+00     3.37321E-10    9.99647E-01     1.11690E+01
 1.90500E+00     3.37440E-10    1.00000E+00     1.11729E+01
      Average Deposit = 11.15698

WAFER 64     V(OUT) =  127842.3     CA(OUT) =   3.289554E-10
R(cm)            CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00     3.31039E-10    9.97823E-01     1.09610E+01
 2.50000E-01     3.31046E-10    9.97843E-01     1.09612E+01
 5.00000E-01     3.31070E-10    9.97916E-01     1.09620E+01
 7.50000E-01     3.31120E-10    9.98067E-01     1.09637E+01
 1.00000E+00     3.31206E-10    9.98325E-01     1.09665E+01
 1.25000E+00     3.31330E-10    9.98699E-01     1.09706E+01
 1.50000E+00     3.31484E-10    9.99163E-01     1.09757E+01
 1.75000E+00     3.31644E-10    9.99647E-01     1.09810E+01
 1.90500E+00     3.31762E-10    1.00000E+00     1.09849E+01
      Average Deposit = 10.96923

WAFER 65     V(OUT) =  127798.9     CA(OUT) =   3.234051E-10
R(cm)            CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00     3.25459E-10    9.97823E-01     1.07762E+01
 2.50000E-01     3.25465E-10    9.97844E-01     1.07764E+01
 5.00000E-01     3.25489E-10    9.97916E-01     1.07772E+01
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 7.50000E-01       3.25538E-10     9.98067E-01       1.07788E+01
 1.00000E+00       3.25623E-10     9.98325E-01       1.07816E+01
 1.25000E+00       3.25744E-10     9.98699E-01       1.07857E+01
 1.50000E+00       3.25896E-10     9.99163E-01       1.07907E+01
 1.75000E+00       3.26054E-10     9.99647E-01       1.07959E+01
 1.90500E+00       3.26169E-10     1.00000E+00       1.07997E+01
        Average Deposit = 10.78432

WAFER 66       V(OUT) =  127756.2      CA(OUT) =  3.17939E-10
R(cm)                 CA(r,dell)       CA/CAI         G(angs./min)
 0.00000E+00       3.19963E-10     9.97823E-01       1.05942E+01
 2.50000E-01       3.19969E-10     9.97844E-01       1.05944E+01
 5.00000E-01       3.19993E-10     9.97916E-01       1.05952E+01
 7.50000E-01       3.20041E-10     9.98067E-01       1.05968E+01
 1.00000E+00       3.20124E-10     9.98325E-01       1.05996E+01
 1.25000E+00       3.20244E-10     9.98699E-01       1.06035E+01
 1.50000E+00       3.20393E-10     9.99163E-01       1.06085E+01
 1.75000E+00       3.20548E-10     9.99647E-01       1.06136E+01
 1.90500E+00       3.20661E-10     1.00000E+00       1.06173E+01
        Average Deposit = 10.6022

WAFER 67       V(OUT) =  127714.2      CA(OUT) =  3.125562E-10
R(cm)                 CA(r,dell)       CA/CAI         G(angs./min)
 0.00000E+00       3.14550E-10     9.97823E-01       1.04150E+01
 2.50000E-01       3.14557E-10     9.97843E-01       1.04152E+01
 5.00000E-01       3.14580E-10     9.97916E-01       1.04160E+01
 7.50000E-01       3.14627E-10     9.98067E-01       1.04176E+01
 1.00000E+00       3.14709E-10     9.98325E-01       1.04203E+01
 1.25000E+00       3.14826E-10     9.98699E-01       1.04241E+01
 1.50000E+00       3.14973E-10     9.99163E-01       1.04290E+01
 1.75000E+00       3.15125E-10     9.99647E-01       1.04340E+01
 1.90500E+00       3.15237E-10     1.00000E+00       1.04377E+01
        Average Deposit = 10.42286

WAFER 68       V(OUT) =  127672.8      CA(OUT) =  3.072557E-10
R(cm)                 CA(r,dell)       CA/CAI         G(angs./min)
 0.00000E+00       3.09220E-10     9.97823E-01       1.02385E+01
 2.50000E-01       3.09227E-10     9.97843E-01       1.02387E+01
 5.00000E-01       3.09249E-10     9.97916E-01       1.02395E+01
 7.50000E-01       3.09296E-10     9.98067E-01       1.02410E+01
 1.00000E+00       3.09376E-10     9.98325E-01       1.02437E+01
 1.25000E+00       3.09492E-10     9.98699E-01       1.02475E+01
 1.50000E+00       3.09636E-10     9.99163E-01       1.02523E+01
 1.75000E+00       3.09786E-10     9.99647E-01       1.02572E+01
 1.90500E+00       3.09895E-10     1.00000E+00       1.02609E+01
        Average Deposit = 10.24625

WAFER 69       V(OUT) =  127632.1      CA(OUT) =  3.020364E-10
R(cm)                 CA(r,dell)       CA/CAI         G(angs./min)
 0.00000E+00       3.03972E-10     9.97823E-01       1.00648E+01
 2.50000E-01       3.03978E-10     9.97844E-01       1.00650E+01
 5.00000E-01       3.04000E-10     9.97916E-01       1.00657E+01
 7.50000E-01       3.04047E-10     9.98067E-01       1.00672E+01
 1.00000E+00       3.04125E-10     9.98325E-01       1.00698E+01
 1.25000E+00       3.04239E-10     9.98699E-01       1.00736E+01
 1.50000E+00       3.04380E-10     9.99163E-01       1.00783E+01
 1.75000E+00       3.04528E-10     9.99647E-01       1.00832E+01
 1.90500E+00       3.04635E-10     1.00000E+00       1.00867E+01
        Average Deposit = 10.07234
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WAFER 70      V(OUT) =  127592      CA(OUT) =  2.968975E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00        2.98804E-10     9.97823E-01      9.89366E+00
 2.50000E-01        2.98811E-10     9.97843E-01      9.89386E+00
 5.00000E-01        2.98832E-10     9.97916E-01      9.89458E+00
 7.50000E-01        2.98878E-10     9.98067E-01      9.89608E+00
 1.00000E+00        2.98955E-10     9.98325E-01      9.89863E+00
 1.25000E+00        2.99067E-10     9.98699E-01      9.90234E+00
 1.50000E+00        2.9920E-10     9.99163E-01     9.90694E+00
 1.75000E+00        2.99351E-10     9.99647E-01      9.91173E+00
 1.90500E+00        2.99456E-10     1.00000E+00      9.91524E+00
       Average Deposit = 9.901109

WAFER 71      V(OUT) =  127552.6     CA(OUT) =   2.918378E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00        2.93716E-10     9.97823E-01      9.72519E+00
 2.50000E-01        2.93722E-10     9.97844E-01      9.72539E+00
 5.00000E-01        2.93744E-10     9.97916E-01      9.72609E+00
 7.50000E-01        2.93788E-10     9.98067E-01      9.72757E+00
 1.00000E+00        2.93864E-10     9.98325E-01      9.73008E+00
 1.25000E+00        2.93974E-10     9.98699E-01      9.73372E+00
 1.50000E+00        2.94111E-10     9.99163E-01      9.73825E+00
 1.75000E+00        2.94253E-10     9.99647E-01      9.74296E+00
 1.90500E+00        2.94357E-10     1.00000E+00      9.74640E+00
       Average Deposit = 9.732512

WAFER 72      V(OUT) =  127513.8     CA(OUT) =   2.868565E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00        2.88707E-10     9.97823E-01      9.55932E+00
 2.50000E-01        2.88713E-10     9.97844E-01      9.55952E+00
 5.00000E-01        2.88734E-10     9.97916E-01      9.56021E+00
 7.50000E-01        2.88778E-10     9.98067E-01      9.56166E+00
 1.00000E+00        2.88852E-10     9.98325E-01      9.56413E+00
 1.25000E+00        2.88960E-10     9.98699E-01      9.56771E+00
 1.50000E+00        2.89095E-10     9.99163E-01      9.57216E+00
 1.75000E+00        2.89235E-10     9.99647E-01      9.57679E+00
 1.90500E+00        2.89337E-10     1.00000E+00      9.58018E+00
       Average Deposit = 9.566522

WAFER 73      V(OUT) =  127475.7     CA(OUT) =   2.819526E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00        2.83775E-10     9.97823E-01      9.39603E+00
 2.50000E-01        2.83781E-10     9.97844E-01      9.39622E+00
 5.00000E-01        2.83802E-10     9.97916E-01      9.39690E+00
 7.50000E-01        2.83845E-10     9.98067E-01      9.39833E+00
 1.00000E+00        2.83918E-10     9.98325E-01      9.40076E+00
 1.25000E+00        2.84024E-10     9.98699E-01      9.40427E+00
 1.50000E+00        2.84156E-10     9.99163E-01      9.40865E+00
 1.75000E+00        2.84294E-10     9.99647E-01      9.41320E+00
 1.90500E+00        2.84394E-10     1.00000E+00      9.41653E+00
       Average Deposit = 9.403107

WAFER 74      V(OUT) =  127438.1     CA(OUT) =   2.771252E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00        2.78920E-10     9.97823E-01      9.23528E+00
 2.50000E-01        2.78926E-10     9.97844E-01      9.23547E+00
 5.00000E-01        2.78946E-10     9.97916E-01      9.23614E+00
 7.50000E-01        2.78989E-10     9.98067E-01      9.23754E+00
 1.00000E+00        2.79061E-10     9.98325E-01      9.23993E+00
 1.25000E+00        2.79165E-10     9.98699E-01      9.24338E+00
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 1.50000E+00      2.79295E-10     9.99163E-01      9.24768E+00
 1.75000E+00      2.79430E-10     9.99647E-01      9.25216E+00
 1.90500E+00      2.79529E-10     1.00000E+00      9.25543E+00
      Average Deposit = 9.242235

WAFER 75       V(OUT) =  127401.2    CA(OUT) =  2.723732E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.74141E-10     9.97823E-01      9.07704E+00
 2.50000E-01      2.74147E-10     9.97844E-01      9.07722E+00
 5.00000E-01      2.74167E-10     9.97916E-01      9.07788E+00
 7.50000E-01      2.74208E-10     9.98067E-01      9.07926E+00
 1.00000E+00      2.74279E-10     9.98325E-01      9.08161E+00
 1.25000E+00      2.74382E-10     9.98699E-01      9.08500E+00
 1.50000E+00      2.74509E-10     9.99163E-01      9.08923E+00
 1.75000E+00      2.74642E-10     9.99647E-01      9.09362E+00
 1.90500E+00      2.74739E-10     1.00000E+00      9.09684E+00
      Average Deposit = 9.083875

WAFER 76       V(OUT) =  127364.9    CA(OUT) =  2.676957E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.69437E-10     9.97823E-01      8.92127E+00
 2.50000E-01      2.69442E-10     9.97844E-01      8.92145E+00
 5.00000E-01      2.69462E-10     9.97916E-01      8.92210E+00
 7.50000E-01      2.69503E-10     9.98067E-01      8.92346E+00
 1.00000E+00      2.69573E-10     9.98325E-01      8.92576E+00
 1.25000E+00      2.69673E-10     9.98699E-01      8.92910E+00
 1.50000E+00      2.69799E-10     9.99163E-01      8.93325E+00
 1.75000E+00      2.69929E-10     9.99647E-01      8.93758E+00
 1.90500E+00      2.70025E-10     1.00000E+00      8.94074E+00
      Average Deposit = 8.927994

WAFER 77       V(OUT) =  127329.1    CA(OUT) =  2.630918E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.64807E-10     9.97823E-01      8.76796E+00
 2.50000E-01      2.64812E-10     9.97844E-01      8.76813E+00
 5.00000E-01      2.64831E-10     9.97916E-01      8.76877E+00
 7.50000E-01      2.64871E-10     9.98067E-01      8.77010E+00
 1.00000E+00      2.64940E-10     9.98325E-01      8.77237E+00
 1.25000E+00      2.65039E-10     9.98699E-01      8.77565E+00
 1.50000E+00      2.65162E-10     9.99163E-01      8.77973E+00
 1.75000E+00      2.65290E-10     9.99647E-01      8.78398E+00
 1.90500E+00      2.65384E-10     1.00000E+00      8.78708E+00
      Average Deposit = 8.774561

WAFER 78       V(OUT) =  127294    CA(OUT) =  2.585606E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.60249E-10     9.97823E-01      8.61705E+00
 2.50000E-01      2.60254E-10     9.97844E-01      8.61723E+00
 5.00000E-01      2.60273E-10     9.97916E-01      8.61786E+00
 7.50000E-01      2.60313E-10     9.98067E-01      8.61916E+00
 1.00000E+00      2.60380E-10     9.98325E-01      8.62139E+00
 1.25000E+00      2.60477E-10     9.98699E-01      8.62462E+00
 1.50000E+00      2.60599E-10     9.99163E-01      8.62863E+00
 1.75000E+00      2.60725E-10     9.99647E-01      8.63280E+00
 1.90500E+00      2.60817E-10     1.00000E+00      8.63585E+00
      Average Deposit = 8.623545

WAFER 79       V(OUT) =  127259.4    CA(OUT) =  2.541011E-10
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.55764E-10     9.97823E-01      8.46854E+00
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 2.50000E-01       2.55769E-10      9.97844E-01      8.46871E+00
 5.00000E-01       2.55787E-10      9.97916E-01      8.46933E+00
 7.50000E-01       2.55826E-10      9.98067E-01      8.47061E+00
 1.00000E+00       2.55892E-10      9.98325E-01      8.47280E+00
 1.25000E+00       2.55988E-10      9.98699E-01      8.47597E+00
 1.50000E+00       2.56107E-10      9.99163E-01      8.47991E+00
 1.75000E+00       2.56231E-10      9.99647E-01      8.48401E+00
 1.90500E+00       2.56322E-10      1.00000E+00      8.48701E+00
       Average Deposit = 8.474916

WAFER 80      V(OUT) =  127225.4      CA(OUT) =  2.497123E-10
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       2.51349E-10      9.97823E-01      8.32237E+00
 2.50000E-01       2.51354E-10      9.97843E-01      8.32254E+00
 5.00000E-01       2.51373E-10      9.97916E-01      8.32315E+00
 7.50000E-01       2.51411E-10      9.98067E-01      8.32441E+00
 1.00000E+00       2.51476E-10      9.98325E-01      8.32656E+00
 1.25000E+00       2.51570E-10      9.98699E-01      8.32968E+00
 1.50000E+00       2.51687E-10      9.99163E-01      8.33355E+00
 1.75000E+00       2.51809E-10      9.99647E-01      8.33758E+00
 1.90500E+00       2.51898E-10      1.00000E+00      8.34053E+00
       Average Deposit = 8.328643

WAFER 81      V(OUT) =  127191.9      CA(OUT) =  2.453934E-10
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       2.47005E-10      9.97823E-01      8.17853E+00
 2.50000E-01       2.47010E-10      9.97844E-01      8.17870E+00
 5.00000E-01       2.47028E-10      9.97916E-01      8.17929E+00
 7.50000E-01       2.47065E-10      9.98067E-01      8.18053E+00
 1.00000E+00       2.47129E-10      9.98325E-01      8.18265E+00
 1.25000E+00       2.47222E-10      9.98699E-01      8.18571E+00
 1.50000E+00       2.47337E-10      9.99163E-01      8.18952E+00
 1.75000E+00       2.47456E-10      9.99647E-01      8.19348E+00
 1.90500E+00       2.47544E-10      1.00000E+00      8.19637E+00
       Average Deposit = 8.184693

WAFER 82      V(OUT) =  127159      CA(OUT) =  2.411433E-10
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       2.42730E-10      9.97823E-01      8.03698E+00
 2.50000E-01       2.42735E-10      9.97844E-01      8.03715E+00
 5.00000E-01       2.42753E-10      9.97916E-01      8.03773E+00
 7.50000E-01       2.42789E-10      9.98067E-01      8.03895E+00
 1.00000E+00       2.42852E-10      9.98325E-01      8.04103E+00
 1.25000E+00       2.42943E-10      9.98699E-01      8.04404E+00
 1.50000E+00       2.43056E-10      9.99163E-01      8.04778E+00
 1.75000E+00       2.43174E-10      9.99647E-01      8.05167E+00
 1.90500E+00       2.43260E-10      1.00000E+00      8.05452E+00
       Average Deposit = 8.043038

WAFER 83      V(OUT) =  127126.6      CA(OUT) =  2.369614E-10
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       2.38523E-10      9.97823E-01      7.89770E+00
 2.50000E-01       2.38528E-10      9.97843E-01      7.89786E+00
 5.00000E-01       2.38545E-10      9.97916E-01      7.89843E+00
 7.50000E-01       2.38582E-10      9.98067E-01      7.89963E+00
 1.00000E+00       2.38643E-10      9.98325E-01      7.90167E+00
 1.25000E+00       2.38733E-10      9.98699E-01      7.90463E+00
 1.50000E+00       2.38844E-10      9.99163E-01      7.90830E+00
 1.75000E+00       2.38959E-10      9.99647E-01      7.91213E+00
 1.90500E+00       2.39044E-10      1.00000E+00      7.91493E+00
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          Average Deposit = 7.903646

WAFER 84      V(OUT) =  127094.8      CA(OUT) =  2.328464E-10
R(cm)               CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00       2.34384E-10      9.97823E-01      7.76064E+00
 2.50000E-01       2.34389E-10      9.97844E-01      7.76080E+00
 5.00000E-01       2.34406E-10      9.97916E-01      7.76136E+00
 7.50000E-01       2.34441E-10      9.98067E-01      7.76254E+00
 1.00000E+00       2.34502E-10      9.98325E-01      7.76455E+00
 1.25000E+00       2.34590E-10      9.98699E-01      7.76745E+00
 1.50000E+00       2.34699E-10      9.99163E-01      7.77106E+00
 1.75000E+00       2.34812E-10      9.99647E-01      7.77482E+00
 1.90500E+00       2.34895E-10      1.00000E+00      7.77757E+00
          Average Deposit = 7.766487

WAFER 85      V(OUT) =  127063.5      CA(OUT) =  2.287978E-10
R(cm)               CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00       2.30311E-10      9.97823E-01      7.62579E+00
 2.50000E-01       2.30316E-10      9.97844E-01      7.62594E+00
 5.00000E-01       2.30333E-10      9.97916E-01      7.62650E+00
 7.50000E-01       2.30368E-10      9.98067E-01      7.62766E+00
 1.00000E+00       2.30427E-10      9.98325E-01      7.62963E+00
 1.25000E+00       2.30513E-10      9.98699E-01      7.63248E+00
 1.50000E+00       2.30621E-10      9.99163E-01      7.63603E+00
 1.75000E+00       2.30732E-10      9.99647E-01      7.63972E+00
 1.90500E+00       2.30814E-10      1.00000E+00      7.64243E+00
          Average Deposit = 7.631534

WAFER 86      V(OUT) =  127032.7      CA(OUT) =  2.248144E-10
R(cm)               CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00       2.26304E-10      9.97823E-01      7.49311E+00
 2.50000E-01       2.26309E-10      9.97844E-01      7.49326E+00
 5.00000E-01       2.26325E-10      9.97916E-01      7.49381E+00
 7.50000E-01       2.26359E-10      9.98067E-01      7.49494E+00
 1.00000E+00       2.26418E-10      9.98325E-01      7.49688E+00
 1.25000E+00       2.26503E-10      9.98699E-01      7.49968E+00
 1.50000E+00       2.26608E-10      9.99163E-01      7.50317E+00
 1.75000E+00       2.26718E-10      9.99647E-01      7.50680E+00
 1.90500E+00       2.26798E-10      1.00000E+00      7.50946E+00
          Average Deposit = 7.498754

WAFER 87      V(OUT) =  127002.5      CA(OUT) =  2.208954E-10
R(cm)               CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00       2.22362E-10      9.97823E-01      7.36257E+00
 2.50000E-01       2.22366E-10      9.97844E-01      7.36272E+00
 5.00000E-01       2.22382E-10      9.97916E-01      7.36326E+00
 7.50000E-01       2.22416E-10      9.98067E-01      7.36437E+00
 1.00000E+00       2.22474E-10      9.98325E-01      7.36628E+00
 1.25000E+00       2.22557E-10      9.98699E-01      7.36903E+00
 1.50000E+00       2.22660E-10      9.99163E-01      7.37246E+00
 1.75000E+00       2.22768E-10      9.99647E-01      7.37603E+00
 1.90500E+00       2.22847E-10      1.00000E+00      7.37863E+00
          Average Deposit = 7.368118

WAFER 88      V(OUT) =  126972.7      CA(OUT) =  2.1704E-10
R(cm)               CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00       2.18483E-10      9.97823E-01      7.23415E+00
 2.50000E-01       2.18487E-10      9.97844E-01      7.23430E+00
 5.00000E-01       2.18503E-10      9.97916E-01      7.23482E+00
 7.50000E-01       2.18537E-10      9.98067E-01      7.23592E+00
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  1.00000E+00      2.18593E-10     9.98325E-01      7.23779E+00
  1.25000E+00      2.18675E-10     9.98699E-01      7.24049E+00
  1.50000E+00      2.18776E-10     9.99163E-01      7.24386E+00
  1.75000E+00      2.18882E-10     9.99647E-01      7.24737E+00
  1.90500E+00      2.18960E-10     1.00000E+00      7.24993E+00
        Average Deposit = 7.239598

WAFER 89      V(OUT) =  126943.4     CA(OUT) =  2.132473E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
  0.00000E+00      2.14667E-10     9.97823E-01      7.10781E+00
  2.50000E-01      2.14672E-10     9.97844E-01      7.10795E+00
  5.00000E-01      2.14687E-10     9.97916E-01      7.10847E+00
  7.50000E-01      2.14720E-10     9.98067E-01      7.10955E+00
  1.00000E+00      2.14775E-10     9.98325E-01      7.11139E+00
  1.25000E+00      2.14856E-10     9.98699E-01      7.11405E+00
  1.50000E+00      2.14956E-10     9.99163E-01      7.11735E+00
  1.75000E+00      2.15060E-10     9.99647E-01      7.12080E+00
  1.90500E+00      2.15136E-10     1.00000E+00      7.12332E+00
        Average Deposit = 7.113164

WAFER 90      V(OUT) =  126914.7     CA(OUT) =  2.095163E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
  0.00000E+00      2.10914E-10     9.97823E-01      6.98353E+00
  2.50000E-01      2.10918E-10     9.97844E-01      6.98367E+00
  5.00000E-01      2.10933E-10     9.97916E-01      6.98418E+00
  7.50000E-01      2.10966E-10     9.98067E-01      6.98524E+00
  1.00000E+00      2.11020E-10     9.98325E-01      6.98704E+00
  1.25000E+00      2.11099E-10     9.98699E-01      6.98965E+00
  1.50000E+00      2.11197E-10     9.99163E-01      6.99291E+00
  1.75000E+00      2.11299E-10     9.99647E-01      6.99629E+00
  1.90500E+00      2.11374E-10     1.00000E+00      6.99876E+00
        Average Deposit = 6.988788

WAFER 91      V(OUT) =  126886.4     CA(OUT) =  2.058463E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
  0.00000E+00      2.07222E-10     9.97823E-01      6.86127E+00
  2.50000E-01      2.07226E-10     9.97844E-01      6.86141E+00
  5.00000E-01      2.07241E-10     9.97916E-01      6.86191E+00
  7.50000E-01      2.07272E-10     9.98067E-01      6.86295E+00
  1.00000E+00      2.07326E-10     9.98325E-01      6.86473E+00
  1.25000E+00      2.07403E-10     9.98699E-01      6.86729E+00
  1.50000E+00      2.07500E-10     9.99163E-01      6.87049E+00
  1.75000E+00      2.07600E-10     9.99647E-01      6.87381E+00
  1.90500E+00      2.07674E-10     1.00000E+00      6.87624E+00
        Average Deposit = 6.866441

WAFER 92      V(OUT) =  126858.6     CA(OUT) =  2.022364E-10
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
  0.00000E+00      2.03590E-10     9.97823E-01      6.74102E+00
  2.50000E-01      2.03594E-10     9.97844E-01      6.74115E+00
  5.00000E-01      2.03609E-10     9.97916E-01      6.74164E+00
  7.50000E-01      2.03639E-10     9.98067E-01      6.74267E+00
  1.00000E+00      2.03692E-10     9.98325E-01      6.74441E+00
  1.25000E+00      2.03768E-10     9.98699E-01      6.74693E+00
  1.50000E+00      2.03863E-10     9.99163E-01      6.75007E+00
  1.75000E+00      2.03962E-10     9.99647E-01      6.75334E+00
  1.90500E+00      2.04034E-10     1.00000E+00      6.75572E+00
        Average Deposit = 6.746094

WAFER 93      V(OUT) =  126831.2     CA(OUT) =  1.986857E-10
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R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00       2.00017E-10     9.97823E-01       6.62273E+00
 2.50000E-01       2.00021E-10     9.97844E-01       6.62287E+00
 5.00000E-01       2.00036E-10     9.97916E-01       6.62335E+00
 7.50000E-01       2.00066E-10     9.98067E-01       6.62435E+00
 1.00000E+00       2.00118E-10     9.98325E-01       6.62606E+00
 1.25000E+00       2.00193E-10     9.98699E-01       6.62854E+00
 1.50000E+00       2.00286E-10     9.99163E-01       6.63163E+00
 1.75000E+00       2.00383E-10     9.99647E-01       6.63483E+00
 1.90500E+00       2.00454E-10     1.00000E+00       6.63718E+00
       Average Deposit = 6.627721

WAFER 94      V(OUT) =  126804.3     CA(OUT) =   1.951934E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00       1.96504E-10     9.97823E-01       6.50639E+00
 2.50000E-01       1.96508E-10     9.97844E-01       6.50652E+00
 5.00000E-01       1.96522E-10     9.97916E-01       6.50700E+00
 7.50000E-01       1.96552E-10     9.98067E-01       6.50798E+00
 1.00000E+00       1.96602E-10     9.98325E-01       6.50967E+00
 1.25000E+00       1.96676E-10     9.98699E-01       6.51210E+00
 1.50000E+00       1.96767E-10     9.99163E-01       6.51513E+00
 1.75000E+00       1.96863E-10     9.99647E-01       6.51828E+00
 1.90500E+00       1.96932E-10     1.00000E+00       6.52059E+00
       Average Deposit = 6.511293

WAFER 95      V(OUT) =  126777.9     CA(OUT) =   1.917587E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00       1.93048E-10     9.97823E-01       6.39197E+00
 2.50000E-01       1.93052E-10     9.97843E-01       6.39210E+00
 5.00000E-01       1.93066E-10     9.97916E-01       6.39256E+00
 7.50000E-01       1.93095E-10     9.98067E-01       6.39353E+00
 1.00000E+00       1.93145E-10     9.98325E-01       6.39518E+00
 1.25000E+00       1.93217E-10     9.98699E-01       6.39757E+00
 1.50000E+00       1.93307E-10     9.99163E-01       6.40055E+00
 1.75000E+00       1.93401E-10     9.99647E-01       6.40365E+00
 1.90500E+00       1.93469E-10     1.00000E+00       6.40591E+00
       Average Deposit = 6.396781

WAFER 96      V(OUT) =  126751.9     CA(OUT) =   1.883808E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00       1.89649E-10     9.97823E-01       6.27943E+00
 2.50000E-01       1.89653E-10     9.97844E-01       6.27956E+00
 5.00000E-01       1.89667E-10     9.97916E-01       6.28001E+00
 7.50000E-01       1.89695E-10     9.98067E-01       6.28097E+00
 1.00000E+00       1.89744E-10     9.98325E-01       6.28259E+00
 1.25000E+00       1.89815E-10     9.98699E-01       6.28494E+00
 1.50000E+00       1.89904E-10     9.99163E-01       6.28786E+00
 1.75000E+00       1.89996E-10     9.99647E-01       6.29090E+00
 1.90500E+00       1.90063E-10     1.00000E+00       6.29313E+00
       Average Deposit = 6.284159

WAFER 97      V(OUT) =  126726.4     CA(OUT) =   1.850588E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00       1.86306E-10     9.97823E-01       6.16875E+00
 2.50000E-01       1.86310E-10     9.97844E-01       6.16888E+00
 5.00000E-01       1.86324E-10     9.97916E-01       6.16933E+00
 7.50000E-01       1.86352E-10     9.98067E-01       6.17026E+00
 1.00000E+00       1.86400E-10     9.98325E-01       6.17186E+00
 1.25000E+00       1.86470E-10     9.98699E-01       6.17417E+00
 1.50000E+00       1.86557E-10     9.99163E-01       6.17704E+00
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 1.75000E+00      1.86647E-10     9.99647E-01      6.18003E+00
 1.90500E+00      1.86713E-10     1.00000E+00      6.18221E+00
      Average Deposit = 6.173401

WAFER 98      V(OUT) =  126701.3     CA(OUT) =  1.817919E-10
R(cm)                CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      1.83019E-10     9.97823E-01      6.05991E+00
 2.50000E-01      1.83023E-10     9.97844E-01      6.06004E+00
 5.00000E-0       1.83036E-10     9.97916E-01      6.06048E+00
 7.50000E-01      1.83064E-10     9.98067E-01      6.06140E+00
 1.00000E+00      1.83111E-10     9.98325E-01      6.06296E+00
 1.25000E+00      1.83180E-10     9.98699E-01      6.06523E+00
 1.50000E+00      1.83265E-10     9.99163E-01      6.06805E+00
 1.75000E+00      1.83354E-10     9.99647E-01      6.07099E+00
 1.90500E+00      1.83419E-10     1.00000E+00      6.07313E+00
      Average Deposit = 6.064478

WAFER 99      V(OUT) =  126676.6     CA(OUT) =  1.785794E-10
R(cm)                CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      1.79787E-10     9.97823E-01      5.95288E+00
 2.50000E-01      1.79790E-10     9.97844E-01      5.95300E+00
 5.00000E-01      1.79803E-10     9.97916E-01      5.95343E+00
 7.50000E-01      1.79831E-10     9.98067E-01      5.95434E+00
 1.00000E+00      1.79877E-10     9.98325E-01      5.95588E+00
 1.25000E+00      1.79944E-10     9.98699E-01      5.95810E+00
 1.50000E+00      1.80028E-10     9.99163E-01      5.96088E+00
 1.75000E+00      1.80115E-10     9.99647E-01      5.96376E+00
 1.90500E+00      1.80179E-10     1.00000E+00      5.96587E+00
      Average Deposit = 5.957365

WAFER 100      V(OUT) =  126652.3     CA(OUT) =  1.754204E-10
R(cm)                CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      1.76608E-10     9.97823E-01      5.84763E+00
 2.50000E-01      1.76612E-10     9.97844E-01      5.84775E+00
 5.00000E-01      1.76624E-10     9.97916E-01      5.84817E+00
 7.50000E-01      1.76651E-10     9.98067E-01      5.84906E+00
 1.00000E+00      1.76697E-10     9.98325E-01      5.85057E+00
 1.25000E+00      1.76763E-10     9.98699E-01      5.85276E+00
 1.50000E+00      1.76845E-10     9.99163E-01      5.85548E+00
 1.75000E+00      1.76931E-10     9.99647E-01      5.85832E+00
 1.90500E+00      1.76993E-10     1.00000E+00      5.86039E+00
      Average Deposit = 5.852036

WAFER 101      V(OUT) =  126628.5     CA(OUT) =  1.723141E-10
R(cm)                CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      1.73482E-10     9.97823E-01      5.74414E+00
 2.50000E-01      1.73486E-10     9.97843E-01      5.74425E+00
 5.00000E-01      1.73498E-10     9.97916E-01      5.74467E+00
 7.50000E-01      1.73525E-10     9.98067E-01      5.74554E+00
 1.00000E+00      1.73570E-10     9.98325E-01      5.74703E+00
 1.25000E+00      1.73634E-10     9.98699E-01      5.74918E+00
 1.50000E+00      1.73715E-10     9.99163E-01      5.75185E+00
 1.75000E+00      1.73799E-10     9.99647E-01      5.75463E+00
 1.90500E+00      1.73861E-10     1.00000E+00      5.75667E+00
      Average Deposit = 5.748464

WAFER 102      V(OUT) =  126605     CA(OUT) =  1.692599E-10
R(cm)                CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      1.70409E-10     9.97823E-01      5.64237E+00
 2.50000E-01      1.70412E-10     9.97844E-01      5.64249E+00
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 5.00000E-01      1.70425E-10     9.97916E-01      5.64290E+00
 7.50000E-01      1.70451E-10     9.98067E-01      5.64375E+00
 1.00000E+00      1.70495E-10     9.98325E-01      5.64521E+00
 1.25000E+00      1.70558E-10     9.98699E-01      5.64732E+00
 1.50000E+00      1.70638E-10     9.99163E-01      5.64995E+00
 1.75000E+00      1.70720E-10     9.99647E-01      5.65268E+00
 1.90500E+00      1.70781E-10     1.00000E+00      5.65468E+00
      Average Deposit = 5.646623

WAFER 103      V(OUT) =  126582     CA(OUT) =  1.662568E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      1.67387E-10     9.97823E-01      5.54231E+00
 2.50000E-01      1.67390E-10     9.97844E-01      5.54243E+00
 5.00000E-01      1.67402E-10     9.97916E-01      5.54283E+00
 7.50000E-01      1.67428E-10     9.98067E-01      5.54367E+00
 1.00000E+00      1.67471E-10     9.98325E-01      5.54510E+00
 1.25000E+00      1.67534E-10     9.98699E-01      5.54718E+00
 1.50000E+00      1.67612E-10     9.99163E-01      5.54976E+00
 1.75000E+00      1.67693E-10     9.99647E-01      5.55244E+00
 1.90500E+00      1.67752E-10     1.00000E+00      5.55440E+00
      Average Deposit = 5.546488

WAFER 104      V(OUT) =  126559.4     CA(OUT) =   1.633042E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      1.64416E-10     9.97823E-01      5.44393E+00
 2.50000E-01      1.64419E-10     9.97843E-01      5.44404E+00
 5.00000E-01      1.64431E-10     9.97916E-01      5.44444E+00
 7.50000E-01      1.64456E-10     9.98067E-01      5.44527E+00
 1.00000E+00      1.64498E-10     9.98325E-01      5.44667E+00
 1.25000E+00      1.64560E-10     9.98699E-01      5.44871E+00
 1.50000E+00      1.64636E-10     9.99163E-01      5.45124E+00
 1.75000E+00      1.64716E-10     9.99647E-01      5.45388E+00
 1.90500E+00      1.64774E-10     1.00000E+00      5.45581E+00
      Average Deposit = 5.448035

WAFER 105      V(OUT) =  126537.1     CA(OUT) =   1.604013E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      1.61494E-10     9.97823E-01      5.34721E+00
 2.50000E-01      1.61498E-10     9.97844E-01      5.34732E+00
 5.00000E-01      1.61509E-10     9.97916E-01      5.34770E+00
 7.50000E-01      1.61534E-10     9.98067E-01      5.34852E+00
 1.00000E+00      1.61576E-10     9.98325E-01      5.34990E+00
 1.25000E+00      1.61636E-10     9.98699E-01      5.35190E+00
 1.50000E+00      1.61711E-10     9.99163E-01      5.35439E+00
 1.75000E+00      1.61789E-10     9.99647E-01      5.35698E+00
 1.90500E+00      1.61847E-10     1.00000E+00      5.35887E+00
      Average Deposit = 5.351236

WAFER 106      V(OUT) =  126515.2     CA(OUT) =   1.575474E-10
R(cm)              CA(r,dell)       CA/CAI       G(angs./min)
 0.00000E+00      1.58622E-10     9.97823E-01      5.25211E+00
 2.50000E-01      1.58626E-10     9.97844E-01      5.25222E+00
 5.00000E-01      1.58637E-10     9.97916E-01      5.25260E+00
 7.50000E-01      1.58661E-10     9.98067E-01      5.25340E+00
 1.00000E+00      1.58702E-10     9.98325E-01      5.25476E+00
 1.25000E+00      1.58762E-10     9.98699E-01      5.25672E+00
 .50000E+00      1.58835E-10     9.99163E-01      5.25917E+00
 1.75000E+00      1.58912E-10     9.99647E-01      5.26171E+00
 1.90500E+00      1.58968E-10     1.00000E+00      5.26357E+00
      Average Deposit = 5.256068
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WAFER 107      V(OUT) =  126493.7     CA(OUT) =  1.547416E-10
R(cm)              CA(r,dell)         CA/CAI         G(angs./min)
 0.00000E+00      1.55799E-10     9.97823E-01     5.15862E+00
 2.50000E-01      1.55802E-10     9.97844E-01     5.15873E+00
 5.00000E-01      1.55813E-10     9.97916E-01     5.15910E+00
 7.50000E-01      1.55837E-10     9.98067E-01     5.15988E+00
 1.00000E+00      1.55877E-10     9.98325E-01     5.16122E+00
 1.25000E+00      1.55935E-10     9.98699E-01     5.16315E+00
 1.50000E+00      1.56008E-10     9.99163E-01     5.16555E+00
 1.75000E+00      1.56083E-10     9.99647E-01     5.16805E+00
 1.90500E+00      1.56139E-10     1.00000E+00     5.16988E+00
       Average Deposit = 5.162507

WAFER 108      V(OUT) =  126472.6     CA(OUT) =  1.519834E-10
R(cm)              CA(r,dell)         CA/CAI         G(angs./min)
 0.00000E+00      1.53023E-10     9.97823E-01     5.06671E+00
 2.50000E-01      1.53026E-10     9.97843E-01     5.06681E+00
 5.00000E-01      1.53037E-10     9.97916E-01     5.06718E+00
 7.50000E-01      1.53060E-10     9.98067E-01     5.06795E+00
 1.00000E+00      1.53100E-10     9.98325E-01     5.06926E+00
 1.25000E+00      1.53157E-10     9.98699E-01     5.07116E+00
 1.50000E+00      1.53228E-10     9.99163E-01     5.07351E+00
 1.75000E+00      1.53303E-10     9.99647E-01     5.07597E+00
 1.90500E+00      1.53357E-10     1.00000E+00     5.07776E+00
       Average Deposit = 5.070527

WAFER 109      V(OUT) =  126451.9     CA(OUT) =  1.49272E-10
R(cm)              CA(r,dell)         CA/CAI         G(angs./min)
 0.00000E+00      1.50294E-10     9.97823E-01     4.97636E+00
 2.50000E-01      1.50297E-10     9.97843E-01     4.97646E+00
 5.00000E-01      1.50308E-10     9.97916E-01     4.97682E+00
 7.50000E-01      1.50331E-10     9.98067E-01     4.97758E+00
 1.00000E+00      1.50370E-10     9.98325E-01     4.97886E+00
 1.25000E+00      1.50426E-10     9.98699E-01     4.98072E+00
 1.50000E+00      1.50496E-10     9.99163E-01     4.98304E+00
 1.75000E+00      1.50569E-10     9.99647E-01     4.98545E+00
 1.90500E+00      1.50622E-10     1.00000E+00     4.98721E+00
       Average Deposit = 4.980107

WAFER 110      V(OUT) =  126431.5     CA(OUT) =  1.466066E-10
R(cm)              CA(r,dell)         CA/CAI         G(angs./min)
 0.00000E+00      1.47612E-10     9.97823E-01     4.88754E+00
 2.50000E-01      1.47615E-10     9.97844E-01     4.88764E+00
 5.00000E-01      1.47625E-10     9.97916E-01     4.88799E+00
 7.50000E-01      1.47648E-10     9.98067E-01     4.88874E+00
 1.00000E+00      1.47686E-10     9.98325E-01     4.89000E+00
 1.25000E+00      1.47741E-10     9.98699E-01     4.89183E+00
 1.50000E+00      1.47810E-10     9.99163E-01     4.89410E+00
 1.75000E+00      1.47881E-10     9.99647E-01     4.89647E+00
 1.90500E+00      1.47934E-10     1.00000E+00     4.89820E+00
       Average Deposit = 4.891221

WAFER 111      V(OUT) =  126411.4     CA(OUT) =  1.439865E-10
R(cm)              CA(r,dell)         CA/CAI         G(angs./min)
 0.00000E+00      1.44975E-10     9.97823E-01     4.80023E+00
 2.50000E-01      1.44978E-10     9.97844E-01     4.80033E+00
 5.00000E-01      1.44988E-10     9.97916E-01     4.80068E+00
 7.50000E-01      1.45010E-10     9.98067E-01     4.80141E+00
 1.00000E+00      1.45048E-10     9.98325E-01     4.80265E+00
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 1.25000E+00     1.45102E-10     9.98699E-01      4.80444E+00
 1.50000E+00     1.45169E-10     9.99163E-01      4.80668E+00
 1.75000E+00     1.45240E-10     9.99647E-01      4.80900E+00
 1.90500E+00     1.45291E-10     1.00000E+00      4.81070E+00
       Average Deposit = 4.803848

WAFER 112      V(OUT) =  126391.7      CA(OUT) =   1.414112E-10
R(cm)              CA(r,dell)          CA/CAI        G(angs./min)
 0.00000E+00     1.42383E-10     9.97823E-01      4.71441E+00
 2.50000E-01     1.42386E-10     9.97843E-01      4.71450E+00
 5.00000E-01     1.42396E-10     9.97916E-01      4.71485E+00
 7.50000E-01     1.42418E-10     9.98067E-01      4.71556E+00
 1.00000E+00     1.42454E-10     9.98325E-01      4.71678E+00
 1.25000E+00     1.42508E-10     9.98699E-01      4.71855E+00
 1.50000E+00     1.42574E-10     9.99163E-01      4.72074E+00
 1.75000E+00     1.42643E-10     9.99647E-01      4.72302E+00
 1.90500E+00     1.42693E-10     1.00000E+00      4.72469E+00
       Average Deposit = 4.717961

WAFER 113      V(OUT) =  126372.4      CA(OUT) =   1.388798E-10
R(cm)              CA(r,dell)          CA/CAI        G(angs./min)
 0.00000E+00     1.39835E-10     9.97823E-01      4.63005E+00
 2.50000E-01     1.39838E-10     9.97843E-01      4.63015E+00
 5.00000E-01     1.39848E-10     9.97916E-01      4.63048E+00
 7.50000E-01     1.39869E-10     9.98067E-01      4.63118E+00
 1.00000E+00     1.39905E-10     9.98325E-01      4.63238E+00
 1.25000E+00     1.39958E-10     9.98699E-01      4.63411E+00
 1.50000E+00     1.40023E-10     9.99163E-01      4.63627E+00
 1.75000E+00     1.40091E-10     9.99647E-01      4.63851E+00
 1.90500E+00     1.40140E-10     1.00000E+00      4.64015E+00
       Average Deposit = 4.633539

WAFER 114      V(OUT) =  126353.3      CA(OUT) =   1.363917E-10
R(cm)              CA(r,dell)          CA/CAI        G(angs./min)
 0.00000E+00     1.37331E-10     9.97823E-01      4.54714E+00
 2.50000E-01     1.37334E-10     9.97843E-01      4.54723E+00
 5.00000E-01     1.37344E-10     9.97916E-01      4.54756E+00
 7.50000E-01     1.37364E-10     9.98067E-01      4.54825E+00
 1.00000E+00     1.37400E-10     9.98325E-01      4.54942E+00
 1.25000E+00     1.37451E-10     9.98699E-01      4.55113E+00
 1.50000E+00     1.37515E-10     9.99163E-01      4.55324E+00
 1.75000E+00     1.37582E-10     9.99647E-01      4.55544E+00
 1.90500E+00     1.37630E-10     1.00000E+00      4.55706E+00
       Average Deposit = 4.550561

WAFER 115      V(OUT) =  126334.6      CA(OUT) =   1.339462E-10
R(cm)              CA(r,dell)          CA/CAI        G(angs./min)
 0.00000E+00     1.34870E-10     9.97823E-01      4.46564E+00
 2.50000E-01     1.34872E-10     9.97844E-01      4.46573E+00
 5.00000E-01     1.34882E-10     9.97916E-01      4.46605E+00
 7.50000E-01     1.34903E-10     9.98067E-01      4.46673E+00
 1.00000E+00     1.34937E-10     9.98325E-01      4.46789E+00
 1.25000E+00     1.34988E-10     9.98699E-01      4.46956E+00
 1.50000E+00     1.35051E-10     9.99163E-01      4.47164E+00
 1.75000E+00     1.35116E-10     9.99647E-01      4.47380E+00
 1.90500E+00     1.35164E-10     1.00000E+00      4.47538E+00
       Average Deposit = 4.469002

WAFER 116      V(OUT) =  126316.3      CA(OUT) =   1.315426E-10
R(cm)              CA(r,dell)          CA/CAI        G(angs./min)
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 0.00000E+00      1.32450E-10     9.97823E-01      4.38554E+00
 2.50000E-01      1.32453E-10     9.97843E-01      4.38563E+00
 5.00000E-01      1.32463E-10     9.97916E-01      4.38595E+00
 7.50000E-01      1.32483E-10     9.98067E-01      4.38661E+00
 1.00000E+00      1.32517E-10     9.98325E-01      4.38775E+00
 1.25000E+00      1.32567E-10     9.98699E-01      4.38939E+00
 1.50000E+00      1.32628E-10     9.99163E-01      4.39143E+00
 1.75000E+00      1.32692E-10     9.99647E-01      4.39355E+00
 1.90500E+00      1.32739E-10     1.00000E+00      4.39511E+00
      Average Deposit = 4.388843

WAFER 117     V(OUT) =  126298.2     CA(OUT) =  1.291804E-10
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.30073E-10     9.97823E-01      4.30681E+00
 2.50000E-01      1.30075E-10     9.97844E-01      4.30690E+00
 5.00000E-01      1.30085E-10     9.97916E-01      4.30721E+00
 7.50000E-01      1.30105E-10     9.98067E-01      4.30787E+00
 1.00000E+00      1.30138E-10     9.98325E-01      4.30898E+00
 1.25000E+00      1.30187E-10     9.98699E-01      4.31059E+00
 1.50000E+00      1.30247E-10     9.99163E-01      4.31260E+00
 1.75000E+00      1.30311E-10     9.99647E-01      4.31468E+00
 1.90500E+00      1.30357E-10     1.00000E+00      4.31621E+00
      Average Deposit = 4.310059

WAFER 118     V(OUT) =  126280.5     CA(OUT) =  1.268589E-10
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.27736E-10     9.97823E-01      4.22944E+00
 2.50000E-01      1.27739E-10     9.97843E-01      4.22953E+00
 5.00000E-01      1.27748E-10     9.97916E-01      4.22984E+00
 7.50000E-01      1.27767E-10     9.98067E-01      4.23048E+00
 1.00000E+00      1.27800E-10     9.98325E-01      4.23157E+00
 1.25000E+00      1.27848E-10     9.98699E-01      4.23316E+00
 1.50000E+00      1.27908E-10     9.99163E-01      4.23512E+00
 1.75000E+00      1.27970E-10     9.99647E-01      4.23717E+00
 1.90500E+00      1.28015E-10     1.00000E+00      4.23867E+00
      Average Deposit = 4.23263

WAFER 119     V(OUT) =  126263.1     CA(OUT) =  1.245773E-10
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.25440E-10     9.97823E-01      4.15341E+00
 2.50000E-01      1.25442E-10     9.97844E-01      4.15349E+00
 5.00000E-01      1.25451E-10     9.97916E-01      4.15379E+00
 7.50000E-01      1.25470E-10     9.98067E-01      4.15442E+00
 1.00000E+00      1.25503E-10     9.98325E-01      4.15550E+00
 1.25000E+00      1.25550E-10     9.98699E-01      4.15705E+00
 1.50000E+00      1.25608E-10     9.99163E-01      4.15898E+00
 1.75000E+00      1.25669E-10     9.99647E-01      4.16100E+00
 1.90500E+00      1.25713E-10     1.00000E+00      4.16247E+00
      Average Deposit = 4.156536

WAFER 120     V(OUT) =  126246       CA(OUT) =  1.223352E-10
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.23183E-10     9.97823E-01      4.07868E+00
 2.50000E-01      1.23185E-10     9.97844E-01      4.07876E+00
 5.00000E-01      1.23194E-10     9.97916E-01      4.07906E+00
 7.50000E-01      1.23213E-10     9.98067E-01      4.07968E+00
 1.00000E+00      1.23245E-10     9.98325E-01      4.08073E+00
 1.25000E+00      1.23291E-10     9.98699E-01      4.08226E+00
 1.50000E+00      1.23348E-10     9.99163E-01      4.08416E+00
 1.75000E+00      1.23408E-10     9.99647E-01      4.08613E+00
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 1.90500E+00      1.23452E-10     1.00000E+00      4.08758E+00
      Average Deposit = 4.081753

WAFER 121      V(OUT) =  126229.2      CA(OUT) =   1.201318E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      1.20965E-10     9.97823E-01      4.00525E+00
 2.50000E-01      1.20967E-10     9.97844E-01      4.00533E+00
 5.00000E-01      1.20976E-10     9.97916E-01      4.00562E+00
 7.50000E-01      1.20995E-10     9.98067E-01      4.00623E+00
 1.00000E+00      1.21026E-10     9.98325E-01      4.00726E+00
 1.25000E+00      1.21071E-10     9.98699E-01      4.00876E+00
 1.50000E+00      1.21127E-10     9.99163E-01      4.01063E+00
 1.75000E+00      1.21186E-10     9.99647E-01      4.01257E+00
 1.90500E+00      1.21229E-10     1.00000E+00      4.01398E+00
      Average Deposit = 4.008264

WAFER 122      V(OUT) =  126212.7      CA(OUT) =   1.179666E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      1.18785E-10     9.97823E-01      3.93308E+00
 2.50000E-01      1.18788E-10     9.97843E-01      3.93316E+00
 5.00000E-01      1.18797E-10     9.97916E-01      3.93345E+00
 7.50000E-01      1.18815E-10     9.98067E-01      3.93404E+00
 1.00000E+00      1.18845E-10     9.98325E-01      3.93506E+00
 1.25000E+00      1.18890E-10     9.98699E-01      3.93653E+00
 1.50000E+00      1.18945E-10     9.99163E-01      3.93836E+00
 1.75000E+00      1.19003E-10     9.99647E-01      3.94027E+00
 1.90500E+00      1.19045E-10     1.00000E+00      3.94166E+00
      Average Deposit = 3.936044

WAFER 123      V(OUT) =  126196.5      CA(OUT) =   1.158389E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      1.16644E-10     9.97823E-01      3.86217E+00
 2.50000E-01      1.16646E-10     9.97844E-01      3.86225E+00
 5.00000E-01      1.16655E-10     9.97916E-01      3.86253E+00
 7.50000E-01      1.16672E-10     9.98067E-01      3.86311E+00
 1.00000E+00      1.16702E-10     9.98325E-01      3.86411E+00
 1.25000E+00      1.16746E-10     9.98699E-01      3.86556E+00
 1.50000E+00      1.16800E-10     9.99163E-01      3.86736E+00
 1.75000E+00      1.16857E-10     9.99647E-01      3.86923E+00
 1.90500E+00      1.16898E-10     1.00000E+00      3.87059E+00
      Average Deposit = 3.865078

WAFER 124      V(OUT) =  126180.5      CA(OUT) =   1.137481E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      1.14539E-10     9.97823E-01      3.79248E+00
 2.50000E-01      1.14542E-10     9.97844E-01      3.79256E+00
 5.00000E-01      1.14550E-10     9.97916E-01      3.79284E+00
 7.50000E-01      1.14567E-10     9.98067E-01      3.79341E+00
 1.00000E+00      1.14597E-10     9.98325E-01      3.79439E+00
 1.25000E+00      1.14640E-10     9.98699E-01      3.79581E+00
 1.50000E+00      1.14693E-10     9.99163E-01      3.79758E+00
 1.75000E+00      1.14749E-10     9.99647E-01      3.79942E+00
 1.90500E+00      1.14789E-10     1.00000E+00      3.80076E+00
      Average Deposit = 3.795342

WAFER 125      V(OUT) =  126164.9      CA(OUT) =   1.116937E-10
R(cm)              CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      1.12471E-10     9.97823E-01      3.72401E+00
 2.50000E-01      1.12474E-10     9.97844E-01      3.72409E+00
 5.00000E-01      1.12482E-10     9.97916E-01      3.72436E+00
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 7.50000E-01      1.12499E-10      9.98067E-01       3.72492E+00
 1.00000E+00      1.12528E-10      9.98325E-01       3.72589E+00
 1.25000E+00      1.12570E-10      9.98699E-01       3.72728E+00
 1.50000E+00      1.12622E-10      9.99163E-01       3.72901E+00
 1.75000E+00      1.12677E-10      9.99647E-01       3.73082E+00
 1.90500E+00      1.12717E-10      1.00000E+00       3.73214E+00
        Average Deposit = 3.726817

WAFER 126       V(OUT) =  126149.5      CA(OUT) =   1.096751E-10
R(cm)                CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.10439E-10      9.97823E-01       3.65673E+00
 2.50000E-01      1.10441E-10      9.97844E-01       3.65681E+00
 5.00000E-01      1.10450E-10      9.97916E-01       3.65707E+00
 7.50000E-01      1.10466E-10      9.98067E-01       3.65763E+00
 1.00000E+00      1.10495E-10      9.98325E-01       3.65857E+00
 1.25000E+00      1.10536E-10      9.98699E-01       3.65994E+00
 1.50000E+00      1.10588E-10      9.99163E-01       3.66164E+00
 1.75000E+00      1.10641E-10      9.99647E-01       3.66341E+00
 1.90500E+00      1.10680E-10      1.00000E+00       3.66471E+00
        Average Deposit = 3.659486

WAFER 127       V(OUT) =  126134.4      CA(OUT) =   1.076917E-10
R(cm)                CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.08443E-10      9.97823E-01       3.59062E+00
 2.50000E-01      1.08445E-10      9.97844E-01       3.59070E+00
 5.00000E-01      1.08453E-10      9.97916E-01       3.59096E+00
 7.50000E-01      1.08469E-10      9.98067E-01       3.59150E+00
 1.00000E+00      1.08497E-10      9.98325E-01       3.59243E+00
 1.25000E+00      1.08538E-10      9.98699E-01       3.59377E+00
 1.50000E+00      1.08588E-10      9.99163E-01       3.59544E+00
 1.75000E+00      1.08641E-10      9.99647E-01       3.59718E+00
 1.90500E+00      1.08679E-10      1.00000E+00       3.59846E+00
        Average Deposit = 3.593327

WAFER 128       V(OUT) =  126119.5      CA(OUT) =   1.057429E-10
R(cm)                CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.06481E-10      9.97823E-01       3.52567E+00
 2.50000E-01      1.06483E-10      9.97844E-01       3.52574E+00
 5.00000E-01      1.06491E-10      9.97916E-01       3.52599E+00
 7.50000E-01      1.06507E-10      9.98067E-01       3.52653E+00
 1.00000E+00      1.06534E-10      9.98325E-01       3.52744E+00
 1.25000E+00      1.06574E-10      9.98699E-01       3.52876E+00
 1.50000E+00      1.06624E-10      9.99163E-01       3.53040E+00
 1.75000E+00      1.06675E-10      9.99647E-01       3.53211E+00
 1.90500E+00      1.06713E-10      1.00000E+00       3.53336E+00
        Average Deposit = 3.528322

WAFER 129       V(OUT) =  126105      CA(OUT) =  1.038281E-10
R(cm)                CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.04553E-10      9.97823E-01       3.46184E+00
 2.50000E-01      1.04555E-10      9.97844E-01       3.46192E+00
 5.00000E-01      1.04563E-10      9.97916E-01       3.46217E+00
 7.50000E-01      1.04579E-10      9.98067E-01       3.46269E+00
 1.00000E+00      1.04606E-10      9.98325E-01       3.46359E+00
 1.25000E+00      1.04645E-10      9.98699E-01       3.46488E+00
 1.50000E+00      1.04694E-10      9.99163E-01       3.46649E+00
 1.75000E+00      1.04744E-10      9.99647E-01       3.46817E+00
 1.90500E+00      1.04781E-10      1.00000E+00       3.46940E+00
        Average Deposit = 3.464452
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WAFER 130      V(OUT) =  126090.6    CA(OUT) =  1.019469E-10
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     1.02660E-10    9.97823E-01     3.39914E+00
 2.50000E-01     1.02662E-10    9.97843E-01     3.39921E+00
 5.00000E-01     1.02669E-10    9.97916E-01     3.39946E+00
 7.50000E-01     1.02685E-10    9.98067E-01     3.39997E+00
 1.00000E+00     1.02711E-10    9.98325E-01     3.40085E+00
 1.25000E+00     1.02750E-10    9.98699E-01     3.40212E+00
 1.50000E+00     1.02797E-10    9.99163E-01     3.40371E+00
 1.75000E+00     1.02847E-10    9.99647E-01     3.40535E+00
 1.90500E+00     1.02884E-10    1.00000E+00     3.40656E+00
       Average Deposit = 3.401701

WAFER 131      V(OUT) =  126076.6    CA(OUT) =  1.000986E-10
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     1.00799E-10    9.97823E-01     3.33753E+00
 2.50000E-01     1.00801E-10    9.97844E-01     3.33760E+00
 5.00000E-01     1.00808E-10    9.97916E-01     3.33784E+00
 7.50000E-01     1.00824E-10    9.98067E-01     3.33835E+00
 1.00000E+00     1.00850E-10    9.98325E-01     3.33921E+00
 1.25000E+00     1.00887E-10    9.98699E-01     3.34046E+00
 1.50000E+00     1.00934E-10    9.99163E-01     3.34202E+00
 1.75000E+00     1.00983E-10    9.99647E-01     3.34363E+00
 1.90500E+00     1.01019E-10    1.00000E+00     3.34481E+00
       Average Deposit = 3.340047

WAFER 132      V(OUT) =  126062.8    CA(OUT) =  9.828274E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     9.89709E-11    9.97823E-01     3.27701E+00
 2.50000E-01     9.89729E-11    9.97844E-01     3.27707E+00
 5.00000E-01     9.89801E-11    9.97916E-01     3.27731E+00
 7.50000E-01     9.89951E-11    9.98067E-01     3.27781E+00
 1.00000E+00     9.90207E-11    9.98325E-01     3.27866E+00
 1.25000E+00     9.90578E-11    9.98699E-01     3.27988E+00
 1.50000E+00     9.91038E-11    9.99163E-01     3.28141E+00
 1.75000E+00     9.91518E-11    9.99647E-01     3.28299E+00
 1.90500E+00     9.91868E-11    1.00000E+00     3.28416E+00
       Average Deposit = 3.279475

WAFER 133      V(OUT) =  126049.2    CA(OUT) =  9.649878E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     9.71750E-11    9.97823E-01     3.21754E+00
 2.50000E-01     9.71770E-11    9.97844E-01     3.21761E+00
 5.00000E-01     9.71840E-11    9.97916E-01     3.21784E+00
 7.50000E-01     9.71988E-11    9.98067E-01     3.21833E+00
 1.00000E+00     9.72239E-11    9.98325E-01     3.21916E+00
 1.25000E+00     9.72603E-11    9.98699E-01     3.22036E+00
 1.50000E+00     9.73055E-11    9.99163E-01     3.22186E+00
 1.75000E+00     9.73526E-11    9.99647E-01     3.22342E+00
 1.90500E+00     9.73870E-11    1.00000E+00     3.22456E+00
       Average Deposit = 3.219966

WAFER 134      V(OUT) =  126035.9    CA(OUT) =  9.474618E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     9.54106E-11    9.97823E-01     3.15912E+00
 2.50000E-01     9.54126E-11    9.97844E-01     3.15919E+00
 5.00000E-01     9.54195E-11    9.97916E-01     3.15942E+00
 7.50000E-01     9.54340E-11    9.98067E-01     3.15990E+00
 1.00000E+00     9.54587E-11    9.98325E-01     3.16071E+00
 1.25000E+00     9.54944E-11    9.98699E-01     3.16189E+00
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 1.50000E+00       9.55388E-11      9.99163E-01       3.16336E+00
 1.75000E+00       9.55850E-11      9.99647E-01       3.16490E+00
 1.90500E+00       9.56188E-11      1.00000E+00       3.16601E+00
      Average Deposit = 3.161502

WAFER 135       V(OUT) =  126022.8     CA(OUT) =  9.302446E-11
R(cm)               CA(r,dell)        CA/CAI      G(angs./min)
 0.00000E+00       9.36773E-11      9.97823E-01       3.10173E+00
 2.50000E-01       9.36792E-11      9.97844E-01       3.10179E+00
 5.00000E-01       9.36860E-11      9.97916E-01       3.10202E+00
 7.50000E-01       9.37002E-11      9.98067E-01       3.10249E+00
 1.00000E+00       9.37245E-11      9.98325E-01       3.10329E+00
 1.25000E+00       9.37595E-11      9.98699E-01       3.10445E+00
 1.50000E+00       9.38031E-11      9.99163E-01       3.10590E+00
 1.75000E+00       9.38485E-11      9.99647E-01       3.10740E+00
 1.90500E+00       9.38817E-11      1.00000E+00       3.10850E+00
      Average Deposit = 3.104067

WAFER 136       V(OUT) =  126009.9     CA(OUT) =  9.133308E-11
R(cm)               CA(r,dell)        CA/CAI      G(angs./min)
 0.00000E+00       9.19745E-11      9.97823E-01       3.04535E+00
 2.50000E-01       9.19764E-11      9.97843E-01       3.04541E+00
 5.00000E-01       9.19831E-11      9.97916E-01       3.04563E+00
 7.50000E-01       9.19970E-11      9.98067E-01       3.04610E+00
 1.00000E+00       9.20208E-11      9.98325E-01       3.04688E+00
 1.25000E+00       9.20552E-11      9.98699E-01       3.04802E+00
 1.50000E+00       9.20980E-11      9.99163E-01       3.04944E+00
 1.75000E+00       9.21426E-11      9.99647E-01       3.05092E+00
 1.90500E+00       9.21752E-11      1.00000E+00       3.05199E+00
      Average Deposit = 3.047644

WAFER 137       V(OUT) =  125997.3     CA(OUT) =  8.967153E-11
R(cm)               CA(r,dell)        CA/CAI      G(angs./min)
 0.00000E+00       9.03018E-11      9.97823E-01       2.98996E+00
 2.50000E-01       9.03036E-11      9.97843E-01       2.99003E+00
 5.00000E-01       9.03102E-11      9.97916E-01       2.99024E+00
 7.50000E-01       9.03239E-11      9.98067E-01       2.99070E+00
 1.00000E+00       9.03472E-11      9.98325E-01       2.99147E+00
 1.25000E+00       9.03810E-11      9.98699E-01       2.99259E+00
 1.50000E+00       9.04231E-11      9.99163E-01       2.99398E+00
 1.75000E+00       9.04668E-11      9.99647E-01       2.99543E+00
 1.90500E+00       9.04988E-11      1.00000E+00       2.99649E+00
      Average Deposit = 2.992217

WAFER 138       V(OUT) =  125984.9     CA(OUT) =  8.803934E-11
R(cm)               CA(r,dell)        CA/CAI      G(angs./min)
 0.00000E+00       8.86586E-11      9.97823E-01       2.93556E+00
 2.50000E-01       8.86604E-11      9.97844E-01       2.93562E+00
 5.00000E-01       8.86668E-11      9.97916E-01       2.93583E+00
 7.50000E-01       8.86803E-11      9.98067E-01       2.93627E+00
 1.00000E+00       8.87032E-11      9.98325E-01       2.93703E+00
 1.25000E+00       8.87364E-11      9.98699E-01       2.93813E+00
 1.50000E+00       8.87776E-11      9.99163E-01       2.93950E+00
 1.75000E+00       8.88206E-11      9.99647E-01       2.94092E+00
 1.90500E+00       8.88520E-11      1.00000E+00       2.94196E+00
      Average Deposit = 2.937768

WAFER 139       V(OUT) =  125972.7     CA(OUT) =  8.643601E-11
R(cm)               CA(r,dell)        CA/CAI      G(angs./min)
 0.00000E+00       8.70444E-11      9.97823E-01       2.88211E+00
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 2.50000E-01      8.70462E-11      9.97844E-01      2.88217E+00
 5.00000E-01      8.70525E-11      9.97916E-01      2.88238E+00
 7.50000E-01      8.70657E-11      9.98067E-01      2.88282E+00
 1.00000E+00      8.70882E-11      9.98325E-01      2.88356E+00
 1.25000E+00      8.71208E-11      9.98699E-01      2.88464E+00
 1.50000E+00      8.71613E-11      9.99163E-01      2.88598E+00
 1.75000E+00      8.72035E-11      9.99647E-01      2.88738E+00
 1.90500E+00      8.72343E-11      1.00000E+00      2.88840E+00
      Average Deposit = 2.884281

WAFER 140     V(OUT) =  125960.7     CA(OUT) =   8.486106E-11
R(cm)             CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      8.54588E-11      9.97823E-01      2.82961E+00
 2.50000E-01      8.54605E-11      9.97844E-01      2.82967E+00
 5.00000E-01      8.54667E-11      9.97916E-01      2.82987E+00
 7.50000E-01      8.54797E-11      9.98067E-01      2.83030E+00
 1.00000E+00      8.55018E-11      9.98325E-01      2.83103E+00
 1.25000E+00      8.55337E-11      9.98699E-01      2.83209E+00
 1.50000E+00      8.55735E-11      9.99163E-01      2.83341E+00
 1.75000E+00      8.56149E-11      9.99647E-01      2.83478E+00
 1.90500E+00      8.56452E-11      1.00000E+00      2.83578E+00
      Average Deposit = 2.83174

WAFER 141     V(OUT) =  125949     CA(OUT) =  8.331403E-11
R(cm)             CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      8.39012E-11      9.97823E-01      2.77804E+00
 2.50000E-01      8.39029E-11      9.97844E-01      2.77809E+00
 5.00000E-01      8.39090E-11      9.97916E-01      2.77829E+00
 7.50000E-01      8.39218E-11      9.98067E-01      2.77872E+00
 1.00000E+00      8.39435E-11      9.98325E-01      2.77944E+00
 1.25000E+00      8.39749E-11      9.98699E-01      2.78047E+00
 1.50000E+00      8.40139E-11      9.99163E-01      2.78177E+00
 1.75000E+00      8.40546E-11      9.99647E-01      2.78311E+00
 1.90500E+00      8.40843E-11      1.00000E+00      2.78410E+00
      Average Deposit = 2.78013

WAFER 142     V(OUT) =  125937.4     CA(OUT) =   8.179443E-11
R(cm)             CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      8.23713E-11      9.97823E-01       ·.72738E+00
 2.50000E-01      8.23730E-11      9.97843E-01      2.72743E+00
 5.00000E-01      8.23790E-11      9.97916E-01      2.72763E+00
 7.50000E-01      8.23915E-11      9.98067E-01      2.72805E+00
 1.00000E+00      8.24128E-11      9.98325E-01      2.72875E+00
 1.25000E+00      8.24436E-11      9.98699E-01      2.72977E+00
 1.50000E+00      8.24819E-11      9.99163E-01      2.73104E+00
 1.75000E+00      8.25218E-11      9.99647E-01      2.73236E+00
 1.90500E+00      8.25510E-11      1.00000E+00      2.73333E+00
      Average Deposit = 2.729435

WAFER 143     V(OUT) =  125926.1     CA(OUT) =   8.030181E-11
R(cm)             CA(r,dell)        CA/CAI         G(angs./min)
 0.00000E+00      8.08685E-11      9.97823E-01      2.67762E+00
 2.50000E-01      8.08702E-11      9.97844E-01      2.67768E+00
 5.00000E-01      8.08761E-11      9.97916E-01      2.67787E+00
 7.50000E-01      8.08883E-11      9.98067E-01      2.67828E+00
 1.00000E+00      8.09092E-11      9.98325E-01      2.67897E+00
 1.25000E+00      8.09395E-11      9.98699E-01      2.67997E+00
 1.50000E+00      8.09771E-11      9.99163E-01      2.68122E+00
 1.75000E+00      8.10163E-11      9.99647E-01      2.68252E+00
 1.90500E+00      8.10450E-11      1.00000E+00      2.68346E+00
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      Average Deposit = 2.679639

WAFER 144     V(OUT) =  125915     CA(OUT) =  7.883573E-11
R(cm)            CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00     7.93925E-11     9.97823E-01     2.62875E+00
 2.50000E-01     7.93941E-11     9.97844E-01     2.62880E+00
 5.00000E-01     7.93998E-11     9.97916E-01     2.62899E+00
 7.50000E-01     7.94119E-11     9.98067E-01     2.62939E+00
 1.00000E+00     7.94324E-11     9.98325E-01     2.63007E+00
 1.25000E+00     7.94621E-11     9.98699E-01     2.63105E+00
 1.50000E+00     7.94991E-11     9.99163E-01     2.63228E+00
 1.75000E+00     7.95375E-11     9.99647E-01     2.63355E+00
 1.90500E+00     7.95657E-11     1.00000E+00     2.63448E+00
      Average Deposit = 2.630728

WAFER 145     V(OUT) =  125904     CA(OUT) =  7.739571E-11
R(cm)            CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00     7.79426E-11     9.97823E-01     2.58074E+00
 2.50000E-01     7.79442E-11     9.97844E-01     2.58080E+00
 5.00000E-01     7.79499E-11     9.97916E-01     2.58098E+00
 7.50000E-01     7.79617E-11     9.98067E-01     2.58137E+00
 1.00000E+00     7.79819E-11     9.98325E-01     2.58204E+00
 1.25000E+00     7.80110E-11     9.98699E-01     2.58301E+00
 1.50000E+00     7.80473E-11     9.99163E-01     2.58421E+00
 1.75000E+00     7.80851E-11     9.99647E-01     2.58546E+00
 1.90500E+00     7.81127E-11     1.00000E+00     2.58637E+00
      Average Deposit = 2.582687

WAFER 146     V(OUT) =  125893.3     CA(OUT) =  7.598134E-11
R(cm)            CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00     7.65186E-11     9.97823E-01     2.53359E+00
 2.50000E-01     7.65202E-11     9.97843E-01     2.53364E+00
 5.00000E-01     7.65257E-11     9.97916E-01     2.53383E+00
 7.50000E-01     7.65373E-11     9.98067E-01     2.53421E+00
 1.00000E+00     7.65571E-11     9.98325E-01     2.53487E+00
 1.25000E+00     7.65857E-11     9.98699E-01     2.53582E+00
 1.50000E+00     7.66214E-11     9.99163E-01     2.53699E+00
 1.75000E+00     7.66584E-11     9.99647E-01     2.53822E+00
 1.90500E+00     7.66855E-11     1.00000E+00     2.53912E+00
      Average Deposit = 2.5355

WAFER 147     V(OUT) =  125882.8     CA(OUT) =  7.459218E-11
R(cm)            CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00     7.51199E-11     9.97823E-01     2.48728E+00
 2.50000E-01     7.51215E-11     9.97844E-01     2.48733E+00
 5.00000E-01     7.51269E-11     9.97916E-01     2.48751E+00
 7.50000E-01     7.51383E-11     9.98067E-01     2.48789E+00
 1.00000E+00     7.51577E-11     9.98325E-01     2.48853E+00
 1.25000E+00     7.51858E-11     9.98699E-01     2.48946E+00
 1.50000E+00     7.52208E-11     9.99163E-01     2.49062E+00
 1.75000E+00     7.52572E-11     9.99647E-01     2.49183E+00
 1.90500E+00     7.52838E-11     1.00000E+00     2.49271E+00
      Average Deposit = 2.489155

WAFER 148     V(OUT) =  125872.4     CA(OUT) =  7.322781E-11
R(cm)            CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00     7.37462E-11     9.97823E-01     2.44180E+00
 2.50000E-01     7.37477E-11     9.97844E-01     2.44185E+00
 5.00000E-01     7.37531E-11     9.97916E-01     2.44202E+00
 7.50000E-01     7.37643E-11     9.98067E-01     2.44239E+00
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 1.00000E+00      7.37833E-11      9.98325E-01       2.44303E+00
 1.25000E+00      7.38109E-11      9.98699E-01       2.44394E+00
 1.50000E+00      7.38453E-11      9.99163E-01       2.44508E+00
 1.75000E+00      7.38810E-11      9.99647E-01       2.44626E+00
 1.90500E+00      7.39071E-11      1.00000E+00       2.44712E+00
      Average Deposit = 2.443636

WAFER 149      V(OUT) =  125862.3      CA(OUT) =   7.18878E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      7.23970E-11      9.97823E-01       2.39712E+00
 2.50000E-01      7.23985E-11      9.97844E-01       2.39717E+00
 5.00000E-01      7.24038E-11      9.97916E-01       2.39735E+00
 7.50000E-01      7.24147E-11      9.98067E-01       2.39771E+00
 1.00000E+00      7.24335E-11      9.98325E-01       2.39833E+00
 1.25000E+00      7.24605E-11      9.98699E-01       2.39923E+00
 1.50000E+00      7.24942E-11      9.99163E-01       2.40034E+00
 1.75000E+00      7.25293E-11      9.99647E-01       2.40150E+00
 1.90500E+00      7.25550E-11      1.00000E+00       2.40235E+00
      Average Deposit = 2.398929

WAFER 150      V(OUT) =  125852.3      CA(OUT) =   7.057175E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      7.10719E-11      9.97823E-01       2.35325E+00
 2.50000E-01      7.10734E-11      9.97844E-01       2.35330E+00
 5.00000E-01      7.10785E-11      9.97916E-01       2.35347E+00
 7.50000E-01      7.10893E-11      9.98067E-01       2.35382E+00
 1.00000E+00      7.11077E-11      9.98325E-01       2.35443E+00
 1.25000E+00      7.11343E-11      9.98699E-01       2.35531E+00
 1.50000E+00      7.11674E-11      9.99163E-01       2.35641E+00
 1.75000E+00      7.12018E-11      9.99647E-01       2.35755E+00
 1.90500E+00      7.12270E-11      1.00000E+00       2.35838E+00
      Average Deposit = 2.355021

WAFER 151      V(OUT) =  125842.5      CA(OUT) =   6.927923E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      6.97705E-11      9.97823E-01       2.31016E+00
 2.50000E-01      6.97720E-11      9.97844E-01       2.31021E+00
 5.00000E-01      6.97770E-11      9.97916E-01       2.31037E+00
 7.50000E-01      6.97876E-11      9.98067E-01       2.31072E+00
 1.00000E+00      6.98057E-11      9.98325E-01       2.31132E+00
 1.25000E+00      6.98318E-11      9.98699E-01       2.31219E+00
 1.50000E+00    6.98642E-11      9.99163E-01      2.31326E+00
 1.75000E+00      6.98980E-11      9.99647E-01       2.31438E+00
 1.90500E+00      6.99228E-11      1.00000E+00       2.31520E+00
      Average Deposit = 2.311899

WAFER 152      V(OUT) =  125832.9      CA(OUT) =   6.800985E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      6.84924E-11      9.97823E-01       2.26784E+00
 2.50000E-01      6.84938E-11      9.97844E-01       2.26788E+00
 5.00000E-01      6.84988E-11      9.97916E-01       2.26805E+00
 7.50000E-01      6.85092E-11      9.98067E-01       2.26839E+00
 1.00000E+00      6.85269E-11      9.98325E-01       2.26898E+00
 1.25000E+00      6.85525E-11      9.98699E-01       2.26983E+00
 1.50000E+00      6.85844E-11      9.99163E-01       2.27088E+00
 1.75000E+00      6.86176E-11      9.99647E-01       2.27198E+00
 1.90500E+00      6.86418E-11      1.00000E+00       2.27279E+00
      Average Deposit = 2.269547

WAFER 153      V(OUT) =  125823.4      CA(OUT) =   6.676321E-11
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R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      6.72372E-11     9.97823E-01      2.22628E+00
 2.50000E-01      6.72386E-11     9.97844E-01      2.22632E+00
 5.00000E-01      6.72434E-11     9.97916E-01      2.22648E+00
 7.50000E-01      6.72537E-11     9.98067E-01      2.22682E+00
 1.00000E+00      6.72710E-11     9.98325E-01      2.22740E+00
 1.25000E+00      6.72962E-11     9.98699E-01      2.22823E+00
 1.50000E+00      6.73275E-11     9.99163E-01      2.22927E+00
 1.75000E+00      6.73601E-11     9.99647E-01      2.23035E+00
 1.90500E+00      6.73839E-11     1.00000E+00      2.23113E+00
       Average Deposit = 2.227955

WAFER 154      V(OUT) =  125814.1     CA(OUT) =  6.553893E-11
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      6.60045E-11     9.97823E-01      2.18546E+00
 2.50000E-01      6.60058E-11     9.97844E-01      2.18551E+00
 5.00000E-01      6.60106E-11     9.97916E-01      2.18566E+00
 7.50000E-01      6.60206E-11     9.98067E-01      2.18600E+00
 1.00000E+00      6.60377E-11     9.98325E-01      2.18656E+00
 1.25000E+00      6.60624E-11     9.98699E-01      2.18738E+00
 1.50000E+00      6.60931E-11     9.99163E-01      2.18840E+00
 1.75000E+00      6.61251E-11     9.99647E-01      2.18946E+00
 1.90500E+00      6.61485E-11     1.00000E+00      2.19023E+00
       Average Deposit = 2.187107

WAFER 155      V(OUT) =  125805     CA(OUT) =  6.433662E-11
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      6.47939E-11     9.97823E-01      2.14538E+00
 2.50000E-01      6.47952E-11     9.97844E-01      2.14542E+00
 5.00000E-01      6.47999E-11     9.97916E-01      2.14558E+00
 7.50000E-01      6.48097E-11     9.98067E-01      2.14590E+00
 1.00000E+00      6.48265E-11     9.98325E-01      2.14646E+00
 1.25000E+00      6.48507E-11     9.98699E-01      2.14726E+00
 1.50000E+00      6.48809E-11     9.99163E-01      2.14826E+00
 1.75000E+00      6.49123E-11     9.99647E-01      2.14930E+00
 1.90500E+00      6.49352E-11     1.00000E+00      2.15006E+00
       Average Deposit = 2.146993

WAFER 156      V(OUT) =  125796.1     CA(OUT) =  6.315591E-11
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      6.36050E-11     9.97823E-01      2.10601E+00
 2.50000E-01      6.36063E-11     9.97843E-01      2.10606E+00
 5.00000E-01      6.36109E-11     9.97916E-01      2.10621E+00
 7.50000E-01      6.36206E-11     9.98067E-01      2.10653E+00
 1.00000E+00      6.36370E-11     9.98325E-01      2.10707E+00
 1.25000E+00      6.36608E-11     9.98699E-01      2.10786E+00
 1.50000E+00      6.36904E-11     9.99163E-01      2.10884E+00
 1.75000E+00      6.37212E-11     9.99647E-01      2.10986E+00
 1.90500E+00      6.37438E-11     1.00000E+00      2.11061E+00
       Average Deposit = 2.107599

WAFER 157      V(OUT) =  125787.3     CA(OUT) =  6.199641E-11
R(cm)              CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      6.24375E-11     9.97823E-01      2.06735E+00
 2.50000E-01      6.24388E-11     9.97844E-01      2.06740E+00
 5.00000E-01      6.24433E-11     9.97916E-01      2.06755E+00
 7.50000E-01      6.24528E-11     9.98067E-01      2.06786E+00
 1.00000E+00      6.24689E-11     9.98325E-01      2.06840E+00
 1.25000E+00      6.24923E-11     9.98699E-01      2.06917E+00
 1.50000E+00      6.25213E-11     9.99163E-01      2.07013E+00
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 1.75000E+00      6.25516E-11     9.99647E-01      2.07113E+00
 1.90500E+00      6.25737E-11     1.00000E+00      2.07187E+00
      Average Deposit = 2.068913

WAFER 158       V(OUT) =  125778.7      CA(OUT) =   6.085777E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      6.12910E-11     9.97823E-01      2.02939E+00
 2.50000E-01      6.12922E-11     9.97844E-01      2.02943E+00
 5.00000E-01      6.12967E-11     9.97916E-01      2.02958E+00
 7.50000E-01      6.13060E-11     9.98067E-01      2.02989E+00
 1.00000E+00      6.13218E-11     9.98325E-01      2.03041E+00
 1.25000E+00      6.13447E-11     9.98699E-01      2.03117E+00
 1.50000E+00      6.13733E-11     9.99163E-01      2.03212E+00
 1.75000E+00      6.14030E-11     9.99647E-01      2.03310E+00
 1.90500E+00      6.14247E-11     1.00000E+00      2.03382E+00
      Average Deposit = 2.030922

WAFER 159       V(OUT) =  125770.2      CA(OUT) =   5.973963E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      6.01651E-11     9.97823E-01      1.99211E+00
 2.50000E-01      6.01663E-11     9.97844E-01      1.99215E+00
 5.00000E-01      6.01707E-11     9.97916E-01      1.99230E+00
 7.50000E-01      6.01798E-11     9.98067E-01      1.99260E+00
 1.00000E+00      6.01954E-11     9.98325E-01      1.99312E+00
 1.25000E+00      6.02179E-11     9.98699E-01      1.99386E+00
 1.50000E+00      6.02459E-11     9.99163E-01      1.99479E+00
 1.75000E+00      6.02750E-11     9.99647E-01      1.99575E+00
 1.90500E+00      6.02963E-11     1.00000E+00      1.99646E+00
      Average Deposit = 1.993614

WAFER 160       V(OUT) =  125761.9      CA(OUT) =   5.864164E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      5.90595E-11     9.97823E-01      1.95551E+00
 2.50000E-01      5.90607E-11     9.97844E-01      1.95555E+00
 5.00000E-01      5.90650E-11     9.97916E-01      1.95569E+00
 7.50000E-01      5.90739E-11     9.98067E-01      1.95598E+00
 1.00000E+00      5.90892E-11     9.98325E-01      1.95649E+00
 1.25000E+00      5.91113E-11     9.98699E-01      1.95722E+00
 1.50000E+00      5.91388E-11     9.99163E-01      1.95813E+00
 1.75000E+00      5.91674E-11     9.99647E-01      1.95908E+00
 1.90500E+00      5.91883E-11     1.00000E+00      1.95977E+00
      Average Deposit = 1.956979

WAFER 161       V(OUT) =  125753.7      CA(OUT) =   5.756345E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      5.79738E-11     9.97823E-01      1.91956E+00
 2.50000E-01      5.79750E-11     9.97844E-01      1.91960E+00
 5.00000E-01      5.79792E-11     9.97916E-01      1.91974E+00
 7.50000E-01      5.79880E-11     9.98067E-01      1.92003E+00
 1.00000E+00      5.80030E-11     9.98325E-01      1.92052E+00
 1.25000E+00      5.80246E-11     9.98699E-01      1.92124E+00
 1.50000E+00      5.80516E-11     9.99163E-01      1.92214E+00
 1.75000E+00      5.80797E-11     9.99647E-01      1.92307E+00
 1.90500E+00      5.81003E-11     1.00000E+00      1.92375E+00
      Average Deposit = 1.921004

WAFER 162       V(OUT) =  125745.7      CA(OUT) =   5.65047E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      5.69077E-11     9.97823E-01      1.88426E+00
 2.50000E-01      5.69088E-11     9.97844E-01      1.88430E+00
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 5.00000E-01     5.69130E-11     9.97916E-01      1.88443E+00
 7.50000E-01     5.69216E-11     9.98067E-01      1.88472E+00
 1.00000E+00     5.69363E-11     9.98325E-01      1.88521E+00
 1.25000E+00     5.69576E-11     9.98699E-01      1.88591E+00
 1.50000E+00     5.69841E-11     9.99163E-01      1.88679E+00
 1.75000E+00     5.70117E-11     9.99647E-01      1.88770E+00
 1.90500E+00     5.70318E-11     1.00000E+00      1.88837E+00
      Average Deposit = 1.885678

WAFER 163     V(OUT) =  125737.8     CA(OUT)  =   5.546507E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     5.58608E-11     9.97823E-01      1.84960E+00
 2.50000E-01     5.58620E-11     9.97844E-01      1.84963E+00
 5.00000E-01     5.58660E-11     9.97916E-01      1.84977E+00
 7.50000E-01     5.58745E-11     9.98067E-01      1.85005E+00
 1.00000E+00     5.58889E-11     9.98325E-01      1.85053E+00
 1.25000E+00     5.59098E-11     9.98699E-01      1.85122E+00
 1.50000E+00     5.59358E-11     9.99163E-01      1.85208E+00
 1.75000E+00     5.59629E-11     9.99647E-01      1.85298E+00
 1.90500E+00     5.59827E-11     1.00000E+00      1.85363E+00
      Average Deposit = 1.850989

WAFER 164     V(OUT) =  125730.1     CA(OUT)  =   5.444423E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     5.48329E-11     9.97823E-01      1.81556E+00
 2.50000E-01     5.48340E-11     9.97844E-01      1.81560E+00
 5.00000E-01     5.48380E-11     9.97916E-01      1.81573E+00
 7.50000E-01     5.48463E-11     9.98067E-01      1.81600E+00
 1.00000E+00     5.48605E-11     9.98325E-01      1.81647E+00
 1.25000E+00     5.48810E-11     9.98699E-01      1.81715E+00
 1.50000E+00     5.49065E-11     9.99163E-01      1.81800E+00
 1.75000E+00     5.49331E-11     9.99647E-01      1.81888E+00
 1.90500E+00     5.49525E-11     1.00000E+00      1.81952E+00
      Average Deposit = 1.816927

WAFER 165     V(OUT) =  125722.5     CA(OUT)  =   5.344184E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     5.38235E-11     9.97823E-01      1.78214E+00
 2.50000E-01     5.38246E-11     9.97844E-01      1.78217E+00
 5.00000E-01     5.38285E-11     9.97916E-01      1.78230E+00
 7.50000E-01     5.38367E-11     9.98067E-01      1.78257E+00
 1.00000E+00     5.38506E-11     9.98325E-01      1.78304E+00
 1.25000E+00     5.38707E-11     9.98699E-01      1.78370E+00
 1.50000E+00     5.38958E-11     9.99163E-01      1.78453E+00
 1.75000E+00     5.39218E-11     9.99647E-01      1.78540E+00
 1.90500E+00     5.39409E-11     1.00000E+00      1.78603E+00
      Average Deposit = 1.783481

WAFER 166     V(OUT) =  125715.1     CA(OUT)  =   5.245759E-11
R(cm)             CA(r,dell)         CA/CAI       G(angs./min)
 0.00000E+00     5.28324E-11     9.97823E-01      1.74932E+00
 2.50000E-01     5.28334E-11     9.97843E-01      1.74936E+00
 5.00000E-01     5.28373E-11     9.97916E-01      1.74948E+00
 7.50000E-01     5.28453E-11     9.98067E-01      1.74975E+00
 1.00000E+00     5.28590E-11     9.98325E-01      1.75020E+00
 1.25000E+00     5.28787E-11     9.98699E-01      1.75086E+00
 1.50000E+00     5.29033E-11     9.99163E-01      1.75167E+00
 1.75000E+00     5.29289E-11     9.99647E-01      1.75252E+00
 1.90500E+00     5.29476E-11     1.00000E+00      1.75314E+00
      Average Deposit = 1.75064
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WAFER 167       V(OUT) =  125707.8     CA(OUT) =   5.149115E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      5.18592E-11     9.97823E-01      1.71710E+00
 2.50000E-01      5.18602E-11     9.97844E-01      1.71713E+00
 5.00000E-01      5.18640E-11     9.97916E-01      1.71726E+00
 7.50000E-01      5.18719E-11     9.98067E-01      1.71752E+00
 1.00000E+00      5.18853E-11     9.98325E-01      1.71796E+00
 1.25000E+00      5.19047E-11     9.98699E-01      1.71861E+00
 1.50000E+00      5.19288E-11     9.99163E-01      1.71940E+00
 1.75000E+00      5.19539E-11     9.99647E-01      1.72024E+00
 1.90500E+00      5.19723E-11     1.00000E+00      1.72084E+00
          Average Deposit = 1.718392

WAFER 168       V(OUT) =  125700.6     CA(OUT) =   5.054222E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      5.09036E-11     9.97823E-01      1.68546E+00
 2.50000E-01      5.09046E-11     9.97844E-01      1.68549E+00
 5.00000E-01      5.09083E-11     9.97916E-01      1.68562E+00
 7.50000E-01      5.09161E-11     9.98067E-01      1.68587E+00
 1.00000E+00      5.09292E-11     9.98325E-01      1.68631E+00
 1.25000E+00      5.09483E-11     9.98699E-01      1.68694E+00
 1.50000E+00      5.09720E-11     9.99163E-01      1.68772E+00
 1.75000E+00      5.09966E-11     9.99647E-01      1.68854E+00
 1.90500E+00      5.10147E-11     1.00000E+00      1.68914E+00
          Average Deposit = 1.686729

WAFER 169       V(OUT) =  125693.5     CA(OUT) =   4.961048E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      4.99654E-11     9.97823E-01      1.65439E+00
 2.50000E-01      4.99664E-11     9.97844E-01      1.65443E+00
 5.00000E-01      4.99700E-11     9.97916E-01      1.65455E+00
 7.50000E-01      4.99776E-11     9.98067E-01      1.65480E+00
 1.00000E+00      4.99905E-11     9.98325E-01      1.65523E+00
 1.25000E+00      5.00092E-11     9.98699E-01      1.65584E+00
 1.50000E+00      5.00325E-11     9.99163E-01      1.65661E+00
 1.75000E+00      5.00567E-11     9.99647E-01      1.65742E+00
 1.90500E+00      5.00744E-11     1.00000E+00      1.65800E+00
          Average Deposit = 1.655639

WAFER 170       V(OUT) =  125686.6     CA(OUT) =   4.869565E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      4.90441E-11     9.97823E-01      1.62389E+00
 2.50000E-01      4.90451E-11     9.97844E-01      1.62392E+00
 5.00000E-01      4.90487E-11     9.97916E-01      1.62404E+00
 7.50000E-01      4.90561E-11     9.98067E-01      1.62429E+00
 1.00000E+00      4.90688E-11     9.98325E-01      1.62471E+00
 1.25000E+00      4.90872E-11     9.98699E-01      1.62532E+00
 1.50000E+00      4.91100E-11     9.99163E-01      1.62607E+00
 1.75000E+00      4.91338E-11     9.99647E-01      1.62686E+00
 1.90500E+00      4.91511E-11     1.00000E+00      1.62743E+00
          Average Deposit = 1.625113

WAFER 171       V(OUT) =  125679.8     CA(OUT) =   4.779741E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      4.81396E-11     9.97823E-01      1.59394E+00
 2.50000E-01      4.81406E-11     9.97844E-01      1.59397E+00
 5.00000E-01      4.81441E-11     9.97916E-01      1.59409E+00
 7.50000E-01      4.81514E-11     9.98067E-01      1.59433E+00
 1.00000E+00      4.81638E-11     9.98325E-01      1.59474E+00
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 1.25000E+00     4.81818E-11     9.98699E-01     1.59534E+00
 1.50000E+00     4.82042E-11     9.99163E-01     1.59608E+00
 1.75000E+00     4.82276E-11     9.99647E-01     1.59685E+00
 1.90500E+00     4.82446E-11     1.00000E+00     1.59742E+00
      Average Deposit = 1.595141

WAFER 172     V(OUT) =  125673.1     CA(OUT) =  4.691549E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.72515E-11     9.97823E-01     1.56453E+00
 2.50000E-01     4.72525E-11     9.97844E-01     1.56457E+00
 5.00000E-01     4.72559E-11     9.97916E-01     1.56468E+00
 7.50000E-01     4.72631E-11     9.98067E-01     1.56492E+00
 1.00000E+00     4.72753E-11     9.98325E-01     1.56532E+00
 1.25000E+00     4.72930E-11     9.98699E-01     1.56591E+00
 1.50000E+00     4.73149E-11     9.99163E-01     1.56664E+00
 1.75000E+00     4.73378E-11     9.99647E-01     1.56739E+00
 1.90500E+00     4.73546E-11     1.00000E+00     1.56795E+00
      Average Deposit = 1.565713

WAFER 173     V(OUT) =  125666.6     CA(OUT) =  4.60496E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.63795E-11     9.97823E-01     1.53566E+00
 2.50000E-01     4.63805E-11     9.97844E-01     1.53569E+00
 5.00000E-01     4.63838E-11     9.97916E-01     1.53581E+00
 7.50000E-01     4.63909E-11     9.98067E-01     1.53604E+00
 1.00000E+00     4.64029E-11     9.98325E-01     1.53644E+00
 1.25000E+00     4.64202E-11     9.98699E-01     1.53701E+00
 1.50000E+00     4.64418E-11     9.99163E-01     1.53773E+00
 1.75000E+00     4.64643E-11     9.99647E-01     1.53847E+00
 1.90500E+00     4.64807E-11     1.00000E+00     1.53901E+00
      Average Deposit = 1.53682

WAFER 174     V(OUT) =  125660.2     CA(OUT) =  4.519944E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.55234E-11     9.97823E-01     1.50732E+00
 2.50000E-01     4.55243E-11     9.97843E-01     1.50735E+00
 5.00000E-01     4.55276E-11     9.97916E-01     1.50746E+00
 7.50000E-01     4.55345E-11     9.98067E-01     1.50768E+00
 1.00000E+00     4.55463E-11     9.98325E-01     1.50807E+00
 1.25000E+00     4.55633E-11     9.98699E-01     1.50864E+00
 1.50000E+00     4.55845E-11     9.99163E-01     1.50934E+00
 1.75000E+00     4.56066E-11     9.99647E-01     1.51007E+00
 1.90500E+00     4.56227E-11     1.00000E+00     1.51060E+00
      Average Deposit = 1.508452

WAFER 175     V(OUT) =  125653.9     CA(OUT) =  4.436475E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00     4.46828E-11     9.97823E-01     1.47948E+00
 2.50000E-01     4.46838E-11     9.97844E-01     1.47951E+00
 5.00000E-01     4.46870E-11     9.97916E-01     1.47962E+00
 7.50000E-01     4.46938E-11     9.98067E-01     1.47985E+00
 1.00000E+00     4.47053E-11     9.98325E-01     1.48023E+00
 1.25000E+00     4.47220E-11     9.98699E-01     1.48078E+00
 1.50000E+00     4.47428E-11     9.99163E-01     1.48147E+00
 1.75000E+00     4.47645E-11     9.99647E-01     1.48219E+00
 1.90500E+00     4.47803E-11     1.00000E+00     1.48271E+00
      Average Deposit = 1.480599

WAFER 176     V(OUT) =  125647.7     CA(OUT) =  4.354525E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
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 0.00000E+00       4.38576E-11      9.97823E-01       1.45216E+00
 2.50000E-01       4.38585E-11      9.97844E-01       1.45219E+00
 5.00000E-01       4.38617E-11      9.97916E-01       1.45229E+00
 7.50000E-01       4.38683E-11      9.98067E-01       1.45251E+00
 1.00000E+00       4.38796E-11      9.98325E-01       1.45289E+00
 1.25000E+00       4.38961E-11      9.98699E-01       1.45343E+00
 1.50000E+00       4.39165E-11      9.99163E-01       1.45411E+00
 1.75000E+00       4.39377E-11      9.99647E-01       1.45481E+00
 1.90500E+00       4.39533E-11      1.00000E+00       1.45533E+00
       Average Deposit = 1.453253

WAFER 177      V(OUT) =  125641.6     CA(OUT) =   4.274066E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       4.30473E-11      9.97823E-01       1.42533E+00
 2.50000E-01       4.30482E-11      9.97844E-01       1.42536E+00
 5.00000E-01       4.30513E-11      9.97916E-01       1.42546E+00
 7.50000E-01       4.30579E-11      9.98067E-01       1.42568E+00
 1.00000E+00       4.30690E-11      9.98325E-01       1.42605E+00
 1.25000E+00       4.30851E-11      9.98699E-01       1.42658E+00
 1.50000E+00       4.31051E-11      9.99163E-01       1.42725E+00
 1.75000E+00       4.31260E-11      9.99647E-01       1.42794E+00
 1.90500E+00       4.31412E-11      1.00000E+00       1.42844E+00
       Average Deposit = 1.426405

WAFER 178      V(OUT) =  125635.6     CA(OUT) =   4.195074E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       4.22518E-11      9.97823E-01       1.39899E+00
 2.50000E-01       4.22527E-11      9.97844E-01       1.39902E+00
 5.00000E-01       4.22558E-11      9.97916E-01       1.39912E+00
 7.50000E-01       4.22622E-11      9.98067E-01       1.39933E+00
 1.00000E+00       4.22731E-11      9.98325E-01       1.39970E+00
 1.25000E+00       4.22889E-11      9.98699E-01       1.40022E+00
 1.50000E+00       4.23086E-11      9.99163E-01       1.40087E+00
 1.75000E+00       4.23291E-11      9.99647E-01       1.40155E+00
 1.90500E+00       4.23440E-11      1.00000E+00       1.40204E+00
       Average Deposit = 1.400046

WAFER 179      V(OUT) =  125629.8     CA(OUT) =   4.117522E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       4.14709E-11      9.97823E-01       1.37313E+00
 2.50000E-01       4.14717E-11      9.97844E-01       1.37316E+00
 5.00000E-01       4.14747E-11      9.97916E-01       1.37326E+00
 7.50000E-01       4.14810E-11      9.98067E-01       1.37347E+00
 1.00000E+00       4.14917E-11      9.98325E-01       1.37382E+00
 1.25000E+00       4.15073E-11      9.98699E-01       1.37434E+00
 1.50000E+00       4.15266E-11      9.99163E-01       1.37498E+00
 1.75000E+00       4.15466E-11      9.99647E-01       1.37564E+00
 1.90500E+00       4.15613E-11      1.00000E+00       1.37613E+00
       Average Deposit = 1.374168

WAFER 180      V(OUT) =  125624     CA(OUT) =  4.041384E-11
R(cm)               CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00       4.07041E-11      9.97823E-01       1.34775E+00
 2.50000E-01       4.07049E-11      9.97843E-01       1.34777E+00
 5.00000E-01       4.07079E-11      9.97916E-01       1.34787E+00
 7.50000E-01       4.07141E-11      9.98067E-01       1.34808E+00
 1.00000E+00       4.07246E-11      9.98325E-01       1.34842E+00
 1.25000E+00       4.07398E-11      9.98699E-01       1.34893E+00
 1.50000E+00       4.07588E-11      9.99163E-01       1.34956E+00
 1.75000E+00       4.07785E-11      9.99647E-01       1.35021E+00
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 1.90500E+00      4.07929E-11     1.00000E+00     1.35069E+00
      Average Deposit = 1.348761

WAFER 181     V(OUT) =  125618.4     CA(OUT) =  3.966635E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      3.99513E-11     9.97823E-01     1.32282E+00
 2.50000E-01      3.99522E-11     9.97843E-01     1.32285E+00
 5.00000E-01      3.99551E-11     9.97916E-01     1.32294E+00
 7.50000E-01      3.99611E-11     9.98067E-01     1.32314E+00
 1.00000E+00      3.99715E-11     9.98325E-01     1.32349E+00
 1.25000E+00      3.99864E-11     9.98699E-01     1.32398E+00
 1.50000E+00      4.00050E-11     9.99163E-01     1.32460E+00
 1.75000E+00      4.00244E-11     9.99647E-01     1.32524E+00
 1.90500E+00      4.00385E-11     1.00000E+00     1.32571E+00
      Average Deposit = 1.323817

WAFER 182     V(OUT) =  125612.8     CA(OUT) =  3.893251E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      3.92123E-11     9.97823E-01     1.29835E+00
 2.50000E-01      3.92131E-11     9.97844E-01     1.29838E+00
 5.00000E-01      3.92160E-11     9.97916E-01     1.29847E+00
 7.50000E-01      3.92219E-11     9.98067E-01     1.29867E+00
 1.00000E+00      3.92321E-11     9.98325E-01     1.29900E+00
 1.25000E+00      3.92467E-11     9.98699E-01     1.29949E+00
 1.50000E+00      3.92650E-11     9.99163E-01     1.30010E+00
 1.75000E+00      3.92840E-11     9.99647E-01     1.30072E+00
 1.90500E+00      3.92979E-11     1.00000E+00     1.30118E+00
      Average Deposit = 1.29933

WAFER 183     V(OUT) =  125607.4     CA(OUT) =  3.821207E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      3.84868E-11     9.97823E-01     1.27433E+00
 2.50000E-01      3.84876E-11     9.97844E-01     1.27435E+00
 5.00000E-01      3.84904E-11     9.97916E-01     1.27445E+00
 7.50000E-01      3.84962E-11     9.98067E-01     1.27464E+00
 1.00000E+00      3.85062E-11     9.98325E-01     1.27497E+00
 1.25000E+00      3.85206E-11     9.98699E-01     1.27545E+00
 1.50000E+00      3.85385E-11     9.99163E-01     1.27604E+00
 1.75000E+00      3.85571E-11     9.99647E-01     1.27666E+00
 1.90500E+00      3.85708E-11     1.00000E+00     1.27711E+00
      Average Deposit = 1.275289

WAFER 184     V(OUT) =  125602     CA(OUT) =  3.750481E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      3.77745E-11     9.97823E-01     1.25074E+00
 2.50000E-01      3.77753E-11     9.97843E-01     1.25077E+00
 5.00000E-01      3.77780E-11     9.97916E-01     1.25086E+00
 7.50000E-01      3.77838E-11     9.98067E-01     1.25105E+00
 1.00000E+00      3.77935E-11     9.98325E-01     1.25137E+00
 1.25000E+00      3.78077E-11     9.98699E-01     1.25184E+00
 1.50000E+00      3.78253E-11     9.99163E-01     1.25242E+00
 1.75000E+00      3.78436E-11     9.99647E-01     1.25303E+00
 1.90500E+00      3.78569E-11     1.00000E+00     1.25347E+00
      Average Deposit = 1.251687

WAFER 185     V(OUT) =  125596.8     CA(OUT) =  3.681047E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      3.70753E-11     9.97823E-01     1.22759E+00
 2.50000E-01      3.70760E-11     9.97844E-01     1.22762E+00
 5.00000E-01      3.70787E-11     9.97916E-01     1.22771E+00
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 7.50000E-01      3.70843E-11     9.98067E-01      1.22789E+00
 1.00000E+00      3.70939E-11     9.98325E-01      1.22821E+00
 1.25000E+00      3.71078E-11     9.98699E-01      1.22867E+00
 1.50000E+00      3.71251E-11     9.99163E-01      1.22924E+00
 1.75000E+00      3.71430E-11     9.99647E-01      1.22984E+00
 1.90500E+00      3.71562E-11     1.00000E+00      1.23027E+00
       Average Deposit = 1.228517

WAFER 186       V(OUT) =  125591.6      CA(OUT) =  3.612882E-11
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.63888E-11     9.97823E-01      1.20486E+00
 2.50000E-01      3.63895E-11     9.97843E-01      1.20489E+00
 5.00000E-01      3.63922E-11     9.97916E-01      1.20497E+00
 7.50000E-01      3.63977E-11     9.98067E-01      1.20516E+00
 1.00000E+00      3.64071E-11     9.98325E-01      1.20547E+00
 1.25000E+00      3.64207E-11     9.98699E-01      1.20592E+00
 1.50000E+00      3.64377E-11     9.99163E-01      1.20648E+00
 1.75000E+00      3.64553E-11     9.99647E-01      1.20706E+00
 1.90500E+00      3.64682E-11     1.00000E+00      1.20749E+00
       Average Deposit = 1.20577

WAFER 187       V(OUT) =  125586.6      CA(OUT) =  3.545966E-11
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.57149E-11     9.97823E-01      1.18255E+00
 2.50000E-01      3.57156E-11     9.97843E-01      1.18257E+00
 5.00000E-01      3.57182E-11     9.97916E-01      1.18266E+00
 7.50000E-01      3.57236E-11     9.98067E-01      1.18284E+00
 1.00000E+00      3.57329E-11     9.98325E-01      1.18314E+00
 1.25000E+00      3.57462E-11     9.98699E-01      1.18359E+00
 1.50000E+00      3.57629E-11     9.99163E-01      1.18414E+00
 1.75000E+00      3.57802E-11     9.99647E-01      1.18471E+00
 1.90500E+00      3.57928E-11     1.00000E+00      1.18513E+00
       Average Deposit = 1.18344

WAFER 188       V(OUT) =  125581.6      CA(OUT) =  3.480274E-11
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.50533E-11     9.97823E-01      1.16064E+00
 2.50000E-01      3.50540E-11     9.97843E-01      1.16067E+00
 5.00000E-01      3.50566E-11     9.97916E-01      1.16075E+00
 7.50000E-01      3.50619E-11     9.98067E-01      1.16093E+00
 1.00000E+00      3.50710E-11     9.98325E01      1.16123E+00
 1.25000E+00      3.50841E-11     9.98699E-01      1.16166E+00
 1.50000E+00      3.51004E-11     9.99163E-01      1.16220E+00
 1.75000E+00      3.51174E-11     9.99647E-01      1.16276E+00
 1.90500E+00      3.51298E-11     1.00000E+00      1.16318E+00
       Average Deposit = 1.161518

WAFER 189       V(OUT) =  125576.8      CA(OUT) =  3.415785E-11
R(cm)               CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.44039E-11     9.97823E-01      1.13914E+00
 2.50000E-01      3.44046E-11     9.97844E-01      1.13916E+00
 5.00000E-01      3.44071E-11     9.97916E-01      1.13925E+00
 7.50000E-01      3.44123E-11     9.98067E-01      1.13942E+00
 1.00000E+00      3.44212E-11     9.98325E-01      1.13971E+00
 1.25000E+00      3.44341E-11     9.98699E-01      1.14014E+00
 1.50000E+00      3.44501E-11     9.99163E-01      1.14067E+00
 1.75000E+00      3.44667E-11     9.99647E-01      1.14122E+00
 1.90500E+00      3.44789E-11     1.00000E+00      1.14162E+00
       Average Deposit = 1.139998
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WAFER 190      V(OUT) =  125572      CA(OUT) =  3.352479E-11
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00      3.37663E-11      9.97823E-01      1.11803E+00
 2.50000E-01      3.37670E-11      9.97844E-01      1.11805E+00
 5.00000E-01      3.37694E-11      9.97916E-01      1.11813E+00
 7.50000E-01      3.37746E-11      9.98067E-01      1.11830E+00
 1.00000E+00      3.37833E-11      9.98325E-01      1.11859E+00
 1.25000E+00      3.37959E-11      9.98699E-01      1.11901E+00
 1.50000E+00      3.38117E-11      9.99163E-01      1.11953E+00
 1.75000E+00      3.38280E-11      9.99647E-01      1.12007E+00
 1.90500E+00      3.38400E-11      1.00000E+00      1.12047E+00
      Average Deposit = 1.118872

WAFER 191      V(OUT) =  125567.3      CA(OUT) =  3.290332E-11
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00      3.31404E-11      9.97823E-01      1.09731E+00
 2.50000E-01      3.31411E-11      9.97844E-01      1.09733E+00
 5.00000E-01      3.31435E-11      9.97916E-01      1.09741E+00
 7.50000E-01      3.31485E-11      9.98067E-01      1.09757E+00
 1.00000E+00      3.31571E-11      9.98325E-01      1.09786E+00
 1.25000E+00      3.31695E-11      9.98699E-01      1.09827E+00
 1.50000E+00      3.31849E-11      9.99163E-01      1.09878E+00
 1.75000E+00      3.32010E-11      9.99647E-01      1.09931E+00
 1.90500E+00      3.32127E-11      1.00000E+00      1.09970E+00
      Average Deposit = 1.098133

WAFER 192      V(OUT) =  125562.7      CA(OUT) =  3.229326E-11
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00      3.25260E-11      9.97823E-01      1.07696E+00
 2.50000E-01      3.25267E-11      9.97844E-01      1.07698E+00
 5.00000E-01      3.25291E-11      9.97916E-01      1.07706E+00
 7.50000E-01      3.25340E-11      9.98067E-01      1.07723E+00
 1.00000E+00      3.25424E-11      9.98325E-01      1.07750E+00
 1.25000E+00      3.25546E-11      9.98699E-01      1.07791E+00
 1.50000E+00      3.25697E-11      9.99163E-01      1.07841E+00
 1.75000E+00      3.25855E-11      9.99647E-01      1.07893E+00
 1.90500E+00      3.25970E-11      1.00000E+00      1.07931E+00
      Average Deposit = 1.077774

WAFER 193      V(OUT) =  125558.2      CA(OUT) =  3.169438E-11
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00      3.19229E-11      9.97823E-01      1.05699E+00
 2.50000E-01      3.19235E-11      9.97843E-01      1.05701E+00
 5.00000E-01      3.19259E-11      9.97916E-01      1.05709E+00
 7.50000E-01      3.19307E-11      9.98067E-01      1.05725E+00
 1.00000E+00      3.19390E-11      9.98325E-01      1.05752E+00
 1.25000E+00      3.19509E-11      9.98699E-01      1.05792E+00
 1.50000E+00      3.19658E-11      9.99163E-01      1.05841E+00
 1.75000E+00      3.19812E-11      9.99647E-01      1.05892E+00
 1.90500E+00      3.19925E-11      1.00000E+00      1.05930E+00
      Average Deposit = 1.057789

WAFER 194      V(OUT) =  125553.7      CA(OUT) =  3.110649E-11
R(cm)              CA(r,dell)        CA/CAI          G(angs./min)
 0.00000E+00      3.13308E-11      9.97823E-01      1.03739E+00
 2.50000E-01      3.13315E-11      9.97843E-01      1.03741E+00
 5.00000E-01      3.13337E-11      9.97916E-01      1.03749E+00
 7.50000E-01      3.13385E-11      9.98067E-01      1.03764E+00
 1.00000E+00      3.13466E-11      9.98325E-01      1.03791E+00
 1.25000E+00      3.13583E-11      9.98699E-01      1.03830E+00
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 1.50000E+00      3.13729E-11     9.99163E-01      1.03878E+00
 1.75000E+00      3.13881E-11     9.99647E-01      1.03928E+00
 1.90500E+00      3.13992E-11     1.00000E+00      1.03965E+00
      Average Deposit = 1.03817

WAFER 195      V(OUT) =  125549.4    CA(OUT) =   3.05294E-11
R(cm)             CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.07496E-11     9.97823E-01      1.01814E+00
 2.50000E-01      3.07503E-11     9.97843E-01      1.01817E+00
 5.00000E-01      3.07525E-11     9.97916E-01      1.01824E+00
 7.50000E-01      3.07572E-11     9.98067E-01      1.01839E+00
 1.00000E+00      3.07651E-11     9.98325E-01      1.01866E+00
 1.25000E+00      3.07766E-11     9.98699E-01      1.01904E+00
 1.50000E+00      3.07909E-11     9.99163E-01      1.01951E+00
 1.75000E+00      3.08058E-11     9.99647E-01      1.02001E+00
 1.90500E+00      3.08167E-11     1.00000E+00      1.02037E+00
      Average Deposit = 1.018912

WAFER 196      V(OUT) =  125545.1    CA(OUT) =   2.996291E-11
R(cm)             CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      3.01791E-11     9.97823E-01      9.99254E-01
 2.50000E-01      3.01797E-11     9.97844E-01      9.99275E-01
 5.00000E-01      3.01819E-11     9.97916E-01      9.99347E-01
 7.50000E-01      3.01865E-11     9.98067E-01      9.99499E-01
 1.00000E+00      3.01943E-11     9.98325E-01      9.99757E-01
 1.25000E+00      3.02056E-11     9.98699E-01      1.00013E+00
 1.50000E+00      3.02196E-11     9.99163E-01      1.00060E+00
 1.75000E+00      3.02343E-11     9.99647E-01      1.00108E+00
 1.90500E+00      3.02449E-11     1.00000E+00      1.00143E+00
      Average Deposit = 1.000007

WAFER 197      V(OUT) =  125540.9    CA(OUT) =   2.940683E-11
R(cm)             CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.96191E-11     9.97823E-01      9.80711E-01
 2.50000E-01      2.96197E-11     9.97844E-01      9.80731E-01
 5.00000E-01      2.96218E-11     9.97916E-01      9.80802E-01
 7.50000E-01      2.96263E-11     9.98067E-01      9.80951E-01
 1.00000E+00      2.96340E-11     9.98325E-01      9.81204E-01
 1.25000E+00      2.96451E-11     9.98699E-01      9.81571E-01
 1.50000E+00      2.96588E-11     9.99163E-01      9.82028E-01
 1.75000E+00      2.96732E-11     9.99647E-01      9.82503E-01
 1.90500E+00      2.96837E-11     1.00000E+00      9.82850E-01
      Average Deposit = .9814496
WAFER 198       V(OUT) =  125536.8    CA(OUT) =   2.886096E-11
R(cm)             CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.90693E-11     9.97823E-01      9.62508E-01
 2.50000E-01      2.90699E-11     9.97844E-01      9.62528E-01
 5.00000E-01      2.90720E-11     9.97916E-01      9.62598E-01
 7.50000E-01      2.90764E-11     9.98067E-01      9.62744E-01
 1.00000E+00      2.90839E-11     9.98325E-01      9.62993E-01
 1.25000E+00      2.90948E-11     9.98699E-01      9.63353E-01
 1.50000E+00      2.91083E-11     9.99163E-01      9.63801E-01
 1.75000E+00      2.91224E-11     9.99647E-01      9.64267E-01
 1.90500E+00      2.91327E-11     1.00000E+00      9.64608E-01
      Average Deposit = .9632332

WAFER 199      V(OUT) =  125532.7    CA(OUT) =   2.832513E-11
R(cm)             CA(r,dell)       CA/CAI        G(angs./min)
 0.00000E+00      2.85297E-11     9.97823E-01      9.44640E-01
 2.50000E-01      2.85302E-11     9.97844E-01      9.44659E-01
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 5.00000E-01     2.85323E-11     9.97916E-01      9.44728E-01
 7.50000E-01     2.85366E-11     9.98067E-01      9.44871E-01
 1.00000E+00     2.85440E-11     9.98325E-01      9.45115E-01
 1.25000E+00     2.85547E-11     9.98699E-01      9.45469E-01
 1.50000E+00     2.85680E-11     9.99163E-01      9.45909E-01
 1.75000E+00     2.85818E-11     9.99647E-01      9.46366E-01
 1.90500E+00     2.85919E-11     1.00000E+00      9.46701E-01
       Average Deposit = .9453516

WAFER 200      V(OUT) =  125528.8    CA(OUT) =   2.779916E-11
R(cm)              CA(r,dell)      CA/CAI        G(angs./min)
 0.00000E+00     2.79999E-11     9.97823E-01      9.27100E-01
 2.50000E-01     2.80005E-11     9.97844E-01      9.27119E-01
 5.00000E-01     2.80025E-11     9.97916E-01      9.27187E-01
 7.50000E-01     2.80068E-11     9.98067E-01      9.27327E-01
 1.00000E+00     2.80140E-11     9.98325E-01      9.27567E-01
 1.25000E+00     2.80245E-11     9.98699E-01      9.27914E-01
 1.50000E+00     2.80375E-11     9.99163E-01      9.28345E-01
 1.75000E+00     2.80511E-11     9.99647E-01      9.28795E-01
 1.90500E+00     2.80610E-11     1.00000E+00      9.29123E-01
       Average Deposit = .9277989

WAFER 201      V(OUT) =  125524.9    CA(OUT) =   2.728287E-11
R(cm)              CA(r,dell)      CA/CAI        G(angs./min)
 0.00000E+00     2.74800E-11     9.97823E-01      9.09884E-01
 2.50000E-01     2.74805E-11     9.97844E-01      9.09902E-01
 5.00000E-01     2.74825E-11     9.97916E-01      9.09968E-01
 7.50000E-01     2.74867E-11     9.98067E-01      9.10106E-01
 1.00000E+00     2.74938E-11     9.98325E-01      9.10342E-01
 1.25000E+00     2.75041E-11     9.98699E-01      9.10682E-01
 1.50000E+00     2.75169E-11     9.99163E-01      9.11105E-01
 1.75000E+00     2.75302E-11     9.99647E-01      9.11546E-01
 1.90500E+00     2.75399E-11     1.00000E+00      9.11869E-01
       Average Deposit = .910569

WAFER 202      V(OUT) =  125521.1    CA(OUT) =   2.677608E-11
R(cm)              CA(r,dell)      CA/CAI        G(angs./min)
 0.00000E+00     2.69696E-11     9.97823E-01      8.92984E-01
 2.50000E-01     2.69701E-11     9.97844E-01      8.93002E-01
 5.00000E-01     2.69721E-11     9.97916E-01      8.93067E-01
 7.50000E-01     2.69762E-11     9.98067E-01      8.93202E-01
 1.00000E+00     2.69831E-11     9.98325E-01      8.93433E-01
 1.25000E+00     2.69932E-11     9.98699E-01      8.93767E-01
 1.50000E+00     2.70058E-11     9.99163E-01      8.94183E-01
 1.75000E+00     2.70188E-11     9.99647E-01      8.94616E-01
 1.90500E+00     2.70284E-11     1.00000E+00      8.94932E-01
       Average Deposit = .8936564

WAFER 203      V(OUT) =  125517.3    CA(OUT) =   2.627862E-11
R(cm)              CA(r,dell)      CA/CAI        G(angs./min)
 0.00000E+00     2.64685E-11     9.97823E-01      8.76395E-01
 2.50000E-01     2.64691E-11     9.97844E-01      8.76413E-01
 5.00000E-01     2.64710E-11     9.97916E-01      8.76476E-01
 7.50000E-01     2.64750E-11     9.98067E-01      8.76609E-01
 1.00000E+00     2.64819E-11     9.98325E-01      8.76836E-01
 1.25000E+00     2.64918E-11     9.98699E-01      8.77164E-01
 1.50000E+00     2.65041E-11     9.99163E-01      8.77572E-01
 1.75000E+00     2.65169E-11     9.99647E-01      8.77996E-01
 1.90500E+00     2.65263E-11     1.00000E+00      8.78307E-01
       Average Deposit = .877055
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WAFER 204      V(OUT) =  125513.6     CA(OUT) =   2.579033E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      2.59768E-11      9.97823E-01      8.60111E-01
 2.50000E-01      2.59773E-11      9.97844E-01      8.60129E-01
 5.00000E-01      2.59792E-11      9.97916E-01      8.60191E-01
 7.50000E-01      2.59831E-11      9.98067E-01      8.60322E-01
 1.00000E+00      2.59898E-11      9.98325E-01      8.60544E-01
 1.25000E+00      2.59996E-11      9.98699E-01      8.60866E-01
 1.50000E+00      2.60116E-11      9.99163E-01      8.61266E-01
 1.75000E+00      2.60242E-11      9.99647E-01      8.61683E-01
 1.90500E+00      2.60334E-11      1.00000E+00      8.61988E-01
        Average Deposit = .8607594

WAFER 205      V(OUT) =  125510     CA(OUT) =  2.531103E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      2.54940E-11      9.97823E-01      8.44128E-01
 2.50000E-01      2.54946E-11      9.97844E-01      8.44145E-01
 5.00000E-01      2.54964E-11      9.97916E-01      8.44206E-01
 7.50000E-01      2.55003E-11      9.98067E-01      8.44335E-01
 1.00000E+00      2.55069E-11      9.98325E-01      8.44553E-01
 1.25000E+00      2.55164E-11      9.98699E-01      8.44869E-01
 1.50000E+00      2.55283E-11      9.99163E-01      8.45261E-01
 1.75000E+00      2.55406E-11      9.99647E-01      8.45671E-01
 1.90500E+00      2.55497E-11      1.00000E+00      8.45970E-01
        Average Deposit = .8447639

WAFER 206      V(OUT) =  125506.5     CA(OUT) =   2.484057E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      2.50202E-11      9.97823E-01      8.28439E-01
 2.50000E-01      2.50207E-11      9.97844E-01      8.28456E-01
 5.00000E-01      2.50225E-11      9.97916E-01      8.28516E-01
 7.50000E-01      2.50263E-11      9.98067E-01      8.28642E-01
 1.00000E+00      2.50328E-11      9.98325E-01      8.28856E-01
 1.25000E+00      2.50422E-11      9.98699E-01      8.29166E-01
 1.50000E+00      2.50538E-11      9.99163E-01      8.29552E-01
 1.75000E+00      2.50659E-11      9.99647E-01      8.29953E-01
 1.90500E+00      2.50748E-11      1.00000E+00      8.30246E-01
        Average Deposit = .8290633

WAFER 207      V(OUT) =  125503     CA(OUT) =  2.437877E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      2.45551E-11      9.97823E-01      8.13039E-01
 2.50000E-01      2.45556E-11      9.97844E-01      8.13056E-01
 5.00000E-01      2.45574E-11      9.97916E-01      8.13115E-01
 7.50000E-01      2.45611E-11      9.98067E-01      8.13238E-01
 1.00000E+00      2.45675E-11      9.98325E-01      8.13449E-01
 1.25000E+00      2.45767E-11      9.98699E-01      8.13753E-01
 1.50000E+00      2.45881E-11      9.99163E-01      8.14131E-01
 1.75000E+00      2.46000E-11      9.99647E-01      8.14525E-01
 1.90500E+00      2.46087E-11      1.00000E+00      8.14813E-01
        Average Deposit = .813652

WAFER 208      V(OUT) =  125499.6     CA(OUT) =   2.39255E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      2.40986E-11      9.97823E-01      7.97924E-01
 2.50000E-01      2.40991E-11      9.97844E-01      7.97940E-01
 5.00000E-01      2.41008E-11      9.97916E-01      7.97998E-01
 7.50000E-01      2.41045E-11      9.98067E-01      7.98119E-01
 1.00000E+00      2.41107E-11      9.98325E-01      7.98325E-01
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 1.25000E+00      2.41197E-11     9.98699E-01      7.98624E-01
 1.50000E+00      2.41310E-11     9.99163E-01      7.98995E-01
 1.75000E+00      2.41426E-11     9.99647E-01      7.99382E-01
 1.90500E+00      2.41512E-11     1.00000E+00      7.99664E-01
      Average Deposit = .7985248

WAFER 209     V(OUT) =  125496.2    CA(OUT) =   2.348059E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      2.36505E-11     9.97823E-01      7.83087E-01
 2.50000E-01      2.36510E-11     9.97844E-01      7.83103E-01
 5.00000E-01      2.36527E-11     9.97916E-01      7.83159E-01
 7.50000E-01      2.36563E-11     9.98067E-01      7.83278E-01
 1.00000E+00      2.36624E-11     9.98325E-01      7.83481E-01
 1.25000E+00      2.36712E-11     9.98699E-01      7.83774E-01
 1.50000E+00      2.36823E-11     9.99163E-01      7.84138E-01
 1.75000E+00      2.36937E-11     9.99647E-01      7.84518E-01
 1.90500E+00      2.37021E-11     1.00000E+00      7.84795E-01
      Average Deposit = .7836766

WAFER 210     V(OUT) =  125492.9    CA(OUT) =   2.304388E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      2.32107E-11     9.97823E-01      7.68524E-01
 2.50000E-01      2.32111E-11     9.97844E-01      7.68539E-01
 5.00000E-01      2.32128E-11     9.97916E-01      7.68595E-01
 7.50000E-01      2.32163E-11     9.98067E-01      7.68712E-01
 1.00000E+00      2.32223E-11     9.98325E-01      7.68910E-01
 1.25000E+00      2.32310E-11     9.98699E-01      7.69198E-01
 1.50000E+00      2.32418E-11     9.99163E-01      7.69556E-01
 1.75000E+00      2.32531E-11     9.99647E-01      7.69928E-01
 1.90500E+00      2.32613E-11     1.00000E+00      7.70200E-01
      Average Deposit = .7691026

WAFER 211     V(OUT) =  125489.7    CA(OUT) =   2.261524E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      2.27790E-11     9.97823E-01      7.54229E-01
 2.50000E-01      2.27794E-11     9.97844E-01      7.54245E-01
 5.00000E-01      2.27811E-11     9.97916E-01      7.54299E-01
 7.50000E-01      2.27845E-11     9.98067E-01      7.54414E-01
 1.00000E+00      2.27904E-11     9.98325E-01      7.54609E-01
 1.25000E+00      2.27989E-11     9.98699E-01      7.54891E-01
 1.50000E+00      2.28095E-11     9.99163E-01      7.55242E-01
 1.75000E+00      2.28206E-11     9.99647E-01      7.55608E-01
 1.90500E+00      2.28286E-11     1.00000E+00      7.55875E-01
      Average Deposit = .7547973

WAFER 212     V(OUT) =  125486.5    CA(OUT) =   2.219451E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      2.23552E-11     9.97823E-01      7.40199E-01
 2.50000E-01      2.23557E-11     9.97844E-01      7.40214E-01
 5.00000E-01      2.23573E-11     9.97916E-01      7.40267E-01
 7.50000E-01      2.23607E-11     9.98067E-01      7.40380E-01
 1.00000E+00      2.23665E-11     9.98325E-01      7.40571E-01
 1.25000E+00      2.23748E-11     9.98699E-01      7.40848E-01
 1.50000E+00      2.23852E-11     9.99163E-01      7.41193E-01
 1.75000E+00      2.23961E-11     9.99647E-01      7.41551E-01
 1.90500E+00      2.24040E-11     1.00000E+00      7.41813E-01
      Average Deposit = .7407562

WAFER 213     V(OUT) =  125483.4    CA(OUT) =   2.178155E-11
R(cm)             CA(r,dell)        CA/CAI        G(angs./min)
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 0.00000E+00      2.19393E-11      9.97823E-01      7.26427E-01
 2.50000E-01      2.19397E-11      9.97844E-01      7.26442E-01
 5.00000E-01      2.19413E-11      9.97916E-01      7.26495E-01
 7.50000E-01      2.19447E-11      9.98067E-01      7.26605E-01
 1.00000E+00      2.19503E-11      9.98325E-01      7.26793E-01
 1.25000E+00      2.19585E-11      9.98699E-01      7.27065E-01
 1.50000E+00      2.19687E-11      9.99163E-01      7.27403E-01
 1.75000E+00      2.19794E-11      9.99647E-01      7.27755E-01
 1.90500E+00      2.19871E-11      1.00000E+00      7.28012E-01
       Average Deposit = .7269744

WAFER 214      V(OUT) =  125480.3     CA(OUT) =   2.137622E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      2.15310E-11      9.97823E-01      7.12910E-01
 2.50000E-01      2.15315E-11      9.97844E-01      7.12925E-01
 5.00000E-01      2.15330E-11      9.97916E-01      7.12976E-01
 7.50000E-01      2.15363E-11      9.98067E-01      7.13085E-01
 1.00000E+00      2.15419E-11      9.98325E-01      7.13269E-01
 1.25000E+00      2.15499E-11      9.98699E-01      7.13536E-01
 1.50000E+00      2.15600E-11      9.99163E-01      7.13868E-01
 1.75000E+00      2.15704E-11      9.99647E-01      7.14213E-01
 1.90500E+00      2.15780E-11      1.00000E+00      7.14465E-01
       Average Deposit = .7134471

WAFER 215      V(OUT) =  125477.3     CA(OUT) =   2.097838E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      2.11303E-11      9.97823E-01      6.99643E-01
 2.50000E-01      2.11308E-11      9.97844E-01      6.99657E-01
 5.00000E-01      2.11323E-11      9.97916E-01      6.99708E-01
 7.50000E-01      2.11355E-11      9.98067E-01      6.99814E-01
 1.00000E+00      2.11410E-11      9.98325E-01      6.99995E-01
 1.25000E+00      2.11489E-11      9.98699E-01      7.00257E-01
 1.50000E+00      2.11587E-11      9.99163E-01      7.00582E-01
 1.75000E+00     2.1160E-11     9.99647E-01     7.00921E-01
 1.90500E+00      2.11764E-11      1.00000E+00      7.01169E-01
       Average Deposit = .7001698

WAFER 216      V(OUT) =  125474.4     CA(OUT) =   2.058789E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      2.07371E-11      9.97823E-01      6.86621E-01
 2.50000E-01      2.07375E-11      9.97844E-01      6.86635E-01
 5.00000E-01      2.07390E-11      9.97916E-01      6.86685E-01
 7.50000E-01      2.07421E-11      9.98067E-01      6.86789E-01
 1.00000E+00      2.07475E-11      9.98325E-01      6.86966E-01
 1.25000E+00      2.07553E-11      9.98699E-01      6.87223E-01
 1.50000E+00      2.07649E-11      9.99163E-01      6.87543E-01
 1.75000E+00      2.07750E-11      9.99647E-01      6.87875E-01
 1.90500E+00      2.07823E-11      1.00000E+00      6.88119E-01
       Average Deposit = .6871379

WAFER 217      V(OUT) =  125471.5     CA(OUT) =   2.020462E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      2.03510E-11      9.97823E-01      6.73839E-01
 2.50000E-01      2.03515E-11      9.97844E-01      6.73853E-01
 5.00000E-01      2.03529E-11      9.97916E-01      6.73902E-01
 7.50000E-01      2.03560E-11      9.98067E-01      6.74004E-01
 1.00000E+00      2.03613E-11      9.98325E-01      6.74178E-01
 1.25000E+00      2.03689E-11      9.98699E-01      6.74430E-01
 1.50000E+00      2.03784E-11      9.99163E-01      6.74744E-01
 1.75000E+00      2.03882E-11      9.99647E-01      6.75071E-01
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 1.90500E+00      2.03954E-11     1.00000E+00      6.75309E-01
      Average Deposit = .6743468

WAFER 218     V(OUT) =  125468.7     CA(OUT) =   1.982844E-11
R(cm)            CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.99722E-11     9.97823E-01      6.61294E-01
 2.50000E-01      1.99726E-11     9.97844E-01      6.61308E-01
 5.00000E-01      1.99740E-11     9.97916E-01      6.61356E-01
 7.50000E-01      1.99770E-11     9.98067E-01      6.61456E-01
 1.00000E+00      1.99822E-11     9.98325E-01      6.61627E-01
 1.25000E+00      1.99897E-11     9.98699E-01      6.61874E-01
 1.50000E+00      1.99990E-11     9.99163E-01      6.62182E-01
 1.75000E+00      2.00087E-11     9.99647E-01      6.62503E-01
 1.90500E+00      2.00157E-11     1.00000E+00      6.62737E-01
      Average Deposit = .6617923

WAFER 219     V(OUT) =  125465.9     CA(OUT) =   1.945922E-11
R(cm)            CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.96003E-11     9.97823E-01      6.48981E-01
 2.50000E-01      1.96007E-11     9.97844E-01      6.48994E-01
 5.00000E-01      1.96021E-11     9.97916E-01      6.49041E-01
 7.50000E-01      1.96051E-11     9.98067E-01      6.49140E-01
 1.00000E+00      1.96101E-11     9.98325E-01      6.49308E-01
 1.25000E+00      1.96175E-11     9.98699E-01      6.49551E-01
 1.50000E+00      1.96266E-11     9.99163E-01      6.49853E-01
 1.75000E+00      1.96361E-11     9.99647E-01      6.50167E-01
 1.90500E+00      1.96430E-11     1.00000E+00      6.50397E-01
      Average Deposit = .64947

WAFER 220     V(OUT) =  125463.1     CA(OUT) =   1.909683E-11
R(cm)            CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.92353E-11     9.97823E-01      6.36896E-01
 2.50000E-01      1.92357E-11     9.97844E-01      6.36909E-01
 5.00000E-01      1.92371E-11     9.97916E-01      6.36955E-01
 7.50000E-01      1.92400E-11     9.98067E-01      6.37052E-01
 1.00000E+00      1.92450E-11     9.98325E-01      6.37216E-01
 1.25000E+00      1.92522E-11     9.98699E-01      6.37455E-01
 1.50000E+00      1.92611E-11     9.99163E-01      6.37751E-01
 1.75000E+00      1.92704E-11     9.99647E-01      6.38060E-01
 1.90500E+00      1.92773E-11     1.00000E+00      6.38285E-01
      Average Deposit = .6373755

WAFER 221     V(OUT) =  125460.5     CA(OUT) =   1.874115E-11
R(cm)            CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.88770E-11     9.97823E-01      6.25034E-01
 2.50000E-01      1.88774E-11     9.97844E-01      6.25047E-01
 5.00000E-01      1.88788E-11     9.97916E-01      6.25092E-01
 7.50000E-01      1.88817E-11     9.98067E-01      6.25187E-01
 1.00000E+00      1.88865E-11     9.98325E-01      6.25349E-01
 1.25000E+00      1.88936E-11     9.98699E-01      6.25582E-01
 1.50000E+00      1.89024E-11     9.99163E-01      6.25873E-01
 1.75000E+00      1.89115E-11     9.99647E-01      6.26176E-01
 1.90500E+00      1.89182E-11     1.00000E+00      6.26398E-01
      Average Deposit = .625505

WAFER 222     V(OUT) =  125457.8     CA(OUT) =   1.839205E-11
R(cm)            CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.85254E-11     9.97823E-01      6.13392E-01
 2.50000E-01      1.85258E-11     9.97844E-01      6.13404E-01
 5.00000E-01      1.85272E-11     9.97916E-01      6.13449E-01
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 7.50000E-01      1.85300E-11     9.98067E-01      6.13542E-01
 1.00000E+00      1.85348E-11     9.98325E-01      6.13701E-01
 1.25000E+00      1.85417E-11     9.98699E-01      6.13930E-01
 1.50000E+00      1.85503E-11     9.99163E-01      6.14216E-01
 1.75000E+00      1.85593E-11     9.99647E-01      6.14513E-01
 1.90500E+00      1.85659E-11     1.00000E+00      6.14730E-01
       Average Deposit = .6138541

WAFER 223      V(OUT) =  125455.2    CA(OUT) =   1.804941E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      1.81803E-11     9.97823E-01      6.01965E-01
 2.50000E-01      1.81807E-11     9.97844E-01      6.01978E-01
 5.00000E-01      1.81820E-11     9.97916E-01      6.02021E-01
 7.50000E-01      1.81848E-11     9.98067E-01      6.02113E-01
 1.00000E+00      1.81895E-11     9.98325E-01      6.02268E-01
 1.25000E+00      1.81963E-11     9.98699E-01      6.02494E-01
 1.50000E+00      1.82047E-11     9.99163E-01      6.02774E-01
 1.75000E+00      1.82136E-11     9.99647E-01      6.03066E-01
 1.90500E+00      1.82200E-11     1.00000E+00      6.03279E-01
       Average Deposit = .6024189

WAFER 224      V(OUT) =  125452.7    CA(OUT) =   1.771312E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      1.78416E-11     9.97823E-01      5.90750E-01
 2.50000E-01      1.78420E-11     9.97844E-01      5.90762E-01
 5.00000E-01      1.78433E-11     9.97916E-01      5.90805E-01
 7.50000E-01      1.78460E-11     9.98067E-01      5.90895E-01
 1.00000E+00      1.78506E-11     9.98325E-01      5.91048E-01
 1.25000E+00      1.78573E-11     9.98699E-01      5.91269E-01
 1.50000E+00      1.78656E-11     9.99163E-01      5.91544E-01
 1.75000E+00      1.78742E-11     9.99647E-01      5.91830E-01
 1.90500E+00      1.78805E-11     1.00000E+00      5.92039E-01
       Average Deposit = .5911955

WAFER 225      V(OUT) =  125450.2    CA(OUT) =   1.738306E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      1.75092E-11     9.97823E-01      5.79743E-01
 2.50000E-01      1.75095E-11     9.97844E-01      5.79755E-01
 5.00000E-01      1.75108E-11     9.97916E-01      5.79797E-01
 7.50000E-01      1.75135E-11     9.98067E-01      5.79885E-01
 1.00000E+00      1.75180E-11     9.98325E-01      5.80035E-01
 1.25000E+00      1.75246E-11     9.98699E-01      5.80252E-01
 1.50000E+00      1.75327E-11     9.99163E-01      5.80522E-01
 1.75000E+00      1.75412E-11     9.99647E-01      5.80803E-01
 1.90500E+00      1.75474E-11     1.00000E+00      5.81008E-01
       Average Deposit = .58018

WAFER 226      V(OUT) =  125447.8    CA(OUT) =   1.705911E-11
R(cm)              CA(r,dell)         CA/CAI        G(angs./min)
 0.00000E+00      1.71829E-11     9.97823E-01      5.68940E-01
 2.50000E-01      1.71833E-11     9.97844E-01      5.68951E-01
 5.00000E-01      1.71845E-11     9.97916E-01      5.68993E-01
 7.50000E-01      1.71871E-11     9.98067E-01      5.69079E-01
 1.00000E+00      1.71916E-11     9.98325E-01      5.69226E-01
 1.25000E+00      1.71980E-11     9.98699E-01      5.69439E-01
 1.50000E+00      1.72060E-11     9.99163E-01      5.69704E-01
 1.75000E+00      1.72143E-11     9.99647E-01      5.69980E-01
 1.90500E+00      1.72204E-11     1.00000E+00      5.70181E-01
       Average Deposit = .5693685
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WAFER 227      V(OUT) =  125445.4     CA(OUT) =  1.674117E-11
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.68627E-11      9.97823E-01      5.58337E-01
 2.50000E-01      1.68630E-11      9.97844E-01      5.58348E-01
 5.00000E-01      1.68642E-11      9.97916E-01      5.58389E-01
 7.50000E-01      1.68668E-11      9.98067E-01      5.58473E-01
 1.00000E+00      1.68712E-11      9.98325E-01      5.58618E-01
 1.25000E+00      1.68775E-11      9.98699E-01      5.58827E-01
 1.50000E+00      1.68853E-11      9.99163E-01      5.59086E-01
 1.75000E+00      1.68935E-11      9.99647E-01      5.59357E-01
 1.90500E+00      1.68995E-11      1.00000E+00      5.59555E-01
       Average Deposit = .5587573

WAFER 228      V(OUT) =  125443     CA(OUT) =  1.642912E-11
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.65484E-11      9.97823E-01      5.47930E-01
 2.50000E-01      1.65487E-11      9.97844E-01      5.47941E-01
 5.00000E-01      1.65499E-11      9.97916E-01      5.47981E-01
 7.50000E-01      1.65524E-11      9.98067E-01      5.48064E-01
 1.00000E+00      1.65567E-11      9.98325E-01      5.48206E-01
 1.25000E+00      1.65629E-11      9.98699E-01      5.48411E-01
 1.50000E+00      1.65706E-11      9.99163E-01      5.48666E-01
 1.75000E+00      1.65786E-11      9.99647E-01      5.48931E-01
 1.90500E+00      1.65845E-11      1.00000E+00      5.49125E-01
       Average Deposit = .5483427

WAFER 229      V(OUT) =  125440.7     CA(OUT) =  1.612286E-11
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.62399E-11      9.97823E-01      5.37716E-01
 2.50000E-01      1.62402E-11      9.97843E-01      5.37727E-01
 5.00000E-01      1.62414E-11      9.97916E-01      5.37766E-01
 7.50000E-01      1.62439E-11      9.98067E-01      5.37848E-01
 1.00000E+00      1.62481E-11      9.98325E-01      5.37987E-01
 1.25000E+00      1.62542E-11      9.98699E-01      5.38188E-01
 1.50000E+00      1.62617E-11      9.99163E-01      5.38438E-01
 1.75000E+00      1.62696E-11      9.99647E-01      5.38699E-01
 1.90500E+00      1.62753E-11      1.00000E+00      5.38889E-01
       Average Deposit = .5381213

WAFER 230      V(OUT) =  125438.5     CA(OUT) =  1.582227E-11
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.59372E-11      9.97823E-01      5.27692E-01
 2.50000E-01      1.59375E-11      9.97844E-01      5.27703E-01
 5.00000E-01      1.59386E-11      9.97916E-01      5.27741E-01
 7.50000E-01      1.59411E-11      9.98067E-01      5.27821E-01
 1.00000E+00      1.59452E-11      9.98325E-01      5.27957E-01
 1.25000E+00      1.59511E-11      9.98699E-01      5.28155E-01
 1.50000E+00      1.59586E-11      9.99163E-01      5.28401E-01
 1.75000E+00      1.59663E-11      9.99647E-01      5.28656E-01
 1.90500E+00      1.59719E-11      1.00000E+00      5.28843E-01
       Average Deposit = .5280894

WAFER 231      V(OUT) =  125436.2     CA(OUT) =  1.552726E-11
R(cm)              CA(r,dell)        CA/CAI        G(angs./min)
 0.00000E+00      1.56400E-11      9.97823E-01      5.17853E-01
 2.50000E-01      1.56403E-11      9.97844E-01      5.17864E-01
 5.00000E-01      1.56415E-11      9.97916E-01      5.17901E-01
 7.50000E-01      1.56438E-11      9.98067E-01      5.17980E-01
 1.00000E+00      1.56479E-11      9.98325E-01      5.18114E-01
 1.25000E+00      1.56537E-11      9.98699E-01      5.18308E-01
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 1.50000E+00      1.56610E-11     9.99163E-01      5.18549E-01
 1.75000E+00      1.56686E-11     9.99647E-01      5.18800E-01
 1.90500E+00      1.56741E-11     1.00000E+00      5.18983E-01
      Average Deposit = .5182435

WAFER 232      V(OUT) =  125434.1     CA(OUT) =   1.523772E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.53484E-11     9.97823E-01      5.08197E-01
 2.50000E-01      1.53487E-11     9.97844E-01      5.08208E-01
 5.00000E-01      1.53498E-11     9.97916E-01      5.08245E-01
 7.50000E-01      1.53521E-11     9.98067E-01      5.08322E-01
 1.00000E+00      1.53561E-11     9.98325E-01      5.08453E-01
 1.25000E+00      1.53619E-11     9.98699E-01      5.08643E-01
 1.50000E+00      1.53690E-11     9.99163E-01      5.08880E-01
 1.75000E+00      1.53764E-11     9.99647E-01      5.09126E-01
 1.90500E+00      1.53819E-11     1.00000E+00      5.09306E-01
      Average Deposit = .5085803

WAFER 233      V(OUT) =  125431.9     CA(OUT) =   1.495356E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.50622E-11     9.97823E-01      4.98721E-01
 2.50000E-01      1.50625E-11     9.97844E-01      4.98731E-01
 5.00000E-01      1.50636E-11     9.97916E-01      4.98767E-01
 7.50000E-01      1.50659E-11     9.98067E-01      4.98843E-01
 1.00000E+00      1.50698E-11     9.98325E-01      4.98972E-01
 1.25000E+00      1.50754E-11     9.98699E-01      4.99158E-01
 1.50000E+00      1.50824E-11     9.99163E-01      4.99390E-01
 1.75000E+00      1.50897E-11     9.99647E-01      4.99632E-01
 1.90500E+00      1.50950E-11     1.00000E+00      4.99809E-01
      Average Deposit = .4990963

WAFER 234      V(OUT) =  125429.8     CA(OUT) =   1.467466E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.47813E-11     9.97823E-01      4.89420E-01
 2.50000E-01      1.47816E-11     9.97844E-01      4.89430E-01
 5.00000E-01      1.47826E-11     9.97916E-01      4.89465E-01
 7.50000E-01      1.47849E-11     9.98067E-01      4.89539E-01
 1.00000E+00      1.47887E-11     9.98325E-01      4.89666E-01
 1.25000E+00      1.47942E-11     9.98699E-01      4.89849E-01
 1.50000E+00      1.48011E-11     9.99163E-01      4.90077E-01
 1.75000E+00      1.48083E-11     9.99647E-01      4.90314E-01
 1.90500E+00      1.48135E-11     1.00000E+00      4.90487E-01
      Average Deposit = .4897883

WAFER 235      V(OUT) =  125427.8     CA(OUT) =   1.440095E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.45056E-11     9.97823E-01      4.80291E-01
 2.50000E-01      1.45059E-11     9.97844E-01      4.80301E-01
 5.00000E-01      1.45069E-11     9.97916E-01      4.80336E-01
 7.50000E-01      1.45091E-11     9.98067E-01      4.80409E-01
 1.00000E+00      1.45129E-11     9.98325E-01      4.80533E-01
 1.25000E+00      1.45183E-11     9.98699E-01      4.80713E-01
 1.50000E+00      1.45251E-11     9.99163E-01      4.80936E-01
 1.75000E+00      1.45321E-11     9.99647E-01      4.81169E-01
 1.90500E+00      1.45372E-11     1.00000E+00      4.81339E-01
      Average Deposit = .480653

WAFER 236      V(OUT) =  125425.7     CA(OUT) =   1.413231E-11
R(cm)              CA(r,dell)        CA/CAI       G(angs./min)
 0.00000E+00      1.42350E-11     9.97823E-01      4.71332E-01
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  2.50000E-01      1.42353E-11     9.97844E-01      4.71342E-01
  5.00000E-01      1.42363E-11     9.97916E-01      4.71376E-01
  7.50000E-01      1.42385E-11     9.98067E-01      4.71448E-01
  1.00000E+00      1.42422E-11     9.98325E-01      4.71569E-01
  1.25000E+00      1.42475E-11     9.98699E-01      4.71746E-01
  1.50000E+00      1.42541E-11     9.99163E-01      4.71965E-01
  1.75000E+00      1.42610E-11     9.99647E-01      4.72194E-01
  1.90500E+00      1.42661E-11     1.00000E+00      4.72361E-01
        Average Deposit = .4716873

WAFER 237     V(OUT) =  125423.7     CA(OUT)  =  1.386866E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
  0.00000E+00      1.39694E-11     9.97823E-01      4.62540E-01
  2.50000E-01      1.39697E-11     9.97844E-01      4.62549E-01
  5.00000E-01      1.39707E-11     9.97916E-01      4.62583E-01
  7.50000E-01      1.39729E-11     9.98067E-01      4.62653E-01
  1.00000E+00      1.39765E-11     9.98325E-01      4.62772E-01
  1.25000E+00      1.39817E-11     9.98699E-01      4.62945E-01
  1.50000E+00      1.39882E-11     9.99163E-01      4.63161E-01
  1.75000E+00      1.39950E-11     9.99647E-01      4.63385E-01
  1.90500E+00      1.39999E-11     1.00000E+00      4.63549E-01
        Average Deposit = .4628881

WAFER 238     V(OUT) =  125421.8     CA(OUT)  =  1.360991E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
  0.00000E+00      1.37088E-11     9.97823E-01      4.53910E-01
  2.50000E-01      1.37091E-11     9.97844E-01      4.53920E-01
  5.00000E-01      1.37101E-11     9.97916E-01      4.53952E-01
  7.50000E-01      1.37122E-11     9.98067E-01      4.54021E-01
  1.00000E+00      1.37157E-11     9.98325E-01      4.54139E-01
  1.25000E+00      1.37209E-11     9.98699E-01      4.54309E-01
  1.50000E+00      1.37272E-11     9.99163E-01      4.54520E-01
  1.75000E+00      1.37339E-11     9.99647E-01      4.54740E-01
  1.90500E+00      1.37387E-11     1.00000E+00      4.54900E-01
        Average Deposit = .4542522

WAFER 239     V(OUT) =  125419.9     CA(OUT)  =  1.335597E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
  0.00000E+00      1.34530E-11     9.97823E-01      4.45441E-01
  2.50000E-01      1.34533E-11     9.97844E-01      4.45450E-01
  5.00000E-01      1.34543E-11     9.97916E-01      4.45483E-01
  7.50000E-01      1.34563E-11     9.98067E-01      4.45550E-01
  1.00000E+00      1.34598E-11     9.98325E-01      4.45665E-01
  1.25000E+00      1.34649E-11     9.98699E-01      4.45832E-01
  1.50000E+00      1.34711E-11     9.99163E-01      4.46039E-01
  1.75000E+00      1.34776E-11     9.99647E-01      4.46255E-01
  1.90500E+00      1.34824E-11     1.00000E+00      4.46413E-01
        Average Deposit = .4457768

WAFER 240     V(OUT) =  125418     CA(OUT)  =  1.310674E-11
R(cm)             CA(r,dell)         CA/CAI        G(angs./min)
  0.00000E+00      1.32020E-11     9.97823E-01      4.37129E-01
  2.50000E-01      1.32023E-11     9.97843E-01      4.37138E-01
  5.00000E-01      1.32032E-11     9.97916E-01      4.37170E-01
  7.50000E-01      1.32053E-11     9.98067E-01      4.37236E-01
  1.00000E+00      1.32087E-11     9.98325E-01      4.37349E-01
  1.25000E+00      1.32136E-11     9.98699E-01      4.37513E-01
  1.50000E+00      1.32197E-11     9.99163E-01      4.37716E-01
  1.75000E+00      1.32261E-11     9.99647E-01      4.37928E-01
  1.90500E+00      1.32308E-11     1.00000E+00      4.38083E-01
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      Average Deposit = .4374587
These quantities are the Reactor section effluents
CA(N+1) = 1.494739E-13        V(N+1) = 125418
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Nomenclature

a	1/2 the wafer spacing divided by the wafer radius
C	molar concentration $gmol/cm^3$
D_{AB}	binary diffusion coefficient
Da	Damköhler number
F	dimensionless concentration profile
J_n	Bessel functions of order n
k_0, k_1, k_2, k_W, k_T,and k_3	are rate contants
N_{Ai}	$(gmol/cm^2sec)$ is molar flux of species A in the i^{th} direction
$\underline{N_A}$	the molar flux (vector)
P	pressure (atm.)
R_W	wafer radius (cm.)
R_T	reactor radius (cm)
R	universal gas constant
Sc	Schmidt number
T	temperature (kelvin)
$\underline{V}$	velocity (vector)
V_i	volumetric flow rate (cm^3/min)
w	Sherwood number
δ	1/2 the wafer spacing
ε	a small parameter
ρ	density (g/cm^3)
μ	viscosity (g/cm-sec)
υ	kinematic visity (eq'n. 5.42)
ξ	dimensionless radius
ζ	dimensionless axial length

Bibliography

1.Bird,R.B.,W.E.Stewart and E.N.Lightfoot, *Transport Phenomena,* John Wiley 1960.

2.Brodkey, R.S. and H.C. Hershey, *Transport Phenomena,* McGraw-Hill 1988.

3.Dash, J.D., *Films on Solid Surfaces,* Academic Press 1975.

4.Froment, G.F. and K.B. Bischoff, *Chemical Reactor Analysis and Design* ,2ndED., John Wiley 1990.

5.Thomas,G.B. and R.L.Finney, *Calculus and Analytic Geometry,* 6thED. Addison Wesley 1984.

6.Churchill,R.V. and J.W.Brown, *Complex Variables and Applications,* 4thED. McGraw-Hill 1984.

7.Oneil, P.V., *Advanced Engineering Mathematics,* Wadsworth 1983.

8.Boyce, W.E. and R.C.DiPrima, *Elementary Differential Equations and Boundary Value Problems,* 3rdED. John Wiley 1977.

9.Hougen, O.A. and K.M. Watson, *Chemical Process Principles (Part 3) Kinetics and Catalysis,* John Wiley 1966.

10.Hougen,O.A. and K.M.Watson, "Solid Catalysts and Reaction Rates", *IE&C.* 35 (1943) 529.

11.Levenspiel, O., *Chemical Reaction Engineering,* 2ndED., John Wiley 1972.

12.Hess, D.W. and K.F. Jensen, *Microelectronics Processing,* ACS 1989.

13.Lee, H.H., *Fundamentals of Microelectronics Processing,* McGraw-Hill 1990.

14.Reid,R.C.,J.M.Prausnitz and T.K.Sherwood, *The Properties of Gases and Liquids,* 3rdED., McGraw-Hill 1977.

15.Schlichting, H., *Boundary-Layer Theory*, 7th ED., McGraw-Hill 1987.

16.Carrier, G.F. and C.E. Pearson, *Partial Differential Equations*, Academic Press 1976.

17.Zauderer, E., *Partial Differential Equations of Applied Math.*, John Wiley 1983.

18.Levy, R.A., *Microelectronis Materials and Processes*, Kluwer Academic 1989.

19.Jensen,K.F. and D.B.Graves,"Modeling and Analysis of Low Pressure CVD Reactors", *J. Electrochem. Soc.*, 130 (1983) 1950.

20.Roenigk, K.F. and K.F. Jensen," Analysis of Multicomponent LPCVD Processes",*ibid.*, 132 (1985) 448.

21.Collingham,M.E. and R.L.Zollars,"Effect of Recycling on the Axial Distribution of Coating Thickness in a Low Pressure CVD Reactor", *ibid.*, 136 (1989) 787.

22.Coltrin,M.E.,R.J.Kee and J.A.Miller, "A Mathematical Model of the Coupled Fluid Mechanics and Chemical Kinetics in a Chemical Vapor Deposition Reactor", *ibid.*, 131 (1984) 425.

23.Roenigk,K.F. and K.F.Jensen,"Low Pressure CVD of Silicon Nitride" *ibid.*, 134 (1987) 1777.

24.Middleman,S. and A.Yeckel, "A Model of the Effects of Diffusion and Convection on the Rate and Uniformity of Deposition in a CVD Reactor", *ibid.*, 133 (1986) 1951.

25.Huppertz,H. and W.L.Engl, "Modeling of Low-Pressure Deposition of SiO_2 by Decomposition of TEOS", *IEEE Trans. Electron Devices*, ED-26 no.4, (1979) 658.

26.Kuiper,A.E.T.,C.J.H. van den Brekel,J. deGroot and G.W. Veltkamp, "Modeling of Low-Pressure CVD Processes", *J. Electrochem. soc.*, 129 (1982) 2288.

27.Van den Brekel,C.H.J. and L.J.M.Bollen, "Low Pressure Deposition of Polycrystalline Silicon from Silane", *J. Crystal Growth,* 54 (1981) 310.

28.Claassen; W.A.P.,J. Bloem;W.G.J.N. Valkenburg and C.H.J.Van den Brekel, "The Deposition of Silicon from Silane in a Low-Pressure Hot-Wall system" *ibid.*, 57 (1982) 259.

29.Hong, J.C. and H.H. Lee, "Uniform Deposition In CVD Reactors with Mounted Wafer Configuration", *ibid.*, g71 (1985) 711.

30.Yang, K.H. and O.A. Hougen, "Determination of Mechanism of Catalyzed Gaseous Reactions", *Chem. Eng. Progress,* 46 (1950) 148.

31.Burden, R.L., J.D. Faires and A.C. Reynolds, *Numerical Analysis,* 2ndED., Prindle, Weber & Schmidt 1981.

32.Probstein,R.F., *Physicochemical Hydrodynamics,* Butterworths 1989.

33.Frank-Kamenetskii, D.A., *Diffusion and Heat Transfer in Chemical Kinetics,* 2ndED., Plenum Press 1969.

34.Froment, G.F., "The Kinetics of Complex catalytic Reactions", *Chem. Eng. Science,* 42 (1987) 1073.

35.Boudart, M., "Classical Catalytic Kinetics: A placebo or the Real Thing ?", *IE&C. Fundam.*, 25 (1986) 656.

36.Boudart, M., "Response to "Classical Catalytic Kinetics: What Is the Point of the Matter?"", *IE&C. Res.*, 28 (1989) 379.

37.Hayward,D.O. and B.M.W.Trapnell,*Chemisorption*,2ndED.,Butterworths 1964.

38.de Boer, J.H., *The Dynamical Character of Adsorption*, 2^{nd}ED., Oxford 1968.

39.Butt, J.B., *Reaction Kinetics and Reactor Design*, Prentice-Hall 1980.

40.Smith, J.M., "Thirty-Five Years of Applied Catalytic Kinetics", *IE&C. Fundam.*, 21 (1982) 327.

41.Castellan, G.W., *Physical Chemistry*, 2^{nd}ED., Addison-Wesley 1971.

42.Desu,S.B., "Decomposition Chemistry of Tetraethoxysilane", *J. Am. Ceramic Soc.*, 72 (1989) 1615.

43.Kalidindi, S.R. and S.B. Desu, "Analytical Model for the Low Pressure Chemical Vapor Deposition of SiO_2 from Tetraethoxysilane" *J. Electrochem. Soc.*, 137 (1990) 624.

44.Vrentas, J.S. and C.M. Vrentas, "Convective Effects in CVD Reactors", *J. Electrochem. Soc.*, 131 (1988) 2108.

45.Bar-Gadda, R., "A Theoretical Prediction of Film Thickness Profiles in a Mixed Convection-Diffusion Regime for the Chemical Vapor Deposition of Polysilicon in Annular Tube", *ibid.* 133 (1986) 2123.