OPTIMIZATION OF A 3-MICRON BCCD PROCESS FOR HIGH DENSITY CCD REGISTERS

by
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APPROVAL PAGE

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ABSTRACT

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In July 1991, Dr. Walter F. Kosonocky proposed a High-Frame-Rate-CCD Imager. The design of the imager is such that the CCD channel width be 3-microns and capable of handling at least 3000 - 5000 electrons per square micron. Using process (SUPREM III) and device (PISCES IIB) simulations, charge handling capacities as a function of implant energy and junction depth were studied. Arsenic implants ranging from 100 to 200keV were driven-in to obtain junction depths between 0.40µm and 0.80µm. As a result of this work it was determined that charge handling capacities as high as 9400 electrons/μm^2 were achievable with implanted doses of 1.6E12 ions/cm^2. This thesis is a description of the simulation and analysis techniques used to optimze the charge handling capacity of a 3µm wide BCCD channel.

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Chapter 1

INTRODUCTION

1.1 Introduction

The research described in this thesis was conducted under the guidance and supervision of Dr. Walter F. Kosonocky, Distinguished Professor of Electrical Engineering and NJIT Foundation Chair of Optoelectronics and Solid State Circuits. Furthermore, this work was done with the support of an Office of Naval Research (ONR) Phase I, SBIR grant to Princeton Scientific Instruments, Inc., Monmouth Junction, New Jersey with the purpose of optimizing the process for construction of high density CCD registers to be used in a high-frame-rate-CCD imager.

Buried-channel charge-coupled devices (BCCD) were modeled using SUPREM III and PISCES IIB to determine a semiconductor process which would maximize the charge handling capacity of a 3-micron BCCD structure used in the high density CCD registers. Suprem III, a one dimensional process simulator was used to model the doping profiles of the BCCD channel region The doping profiles were then exported to PISCES IIB which was used to model the devices electrical characteristics

Chapter 2 describes the principles of charge storage and transfer in the in the BCCD.

A brief description of the high density CCD register. and the constraints its design imposes on the BCCD process are presented in Chapter 3.

Chapter 4 contains a description of the SUPREM III and PISCES IIB input cards that were most important to completing this work.

The results of the SUPREM III process simulations and PISCES IIB device simulations are discussed in Chapter 5.

Finally In Chapter 6, the conclusions are presented and future work is discussed.

1.2 Software Tools

At the NJIT Image Sensors/VLSI Design and Simulation Laboratory in the Electronic Imaging Center (EIC), research is being conducted in the field of semiconductor process and device optimization. To aid this research there exists a wide variety of software capable of simulating modern integrated circuit technologies. Some of the various tools are capable of simulating behavioral and gate level logic of VLSI circuits, semiconductor processes, or electrical characteristics of semiconductor devices. Among those available are three which have significance in this work, they are SUPREM III, SUPREM IV, and PISCES IIB.

SUPREM III is a program which simulates the various steps used in silicon processing, such as diffusion, deposition and ion implantation. SUPREM IV is a two dimensional analog of SUPREM III. Since a large numbers of simulations needed to be run in order to complete this work, SUPREM III was used exclusively because it provides results in a matter of minutes, while SUPREM IV simulations can take up to tens of hours to run.

The PISCES IIB program is a two dimensional Poisson and current continuity equations solver. Doping profiles from either SUPREM III or SUPREM IV may be exported to PISCES IIB, which then solves for the potential distributions and carrier concentrations everywhere in the device.

It should be noted that SUPREM III, SUPREM IV and PISCES IIB were created at Stanford University Integrated Circuits Laboratory during the 1980's and have served to aid in the growth of integrated circuit technology. A description of the input cards used in the SUPREM III and PISCES IIB simulations are given in Chapter 4

Chapter 2

AN OVERVIEW of the BURIED-CHANNEL CHARGE-COUPLED DEVICE

2.1 Introduction

Since the charge-coupled device (CCD) was introduced in 1970 [1], it has been considered for use in a wide variety of applications, ranging from high density VLSI memory circuits to visible and infrared imagers [2] - [5].

The CCD can be thought of as a shift register consisting of closely spaced MOS capacitors operating in the non-equilibrium mode of deep depletion. It is a unique device in that it is a true integrated circuit, in other words there is no combination of discrete circuit elements that are the equivalent of the CCD [6].

In its simplest form the CCD consists of a semiconductor material covered by a thin insulator (usually SiO_2 or Si_3N_4) and an overlying metal gate (usually polysilicon), as shown in Fig. 2.1a for a p- type substrate. This device introduced by Boyle and Smith [1], is referred to as a Surface-Channel Charge-Coupled Device (SCCD), since the signal (minority carriers) stored under the gates is located near the Si / SiO_2 interface as shown in the energy band diagram of Fig. 2 1b

In the SCCD fast interface states play an important role in the charge transfer efficiency and operating speed of the device. Fast interface states acquire charge as signal is introduced to the well, but are reluctant to give them up, and empty at a slower rate that depends upon the energy difference between the interface state and the conduction band [7] - [10], therefore limiting the speed of operation of the SCCD.

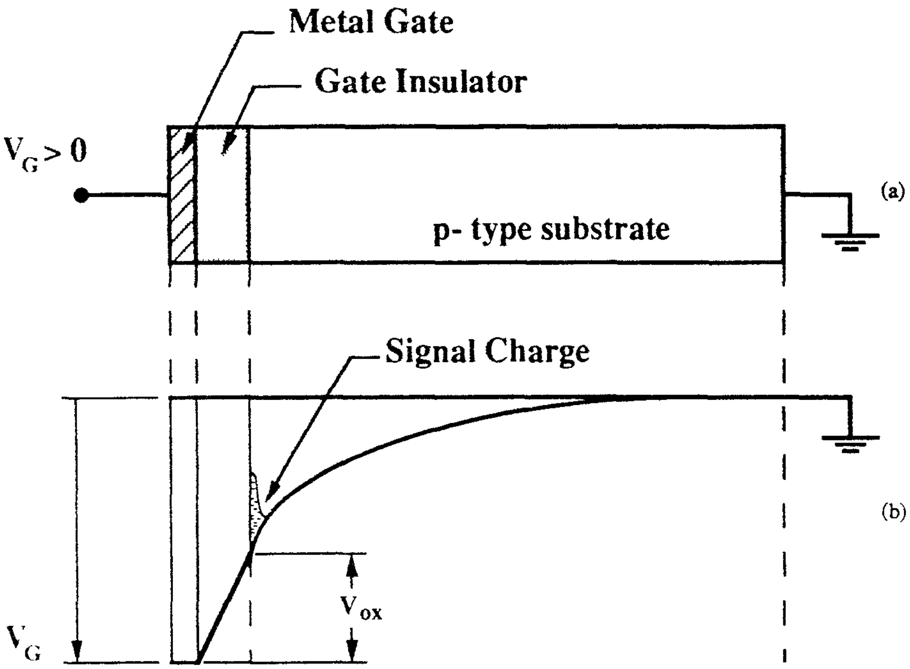

Figure 2.1 (a) Surface channel CCD device structure for p- type substrate. (b) Energy band diagram of SCCD illustrating the principle of charge storage.

The basic structure of the BCCD shown for a p- type substrate in Fig. 2.2a, consists of a shallow implanted region of opposite conductivity to that of the substrate. The main advantage of the BCCD compared with the SCCD is that majority carrier charge is stored in the bulk of the semiconductor away from interface traps, as shown in the energy band diagram of Fig 2.2b. By avoiding the problems associated with interface trapping the BCCD can be operated at higher clock rates with greater charge transfer efficiency than the SCCD. The advantages of the BCCD do not come without cost, while the BCCD can operate at higher clock rates than the SCCD, its maximum charge handling capacity is 1/4 to 1/3 less than that of the SCCD [9].

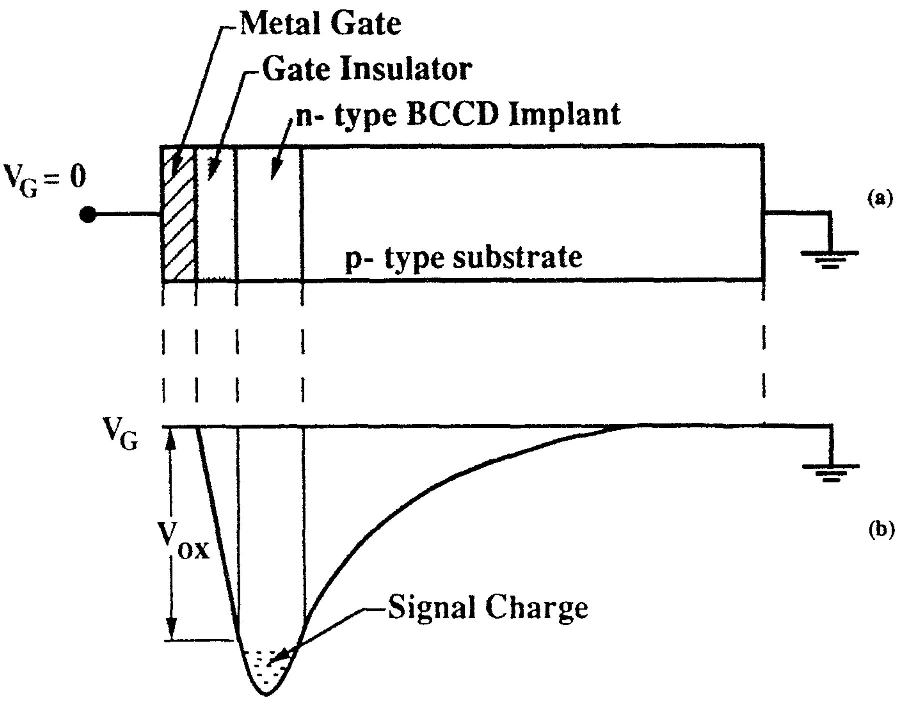

Figure 2.2 (a) Buried-channel charge-coupled device structure for p- type substrate. (b) Energy band diagram of BCCD illustrating the principle of charge storage.

2.2 Charge Storage in the BCCD

In the BCCD potential maximums occur in the implanted region, causing electrons (in the case of p- type substrate) to be stored in the bulk. Shown in Fig. 2 3 are typical potential profiles generated by PISCES IIB of a BCCD for empty well, full well and pinned well cases.

As a negative voltage is applied to the gate of the BCCD, holes from the channel stops are attracted to the Si / SiO_2 interface under the gate, causing the peak potential in the channel to decrease. If the potential applied to the gate is allowed to become increasingly more negative, at some point the potential of the valance band at the Si /

SiO_2 interface reaches the the potential of the valence band in the bulk. Assuming that the substrate is grounded, the the holes from the channel stops "pin" the valence band at the interface to ground, and no further reduction in channel potential occurs. The gate voltage

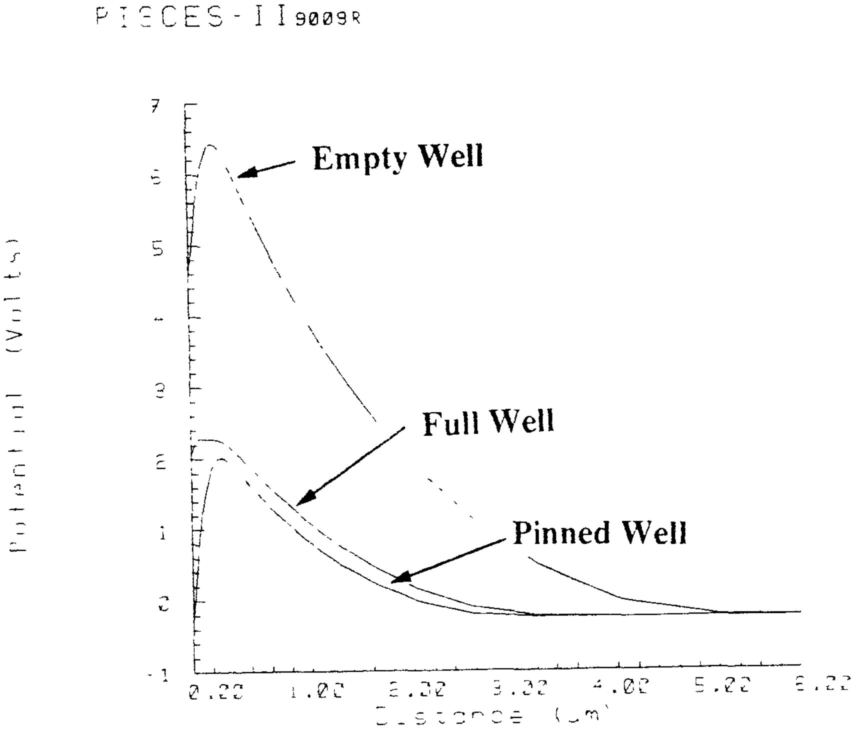

Figure 2.3 Typical potential profiles for the empty, full and pinned well cases.

at which this condition is reached is referred to as the pinning voltage [7]. When the device is operated with an applied gate potential equal to or more negative (for a p-type substrate) than the pinning voltage the device is said to be operating in the pinning condition.

If the voltage applied to the gate of the BCCD is suddenly changed from the pinning voltage to ground, the implanted region becomes depleted of free charge. During the time before the potential of the channel region begins to collapse due to thermally generated carriers, the well is referred to as empty. This is the case of deep depletion.

As charge is generated either thermally, electrically or optically the signal, electrons for a p- type substrate, move to the potential maximum. The addition of negative charge causes the peak and suface potentials of the channel to become less positive. Eventually with the continued addition of charge, the peak potential of the well will either become less positive than the surface potential or will collapse to a value less than the peak channel potential of the well in the pinned condition. In the case of the surface potential exceeding the peak potential, charge will reach the surface and be trapped in fast interface states. If the former occurs charge will not be confined to the storage region under the gate. Therefore to store and confine charge in a BCCD two constraints must be set on the full well condition [10]. The first being that the peak potential of a full well be at least 10 kT greater than the surface potential. This ensures that signal will not reach the Si / SiO_2 interface and be trapped in fast interface states and that fringing fields will be sufficent to achieve good charge transfer efficiency [10]. The second, that the peak potential of the full well be at least 10 kT greater than the peak potential of the pinned well causing charge to be confined under a given gate.

2.3 The BCCD Equation for a Gaussian Doping Profile

Figure 2.4a defines the variables used to describe a gaussian doping distribution for the BCCD implant, while Fig 2.4b defines the variables used to describe the potential distribution in the presence and absence of free charge in the implanted region. According to Chatterjee and Taylor [10], for a BCCD in the empty well state, the buried-channel exhibits a potential maximum, Φ_m at a distance X_p from the Si / SiO_2 interface. Φ_m and X_p as described by the doping distributions implant parameters are given by,

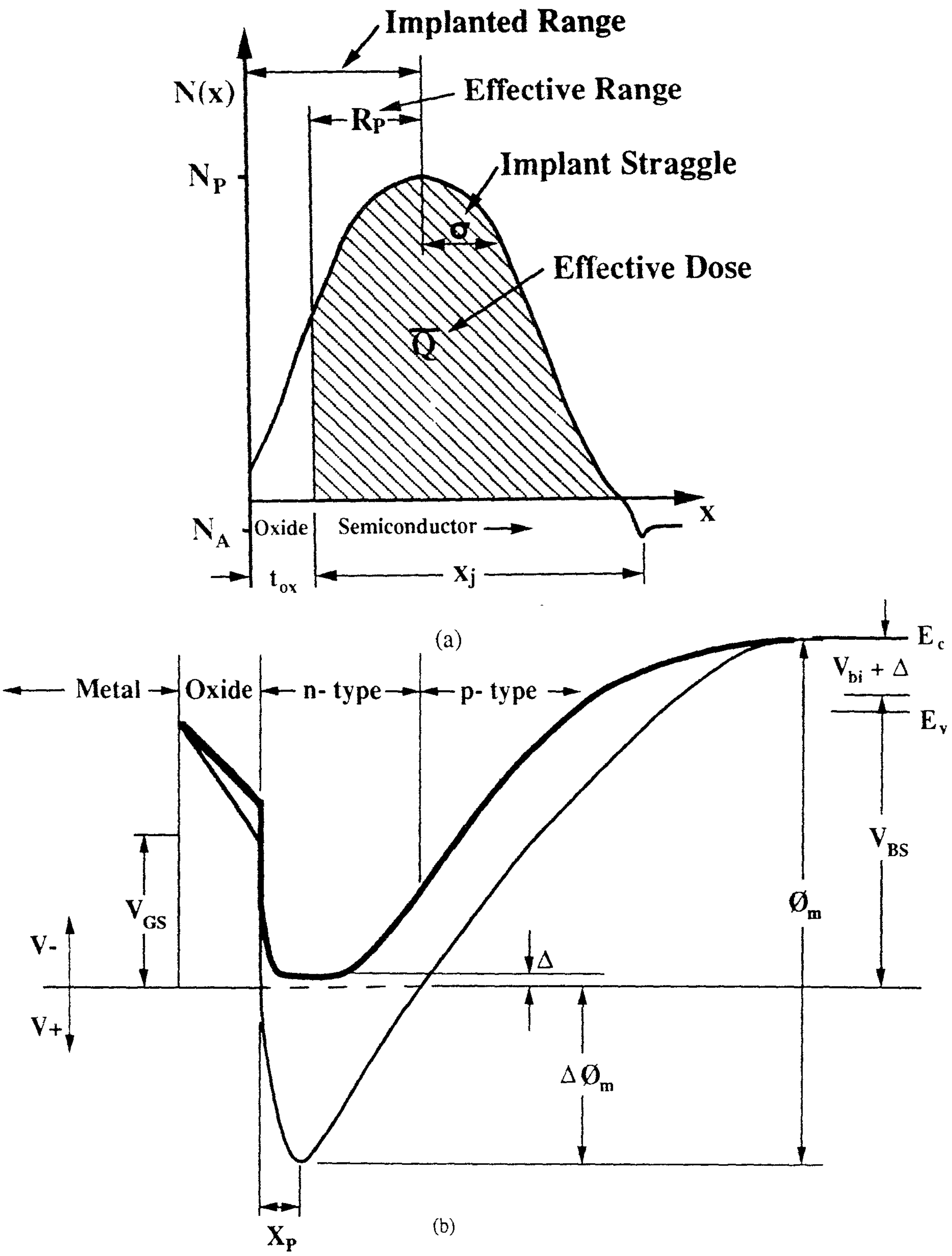

Figure 2.4 (a) Definitions of the doping profile parameters and (b) the potential distribution parameters used in the BCCD equations [1] - [6].

$$\phi_m = \left\{ \left\{ \frac{\varepsilon Q N_A}{2 C_G^2} + \frac{q \bar{Q}}{C_G} \left\{ 1 - \frac{C_G \bar{Q}}{C_\sigma Q} \right\} + V_{GS} + V_{FB} - V_{BS} + V_{bi} \right\}^{\frac{1}{2}} - \frac{1}{C_G} \left\{ \frac{\varepsilon q N_A}{2} \right\}^{\frac{1}{2}} \right\}^2 \qquad [1]$$

and

$$X_P = R_P + \sqrt{2}\, \sigma\, erf^{-1} \left\{ 1 - \frac{2 N_A}{Q} \left\{ \frac{2 \varepsilon_{Si}}{q N_A} \phi_m \right\}^{\frac{1}{2}} \right\} \qquad [2]$$

Where N_A is the doping concentration of the substrate, Q is the implanted dose, $\bar{Q}$ is the effective dose, R_P is the effective projected range and σ is the lateral straggle of the implanted ions. V_{FB} is the flat band voltage . V_{GS} is the applied gate voltage, V_{BS} is the potential of the Fermi Level in the bulk and V_{bi} is the contact potential of the junction. The remaining quantities are defined as follows,

$$\frac{1}{C_G} = \frac{t_{ox}}{\varepsilon_{ox}} + \frac{R_P}{\varepsilon_{Si}} + \sqrt{8/\pi}\, \frac{\sigma}{\varepsilon_{Si}} \qquad [3]$$

$$\frac{1}{C_\sigma} = \sqrt{8/\pi}\, \frac{\sigma}{\varepsilon_{Si}} \qquad [4]$$

$$\bar{Q} = \frac{Q}{2} \left\{ 1 + erf \left\{ \frac{R_P}{\sqrt{2}\, \sigma} \right\} \right\}. \qquad [5]$$

where C_G is the effective gate capacitance and C_σ is the effective depletion capacitatnce. As charge is introduced into the well the potential maximum decreases by $\Delta\Phi_m$, and the free charge present in the well is given as a function of $\Delta\Phi_m$ by,

$$Q_n \left[\Delta\phi_m \right] = \frac{Q}{2} \Bigg\{ 1 + \frac{C_\sigma}{C_G} - \frac{2 N_A}{Q} \left\{ \frac{2 \varepsilon}{q \, N_A} \left\{ \phi_m - \Delta\phi_m \right\} \right\}^{\frac{1}{2}} - \left\{ \left\{ \frac{C_\sigma}{C_G} - 2 \, \frac{\sqrt{2 \, \varepsilon \, q \, N_A \, \Delta\phi_m}}{q \, Q} \right\}^2 - \frac{4 \, C_\sigma}{q \, Q} \Delta\phi_m \right\}^{\frac{1}{2}} \Bigg\} \qquad [6]$$

Since $\Delta\Phi_m$ is a monotonically increasing function of signal, it is clear from equation [6] that the charge handling capacity, Q_n is a maximum when $\Delta\Phi_m$ is maximized. Furthermore as the junction depth of the BCCD implant increases, the effective depletion capacitance decreases resulting in a decrease in charge handling capacity. Therefore for any given process there exists a particular junction depth for the BCCD implant that will result in a maximum in charge handling capacity.

2.4 Charge Transport in a BCCD

A unique quality of the CCD is that it can not only store charge but also transfer it from under one gate to the next. Since, the maximum channel potential in a CCD depends upon the applied gate voltage, the location of the potential maximum can be controlled by applying gate voltages in an appropriate fashion [6], [11]. Consider the device structure of Fig. 2.5a, the potential diagram of Fig 2.5b and the timing diagram of Fig. 2.5c. At time, t_1 the most positive gate voltage has been applied to clock phase Φ_1 resulting in a potential maximum under that gate. Charge is confined under gate Φ_1 by virtue of the potentials applied to adjacent gates. At time t_2, the potential applied to Φ_1 has been reduced, while the potential to clock phase Φ_2 has been increased to the most positive gate voltage applied, resulting in the potential

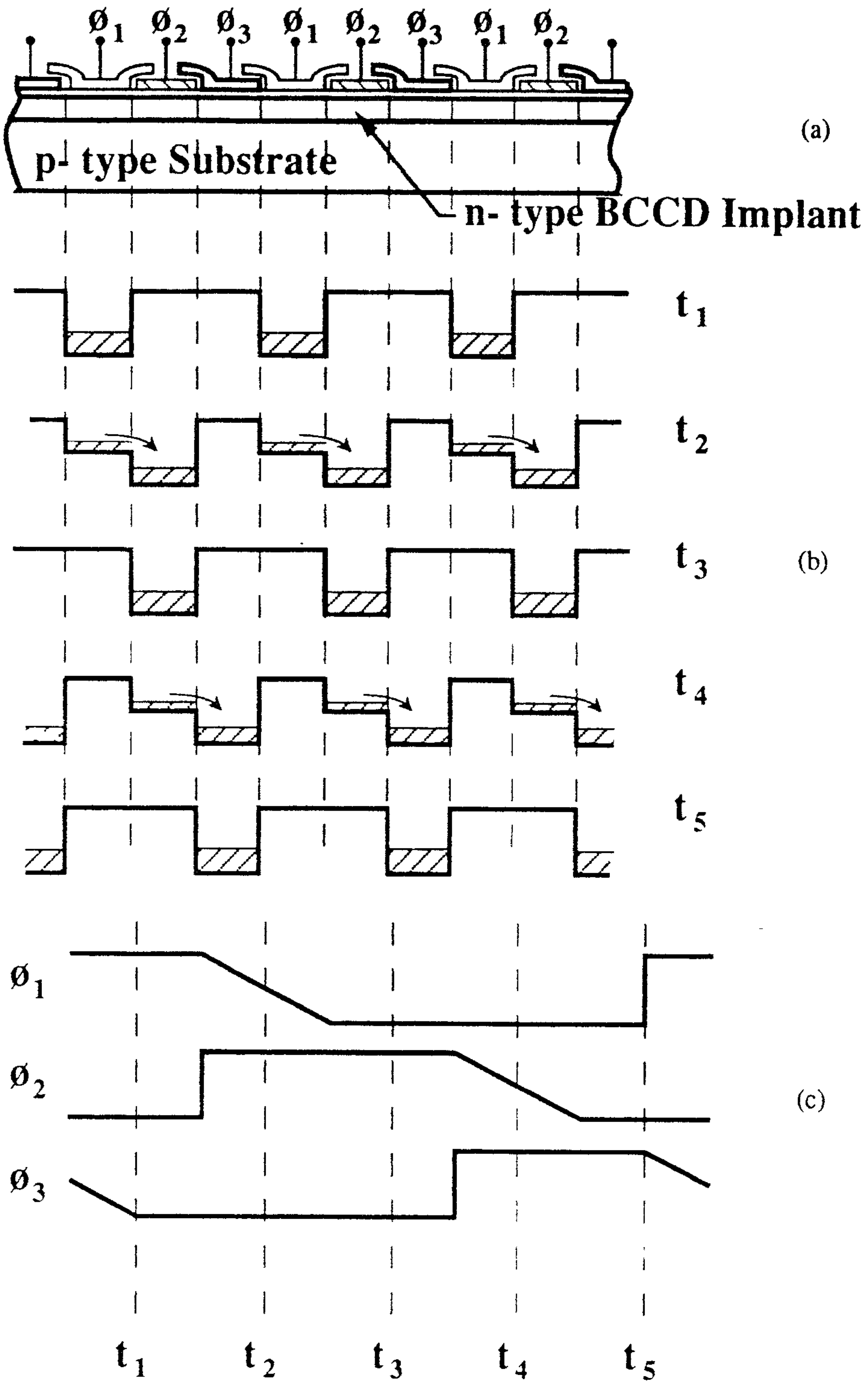

Figure 2.5 (a) Cross-sectional view of three phase BCCD structure. (b) Potential diagrams illustrating charge transfer in a three phase BCCD. (c) Timing diagram for three phase BCCD.

maximum moving from under Φ_1 to under Φ_2. This causes the free electrons to move from under Φ_1 to under Φ_2. At time t_3, the potential on Φ_1 has been removed and the most positive gate voltage is now applied to clock phase Φ_2. The local potential maximum results in charge being confined under clock phase Φ_2. If the cycle is now repeated with clock phases Φ_2 and Φ_3, charge will once again be transferred, but this time from under Φ_2 to under Φ_3.

Charge transfer in CCD's is driven by three effects [6] - [8], Self induced drift, thermal diffusion and drift due to fringing fields which result from externally applied potentials. Self induced drift or charge repulsion becomes an unimportant effect after approximately 99 percent of the charge has been transferred. Therefore, the limitations on charge transfer efficiency are imposed by the thermal diffusion and fringing field effects. The time constant for thermal diffusion is given in equation [7], where L is

$$T_{th} \approx \frac{L}{\mu E} = \frac{L}{\mu k T / q L} = \frac{L^2}{D} \qquad [7]$$

the length of the gate and D is the diffusion constant of the carriers in the channel region. For a device with a gate length of 3μm and channel diffusion constant of 10 cm^2/sec, the thermal time constant is approximately 10 nanoseconds. In order for 99.99 percent of the charge transfer to occur due to thermal diffusion approximately 10 time constants are required, thus limiting the operating frequency to about 10MHz.

When an external voltage is applied to the gate of the CCD, electric fields are generated that are primarily perpindicular to the direction of charge transfer Although most of the externally generated field is perpindicular to the direction of charge transfer, there is a componenet that is generated in the direction of charge transfer. If we assume the simplified case of the silicon being an infinite dielectric then we can write the strength of the fringing field as,

$$E_{\min} = 3.2 \frac{V}{L} \frac{t_{ox}}{L} \qquad [8]$$

where L is the length of the gate, t_{ox} is the thickness of the gate oxide and V is the externally applied gate voltage. The time constant associated with the fringing fields can then be written as a function of E_{min} and is given as,

$$T_f = \frac{L}{\mu E_{\min}} = \frac{L^3}{3.2 \mu V t_{ox}}, \qquad [9]$$

where μ the mobility of the free charge in the channel region and the other terms are as defined above. So, for a gate length of 3μm, μ of 400 cm^2/sec, t_{ox} of 0.065μm and an applied gate voltage of 10 volts, the time constant due to fringing fields is approximately 325 picoseconds. Therefore to transfer 99.99 percent of the charge due to the fringing fields takes about 10 time constants, limiting the frequency of operation to about 300MHz. Clearly the fringing field effect is important in transferring the final 1 percent of charge at high frequencies of operation.

Chapter 3

PROCESS CONSTRAINTS IMPOSED by the DESIGN of the HIGH DENSITY CCD REGISTER

3.1 The High Density CCD Register

The high density CCD register is a three phase vertical CCD which makes use of three levels of polysilicon. Although the high density register only uses three levels of polysilicon, the high-frame-rate-CCD imager imposes the additional requirement of 4 levels of polysilicon in order to realize its design. The high density register uses polysilicon levels 2, 3 and 4 to transfer and store signal, while the level 1 polysilicon layer is used as an electronically controlled channel stop region that regulates the vertical flow of charge.

Horizontally each stage of the high density register consists of a 1 design rule channel stop region and a 2 design rule channel region, resulting in a stage width of 3 design rules. Vertically each stage of the register consists of three gates each 1 design rule in length, resulting in a single stage dimension of 3 by 3 design rules as shown in Fig. 3.1. For a 1.5μm process this results in a 3μm BCCD channel width, a 1.5μm wide channel stop region and a 3μm single stage length.

A more detailed description of the high-frame-rate-CCD imager will be presented in a later report.

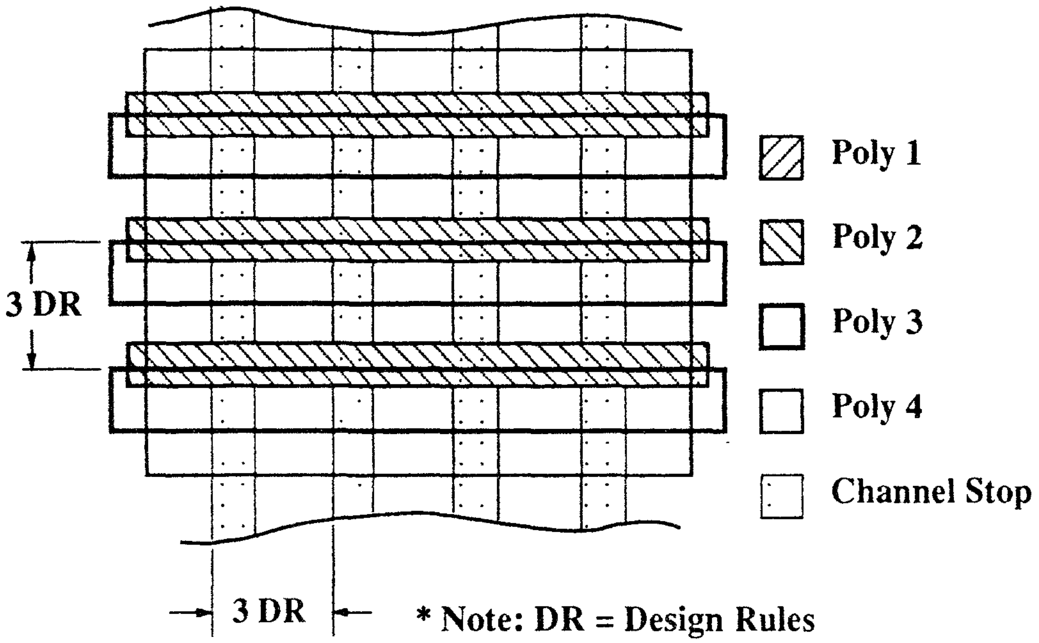

Figure 3.1 Layout of a small section of the high density CCD register.

3.2 Processing Considerations

3.2.1 Lateral Diffusion

To obtain narrow CCD channels it is necessary to maintain shallow junctions, so that the channel stop regions can effectviely prevent the spreading of signal from channel to channel. Typically lateral diffusion occurs at a rate of 0 6µm for every 1.0µm of vertical diffusion. Therefore in order to maintain channel stop widths on the order of 0.5µm it is necessary to limit the extent of vertical diffusion to approximately 1 0µm. However, the width of the channel stop region is not a sufficient measure of its effectiveness.

To determine if the channel stop will be effective it becomes necessary to look at the peak channel stop potential in the pinned condition versus the peak channel potential in the full well condition. To confine charge to the channel region, the peak channel stop potential in the full well condition must be less positive than the peak channel potential in the pinned condition as shown in Fig. 3.2. This provides the necessary barrier to confine the signal to its respective channel.

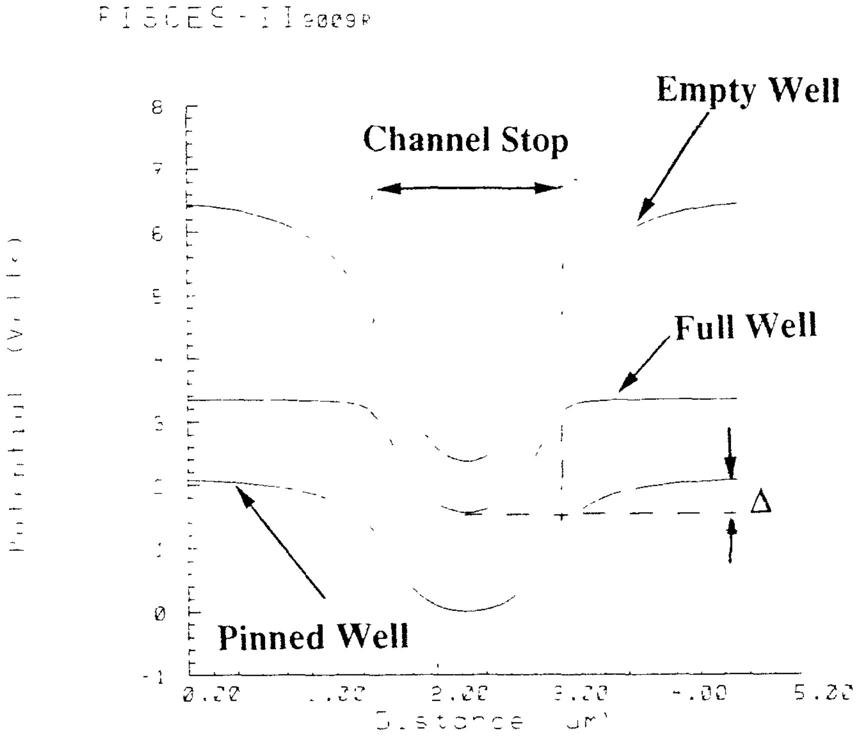

Figure 3.2 Typical PISCES IIB simulated peak potentials of the empty, full and pinned well condition across the channel, where Δ is the barrier needed such that a channel stop will be effective in confining charge to the channel region.

3.2.2 Gate Insulator

Since each level of polysilicon corresponds to a different clock phase it becomes desirable to have all levels of polysilicon the same distance from the Si / SiO_2 interface. This will ensure that each clock phase will require the same applied voltage to achieve the same effect under each gate. To accomplish this, the gate insulator is comprised of a Si_3N_4 layer over a SiO_2 layer. First, the gate oxide is thermally grown, then the nitride is deposited. Since Si_3N_4 oxidizes at a rate considerably slower than that of SiO_2, polysilicon could then be deposited, etched and oxidized without any further increase in the thickness of the gate insulator.

The additional consideration of fringing field effects is made when determining the thickness of the insulating layers. To maximize fringing field effects it is desirable to have as thin as possible insulator, while not sacrificing its dielectric properties. In private conversations with Dr. Kosonocky it was determined that the thinnest effective insulating layers that could be fabricated would be 0.04μm of SiO_2 and 0.05μm of Si_3N_4.

3.2.3 Maximum Electric Fields

As device sizes become smaller maximum electric field constraints become important. In modern process technologies films with excellent crystal qualities can be fabricated, but even the best materials exhibit dielectric breakdown as critical field strengths are reached. For good quality silicon, breakdown effects are a function of both applied voltages and doping concentrations Abrupt silicon pn junctions breakdown characteristics are dependent on the background doping concentrations of the lightly doped side of the junction as illustrated in Fig 3.3 For background doping levels of 3.0E14 ions/cm^2 the critical field strength is approximately 2 0E5 V/cm [12]. In SiO_2 and Si_3N_4 the critical field strength is dependent on the quality of the material as well as its thickness. For thin oxides and nitrides the critical field strength is approximately 1.0E7 V/cm [13], [14].

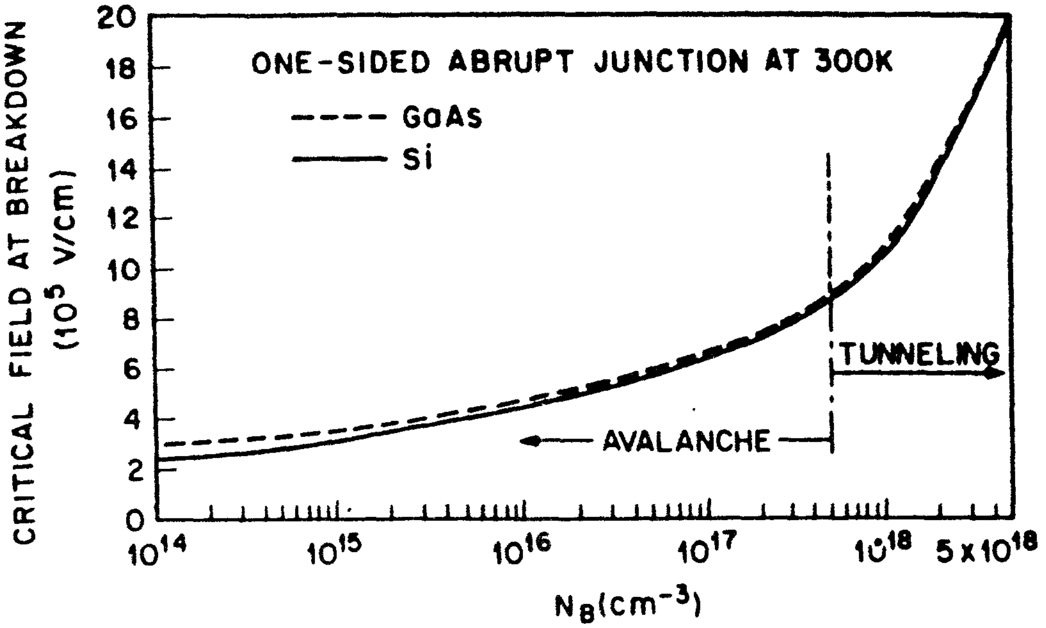

Figure 3.3 Critical fields strength for an abrupt pn junctions.

3.3 Summary of Process Constraints

The constraints imposed by the design of the imager and the process technologies available result in a description of the process parameters. These parmeters are that the process have 4 levels of polysilicon, have an insulator consisting of 0.04µm of SiO_2 covered by 0.05µm of Si_3N_4. Where one level of polysilicon is used as a controllable field plate and the other levels (poly -2, -3 and -4) are used to implement the 3-phase BCCD registers. Additionally, the junction depth of the BCCD implant must be limited to 1.0µm of vertical diffusion resulting in approximately 0.5µm wide channel stop regions. Finally, maximum electric field strengths must be limited to approximately 2.0E5 V/cm in Si and 1.0E7 V/cm in SiO_2 and Si_3N_4 films. Figures 3.4 and 3.5 illustrate the resulting cross-sectional structures of the CCD when the constraints of design and processing technology have been imposed.

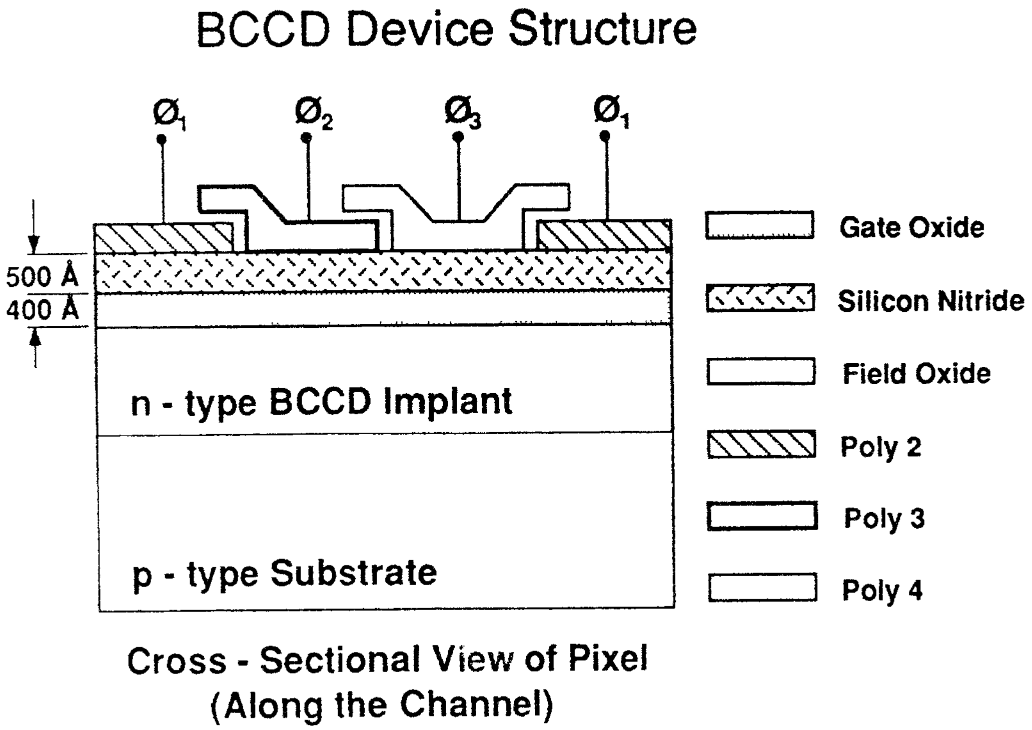

Figure 3.4 Cross-sectional view of the BCCD along the channel with design. and process constraints imposed.

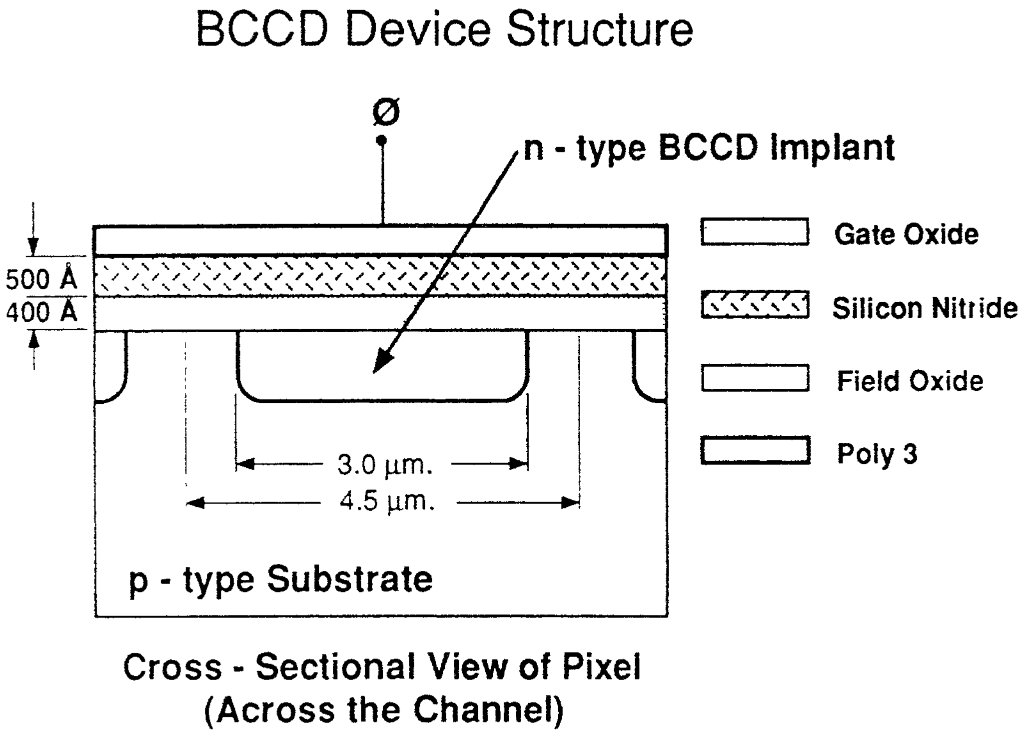

Figure 3.5 Cross-sectional view of the BCCD across the channel with design. and process constraints imposed.

Chapter 4

SUPREM III and PISCES IIB INPUT CARDS

4.1 Introduction

Modeling of device processes and electrical characteristics is an essential part of today's integrated circuit technology. Simulation is a great time and money saver since, devices are not fabricated until after intensive simulations have been done and the desired results have been acquired. SUPREM III is a one dimensional process simulator capable of modeling semiconductor fabrication steps such as diffusion and ion implantation. It is also capable of exporting its results to PISCES IIB

Pisces IIB is a two dimensional Poisson's and current continuity equation solver. It has the ability to determine the electrostatic potentials and carrier densities everywhere in a two dimensional semiconductor structure.

The following sections describe the SUPREM III and PISCES IIB input cards that were most important in completing this work. It should in no way be construed as a complete set of instructions for either software package. For a more complete description of the input card specifications the SUPREM III or PISCES IIB user manuals should be consulted.

A complete set of SUPREM III input decks used in this work may be found in Appendix A, and for PISCES IIB in Appendix B.

4.2 SUPREM III Input Cards

4.2.1 The Initialize Card

SUPREM III requires information about the material choosen for the simulation. The information about the wafer is provided in the *INITIALIZE* card which may look as follows:

INITIALIZE <100> Silicon Boron Concentration=3.0E14

+ Thickness=3.0 dx=0.005 xdx=0 001 Spaces=400.

The statement contains information about the wafer concerning its type, orientation, dopant concentration and dopant species. Since in silicon the <100> orientation is preferred in MOS structures. because the density of interface trap states is less than for the other orientations it has been used in this example. but could just as easily been specified as <110> or <111>. The dopant species used in this example is boron with a concentration of 3.0E14 ions/cm^3. SUPREM III also can model wafers with dopant species of phosphorus, arsenic and antimony.

The remainder of the input card tells SUPREM III how to set up the grid structure on which the simulation is to be performed. Thickness indicates to SUPREM III the extent of the simulation, dx sets the spacing between successive nodes and xdx sets the location of the first node. The spaces command sets the total number of spaces between nodes to be used in a given material

4.2.2 The Diffusion Card

The *DIFFUSION* card is used for a variety of functions which include oxidation, ambient anneal and solid solubility drive in. A few typical *DIFFUSION* cards might look as follows:

DIFFUSION Temperature=900 Time=33 T.Rate=-3 Nitrogen

DIFFUSION Temperature=800 Time=38 WetO2 HCl%=2.0

DIFFUSION Temperature=950 Time=15 Gas.Concentratrion= 3.1585e20 Phosphorus

The first statement simulates a nitrogen ambient drive in that lasts for 33 minutes and starts at 900°C. The temperature is ramped downward at a rate of 3 degrees per minute.

The second statement shown above simulates a wet thermal oxidation in the presence of 2.0% HCl at 800°C for 38 minutes.

The final diffusion statement shown simulates a solid solubility drive in of phosphorus gas at a temperature of 950°C for 15 minutes This statement is used to change the electrical characteristics of polysilicon from neutral to n- type and follows a polysilicon deposition.

4.2.3 The Deposition Card

The *DEPOSITION* card is used to simulate chemical vapor depositions It requires a temperature specification, material specification and the number of spaces to be used in the region. A typical *DEPOSITION* card may look as follows·

DEPOSITION Polysilicon Thickness=0 60 Temperature=560 Spaces=5

In this example 0.6μm of polysilicon is deposited at 560°C. The space command has the same meaning as when used in the initialize card.

4.2.4 The Implant Card

This card instructs SUPREM III to simulate an ion implantation step. It requires information about the species to be implanted, the energy of the implant, the dose and the implant model to be used. A typical *IMPLANT* card would look as follows:

IMPLANT Arsenic Dose=1.6E12 Energy=150 Pearson

The effect of this card is to simulate an ion implantation whose dose of arsenic is 1.6E12 ions/cm^2 at an energy of 150 keV. The card also instructs SUPREM III to assume a pearson distribution for the implanted species. Gaussian and two sided Gaussian distributions are also available. As with all of the other input cards any of the available species may be implanted.

4.2.5 The Etch Card

The *ETCH* card as the name implies is used to remove material from the simulated structure. A typical *ETCH* card follows:

ETCH Oxide ALL

The *ETCH* card requires that any valid material be specified and will remove that material providing that it is the exposed layer in the simulated structure

4.2.6 The Print Card

SUPREM III will solve diffusion, oxidation and deposition equations for each step specified in the input deck. It is often desirable to view the results of intermediate

```
layer    material type       thickness    dx      dxmin  top  bottom   orientation
 no                          (microns)   (microns)     node   node   or grain size
  7     OXIDE                   0.0926 0.0100 0.0010   84     87
  6     POLYSILICON             0.5593 0.0100 0.0010   88     91        1.4213
  5     OXIDE                   0.4101 0.0100 0.0010   92     96
  4     POLYSILICON             0.4196 0.0100 0.0010   97     99        1.6893
  3     NITRIDE                 0.0500 0.0100 0.0010  100    105
  2     OXIDE                   0.0395 0.0100 0.0010  106    119
  1     SILICON                 2.9740 0.0010 0.0010  120    500        <100>

                          Integrated Dopant
layer            Net                         Total
 no.      active       chemical       active       chemical
  7     0.0000E+00   6.4743E+13   0.0000E+00   6.4743E+13
  6     3.8779E+15   4.6293E+15   3.8779E+15   4.6293E+15
  5     0.0000E+00   2.7332E+14   0.0000E+00   2.7332E+14
  4     3.4362E+15   4.3649E+15   3.4362E+15   4.3649E+15
  3     0 0000E+00   5 2019E+13   0.0000E+00   5.2019E+13
  2     0.0000E+00   8.7885E+10   0.0000E+00   9.1496E+10
  1     1.3998E+12   1.3998E+12   1.5727E+12   1 5727E+12
 sum    7 3155E+15   9.3858E+15   7.3157E+15   9 3859E+15

                          Integrated Dopant
layer        PHOSPHORUS                    ARSENIC
 no       active       chemical       active       chemical
  7     0.0000E+00   6 4743E+13   0.0000E+00   0.0000E+00
  6     3.8779E+15   4 6293E+15   0.0000E+00   0.0000E+00
  5     0 0000E+00   2 7332E+14   0.0000E+00   0.0000E+00
  4     3.4362E+15   4 3649E+15   0.0000E+00   0.0000E+00
  3     0.0000E+00   5 2019E+13   0.0000E+00   3.9438E+07
  2     0.0000E+00   0 0000E+00   0.0000E+00   8.9691E+10
  1     0.0000E+00   0.0000E+00   1.4862E+12   1.4862E+12
 sum    7.3141E+15   9 3843E+15   1.4862E+12   1 5760E+12

                          Integrated Dopant
layer         BORON
 no.      active       chemical
  7     0.0000E+00   0 0000E+00
  6     0.0000E+00   0.0000E+00
  5     0.0000E+00   0 0000E+00
  4     0 0000E+00   0.0000E+00
  3     0 0000E+00   6 4678E+07
  2     0.0000E+00   1 8053E+09
  1     8.6457E+10   8 6457E+10
 sum    8.6457E+10   8.8327E+10

                Junction Depths and Integrated Dopant
               Concentrations for Each Diffused Region
layer  region  type  junction depth       net            total
 no.     no            (microns)       active Qd      chemical Qd
  7       1     n        0.0000       0 0000E+00     6 4743E+13
  6       1     n        0 0000       3.8779E+15     4.6293E+15
  5       1     n        0 0000       0.0000E+00     2.7332E+14
  4       1     n        0 0000       3 4362E+15     4 3649E+15
  3       2     n        0 0000       0 0000E+00     5.2019E+13
  3       1     p        0 2500       0.0000E+00     0 0000E+00
  2       2     p        0 0000       0.0000E+00     2 5781E+07
  2       1     n        0 0012       0 0000E+00     9 0628E+10
  1       2     n        0 0000       1 4755E+12     1 4949E+12
  1       1     p        0 4116       7 5760E+10     7 7512E+10
```

Figure 4.1 Typical SUPREM III output from *PRINT* input card

steps as well as final doping profiles. The *PRINT* card when inserted into the input deck causes SUPREM III to print the status of the previous structure. Information such as layer thicknesses and concentrations may be written to the terminal or a file. A typical *PRINT* card follows:

PRINT Concentration Net Active Xmin=0.00 Xmax=0.50 Filename=Outfile

This card instructs SUPREM III to write information about the net active concentrations of the layers that exist between the surface and 0.50μm into the structure. A typical output from a SUPREM III print statement is shown in Fig. 4.1.

4.2.7 The Savefile Card

The final SUPREM III input card of interest to this work is the *SAVEFILE* card. The *SAVEFILE* card allows the user to save a structure for further use in subsequent SUPREM III simulations or to write a structure which is compatible to the PISCES IIB format. The *SAVEFILE* card given below is used to write a file called outfile which is usable by PISCES IIB:

SAVEFILE Filename=Outfile Export

4.2.8 SUPREM III Output

When the SUPREM III input cards discussed above are put together to form an input deck, doping profiles are generated and exported to PISCES IIB. Shown below in Fig 4.2 is a doping profile obtained by running a SUPREM III simulation. The Doping profile shown is for a structure with a junction depth of 0.55μm, for an arsenic dose of 1.6E12 ions/cm^2 and implant energy of 150keV

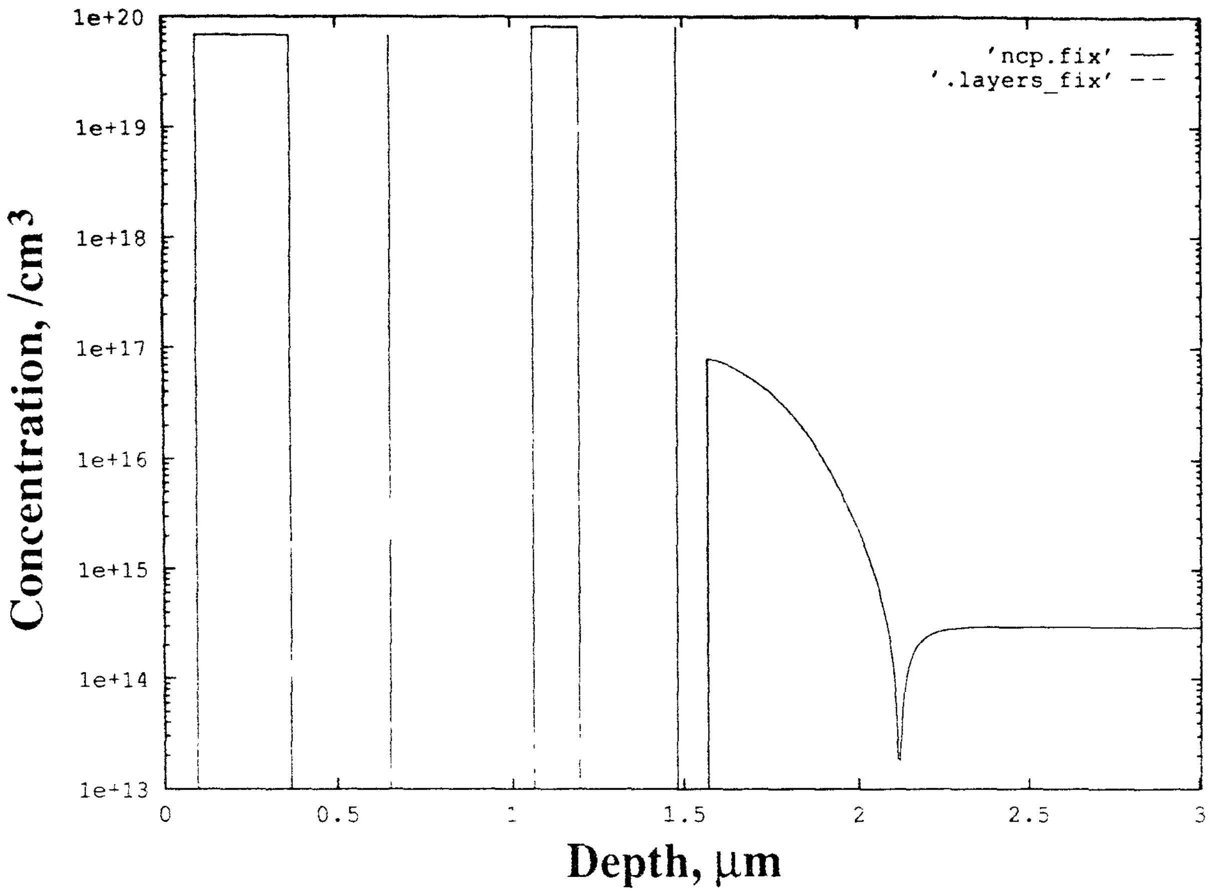

Figure 4.2 Doping profile obtained from SUPREM III for a 150keV Arsenic implant of dose 1.6E12 ions/cm^2

4.3 PISCES IIB Input Cards

4.3.1 The Mesh Card

As with most numerical simulations, PISCES IIB requires a grid or mesh structure be defined so that solutions can be found by analyzing adjacent nodes in the mesh. The PISCES IIB *MESH* card consists of three statements, the *MESH* definition card, the *X.MESH* card and the *Y.MESH* card. A typical *MESH* defintion card is shown below:

```
MESH Rectangular NX=60 NY=50 Fli.Diag Outf=Meshout
```

The previous statement initiates the generation of a rectangular mesh with 60 vertical lines and 50 horizontal lines. The *Fli.Dia* command causes the diagonals about the center of the mesh to be flipped. The *Outf* command instructs PISCES IIB to write the mesh to a file in this example called *Meshout*, which can be used in later analysis. The *X.MESH* and *Y.MESH* define the locations of the vertical lines and horizontal lines respectively. Typical *X.MESH* cards follow:

```
X.MESH  N=1  Location=0.00  Ratio=1.00
X.MESH  N=5  Location=1.00  Ratio=1.00
X.MESH  N=10 Location=1.50  Ratio=0.75
X.MESH  N=15 Location=3.00  Ratio=1.50
```

In this example the *X.MESH* cards define the location of the first, fifth, tenth and fifteenth vertical lines and the relative spacing between them. The *Location* command tells PISCES IIB where to place each line that has been defined. In ths example the first line is placed at x=0.00µm, the fifth line at x=1.00µm the tenth at 1.50µm and the fifteenth at 3.00µm. The *Ratio* command tells PISCES IIB how to place the lines that fall between the ones that are defined. In this example the lines inserted between lines 1 and 5 are evenly spaced, this is accomplished by setting *Ratio=1.0*. The spacing between the fifth and tenth line however becomes smaller as subsequent lines are placed, this is done by setting ratio less than 1.0. Finally, the spacing between the tenth and fifteenth lines becomes larger as subsequent lines are placed, this is accomplished by setting the value of ratio greater than 1.0. A typical mesh that was used in this work is shown in Fig. 4.3.

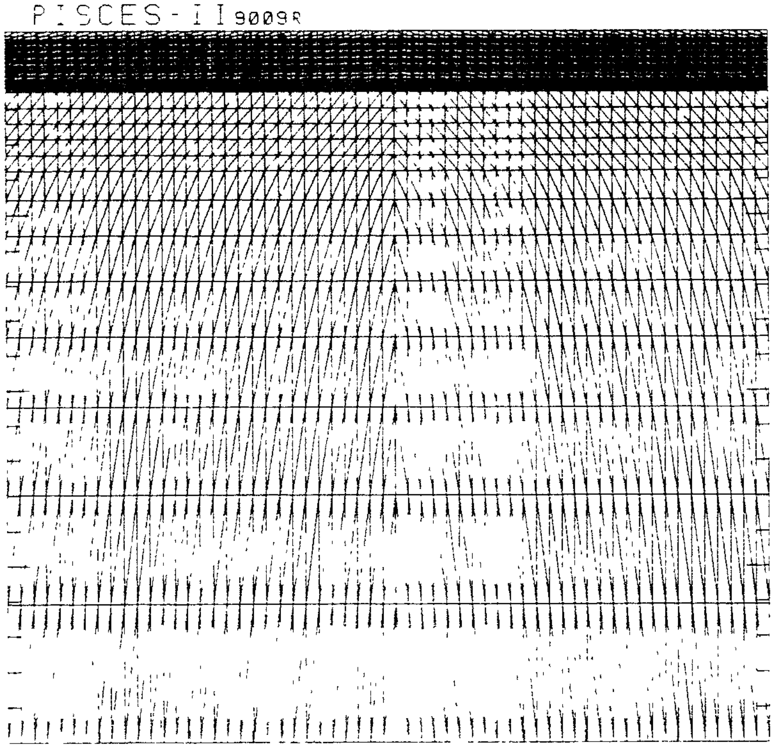

Figure 4.3 A mesh generated by PISCES IIB using the *MESH*, *X.MESH* and *Y.MESH* Cards.

4.3.2 The Region Card

The *REGION* card defines the location and type of materials in a rectangular mesh. A typical *REGION* card is given below:

REGION NUM=1 IX.LOW=1 IX.HIGH=10 IY.LOW=1 IY.HIGH=20 SILICON

This card defines region 1 as silicon, located in a rectangular mesh from vertical line 1 to vertical line 10 and from horizontal line 1 to horizontal line 20. Only one type of semiconductor material may be used during a PISCES IIB simulation so any subsequent semiconductor region definitions must be of silicon. There is a maximum of 8 regions allowed by PISCES IIB and every triangle in a mesh must be in a region before a numerical simulation can be run.

4.3.3 The Electrode Card

The *ELECTRODE* card is used to define where electrical contacts are to be made to the semiconductor material. A typical *ELECTRODE* card is given below:

```
ELECTRODE NUM=1 IX.LOW=1 IX.HIGH=10 IY.LOW=1 IY.HIGH=1
```

This card instructs PISCES IIB to place electrode 1 on the surface of region 1 as defined in section 4.3.2.

4.3.4 The Doping Card

To give PISCES IIB doping profiles, they must be defined using the *DOPING* card. Doping profiles can either be constructed analytically or be imported from SUPREM III or SUPREM IV. The following *DOPING* cards give example for both cases:

```
DOPING Uniform Region=3 Concentration=3 0E14 p.type

DOPING Gaussian Region=3 Concentration=2 0E17 n type
+ Junction=0 040 Peak=0.025

DOPING SUPREM3 Region=2 Infile=SUP3PRO Phosphorus
+ X.Left=1.5 X.Right=4.5 Lateral.Ratio=0 6
```

The first *DOPING* card analytically defines a uniformly doped p-type region of concentration 3.0E14 ions/cm^2 over the entire extent of the simulation in region 3 as defined by a *REGION* card. The second *DOPING* card analytically defines a n-type gaussian doping profile with peak concentration of 2.0E17 ions/cm^2 located 0.025μm microns from the surface of region 3 and a junction depth 0.040μm from the surface of region 3. The third *DOPING* card imports a phosphorus doping profile from a SUPREM III file named *SUP3PRO.* The card instructs PISCES IIB to place the profile starting at the surface of region 2, in the area defined by the *X.MESH* cards from x = 1.5μm to x = 4.5μm. The card also tells PISCES IIB to spread the doping profile laterally from the defined limits, 0.6μm for every 1.0μm of vertical depth, this adds some realism to the SUPREM III doping profiles when they are translated into two dimensions.

4.3.5 The Contact Card

The *CONTACT* card is used to define the material to be used for an electrode definition. Consider the following contact card when used in conjunction with the electrode definition of section 4.3 3:

CONTACT NUM=1 N.Poly

This card defines the material to be used for electrode 1 as n-type polysilicon. Materials such as aluminum, molybdenum, and tungsten among others may also be used to simulate contacts The work function of a contact may also be specified in order to add flexibilty to the simualtion when a particular type of contact is not defined by PISCES IIB.

4.3.6 The Symbolic Card

The *SYMBOLIC* card allows the user to define the numerical technique to be used by PISCES IIB during the simulation. It also allows the user to define which carries are to be solved for explicitly during the simulation. A typical *SYMBOLIC* card follows:

SYMBOLIC Newton Carriers=0

The card shown above tells PISCES IIB to perform the analysis using Newtons Method for 0 carriers. This means that only the electrostatic potential is solve for explicitly. The carrier concentrations are then determined from the electrostatic potentials. It is of interest to note that when only Poisson's equation needs to be solved that 0 carriers may be used. If the current continuity equation also needs to be solved then at least one carrier must be specified. PISCES IIB also allows the Gummel Method to be used to numerically determine the electrostatic potential and carrier concentrations. The card shown above was used during this work, because for the static condition in a CCD ideally there is no current flow and the current continuity equation has no singular solution.

4.3.7 The Solve Card

The final card of interest used during this work is the *SOLVE* card. The *SOLVE* card is used to instruct PISCES IIB about the boundary conditions to be used during a simulation. A few typical *SOLVE* card used during this work are shown below:

SOLVE Initial V1=0.00 V2=0.00 N.Bias=0.00 P.Bias=0.00 Outf=SOLOUT

```
SOLVE  Previous  V1=0.00  V2=0.00  N.Bias=5.00  P.Bias=0.00  Outf=Quasi.5
SOLVE  Previous  V1=-4.5  V2=0.00  N.Bias=10.0  P.Bias=0.00  Outf=Pin.4.5
```

In the first example given above, PISCES IIB is told that the solution to be found is the initial solution. This tells PISCES IIB to make an educated guess about the electrostatic potentials and carrier densities. The card also defines the boundary conditions to be used during the simulation. In this case the voltage applied to electrodes 1 and 2 is set to 0 volts, and that the quasi-fermi levels for both electrons and holes be set to their thermal equilibrium values. The quasi-fermi levels for carriers that are not being solved for are controlled by the *N.Bias* and *P.Bias* commands respectively. The card also instructs PISCES IIB to write the solutions to a file called *SOLOUT*. In the second *SOLVE* statement shown, PISCES IIB is instructed to use the previous solution as the best guess to start the numerical method. The quasi-fermi level for electrons has also been raised causing the structure to become depleted of electrons. The solution to this simulation is written to a file called *Quasi.5* In the final *SOLVE* statement shown above, the voltage applied to electrode 1 is specified as -4.5 volts and the quasi-fermi level for electrons is set to 10eV above its equilibrium value. This causes the PISCES IIB to deplete the structure of free electrons while applying a negative gate voltage. PISCES IIB also writes the solution to an output file called *Pin.4.5*

Chapter 5

RESULTS of SUPREM III and PISCES IIB BCCD SIMULATIONS

5.1 Introduction

SUPREM III and PISCES IIB simulations were run in an attempt to optimize the charge handling capacity of a 3μm BCCD.

Initially, SUPREM III simulations were performed to determine the best dopant species to be used for the BCCD implant, such that junction depths ranging from 0.40μm to 0.80μm could be achieved with reasonable drive-in and anneal times.

Next, SUPREM III and PISCES IIB simulations were carried out for an implanted dose of 1.3E12 arsenic ions/cm^2 at junction depths ranging from 0.40μm to 0.80μm at an implant energy of 100keV. These simulations provided insight into the maximum dose that could be implanted into a shallow junction, while observing the constraint set on allowable electric fields in the silicon region.

The implanted dose was then increased to 1 6E12 arsenic ions/cm^2 and simulations were run for junction depths ranging from 0.40μm to 0.80μm and implant energies between 100 and 200keV. The maximum charge handling capacity and electric fields was determined for each of these simulations Charge Handling capcity was determined by operating the CCD with gate voltages between ground and the pinning voltage for all of the simulations run in this work. This method of operation allows for the storage of more signal than does that of clock voltages that range from ground to positive values (pinning voltages for a p-type substrate are negative).

SUPREM III profiles were exported to PISCES IIB and given 2-dimensional qualities Doping profiles obtained from all of the SUPREM III simulations run for this work are shown in Appendix C.

The electrical characteristics of the BCCD were then determined using PISCES IIB. Figure 5.1 is an illustration of structure that was used during PISCES IIB simulations of the 3μm BCCD. The extent of the simulated structures was 5.0μm horizontally

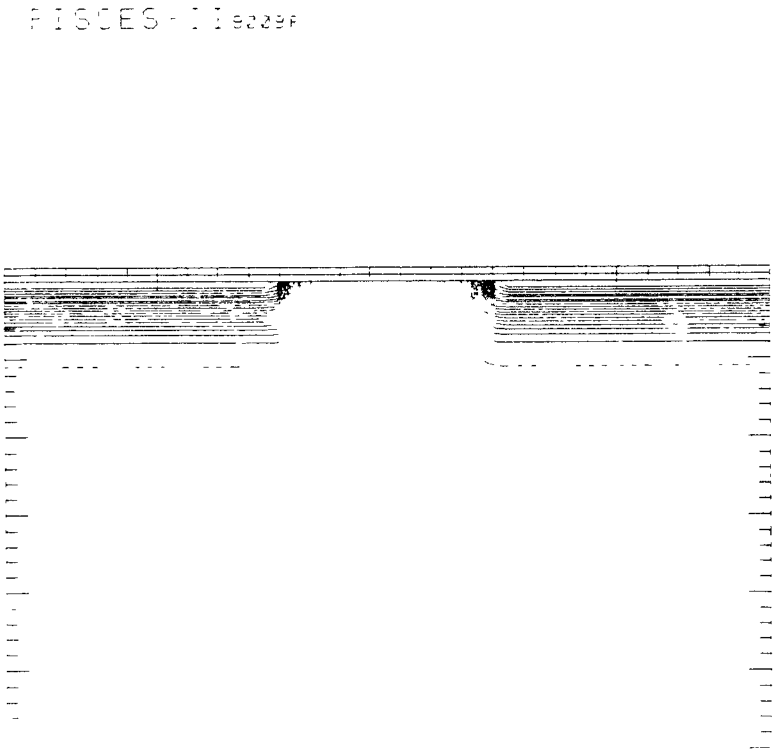

Figure 5 1 Pisces IIB simulated BCCD structure The shaded regions indicate BCCD implant regions.

and 8 0μm vertically It was felt that if the line of symmetry for the PISCES IIB simulations was choosen as the center of the channel stop region, at least two BCCD channel regions needed to be simulated to account for channel stop narrowing. This would have resulted in the horizontal extent of the simulation being 9.0μm. Therefore, the line of symmetry was choosen as the center of the BCCD channel so that the effects of lateral diffusion into the channel stop regions would be accounted for, while allowing maximum resolution of the mesh structure to be achieved.

Potential profiles and cross-sections as well as electric field profiles for all of the PISCES IIB simulations done for this work are shown in Appendix D. The following sections of this chapter provide greater detail about the results obtained during the aforementioned simulations.

5.2 Investigation of Dopants for Shallow BCCD Implants

In order to better understand the processes of ion implantation and drive-in, SUPREM III simulations were performed using both phosphorus and arsenic as the implanted species. Ions were implanted into a silicon substrate through a protective oxide layer 197 angstroms thick. Next, the implanted dose was driven in and annealed for various times until the desired junction depth was achieved. The protective oxide layer was then etched, followed by a wet thermal oxidation used to grow the gate oxide. Finally, Si_3N_4 was deposited. Then using output from the SUPREM III *PRINT* statement, the percentage of the implanted dose remaining in the silicon was determined. As can be seen in Table 5.1, for shallow implants a larger and more constant percentage of arsenic remains in the substrate than does phosphorus. Therefore arsenic was selected as a more appropriate choice for the BCCD implant and was used for all subsuquent simulations, because the study was meant to be a means of comparing charge handling capacities of various CCD structures as a function of implant energy and junction depth, not effective dose.

At this time it may be appropriate to note that the results of these simulations have led to some question. Since the segregation coefficients of both arsenic and phosphorus at a Si / SiO_2 interface are 0.0333 in the oxide and 1.00 in the silicon, in both cases similar amounts of dopant should have been "plowed" into the silicon resulting in almost all of the implanted dose remaining in the substrate after drive-in. A possible explanation for larger percentages of arsenic remaining in the silicon after drive-in may be due to the differences in diffusion coefficients between arsenic and phosphorus. The diffusion coefficient used by SUPREM III for arsenic in silicon was 4.80E10μm^2/s, and for phosphorus in silicon, 2.31E10μm^2/s, but in SiO_2 the diffusion coefficient for arsenic was 1.05E10μm^2/s and for phosphorus 4.56E7μm^2/s. This means that in silicon, both arsenic and phosphorus diffuse at about the same rate, but in SiO_2 arsenic diffuses at a much faster rate. The implications are that in a side by side comparison, with equal amounts of phosporus in one case and arsenic in the other, in the SiO_2 region more arsenic reaches the Si / SiO_2 interface than does phosphorus in a given amount of time, therefore more arsenic will be "plowed" into the silicon than phosphorus for equal drive-in times and temperatures. This line of reasoning is valid only if approximately equal amounts of dopant ions lie in the SiO_2 region prior to drive-in, as is the case for shallow implants.

5.3 BCCD Simulations for an Implanted Dose of 1.3E12 Arsenic Ions/cm^2

Doping profiles for an arsenic implant of 1.3E12 ions/cm^2 at 100keV,and junction depths ranging from 0.40μm to 0.80μm were simulated using SUPREM III. In turn each of these profiles were imported to PISCES IIB, where their electrical characteristics were modeled. Shown in Fig. 5.2a, are PISCES IIB simulated potential profiles

Table 5.1 Dose Fraction Remaining in Silicon After Drive-In

IMPLANT	ANNEAL / DRIVE-IN Nitrogen Ambient	JUNCTION DEPTH (μm)	DOSE FRACTION REMAINING IN Si
150keV Phosphorus	1100°C 46 Minutes	1.1808μm	0.864
150keV Phosphorus	1100°C 16 Minutes	0.9353μm	0.843
150keV Phosphorus	1100°C 6 Minutes	0.8266μm	0.839
50keV Phosphorus	1100°C 6 Minutes	0.6620μm	0.730
150keV Arsenic	1100°C 64 Minutes	0.6023μm	0.955
150keV Arsenic	1100°C 46 Minutes	0.5515μm	0.951
150keV Arsenic	1100°C 31 Minutes	0.5028μm	0.947
100keV Arsenic	1100°C 14 Minutes	0.4008μm	0.926

** Note: All Processes Have an Additional Drive-In of 99 Minutes at a Temperature of 1100°C Ramped Downward at 3°C per Minute

for a BCCD with an implanted junction depth of 0.50μm, as a function of signal charge. The potential cross-sections, across the BCCD channel for the same simulation are shown in Fig. 5.2b.

Peak and surface potentials for the empty, full and pinned solutions were determined as a function of junction depth and are plotted in Fig. 5.3 and shown in tabular form in Table 5.2. The maximum charge handling capacity was then determined and plotted as a function of junction depth and are shown in Fig 5.4. It can be seen by comparing Fig. 5.3 and Fig. 5.4 that the maximum charge handling capacity is achieved when both constraints placed on the full well are satisfied simultaneously. In other words when the peak potential of the full well is both, 10kT greater than the surface potential of the full well and 10kT greater than the peak potential of the pinned well, the charge handling capacity is maximized.

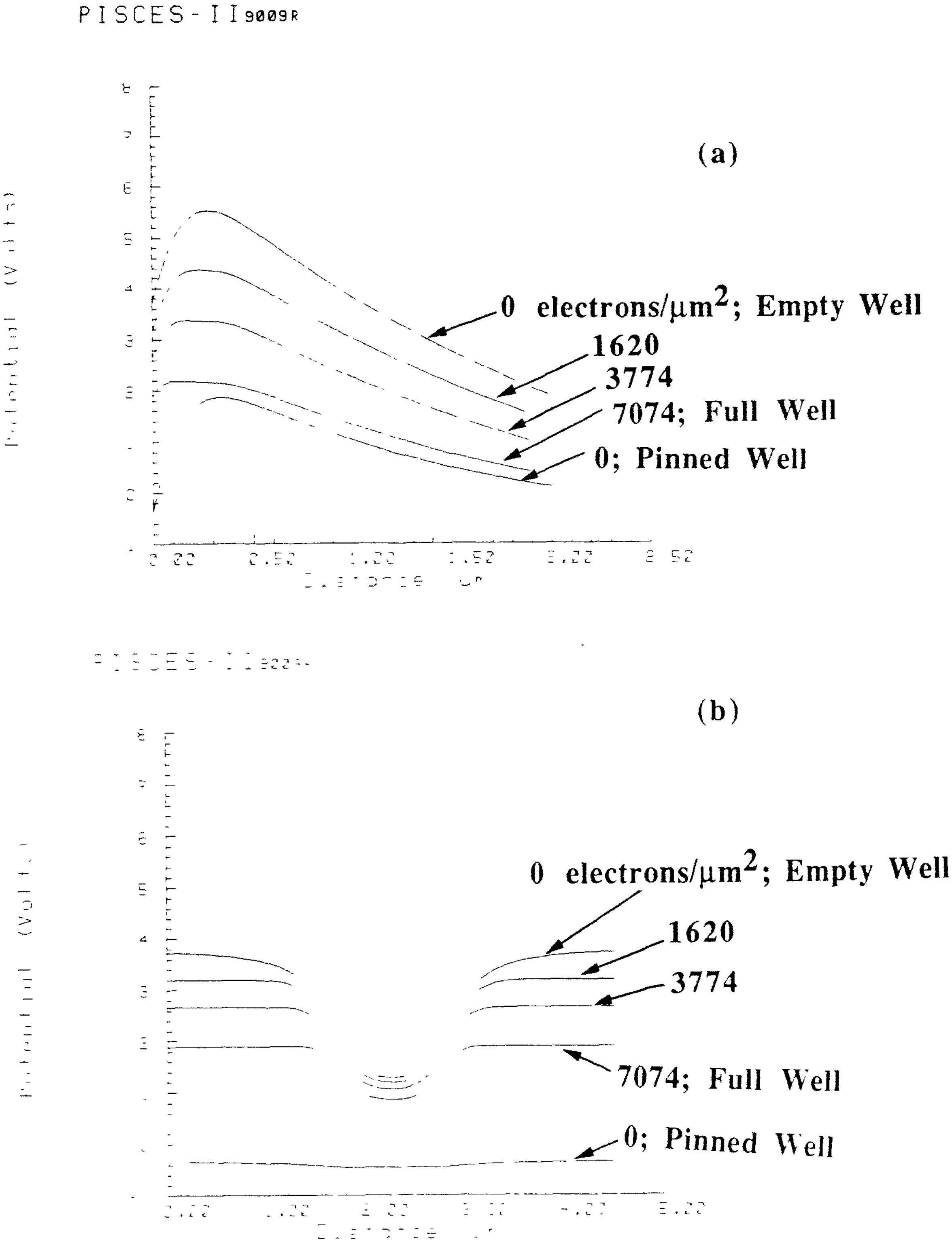

Figure 5.2 (a) Potential profiles simulated by PISCES IIB for a 100keV arsenic implant for a dose of 1.3E12 ions/cm^2, (b) Potential cross-sections across the channel region for the same simulation.

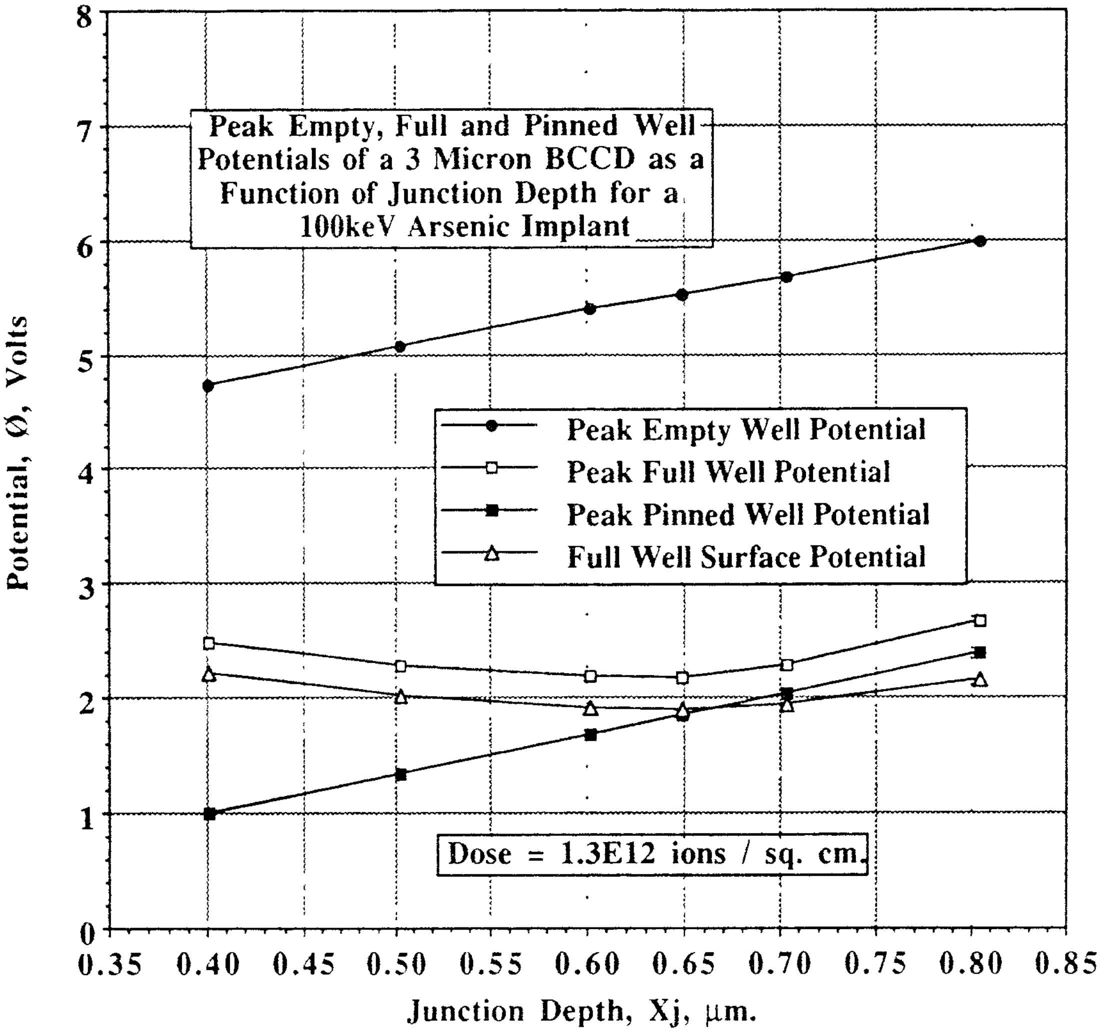

Figure 5.3 Full well surface potential and peak empty, full and pinned well potentials as a function of junction depth for a 100keV arsenic implant of 1.3E12 ions/cm^2.

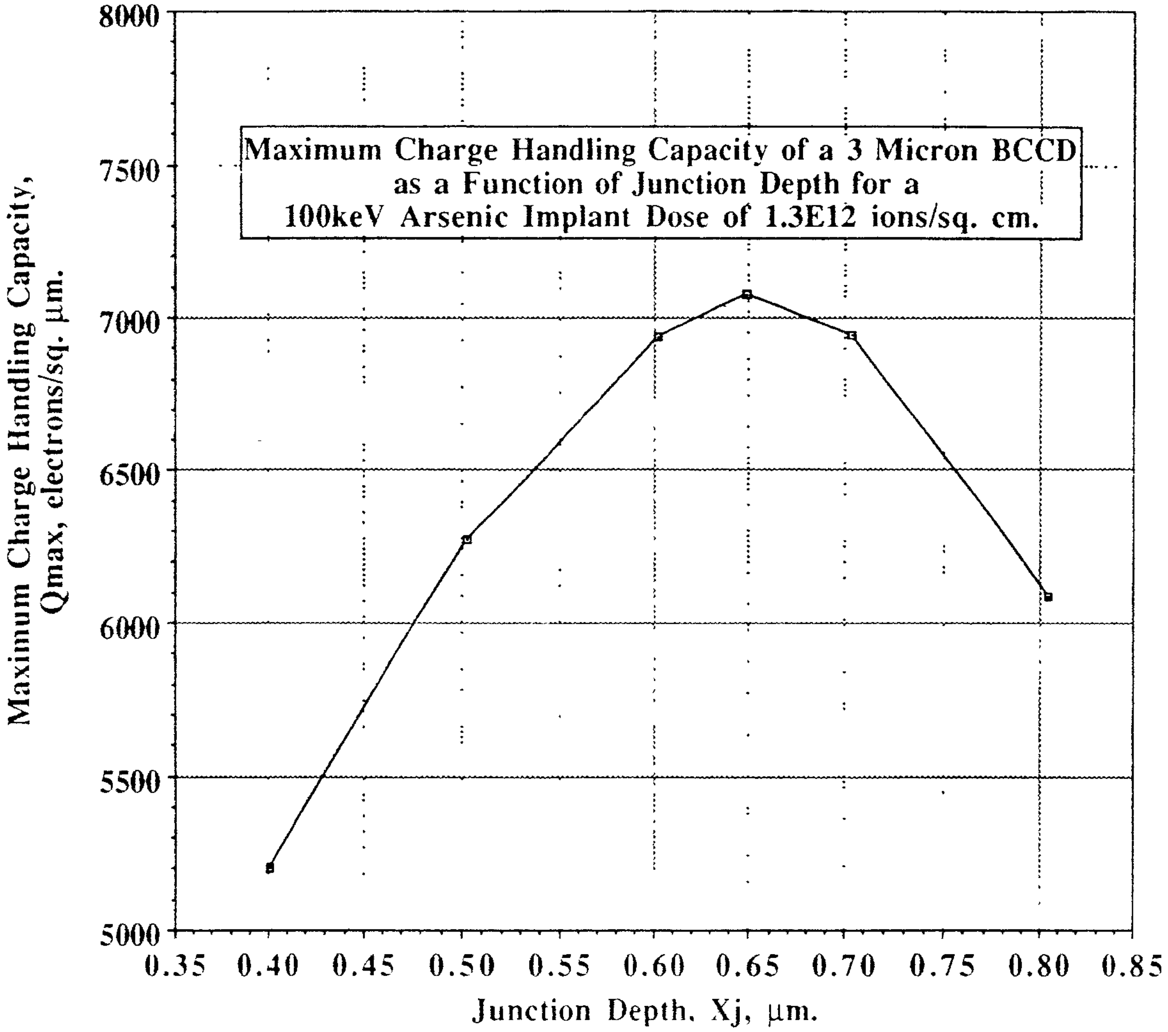

Figure 5.4 Maximum charge handling capacity as a function of junction depth for a 100keV arsenic implant of 1.3E12 ions/cm^2

Table 5.2 Device Potentials as a Function of Junction Depth for a 100keV Arsenic Implant Dose = 1.3E12 ions /cm^2

Junction Depth (μm)	Maximum Empty Well Potential (Volts)	Maximum Full Well Potential (Volts)	Maximum Pinned Well Potential (Volts)
0.40	4.738	2.488	1.000
0.50	5.077	2.285	1.337
0.60	5.389	2.182	1.684
0.65	5.526	2.179	1.849
0.70	5.679	2.278	2.028
0.80	5.988	2.672	2.384

Figure 5 5 shows the electric field profiles for the empty, full and pinned well cases of this simulation. It should be noted that the maximum electric fields were always achieved in the pinned condition. The maximum electric field for the cases of empty, full and pinned wells are shown as a function of junction depth for a 100keV arsenic implant with a dose of 1.3E12 ions/cm^2. Since the maximum electric field is a strong function of doping, as would be expected it is relatively constant as a function of junction depth. By setting the maximum allowable electric field to 2.0E5 V/cm and scaling it linearly with implanted dose it was determined that to achieve the maximum electric field a dose of 1 6E12 ions/cm^2 was required. The method of analysis described above has been used throughout the remainder of this work

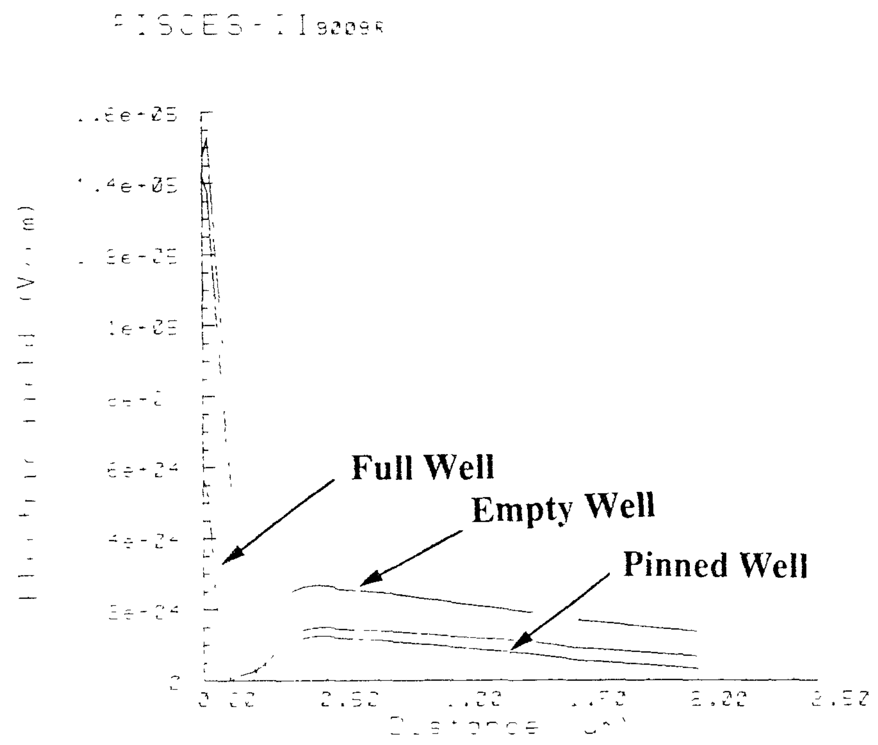

Figure 5.5 Simulated electric field profiles for 100keV arsenic implant of dose 1.3E12 ions/cm^2 for the empty, full, and pinned well solutions

5.4 BCCD Simulations for an Implanted Dose of 1.6E12 Arsenic Ions/cm^2

5.4.1 Case 1 - Implant Energy of 100keV

The first case investigated was for an 100keV arsenic implant of dose 1.6E12 ions/cm^2. Using Suprem III, anneal times were varied to obtain junction depths ranging from 0.40µm to 0.80µm. The device potentials and carrier densities were then solved for numerically using PISCES IIB. Shown in Fig. 5.6 is a plot of maximum empty, full and pinned well potentials as a function of junction depth, which are also presented in tabular form in Table 5.3. As can be seen from this figure both constraints

Table 5.3 Device Potentials as a Function of Junction Depth for a 100keV Arsenic Implant Dose = 1.6E12 ions/cm^2

Junction Depth (µm)	Maximum Empty Well Potential (Volts)	Maximum Full Well Potential (Volts)	Maximum Pinned Well Potential (Volts)
0.40	5.762	2.696	1.301
0.50	6.176	2.493	1.705
0.55	6.373	2.391	1.957
0.60	6.564	2.489	2.169
0.70	6.957	2.883	2.597
0.80	7.339	3.279	3.019

or the full well are satisfied simultaneously, for a junction depth of 0.55µm. Charge handling capacity was then plotted as a function of junction depth and is shown graphically in Fig. 5.7. It is clear that the maximum in charge handling capacity is achieved as before, when both constraints placed upon the full well condition are satisfied. The maximum charge handling capacity achieved for this implant energy was 8983 electrons/µm^2 at a maximum electric field in the pinned condition of 1.90E5 V/cm in silicon. Charge handling capacity and the maximum electric fields in the Si, the SiO_2 and the Si_3N_4 for the pinned condition as a function of junction depth are reported in Table 5.4. Potential profiles and cross-sections as well as electric field profiles can be found for this and all other simulations done for this work in Appendix D.

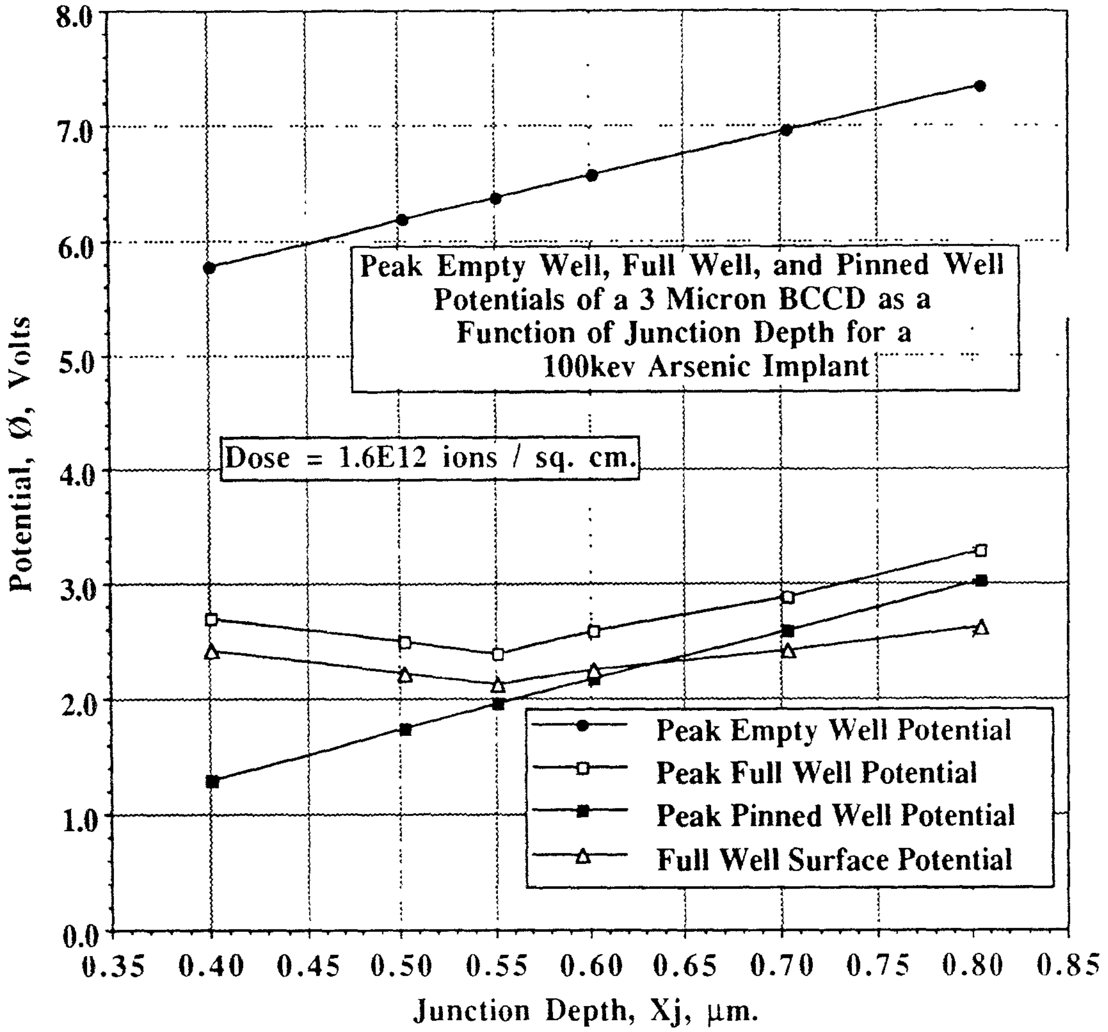

Figure 5.6 Full well surface potential and peak empty, full and pinned well potentials as a function of junction depth for a 100keV arsenic implant of 1.6E12 ions/cm^2.

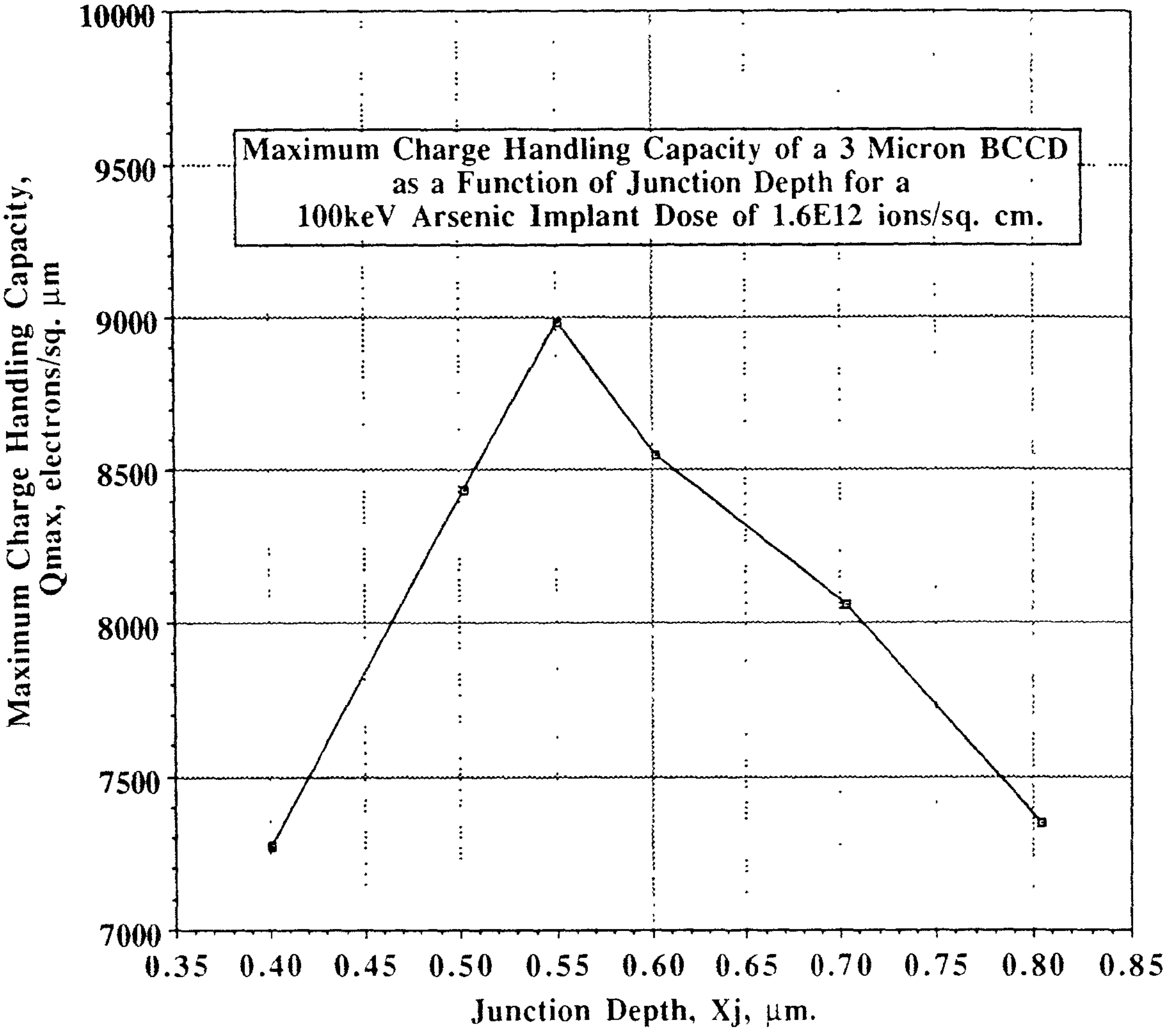

Figure 5.7 Maximum charge handling capacity as a function of junction depth for a 100keV arsenic implant of 1.6E12 ions/cm^2

Table 5.4 Maximum Charge Handling Capacity and Electric Fields as a Function of Junction Depth For a 100keV Arsenic Implant Dose = 1.6E12 ions / cm^2

Junction Depth (μm)	Maximum Charge Handling Capacity (electrons / μm^2)	Maximum Electric Field in:		
		Silicon (V/cm)	Silicon Nitride (V/cm)	Silicon Dioxide (V/cm)
0.40	7274	1.88E5	3.40E5	6.54E5
0.50	8435	1.86E5	3.53E5	6.56E5
0.55	8983	1.90E5	3.41E5	6.56E5
0.60	8863	1.90E5	3.41E5	6.56E5
0.70	8059	1.89E5	3.41E5	6.60E5
0.80	7345	1.89E5	3.41E5	6.55E5

5.4.2 Case 2 - Implant Energy of 150keV

The implant energy was then increased to 150keV, in order to observe the effect of implanted range on the maximum charge handling capacity. A slight increase in charge handling capacity was observed as was suggested by Chatterjee and Taylor [10]. Maximum empty, full and pinned well potentials are presented in Fig. 5.8 and Table 5.5, and as before indicate a charge handling capacity maximum at a junction depth of 0.55μm. This is in agreement with the results obtained and displayed graphically in Fig. 5.9. The maximum charge handling capacity was found to be 9394 electrons/μm^2 at a maximum electric field in the pinned condition of 1.91E5 V/cm. The charge handling capacity and maximum electric field for the pinned condition are reported in Table 5.6 as a function of junction depth.

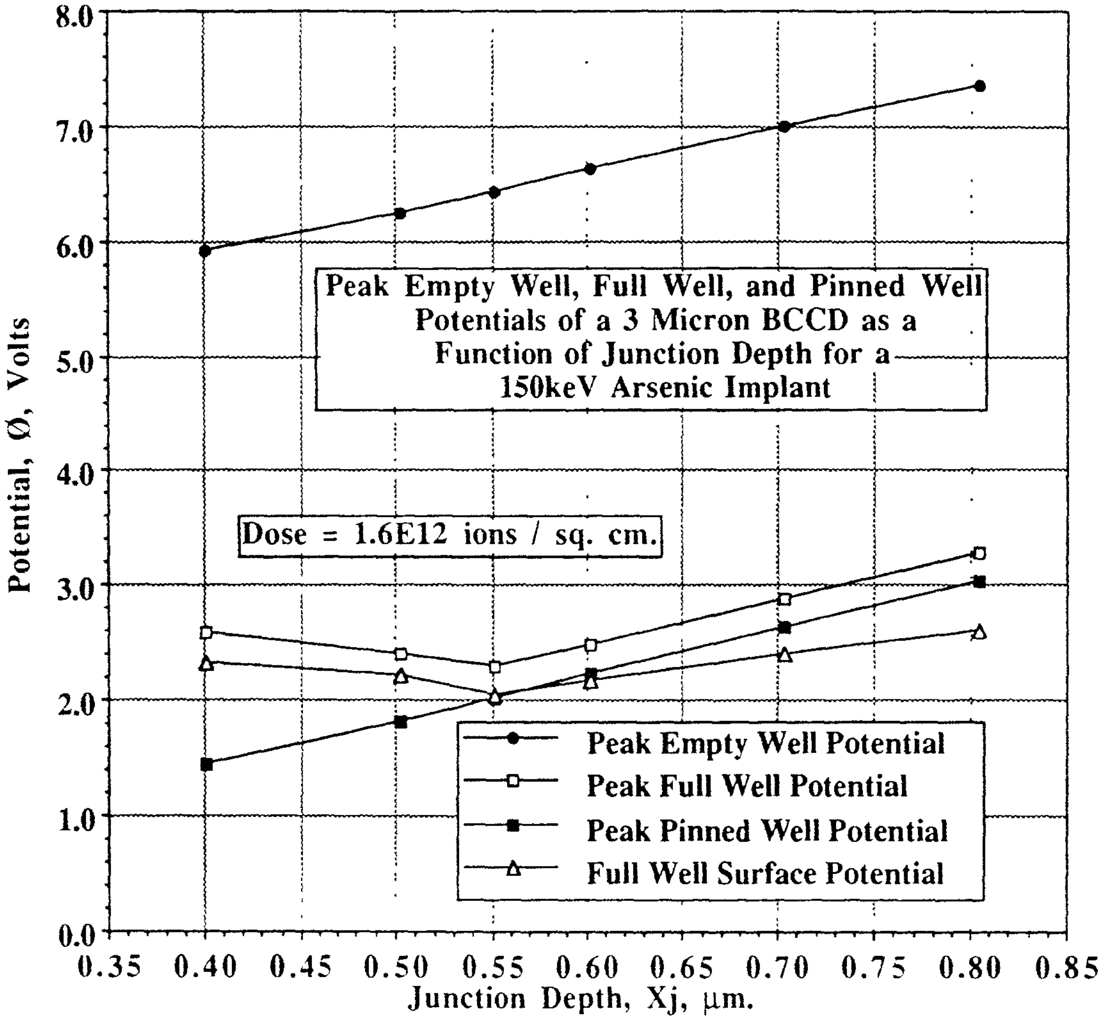

Figure 5.8 Full well surface potential and peak empty, full and pinned well potentials as a function of junction depth for a 150keV arsenic implant of 1.6E12 ions/cm^2.

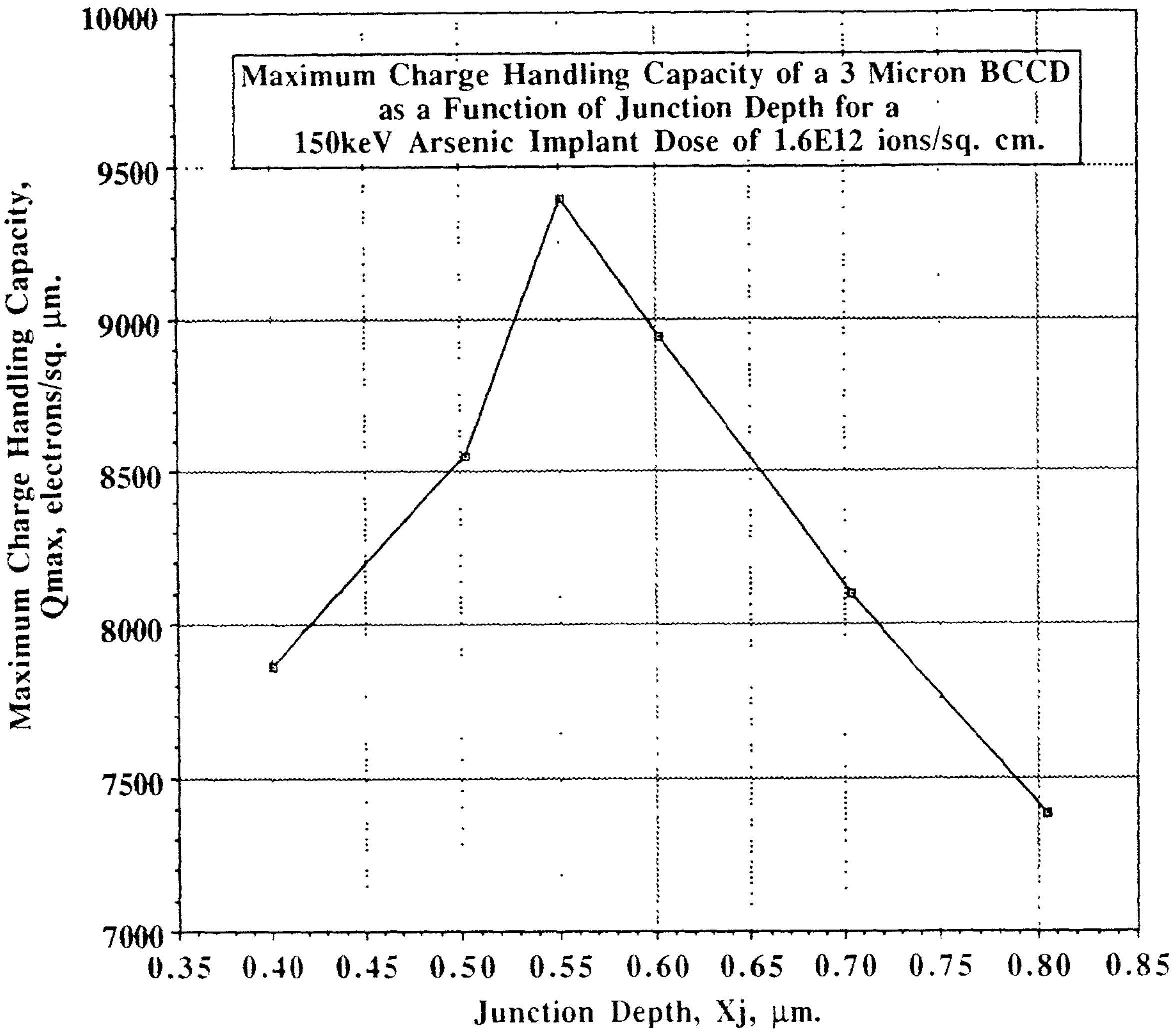

Figure 5.9 Maximum charge handling capacity as a function of junction depth for a 150keV arsenic implant of 1.6E12 ions/cm^2

Table 5.5 Device Potentials as a Function of Junction Depth for a 150keV Arsenic Implant Dose = 1.6E12 ions /cm^2

Junction Depth (μm)	Maximum Empty Well Potential (Volts)	Maximum Full Well Potential (Volts)	Maximum Pinned Well Potential (Volts)
0.40	5.919	2.596	1.446
0.50	6.250	2.492	1.816
0.55	6.431	2.291	2.016
0.60	6.628	2.488	2.229
0.70	6.993	2.883	2.636
0.80	7.360	3.278	3.037

Table 5.6 Maximum Charge Handling Capacity and
Electric Fields as a Function of Junction Depth
For a 150keV Arsenic Implant Dose = 1.6E12 ions / cm^2

Junction Depth (μm)	Maximum Charge Handling Capacity (electrons / μm^2)	Maximum Electric Field in:		
		Silicon (V/cm)	Silicon Nitride (V/cm)	Silicon Dioxide (V/cm)
0.40	7859	1.92E5	3.41E5	6.56E5
0.50	8549	1.91E5	3.41E5	6.57E5
0.55	9394	1.91E5	3.41E5	6.57E5
0.60	8945	1.91E5	3.41E5	6.56E5
0.70	8099	1.90E5	3.41E5	6.56E5
0.80	7380	1.89E5	3.41E5	6.55E5

5.4.3 Case 3 - Implant Energy of 175keV

Once again using SUPREM III, an arsenic implant was simulated, but this time at 175keV for junction depths ranging from 0.40µm to .80µm. In this case the maximum charge handling capacity was observed at 0.55µm as would be indicated by by the plot of peak empty, full and pinned well potentials, shown in Fig. 5.10, but no further increase in charge handling capacity was noted. Charge handling capacity as a function of junction depth is shown in Fig. 5.11. Peak empty, full and pinned well potentials are also presented in tabular form in Table 5.7. In this case the maximum charge handling capacity observed was 9133 electrons/μm^2 at maximum electric field of 1.92 V/cm in the pinned condition. Charge handling capacity and maximum electric fields in the pinned condition as a function of junction depth are reported in Table 5.8.

Table 5.7 Device Potentials as a Function of Junction Depth for a 175keV Arsenic Implant Dose = 1.6E12 ions /cm^2

Junction Depth (µm)	Maximum Empty Well Potential (Volts)	Maximum Full Well Potential (Volts)	Maximum Pinned Well Potential (Volts)
0.40	6.060	2.497	1.537
0.50	6.333	2.392	1.898
0.55	6.489	2.390	2.073
0.60	6.614	2.488	2.257
0.70	7.020	2.883	2.663
0.80	7.381	3.378	3.059

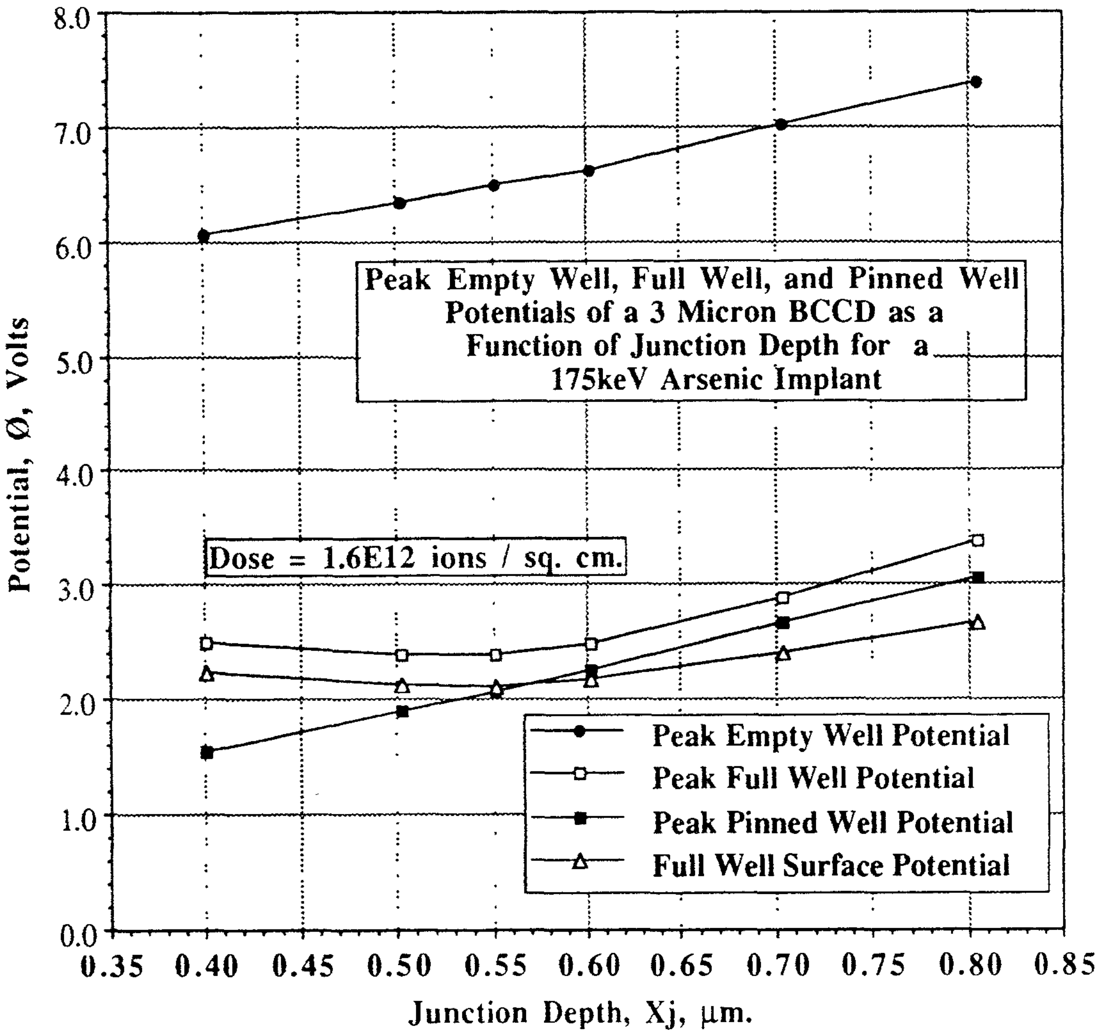

Figure 5.10 Full well surface potential and peak empty, full and pinned well potentials as a function of junction depth for a 175keV arsenic implant of 1.6E12 ions/cm^2.

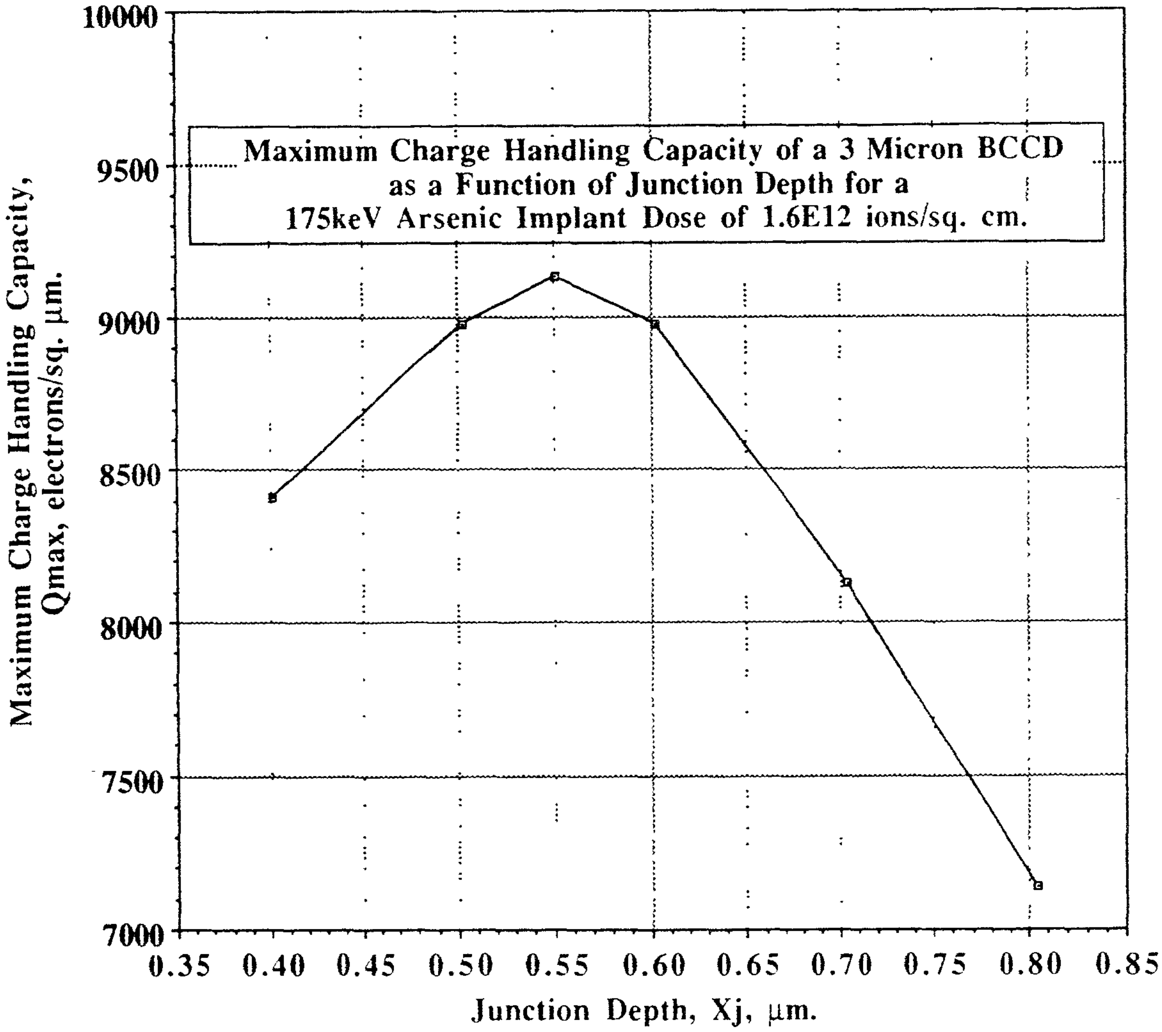

Figure 5.11 Maximum charge handling capacity as a function of junction depth for a 175keV arsenic implant of 1.6E12 ions/cm^2.

Table 5.8 Maximum Charge Handling Capacity and Electric Fields as a Function of Junction Depth For a 175keV Arsenic Implant Dose = 1.6E12 ions / cm^2

Junction Depth (μm)	Maximum Charge Handling Capacity (electrons / μm^2)	Maximum Electric Field in: Silicon (V/cm)	Silicon Nitride (V/cm)	Silicon Dioxide (V/cm)
0.40	8412	1.95E5	3.47E5	6.67E5
0.50	8979	1.92E5	3.42E5	6.57E5
0.55	9133	1.92E5	3.42E5	6.57E5
0.60	8976	1.91E5	3.41E5	6.57E5
0.70	8129	1.90E5	3.41E5	6.56E5
0.80	7140	1.90E5	3.41E5	6.55E5

5.4.4 Case 4 - Implant Energy of 200keV

The final case simulated was for an implant energy of 200keV. In this case the plot of peak empty, full and pinned well potentials is deceiving. Although the plot shown in Fig. 5.12 would tend to indicate that the charge handling capacity should lie at a junction depth of 0.55μm it actually occurs at a junction depth of 0.40μm as shown in Fig. 5.13. The peak values of potential for the empty, full and pinned well conditions are given in Table 5.9.

Closer examination of equation [6] would imply that the ratio of depletion capacitance to gate capacitance, C_σ / C_G has become the dominant effect in charge handling capacity, whereas in the previous cases presented the dominant effect was due to the change in potential, $\Delta\Phi_m$ from empty to full well conditions. The maximum charge handling capacity for this case was determined to be 9426 electrons/μm with a maximum electric field of 1.99 V/cm in the pinned condition. The charge handling capacity

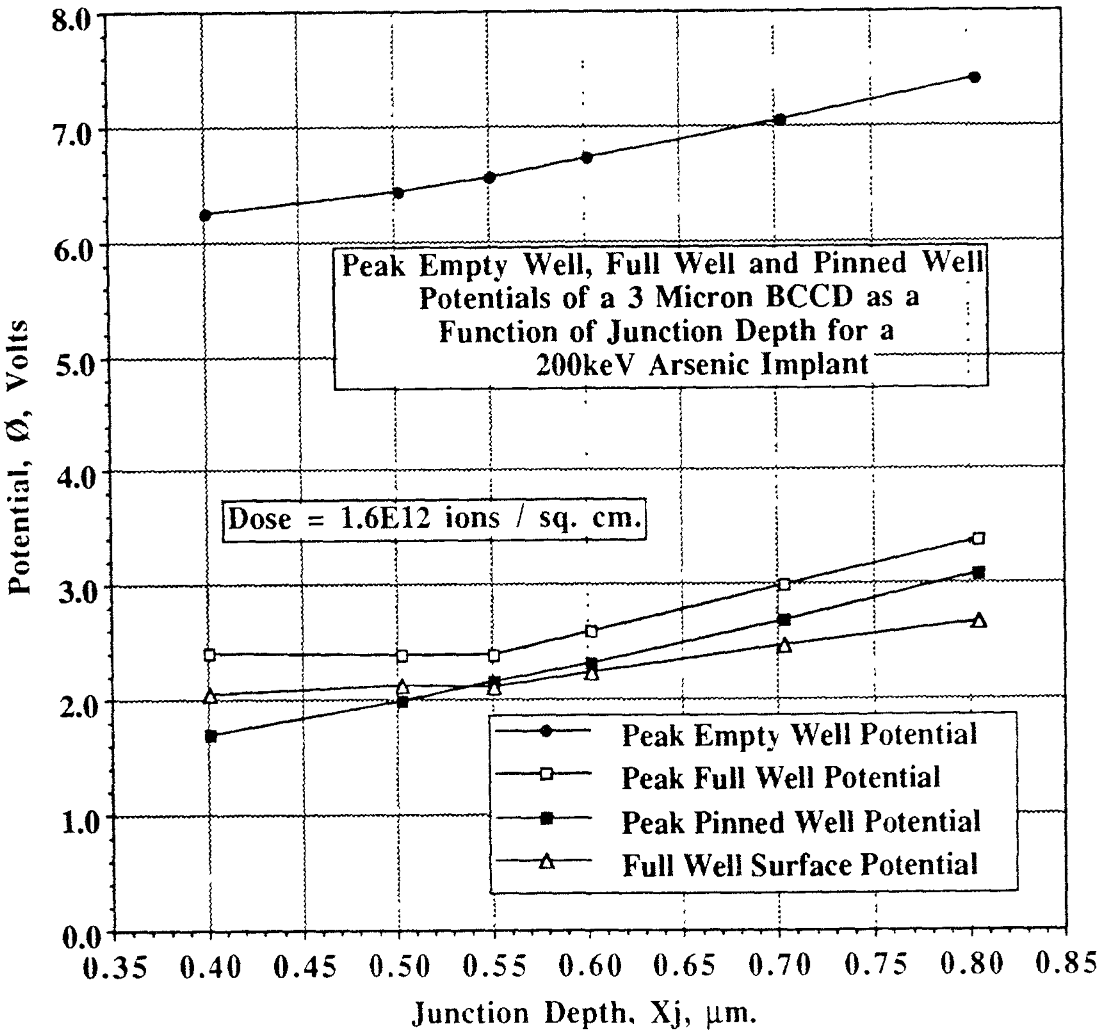

Figure 5.12 Full well surface potential and peak empty, full and pinned well potentials as a function of junction depth for a 200keV arsenic implant of 1.6E12 ions/cm^2.

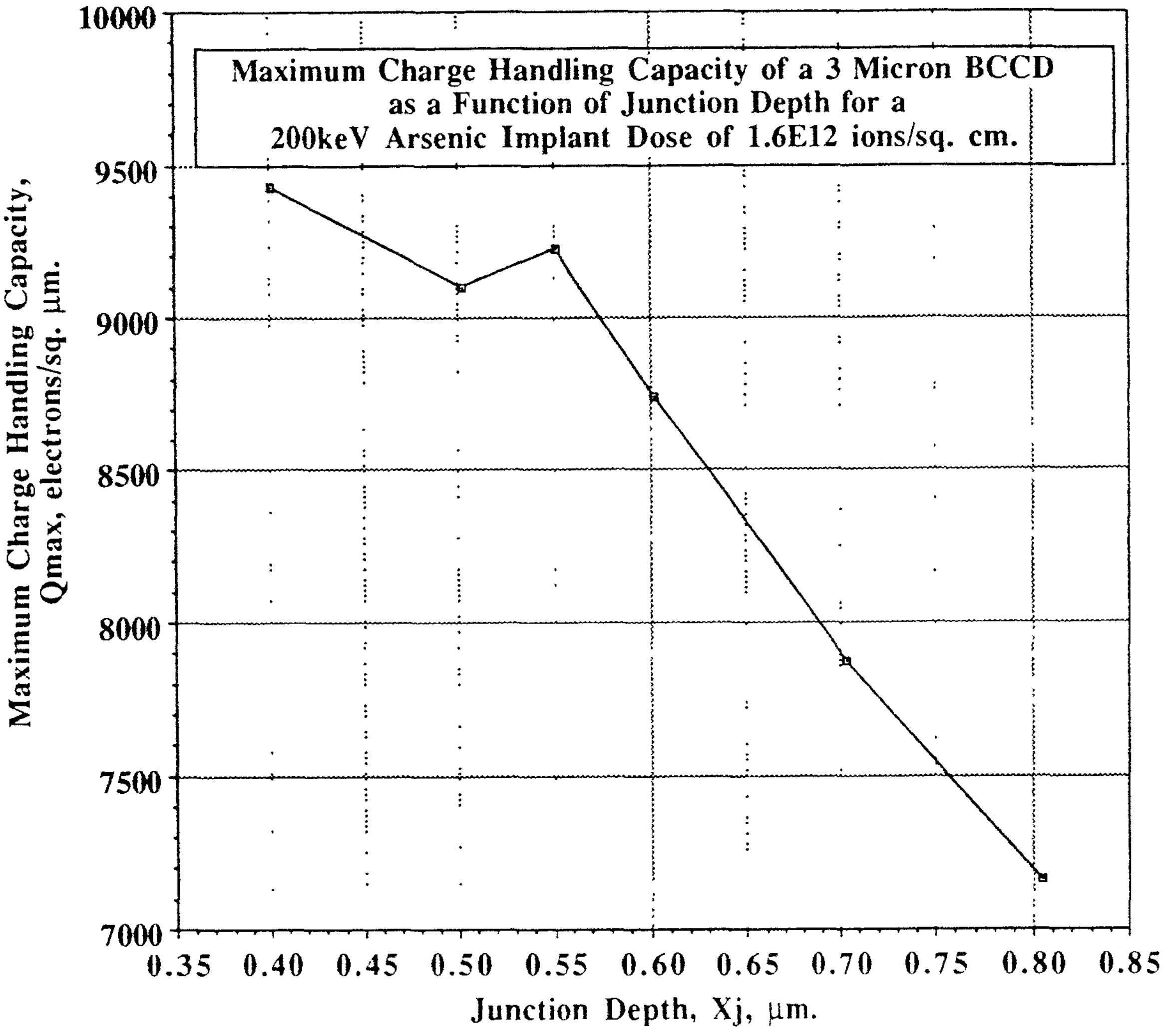

Figure 5.13 Maximum charge handling capacity as a function of junction depth for a 200keV arsenic implant of 1.6E12 ions/cm^2.

Table 5.9 Device Potentials as a Function of Junction Depth for a 200keV Arsenic Implant Dose = 1.6E12 ions /cm^2

Junction Depth (μm)	Maximum Empty Well Potential (Volts)	Maximum Full Well Potential (Volts)	Maximum Pinned Well Potential (Volts)
0.40	6.250	2.397	1.694
0.50	6.421	2.292	1.981
0.55	6.557	2.389	2.151
0.60	6.715	2.587	2.316
0.70	7.043	2.986	2.686
0.80	7.397	3.378	3.076

and maximum electric fields in the pinned condition are reported in Table 5.10. It is significant to note though at a junction depth of 0.55μm the charge handling capacity is 9225 electrons/μm^2 at a maximum electric field in the pinned condition of 1.93E5 V/cm.

Table 5.10 Maximum Charge Handling Capacity and Electric Fields as a Function of Junction Depth For a 200keV Arsenic Implant Dose = 1.6E12 ions / cm^2

Junction Depth (μm)	Maximum Charge Handling Capacity (electrons / μm^2)	Maximum Electric Field in:		
		Silicon (V/cm)	Silicon Nitride (V/cm)	Silicon Dioxide (V/cm)
0.40	9426	1.99E5	3.48E5	6.70E5
0.50	9098	1.94E5	3.42E5	6.58E5
0.55	9225	1.93E5	3.42E5	6.57E5
0.60	8738	1.92E5	3.42E5	6.57E5
0.70	7871	1.91E5	3.41E5	6.56E5
0.80	7160	1.90E5	3.41E5	6.55E5

5.5 A Comparison of Charge Handling Capacity versus Implant Energy

It is interesting to look at the charge handling capacity for each of the cases presented in Section 5.5 with respect to each other. Figure 5.14 presents charge handling capacity versus junction depth as a function of implant energy. In this figure it becomes clear that the maximum charge handling capacity for this process is dominated by the effect of the difference between peak empty well and peak full well potentials, $\Delta\Phi_m$ as given by Fig. 2.4b , except in the case of the 0.40μm junction. At this point one might be led to beleive that for most of the cases the tradeoff between the ratio of depletion capacitance to gate capacitance and $\Delta\Phi_m$ reaches what might be referred to as a happy medium and the charge handling capacity is maximized at a junction depth of 0.55μm Although from this Fig. it is not clear why the 200keV implant at a junction depth of 0.40μm exhibits a maximum in charge handling capacity while for the other cases the maximum occurs at 0.55μm. To gain better insight into this apparent outlier in charge handling capacity, ones attention must be drawn to Fig. 5.15. Figure 5.15 is a plot of charge handling capacity versus implant energy as a function of junction depth. While in the cases of 100, 150 and 175keV implants the charge handling capacity at a given junction depth remains relatively constant, the 200keV case indicates a clear upward trend as a function of decreasing junction depth. This would lead one to believe that the effect of the ratio of depletion capacitance to gate capacitance, C_σ / C_G is a strong function of implanted range and on further inspection of equations [3] and [4], it is clear that this ratio increases with projected range. At this point it becomes clear that this effect dominates for the case of the 200keV implant at a junction depth of 0.40μm.

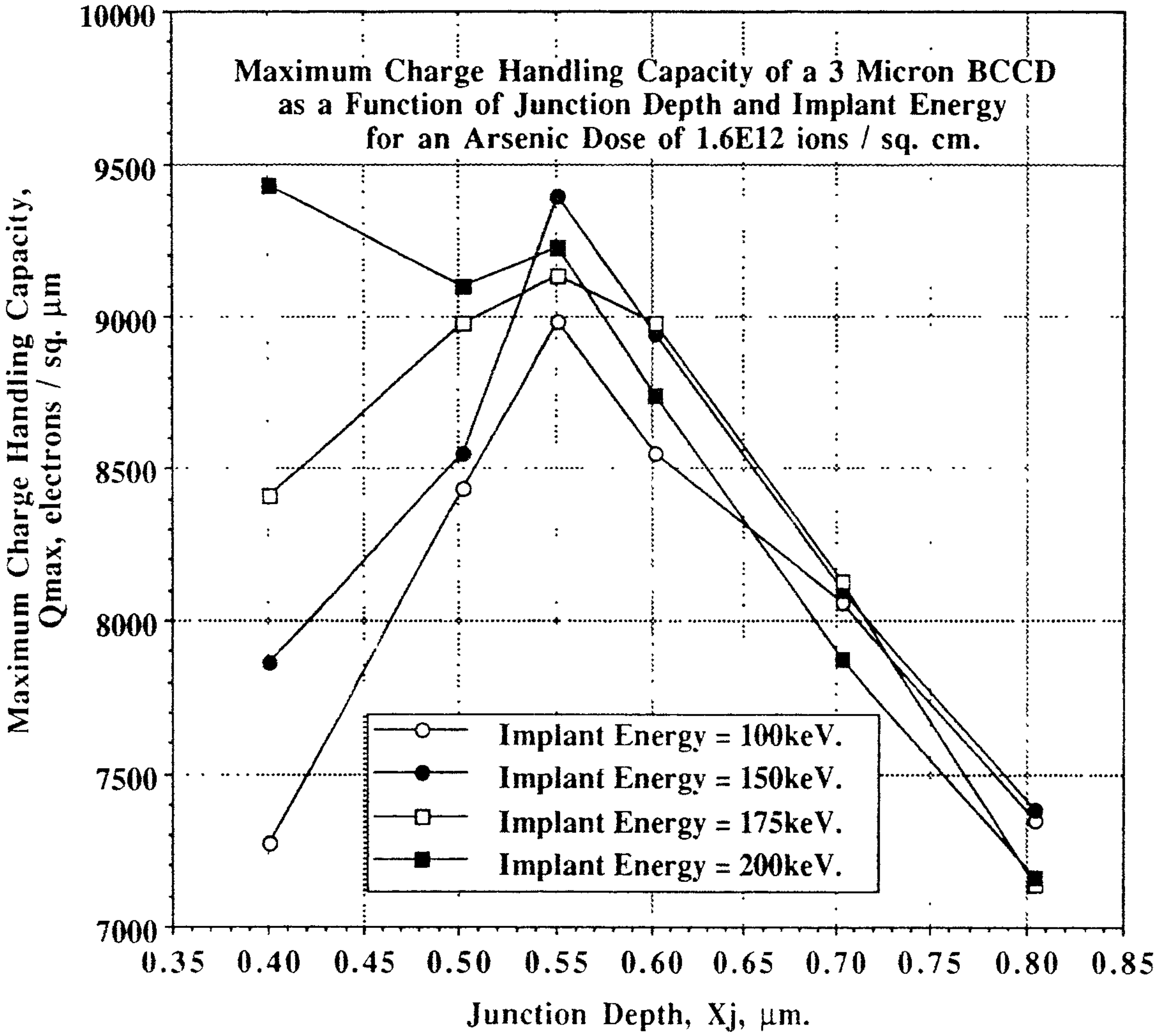

Figure 5.14 Maximum charge handling capacity versus junction depth as a function of implant energy.

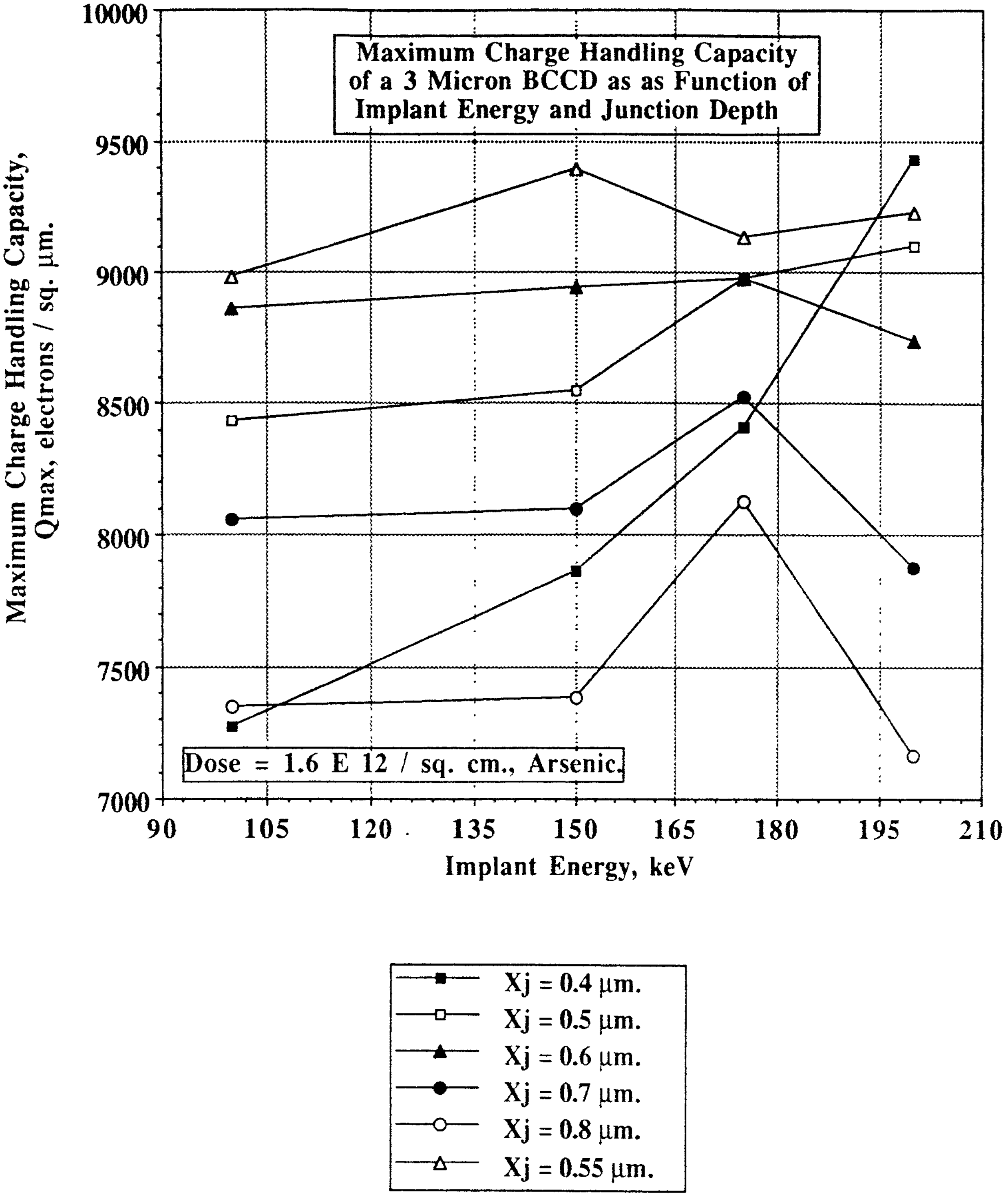

Figure 5.15 Maximum charge handling capacity versus implant energy as a function of junction depth.

Chapter 6

CONCLUSIONS and FUTURE WORK

6.1 Conclusions

Making use of SUPREM III and PISCES IIB a study into the effects of implant energy and junction depth on the charge handling capacity of a 3µm BCCD were conducted. The results of the study indicate that charge handling capacities as high as 9426 electrons/µm^2 could be achieved with a 200keV arsenic implant, a dose of 1.6E12 ions/cm^2 and a junction depth of 0.40µm. Peak potentials in the empty well condition were 6.25 volts and the pinning condition was achieved with an applied gate voltage of -5.2 volts. This resulted in maximum electric fields in the silicon region of 1.93E5 V/cm, which were less than the critical field strengths for silicon reported in Shur [13].

This study was performed using relatively a high temperature (1100°C) drive-in and anneal cycle in order to make resonable comparisons on the effects of differnt implant energies and junction depths. This could result in damage to the silicon, therefore lower temperature heat cycles should be used when the devices are actually fabricated. In order to achieve the same junction depth at 1000°C it is necessary to drive-in the implant for 4 times as long as at 1100°C.

Additionally, the results of this work should be made use of in a full two dimensional simulation using SUPREM IV, in order to better understand the effects of lateral diffusion and to study the effects of fringing fields on the charge transfer efficiency. This may be accomplished by exporting the results obtained from SUPREM IV to PISCES IIB and running a transient simulation.

Finally, it should be noted that the results of this thesis are in good agreement with the theory presented by Chatterjee and Taylor [10].

6.2 Future Work

The information contained in this thesis is at best a preliminary study of the effects of implant energy and junction depth on a 3μm BCCD. Possible direction for future work includes, studying the effects of double implants on the charge handling capacity and fringing fields in BCCD's. This technique would make use of a high energy arsenic implant and a lower energy phosphorus implant.

A more detailed study of the effects of lateral diffusion on the ability of channel stops to confine signal to the channel region in narrow channel BCCD's is also required.

Finally, the effects of a low energy boron implant at the Si / SiO_2 interface should be studied to determine its effect on device potentials and charge handling capacity and as a possible means of reducing the power consumption of the BCCD when operated at high clock rates.

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Appendix A

SUPREM III Process Simulation Input Decks

Process Simulation used to Obtain 0.40µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
TITLE      High-Frame-Rate-CCD Process Simualtion
INITIALIZE <100> Silicon Boron Concentraction=3.0e14
+          Thickness=3 0 DX=0.001 XDX=0 001 Spaces=400
DIFFUSION  Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT    Arsenic Energy=100 Dose=1 6e12
DIFFUSION  Temperature=1100 Time=14  Nitrogen
DIFFUSION  Temperature=1100 Time=99 T Rate=-3 Nitrogen
ETCH       Oxide All
DIFFUSION  Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION  Temperature=900 Time=18 WetO2 HCL%=2 0
DEPOSIT    Nitride Temp=560 Thickness=0 05 spaces=5
DIFFUSION  Temperature=900 Time=10 Nitrogen
DIFFUSION  Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION  Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION  Temperature=950 Time=5 Nitrogen
DIFFUSION  Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION  Temperature=950 Time=10 Nitrogen
DIFFUSION  Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION  Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION  Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION  Temperature=900 Time=10 Nitrogen
DIFFUSION  Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION  Temperature=950 Time=15 Nitrogen
DIFFUSION  Time=15 Temp=950 Gas.Conc=3 1585e20 Phosphorus
DIFFUSION  Temperature=950 Time=10 Nitrogen
DIFFUSION  Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH       Polysilicon All
DIFFUSION  Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION  Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH      Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 T.me=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=60 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.50µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
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INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=100 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=40  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.55µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
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INITIALIZE  <100> Silicon Boron Concentraction=3 0e14
+           Thickness=3 0 DX=0 001 XDX=0 001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2 0
IMPLANT     Arsenic Energy=100 Dose=1 6e12
DIFFUSION   Temperature=1100 Time=55  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2 0
DEPOSIT     Nitride Temp=560 Thickness=0 05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.60μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=100 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=72  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.70µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=100 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=112 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.80µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 100keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=100 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=161 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.40μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3 0e14
+           Thickness=3.0 DX=0 001 XDX=0 001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2 0
IMPLANT     Arsenic Energy=150 Dose=1 6e12
DIFFUSION   Temperature=1100 Time=7   Nitrogen
DIFFUSION   Temperature=1100 Time=99 T Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.50μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=150 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=31  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION  Temperature=900 Time=10 Nitrogen
DIFFUSION  Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT   Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION  Temperature=950 Time=15 Nitrogen
DIFFUSION  Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION  Temperature=950 Time=10 Nitrogen
DIFFUSION  Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH     Polysilicon All
DIFFUSION  Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION  Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION  Temperature=900 Time=10 Nitrogen
DIFFUSION  Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT   Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION  Temperature=950 Time=15 Nitrogen
DIFFUSION  Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION  Temperature=950 Time=10 Nitrogen
DIFFUSION  Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION  Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION  Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION  Temperature=900 Time=10 Nitrogen
DIFFUSION  Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION  Temperature=800 Time=15 Nitrogen
DIFFUSION  Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION  Temperature=800 Time=10 Nitrogen
DIFFUSION  Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION  Temperature=1000 Time=30 Nitrogen
DIFFUSION  Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION  Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION  Temperature=950 Time=15 Nitrogen
DIFFUSION  Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION  Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION  Temperature=950 Time=15 Nitrogen
DIFFUSION  Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.55µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=150 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=46  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.60μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=150 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=64  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH      Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.70µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentration=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=150 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=103 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.80μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 150keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=150 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=149 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.40μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION    Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT      Arsenic Energy=175 Dose=1.6e12
DIFFUSION    Temperature=1100 Time=3   Nitrogen
DIFFUSION    Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH         Oxide All
DIFFUSION    Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION    Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT      Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION    Temperature=900 Time=10 Nitrogen
DIFFUSION    Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT      Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION    Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION    Temperature=950 Time=5 Nitrogen
DIFFUSION    Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION    Temperature=950 Time=10 Nitrogen
DIFFUSION    Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION    Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION    Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION    Temperature=900 Time=10 Nitrogen
DIFFUSION    Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT      Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION    Temperature=950 Time=15 Nitrogen
DIFFUSION    Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION    Temperature=950 Time=10 Nitrogen
DIFFUSION    Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH         Polysilicon All
DIFFUSION    Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION    Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.50μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentration=3.0e14
+          Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=175 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=27  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.55μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=175 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=41  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH      Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.60µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=175 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=57  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.70μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+          Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=175 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=97  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.80μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 175keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=175 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=143 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.40μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=200 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=25 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
```

```
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.50μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=200 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=21  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.55μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=200 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=36  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH       Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.60μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE        High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentration=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=200 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=51  Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH       Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT    Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2 0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.70μm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3 0e14
+           Thickness=3 0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2 0
IMPLANT     Arsenic Energy=200 Dose=1 6e12
DIFFUSION   Temperature=1100 Time=89 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2 0
DEPOSIT     Nitride Temp=560 Thickness=0 05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0 6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3 1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2 0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
```

Process Simulation used to Obtain 0.80µm Junction Depth for an Arsenic Implant, Dose = 1.6E12 ions/cm^2 at 200keV, with 4 Levels of Polysilicon

```
TITLE       High-Frame-Rate-CCD Process Simualtion
INITIALIZE  <100> Silicon Boron Concentraction=3.0e14
+           Thickness=3.0 DX=0.001 XDX=0.001 Spaces=400
DIFFUSION   Temperature=800 Time=38 WetO2 HCL%=2.0
IMPLANT     Arsenic Energy=200 Dose=1.6e12
DIFFUSION   Temperature=1100 Time=135 Nitrogen
DIFFUSION   Temperature=1100 Time=99 T.Rate=-3 Nitrogen
ETCH        Oxide All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=18 WetO2 HCL%=2.0
DEPOSIT     Nitride Temp=560 Thickness=0.05 spaces=5
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=5 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
```

```
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
ETCH        Polysilicon All
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=31 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DEPOSIT     Polysilicon Temperature=560 Thickness=0.6 Spaces=5
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Time=15 Temp=950 Gas.Conc=3.1585e20 Phosphorus
DIFFUSION   Temperature=950 Time=10 Nitrogen
DIFFUSION   Temperature=950 Time=30 T.Rate=-5 Nitrogen
DIFFUSION   Temperature=800 Time=20 T.Rate=5 Nitrogen
DIFFUSION   Temperature=900 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=900 Time=10 Nitrogen
DIFFUSION   Temperature=900 Time=33 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=15 Nitrogen
DIFFUSION   Temperature=800 Time=10 WetO2 HCL%=2.0
DIFFUSION   Temperature=800 Time=10 Nitrogen
DIFFUSION   Temperature=800 Time=40 T.Rate=5 Nitrogen
DIFFUSION   Temperature=1000 Time=30 Nitrogen
DIFFUSION   Temperature=1000 Time=66 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
DIFFUSION   Temperature=950 Time=50 T.Rate=-3 Nitrogen
DIFFUSION   Temperature=800 Time=30 T.Rate=5 Nitrogen
DIFFUSION   Temperature=950 Time=15 Nitrogen
```

Appendix B

PISCES IIB Device Simulation Input Decks

PISCES IIB Input Deck used to Import SUPREM III Output File

```
MESH RECTANGULAR NX=60 NY=50 DIAG FLI OUTF=DOSE/D3 9/MESH.3.9
X.M     N=1      LOCATION= 0 0000    RATIO=1.00
X.M     N=60     LOCATION= 5 0000    RATIO=1.00
Y.M     N=1      LOCATION=-0.0895    RATIO=1.00
Y M     N=2      LOCATION=-0.0405    RATIO=1 00
Y M     N=6      LOCATION=-0.0395    RATIO=1.00
Y M     N=7      LOCATION=-0 0010    RATIO=0.50
Y M     N=11     LOCATION= 0 0000    RATIO=0 50
Y M     N=23     LOCATION= 0 3250    RATIO=1 00
Y M     N=37     LOCATION= 0 6500    RATIO=1.00
Y.M     N=42     LOCATION= 1 5000    RATIO=1.00
Y.M     N=50     LOCATION= 8 0000    RATIO=1.25
REGION  NUM=1   IX LOW=1   IX HIGH=60   IY LOW=1    IY HIGH=4    NITRIDE
REGION  NUM=2   IX LOW=1   IX HIGH=60   IY LOW=4    IY HIGH=10   OXIDE
REGION  NUM=3   IX LOW=1   IX HIGH=60   IY LOW=10   IY HIGH=50   SILICON
ELEC   NUM=1   IX LOW=1   IX.HIGH=60   IY.LOW=1   IY HIGH=1
ELEC   NUM=2   IX LOW=1   IX HIGH=60   IY LOW=50  IY HIGH=50
DOPING  SUPREM3  X LOW=0 00  X RATIO=5 00  START=0 000
+  INFILE=DOSE/D3 9/3.9  BORON
DOPING  SUPREM3  X.LOW=0 00  X.RATIO=1 75  START=0 000
+  INFILE=DOSE/D3 9/3 9  ARSENIC  RATIO LATERAL=0 6
DOPING  SUPREM3  X LOW=3 25  X RATIO=5 00  START=0 000
+  INFILE=DOSE/D3 9/3 9  ARSENIC  RATIO LATERAL=0 6
CONTACT NUM=1 N POLY
SYMB CARRIERS=0
INTERFACE  QF=1 0E10  S N=1 0E4  S P=1 0e4
MODELS TEMP=300
SOLVE INIT  N BIAS=0 0  P BIAS=0 0  OUTF=DOSE/D3 9/3 9 OUT
END
```

PISCES IIB Input Deck used to Depelte the Structure of Free Electrons

```
TITLE DEPLETE STRUCTURE
MESH INFILE=DOSE/D3.9/MESH 3.9
CONTACT NUM=1 N.POLY
SYMB CARRIERS=0
METHOD ITLIMIT=60
INTERFACE  QF=1E10  S N=1 0E4  S.P=1 0e4
MODELS TEMP=300
LOAD INFILE=dOSE/D3 9/3 9.OUT
SOLVE  V1=0.0  V2=0.0   N.BIAS=1 0   P.BIAS=0  PREVIOUS  OUTF=DOSE/D3.9/QF 1
SOLVE  V1=0.0  V2=0 0   N.BIAS=2 0   P.BIAS=0  PREVIOUS  OUTF=DOSE/D3.9/QF 2
SOLVE  V1=0 0  V2=0 0   N BIAS=3.0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 3
SOLVE  V1=0 0  V2=0 0   N.BIAS=4 0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 4
SOLVE  V1=0 0  V2=0 0   N BIAS=5 0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 5
SOLVE  V1=0 0  V2=0 0   N BIAS=6 0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 6
SOLVE  V1=0 0  V2=0 0   N BIAS=7.0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 7
SOLVE  V1=0 0  V2=0 0   N BIAS=8 0   P.BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 8
SOLVE  V1=0 0  V2=0 0   N BIAS=9 0   P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF.9
SOLVE  V1=0 0  V2=0 0   N BIAS=10 0  P BIAS=0  PREVIOUS  OUTF=DOSE/D3 9/QF 10
END
```

PISCES IIB Input Deck used to Determine the Pinning Voltage

```
TITLE FIND PINNING VOLTAGE
MESH INFILE=DOSE/D3.9/MESH.3.9
CONTACT NUM=1 N.POLY
SYMB CARRIERS=0
METHOD ITLIMIT=100
INTERFACE QF=1.0E10 S.N=1.0E4 S.P=1.0E4
MODELS TEMP=300
LOAD INFILE=DOSE/D3.9/QF.10
SOLVE  V1=-1.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.1
SOLVE  V1=-2.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.2
SOLVE  V1=-3.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.3
SOLVE  V1=-4.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.4
SOLVE  V1=-5.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.5
SOLVE  V1=-6.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.6
SOLVE  V1=-7.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.7
SOLVE  V1=-8.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.8
SOLVE  V1=-9.0  V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.9
SOLVE  V1=-10.0 V2=0.00 N.BIAS=10.0 P.BIAS=0.0 PREVIOUS OUTF=DOSE/D3.9/PIN.10
END
```

PISCES IIB Input Deck used to Extract Integrated Electron Concentrations, Solutions and Electric Field Quantities

```
TITLE EXTRACT
MESH INFILE=DOSE/D3.9/MESH.3 9
CONTACT NUM=1 N.POLY
INTERFACE QF=1 0E10 S N=1.0E4 S.P=1.0E4
MODELS TEMP=300
LOAD INFILE=DOSE/D3 9/PIN 5.2
LOAD INFILE=DOSE/D3 9/QF 3
LOAD INFILE=DOSE/D3 9/QF.9
EXTRACT ELECTRONS  X MIN=0 25 X.MAX=4 75 Y MIN=0.00 Y MAX=8 0
PRINT QUE  X.MIN=0 25 X MAX=4.75 Y.MIN=0 000 Y.MAX=0 000
PRINT POINTS  X MIN=4 74 X MAX=4 75 Y MIN=0 00 Y.MAX=8.00
PRINT SOLUTION  X MIN=4 74 X MAX=4 75 Y MIN=0 00 Y MAX=8 00
END
```

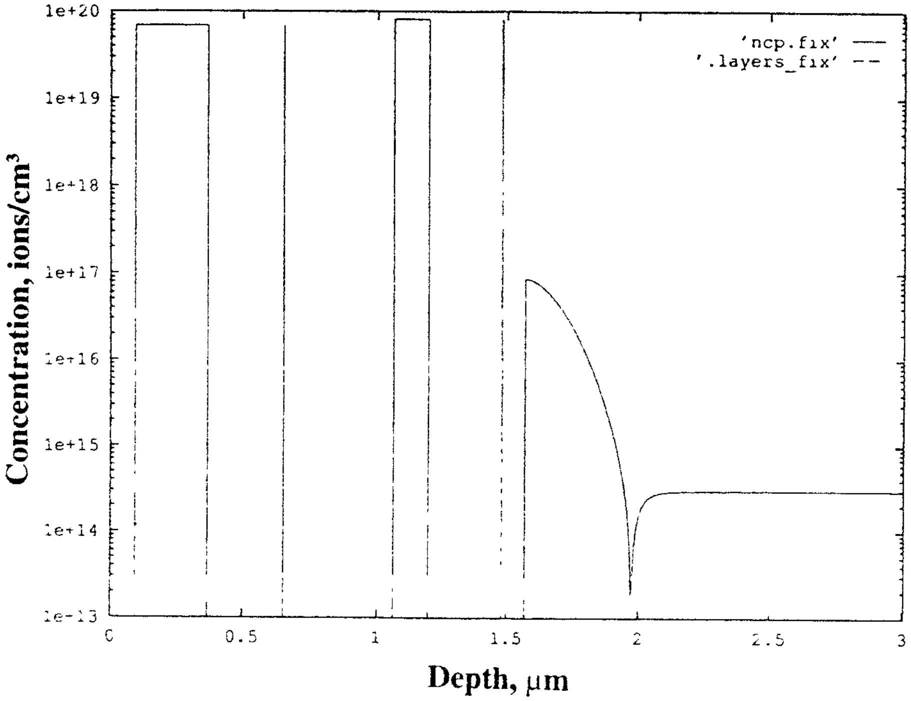
PISCES IIB Input Deck used to Plot Various Quantities

```
TITLE PLOT QUANTITIES
OPT PLOTDEV=SAVE
MESH INFILE=DOSE/D3.9/MESH.3.9
CONTACT NUM=1 N.POLY
INTERFACE QF=1E10 S.N=1.0E4 S.P=1.0e4
MODELS TEMP=300
LOAD INFILE=DOSE/D3.9/3.9.OUT
LOAD INFILE=DOSE/D3.9/QF.5
LOAD INFILE=DOSE/D3.9/QF.2
PLOT.1D ABS LOG DOPING X.S=4.75 X.E=4.75 Y.S=0.00 Y.E=6.00 PAUSE
PLOT.1D ABS LOG DOPING X.S=0.00 X.E=4.75 Y.S=0.00 Y.E=0.00 PAUSE
PLOT.2D  JUNCTION DEPL.EDGE  L.DEPLE=3  X.MIN=0.00 X.MAX=4.75 Y.MIN=-0.0895
PLOT.2D GRID X.MIN=0.00 X.MAX=4.75 Y.MIN=0.00
+ NO.FILL  L.JUNCT=2 BOUNDARY
CONTOUR  POTEN   NC=20
LOAD INFILE=DOSE/D3.9/QF.9
PLOT.1D POTEN X.S=4.75 X.E=4.75 Y.S=0.00 Y.E=6.00
LOAD INFILE=DOSE/D3.9/QF.1.9
PLOT.1D POTEN X.S=4.75 X.E=4.75 Y.S=0.00 Y.E=6.00 UNCH
LOAD INFILE=DOSE/D3.9/PIN.5.2
PLOT.1D POTEN X.S=4.75 X.E=4.75 Y.S=0.00 Y.E=6.00 UNCH  PAUSE
LOAD INFILE=DOSE/D3.9/QF.9
PLOT.1D POTEN MIN=-0.5 MAX=5.0 X.S=0.25 X.E=4.75 Y.S=0.00 Y.E=0.00
LOAD INFILE=DOSE/D3.9/QF.1.9
PLOT.1D POTEN X.S=0.25 X.E=4.75 Y.S=0.00 Y.E=0.00 UNCH
LOAD INFILE=DOSE/D3.9/PIN.5.2
PLOT.1D POTEN X.S=0.25 X.E=4.75 Y.S=0.00 Y.E=0.00 UNCH
END
```

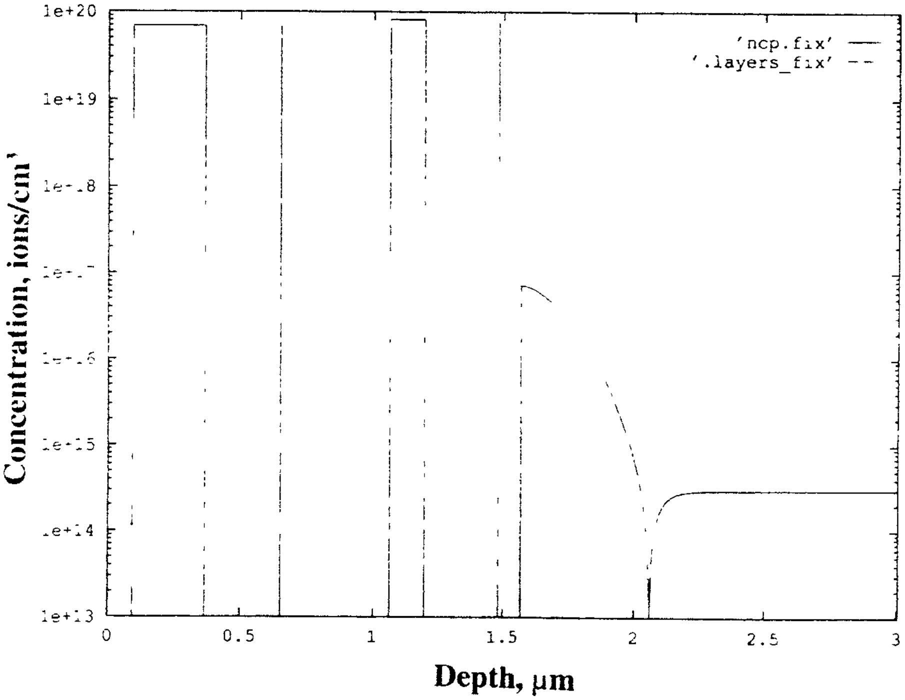
Appendix C

SUPREM III Doping Profiles

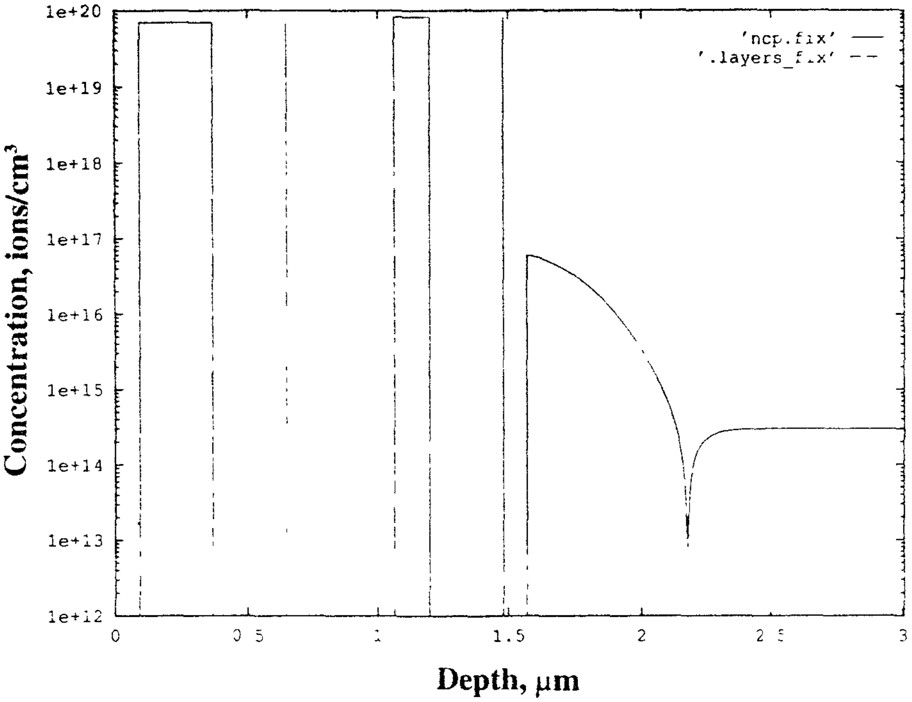
SUPREM III Doping Profile for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



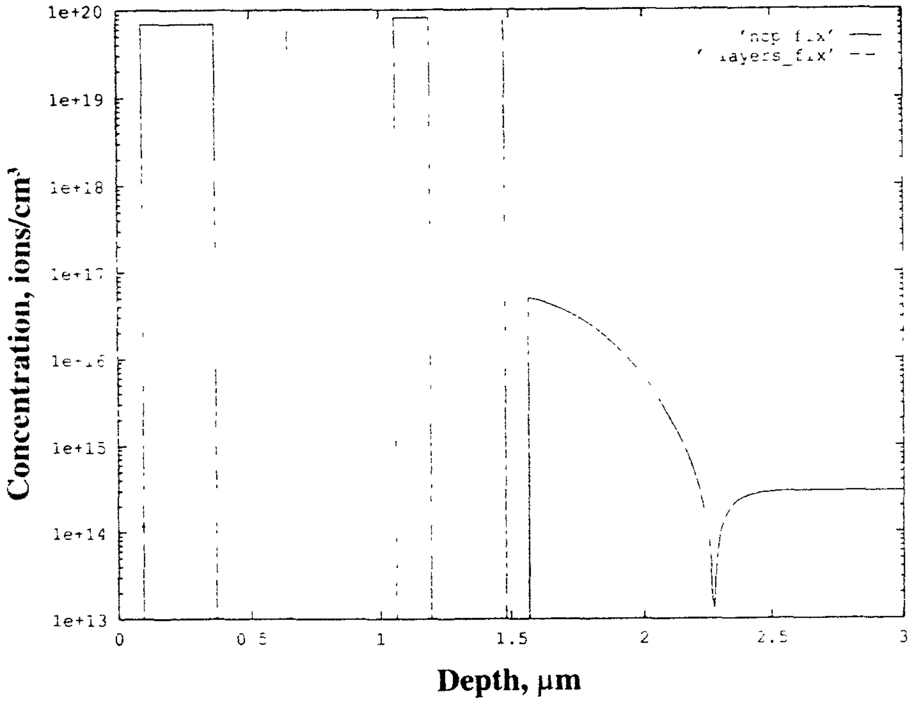
SUPREM III Doping Profile for a Junction Depth of 0.50μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



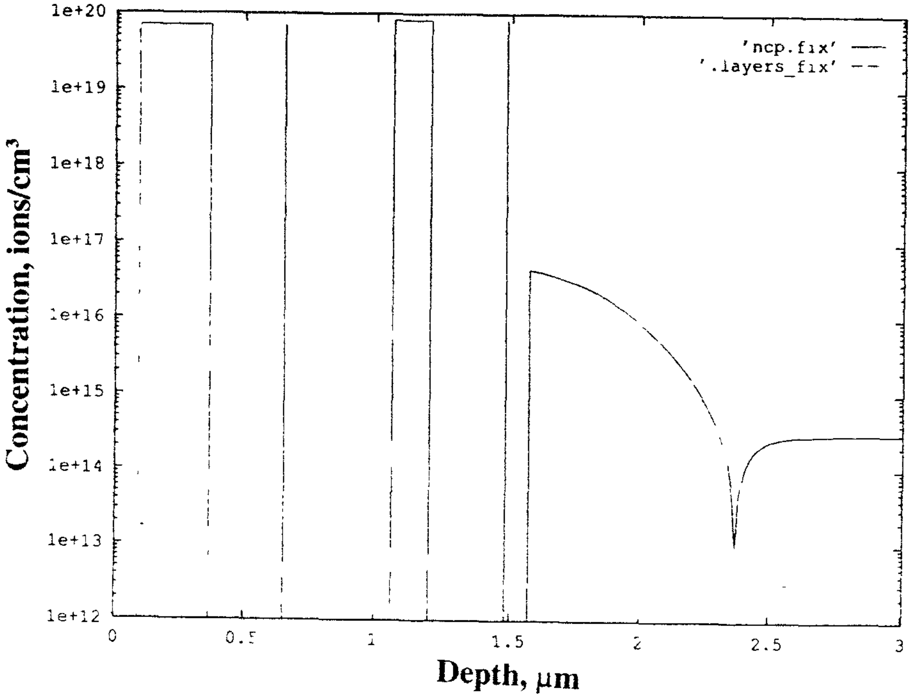
SUPREM III Doping Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



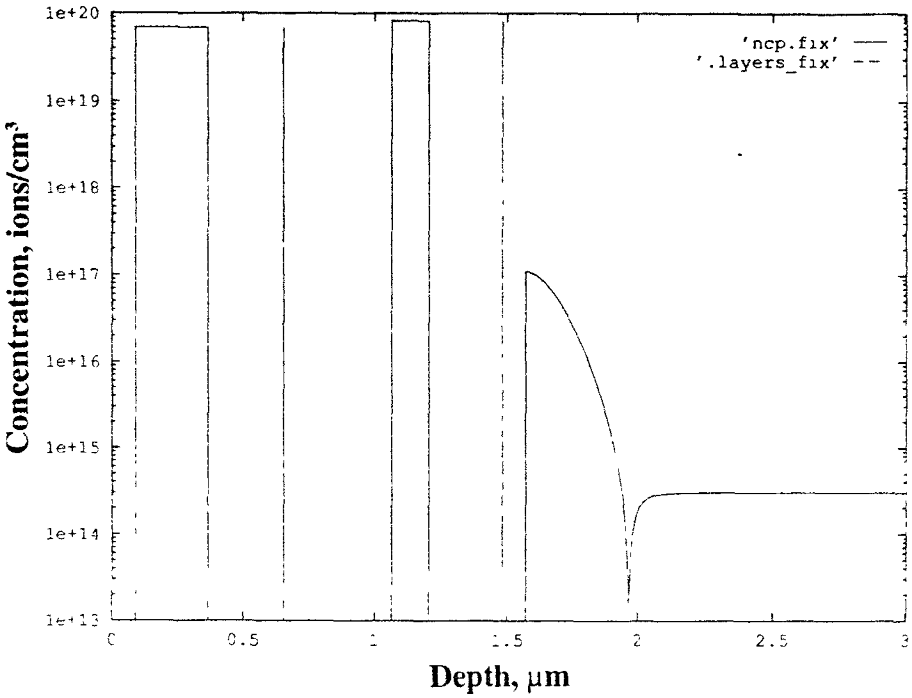
SUPREM III Doping Profile for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



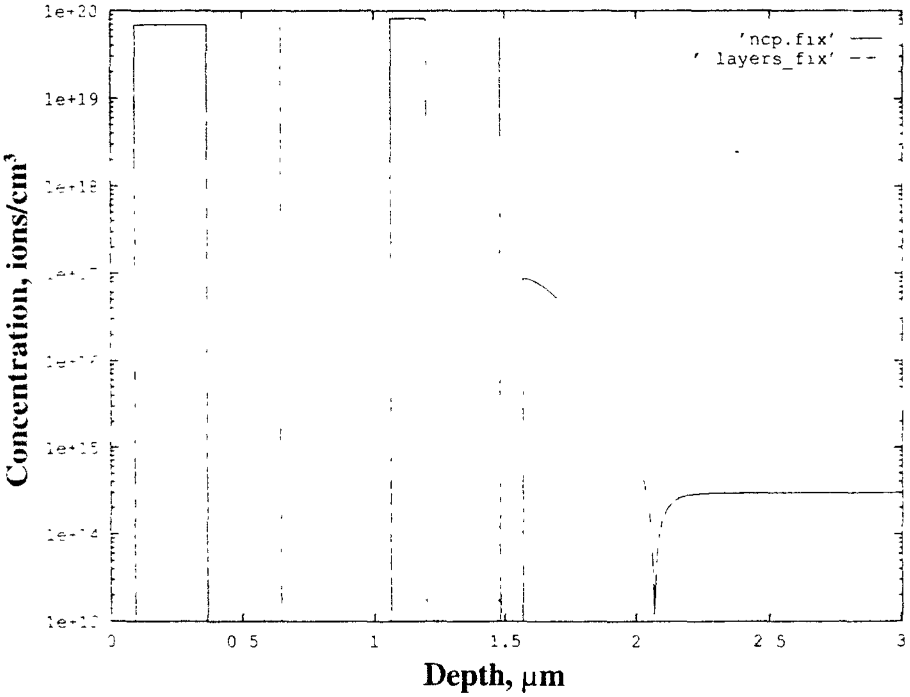
SUPREM III Doping Profile for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



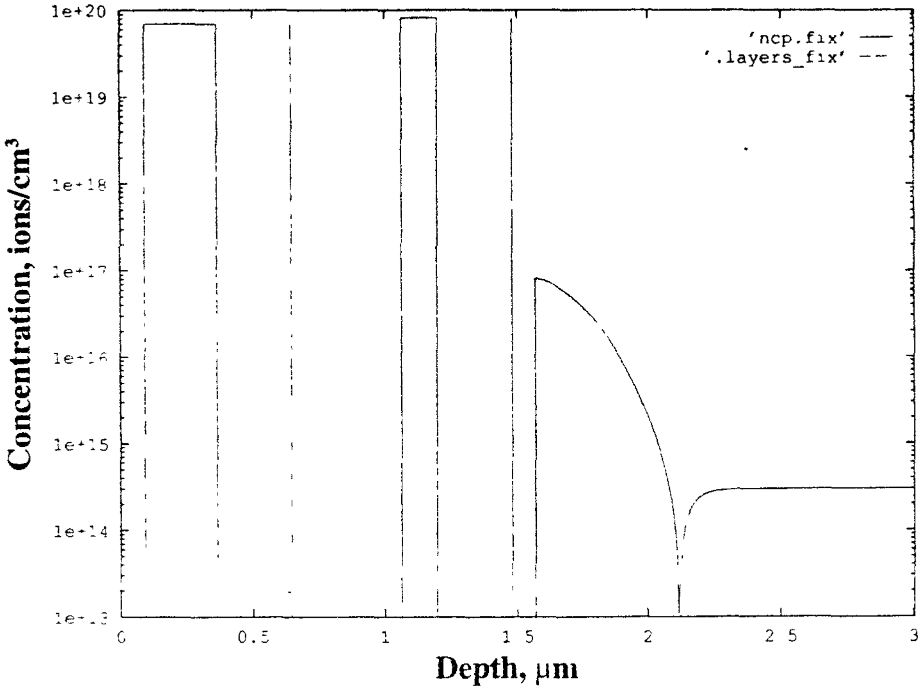
SUPREM III Doping Profile for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



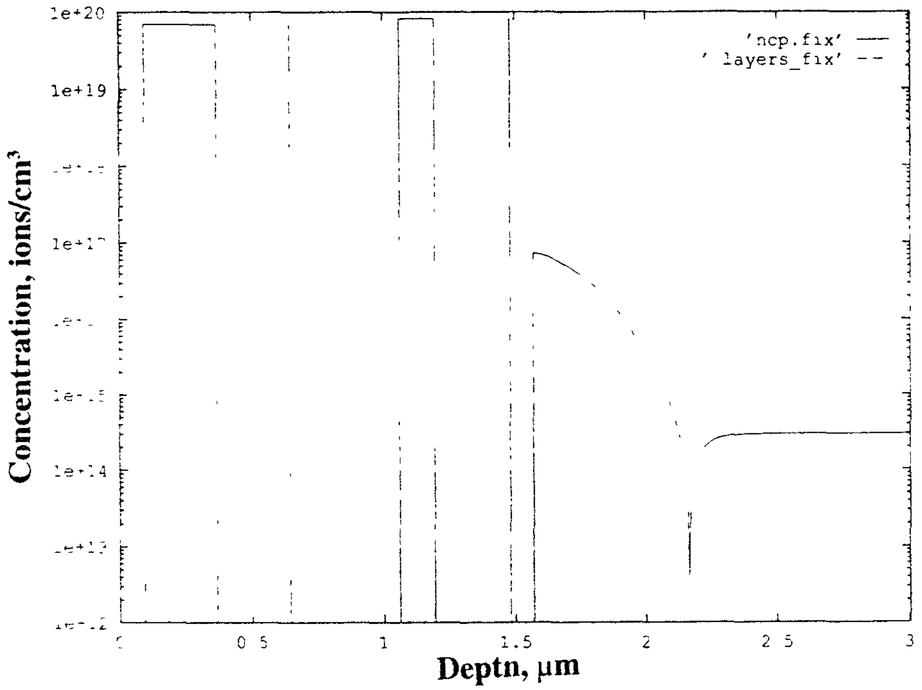
SUPREM III Doping Profile for a Junction Depth of 0.50μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



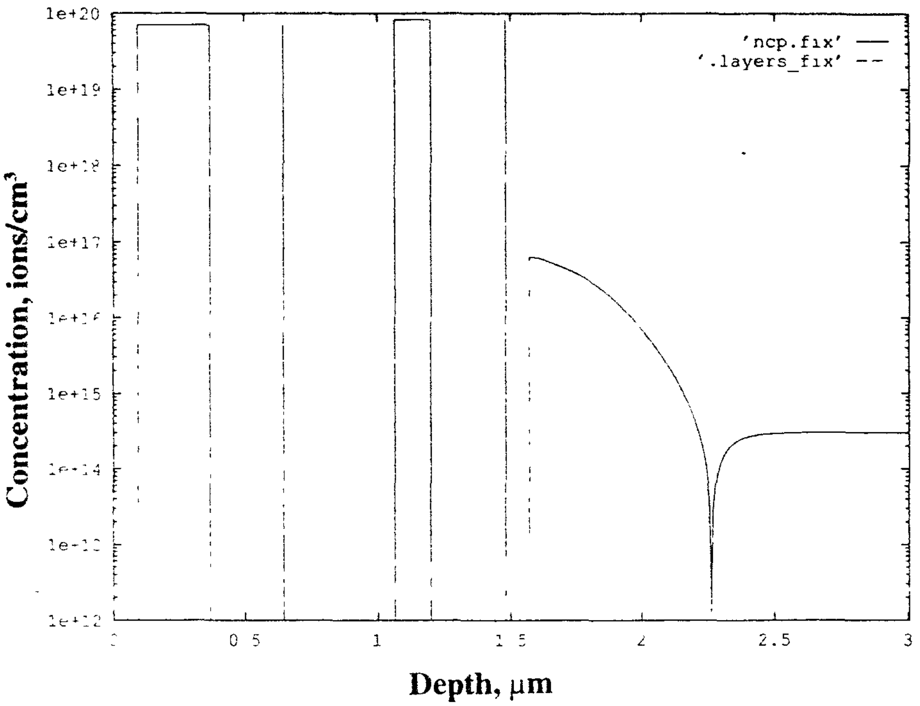
SUPREM III Doping Profile for a Junction Depth of 0.55μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



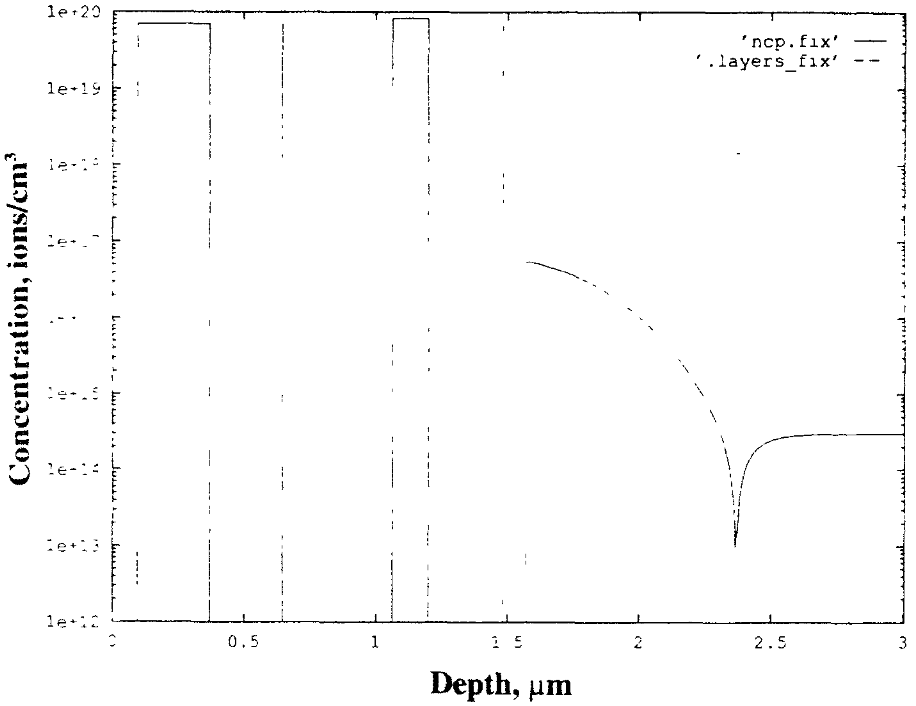
SUPREM III Doping Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



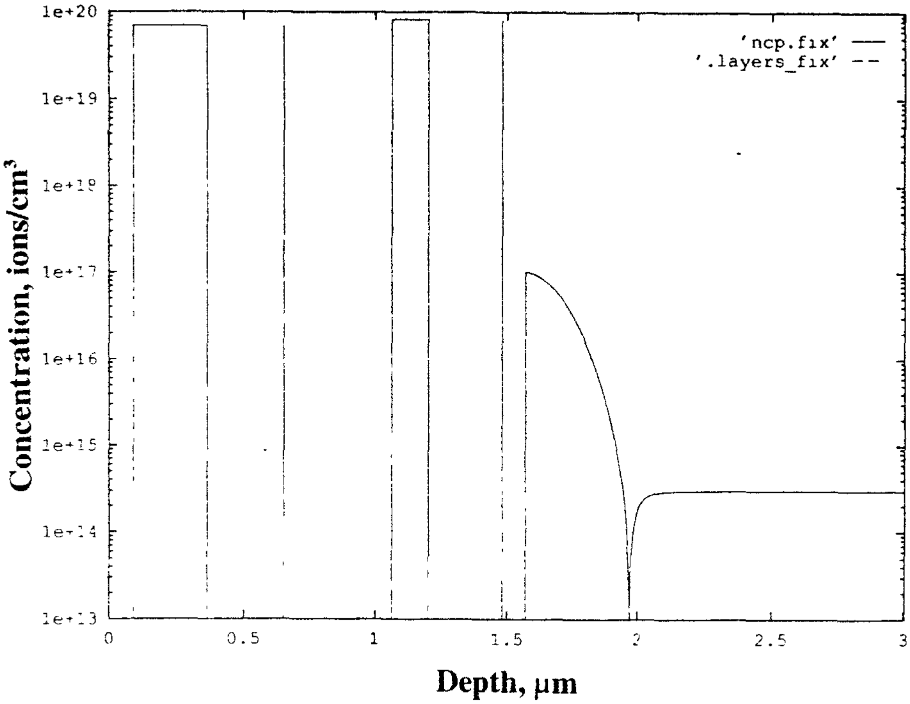
SUPREM III Doping Profile for a Junction Depth of 0.70µm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



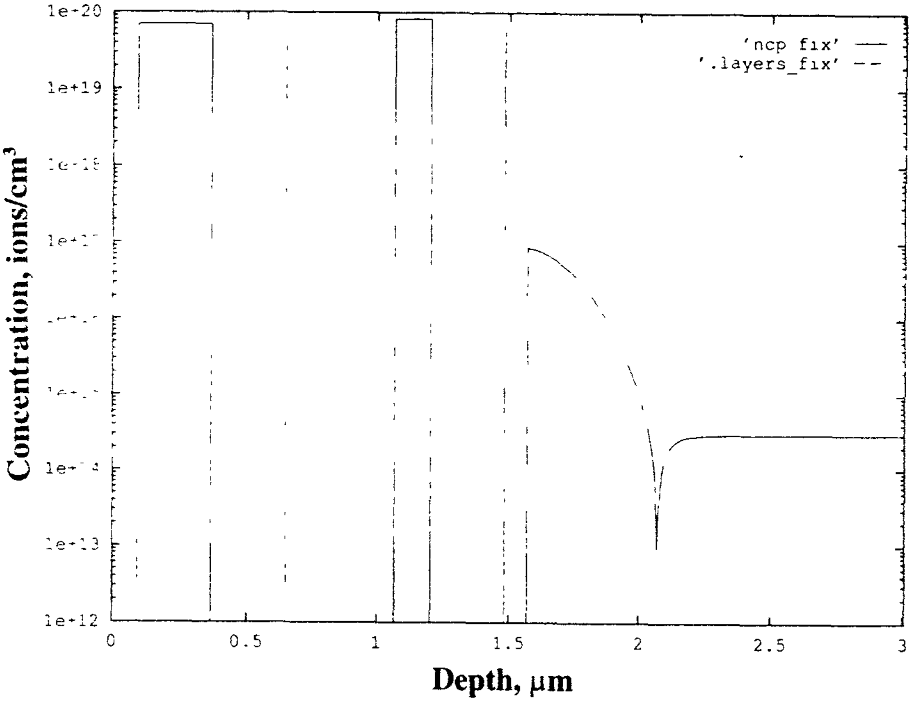
SUPREM III Doping Profile for a Junction Depth of 0.80µm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



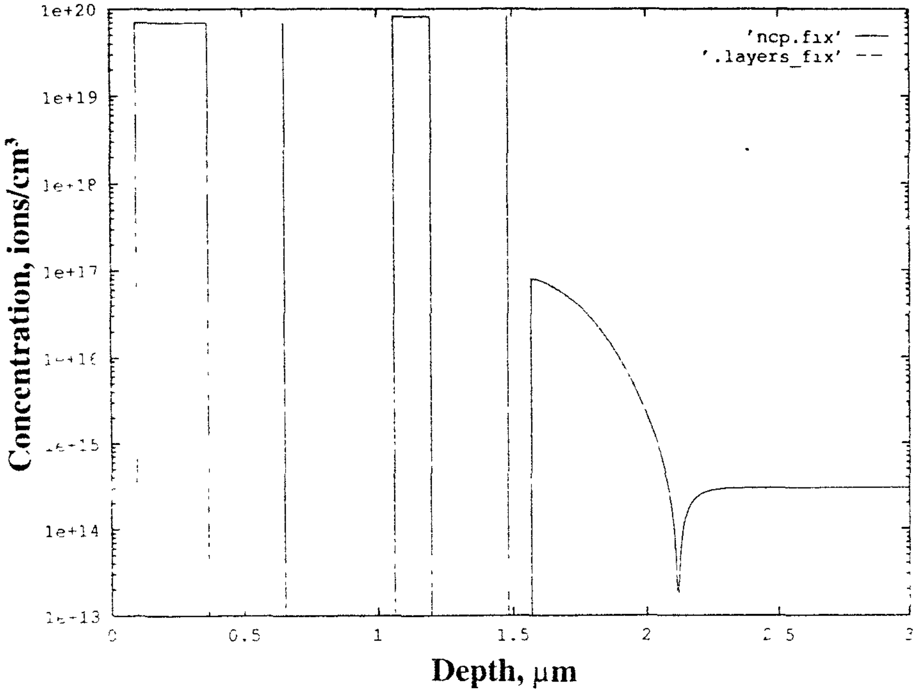
SUPREM III Doping Profile for a Junction Depth of 0.40μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



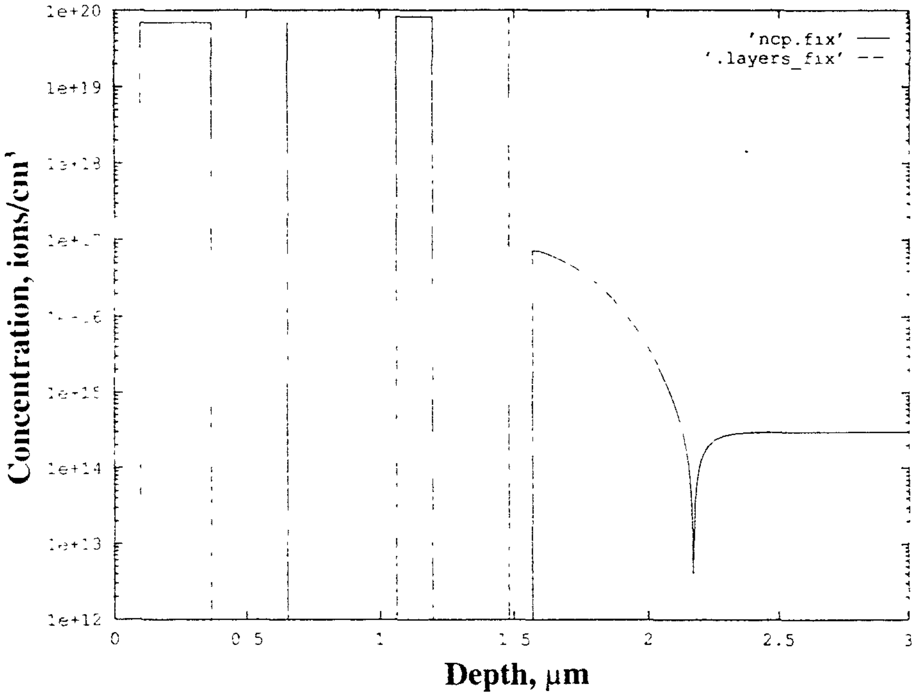
SUPREM III Doping Profile for a Junction Depth of 0.50μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



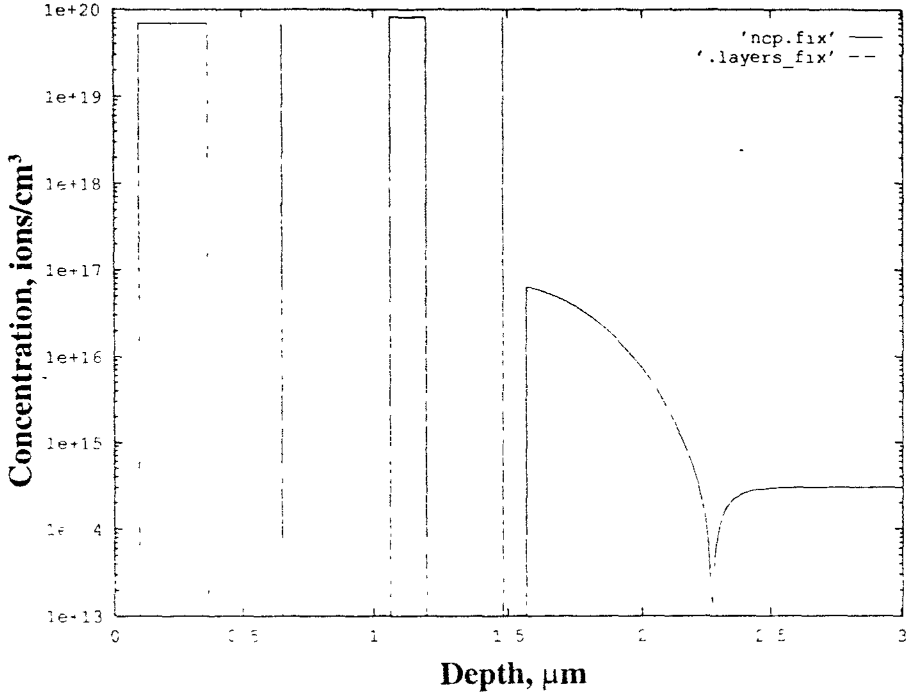
SUPREM III Doping Profile for a Junction Depth of 0.55µm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



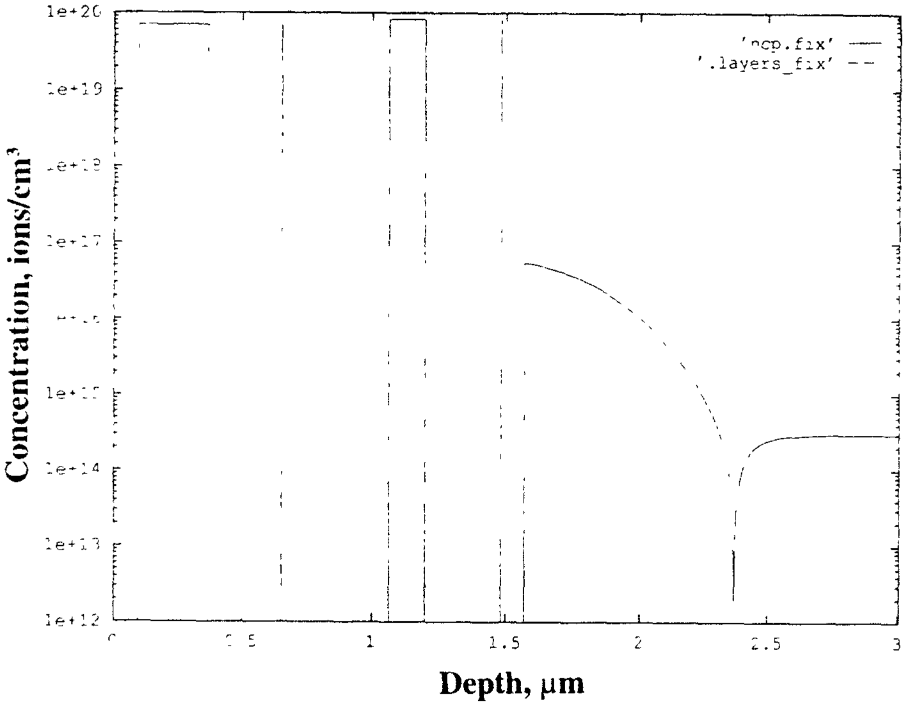
SUPREM III Doping Profile for a Junction Depth of 0.60µm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



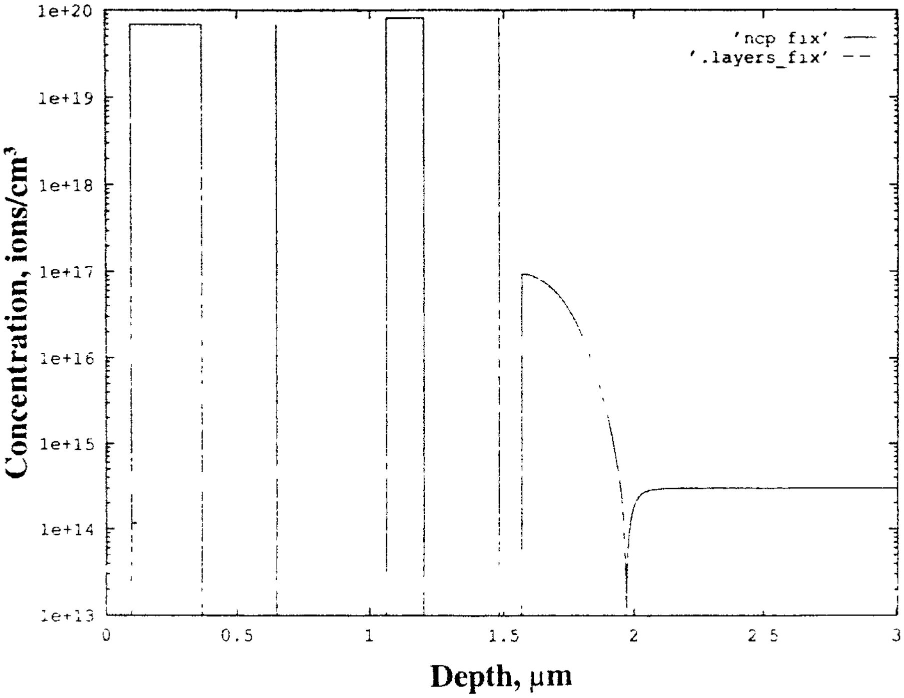
SUPREM III Doping Profile for a Junction Depth of 0.70μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



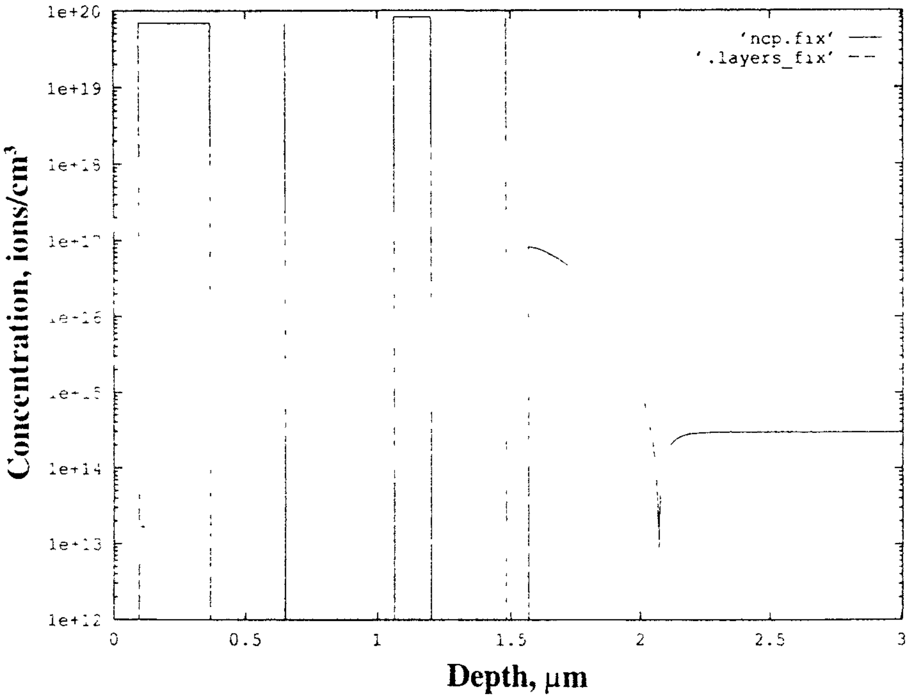
SUPREM III Doping Profile for a Junction Depth of 0.80μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



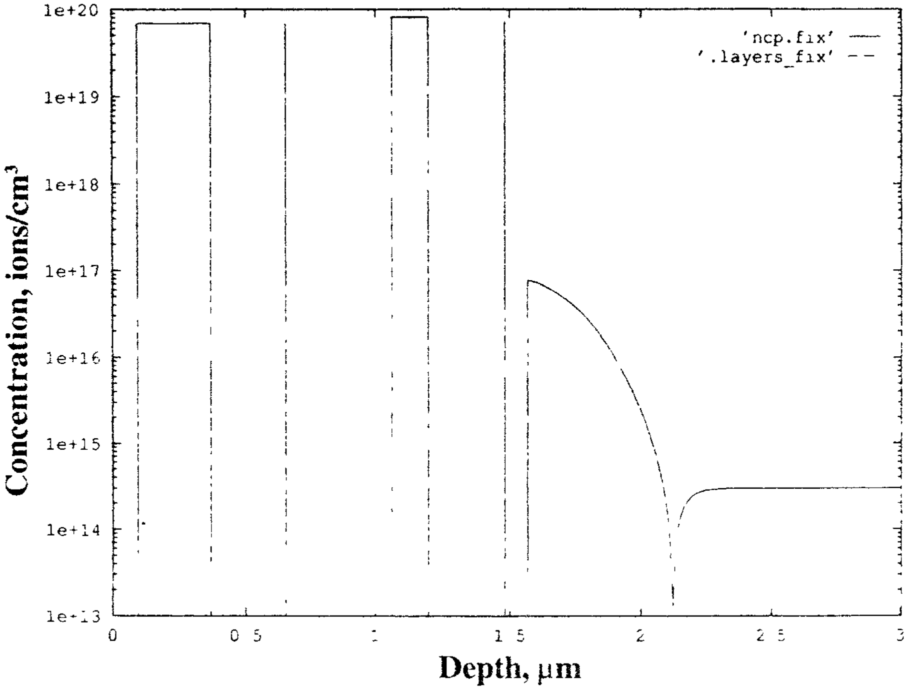
SUPREM III Doping Profile for a Junction Depth of 0.40μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



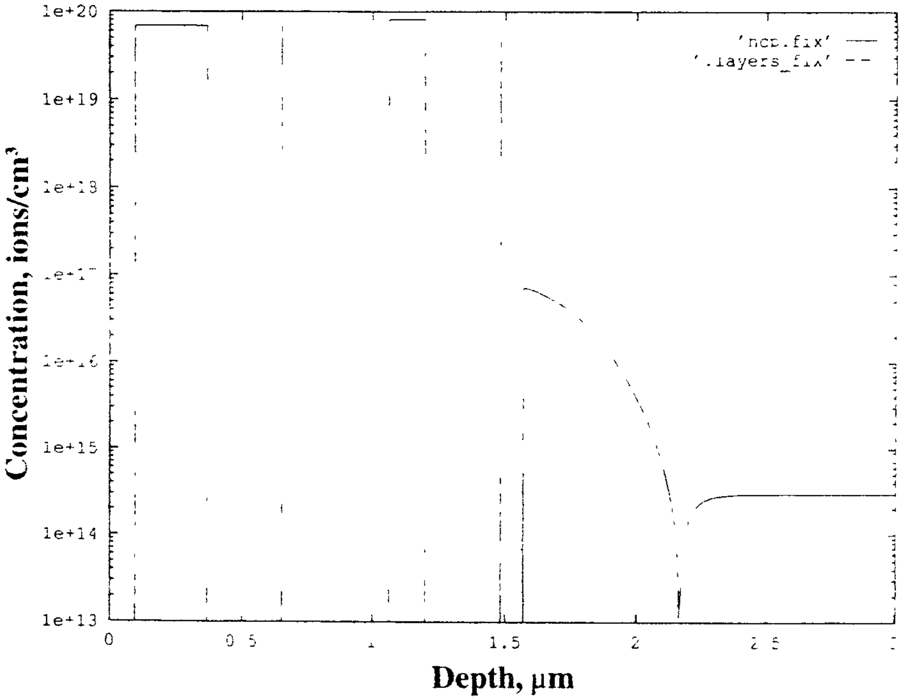
SUPREM III Doping Profile for a Junction Depth of 0.50μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



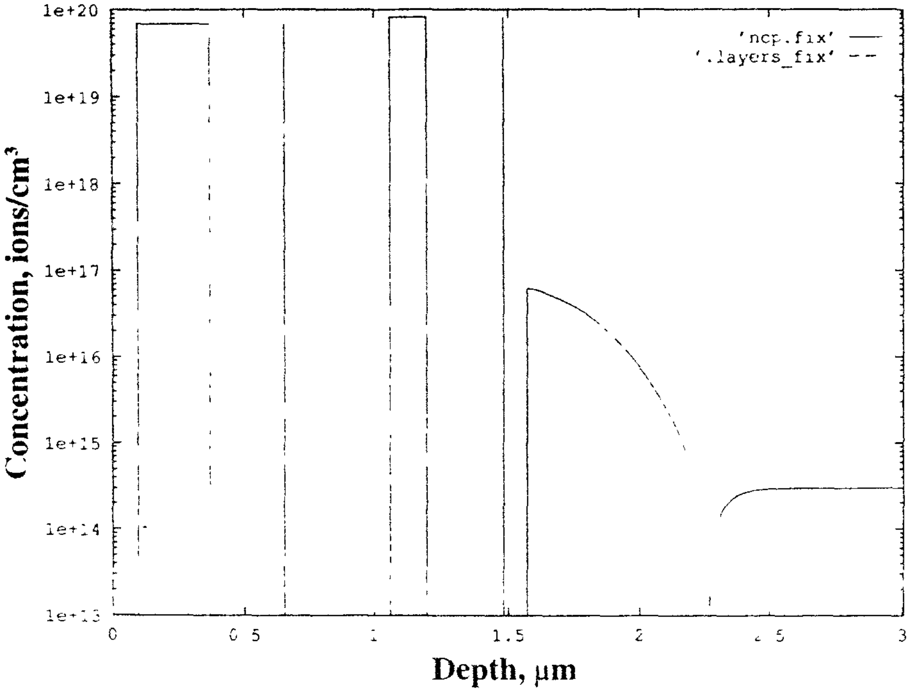
SUPREM III Doping Profile for a Junction Depth of 0.55μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



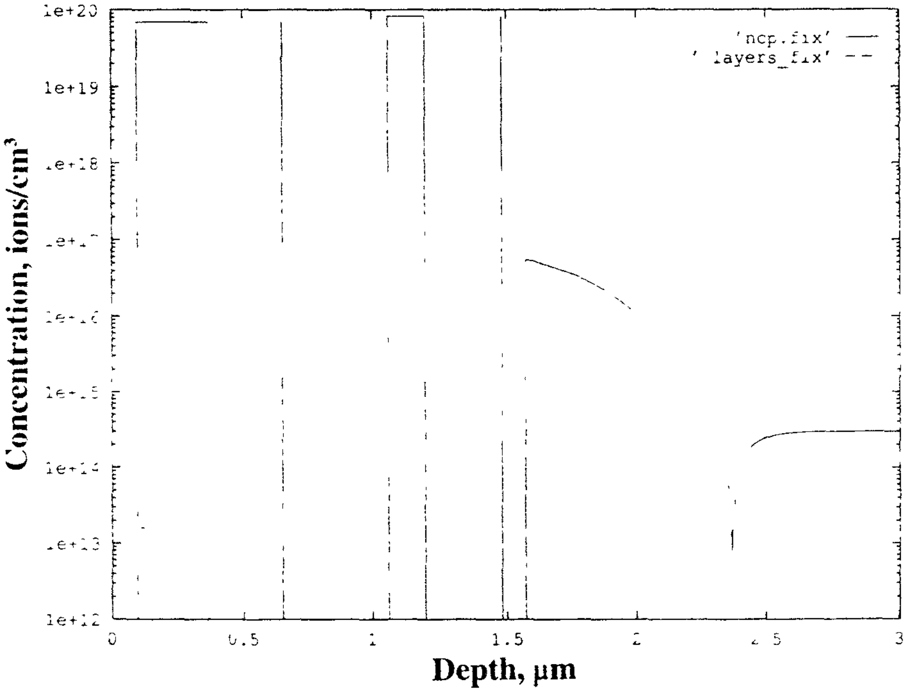
SUPREM III Doping Profile for a Junction Depth of 0.60μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



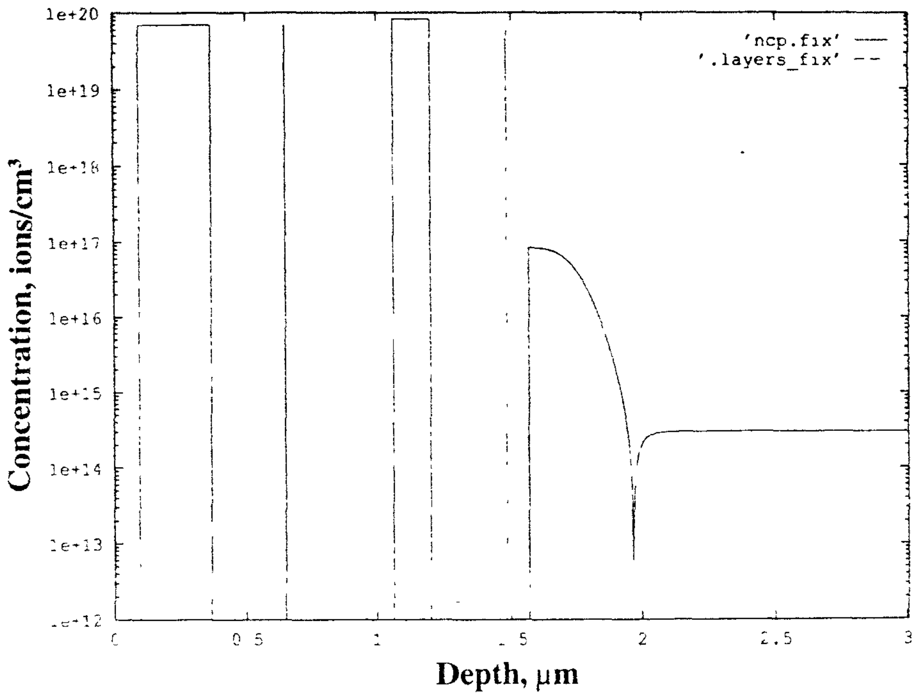
SUPREM III Doping Profile for a Junction Depth of 0.70μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



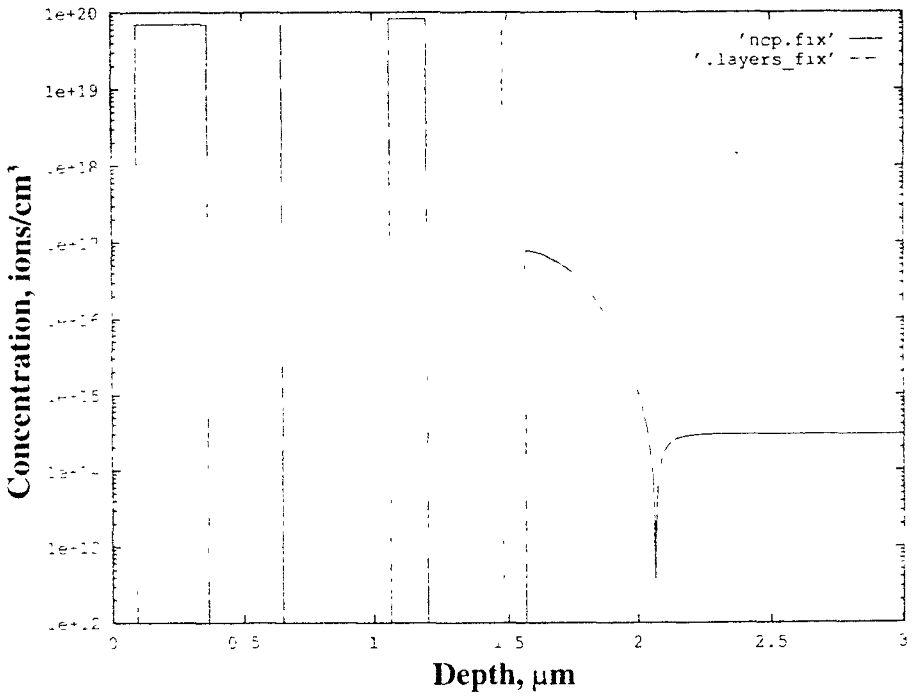
SUPREM III Doping Profile for a Junction Depth of 0.80μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



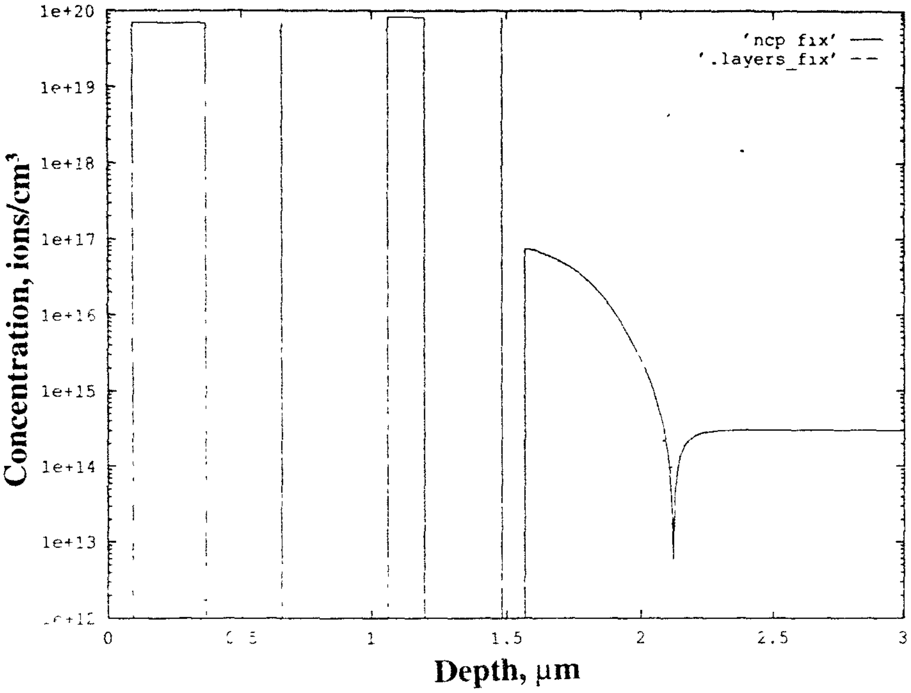
SUPREM III Doping Profile for a Junction Depth of 0.40µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



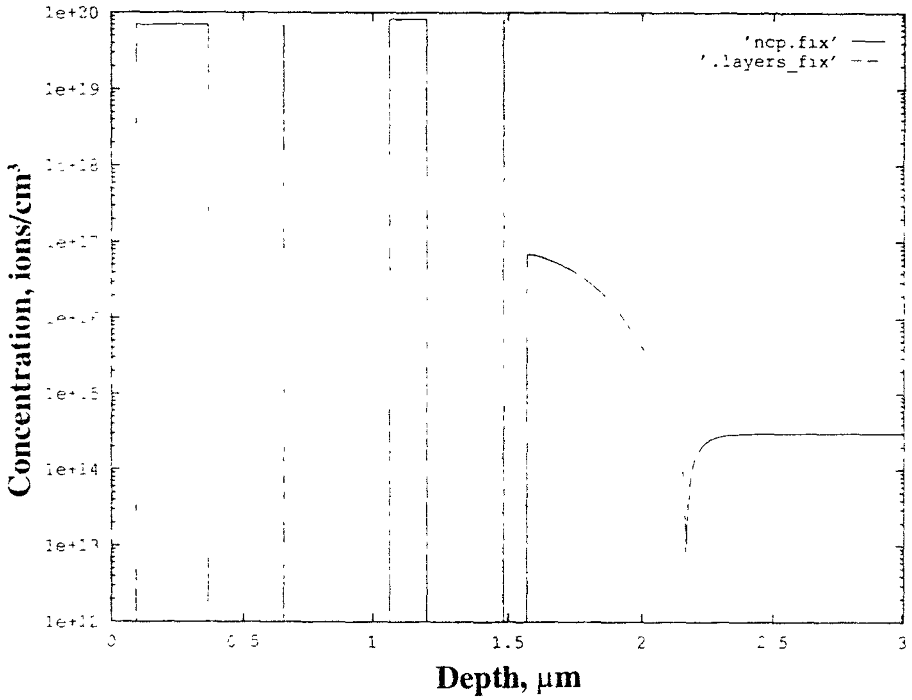
SUPREM III Doping Profile for a Junction Depth of 0.50µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



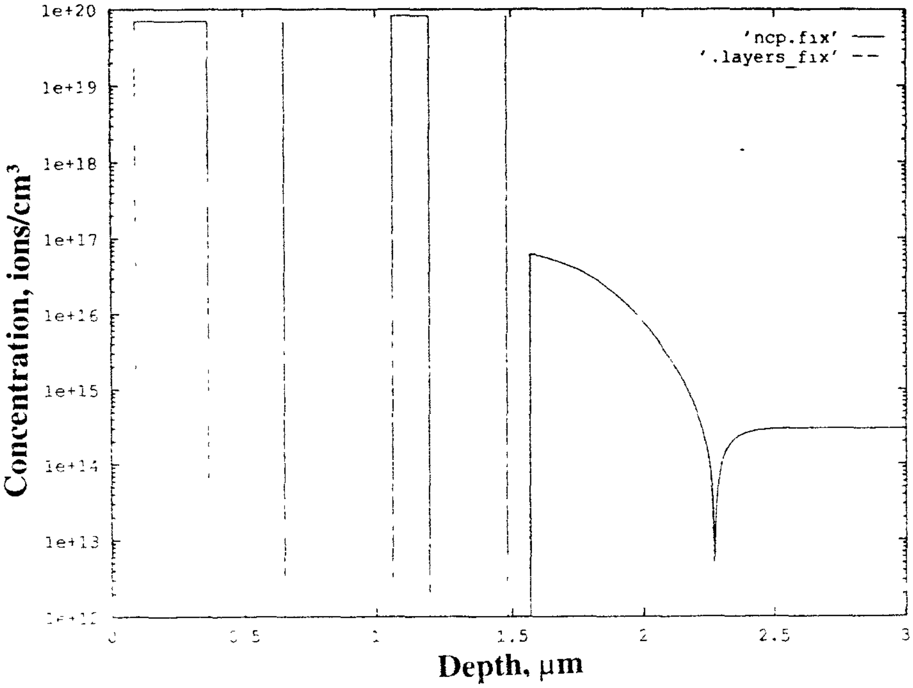
SUPREM III Doping Profile for a Junction Depth of 0.55μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



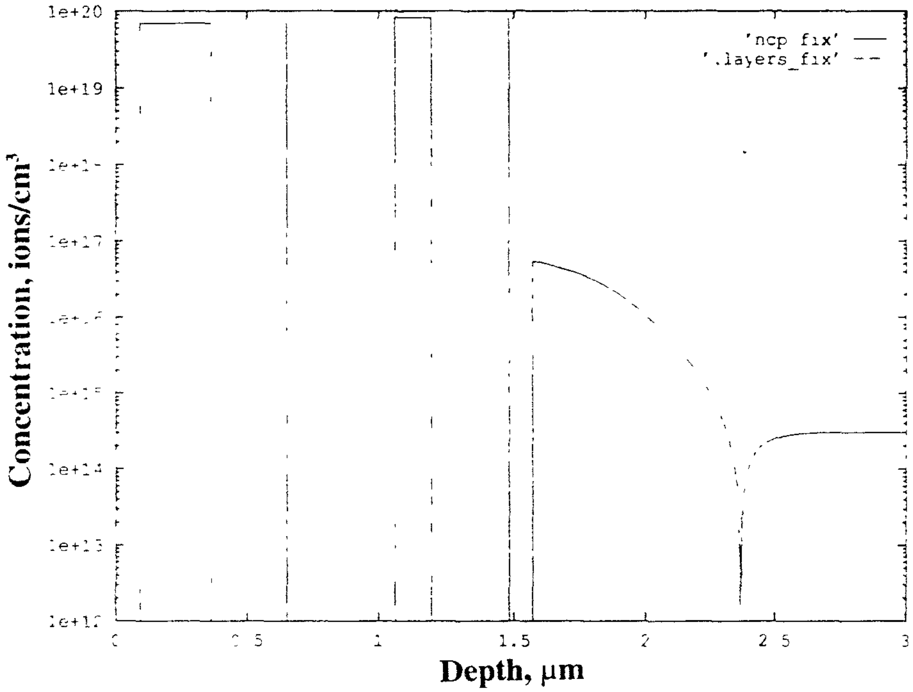
SUPREM III Doping Profile for a Junction Depth of 0.60μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



SUPREM III Doping Profile for a Junction Depth of 0.70μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



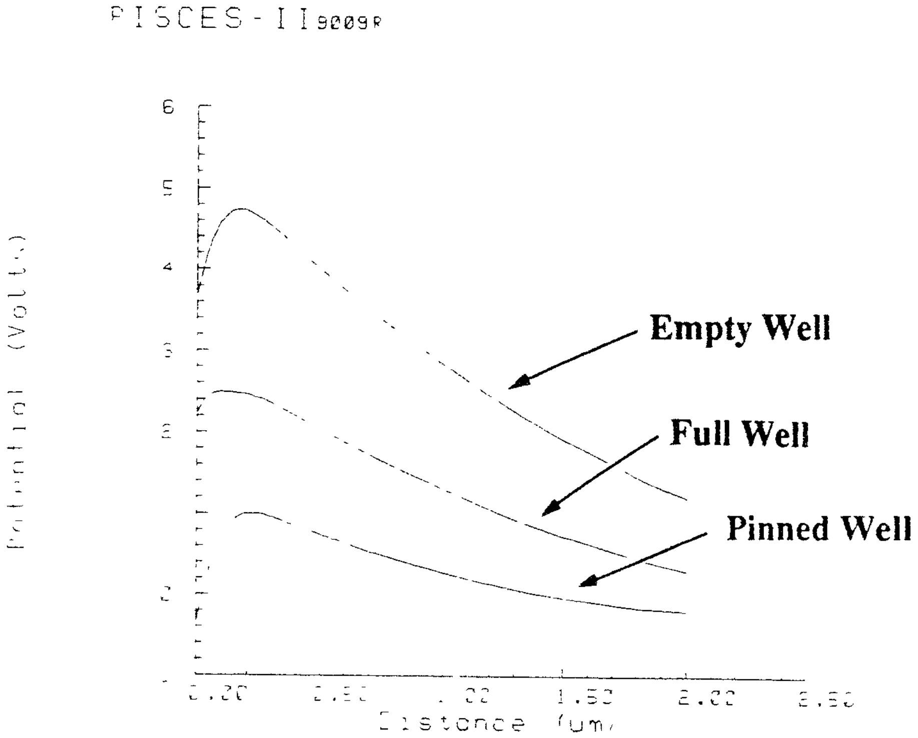
SUPREM III Doping Profile for a Junction Depth of 0.80μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



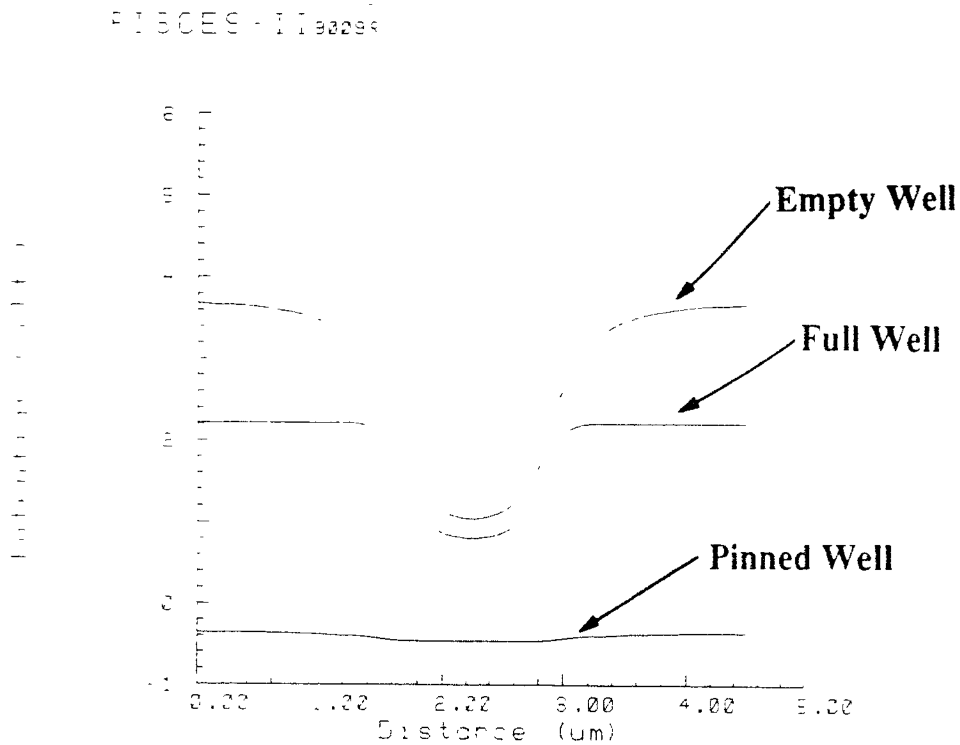
Appendix D

PISCES IIB Potential and Electric Field Profiles

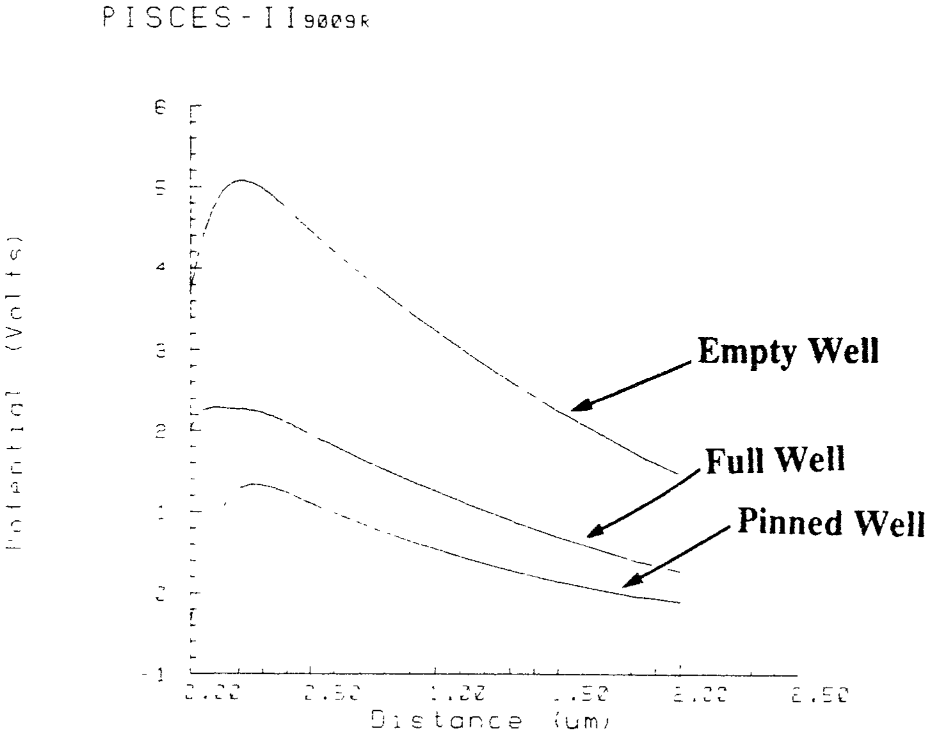
PISCES IIB Potential Profile for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



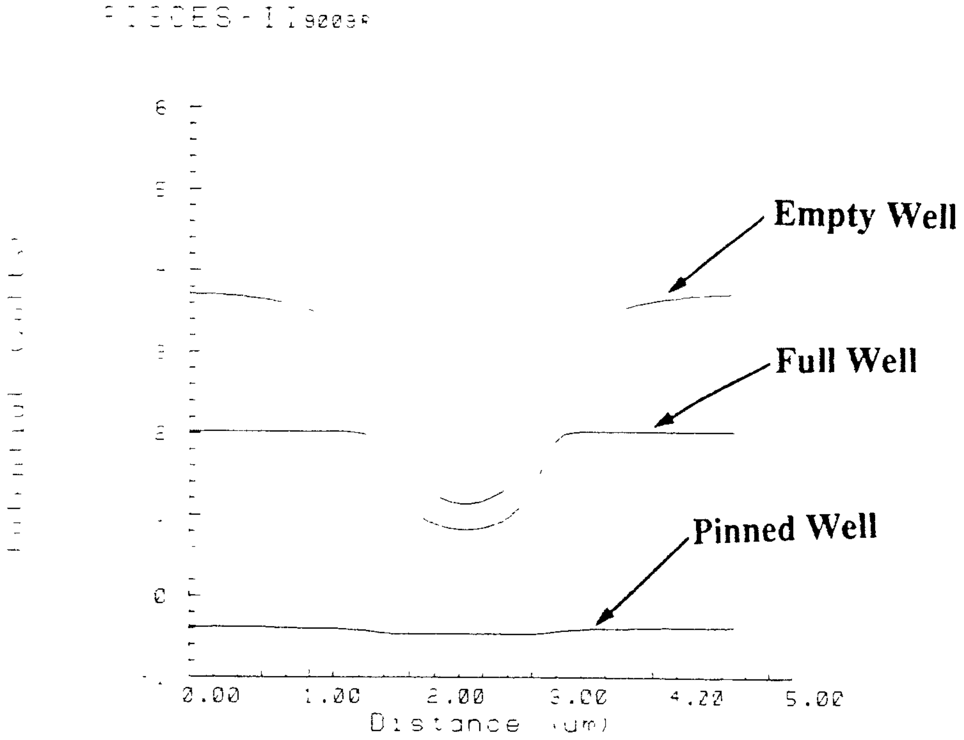
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



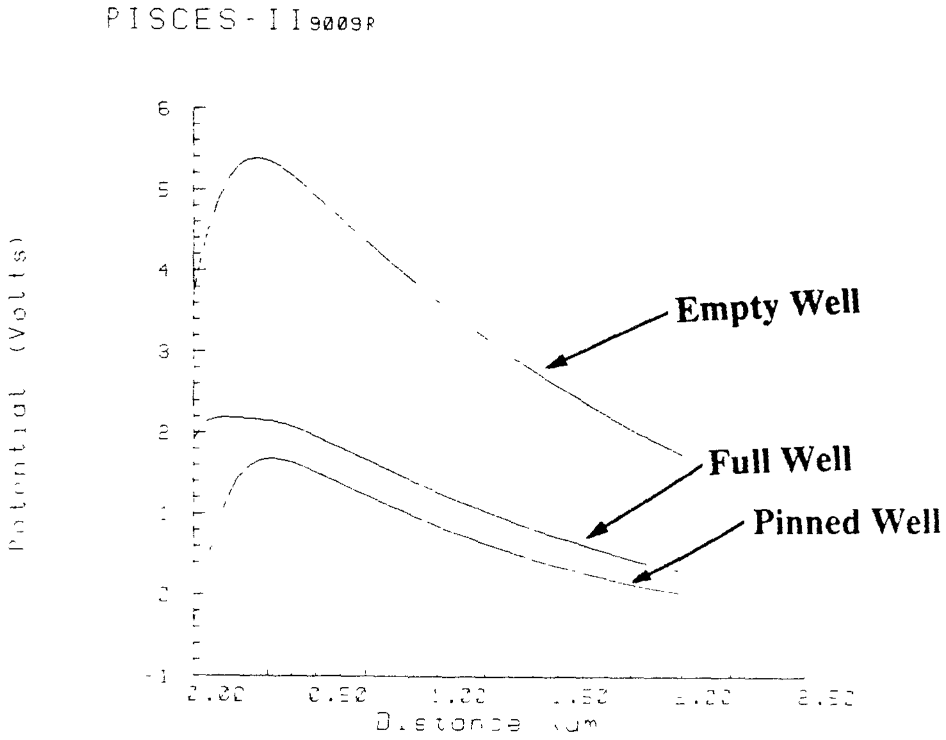
PISCES IIB Potential Profile for a Junction Depth of 0.50µm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



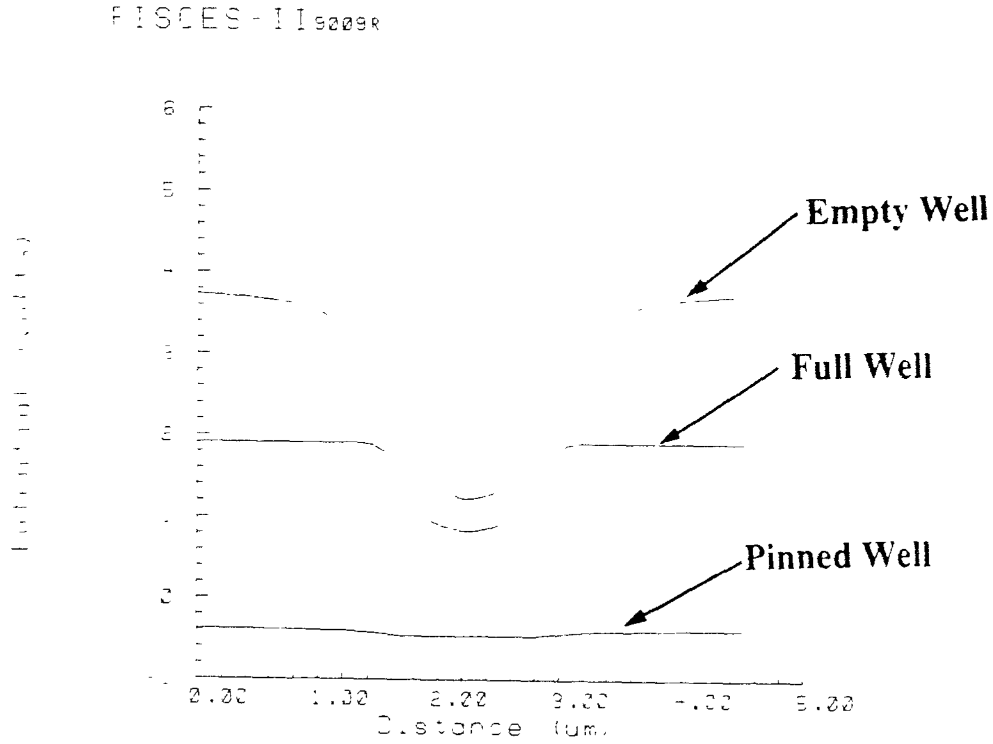
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.50µm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



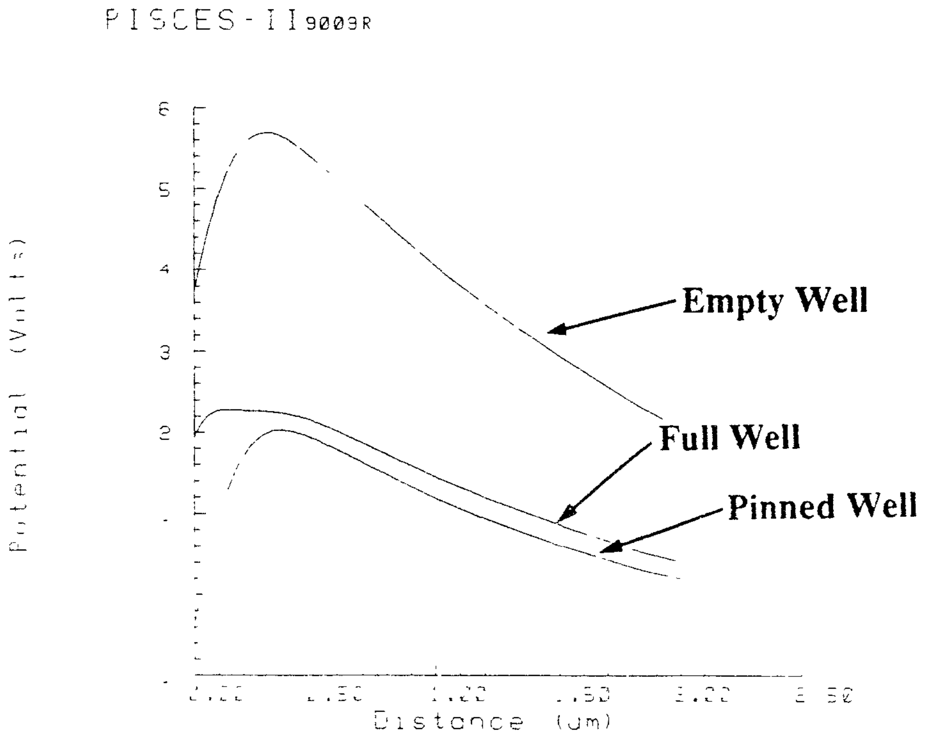
PISCES IIB Potential Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



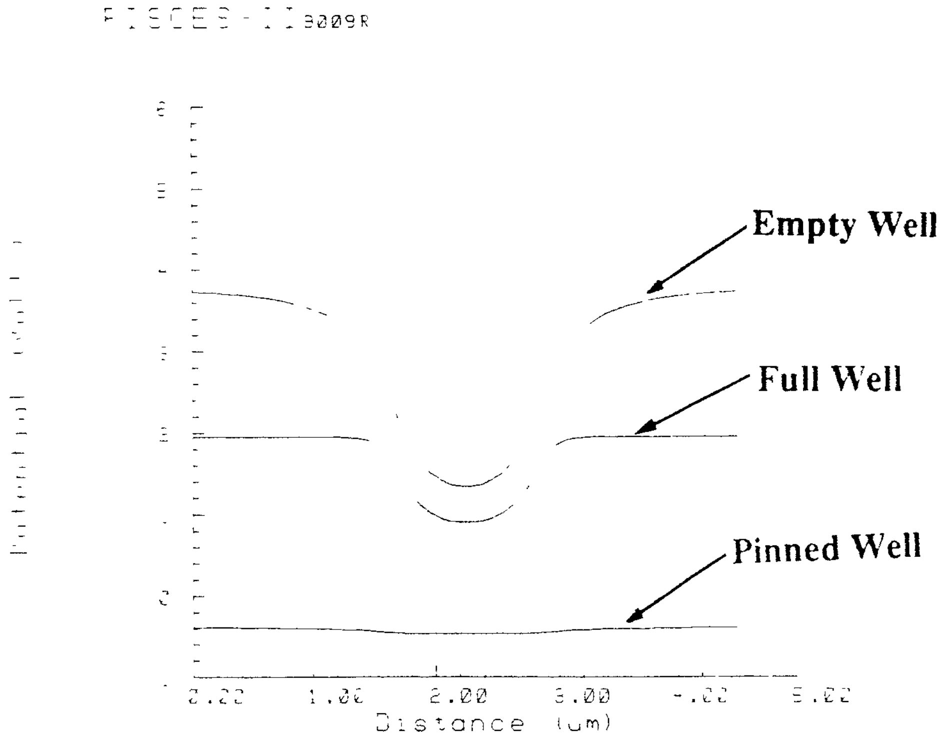
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



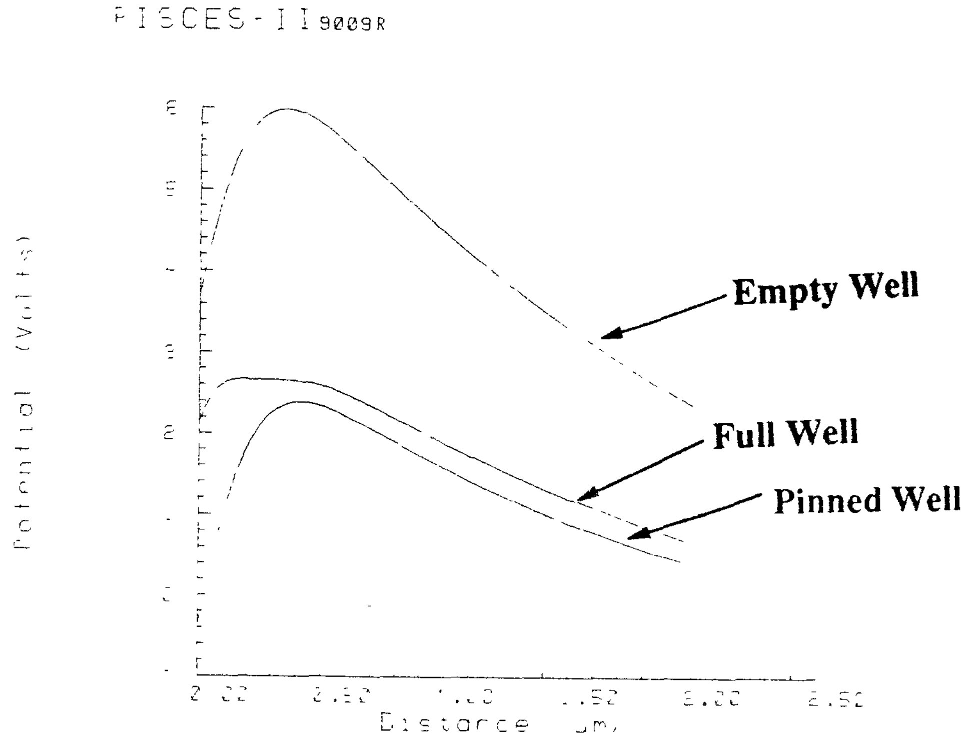
PISCES IIB Potential Profile for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



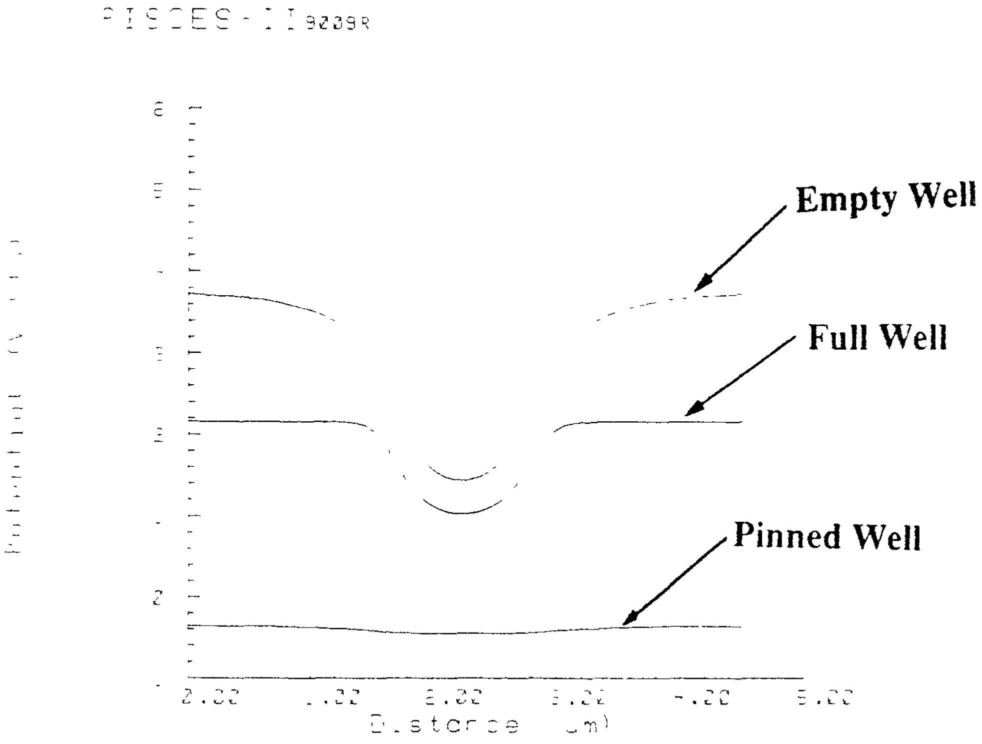
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



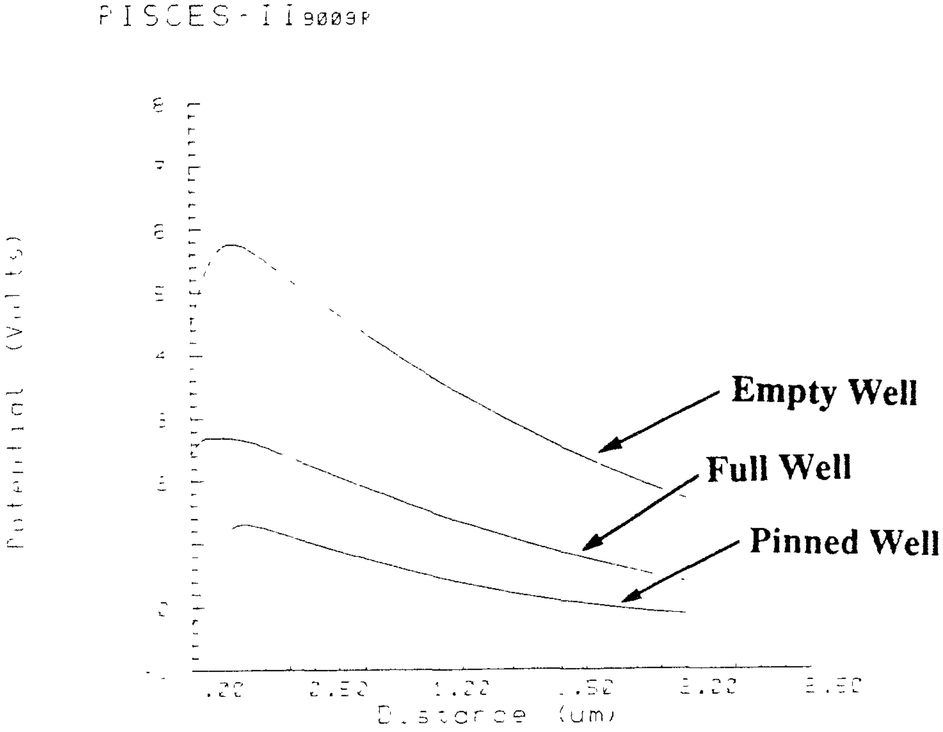
PISCES IIB Potential Profile for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



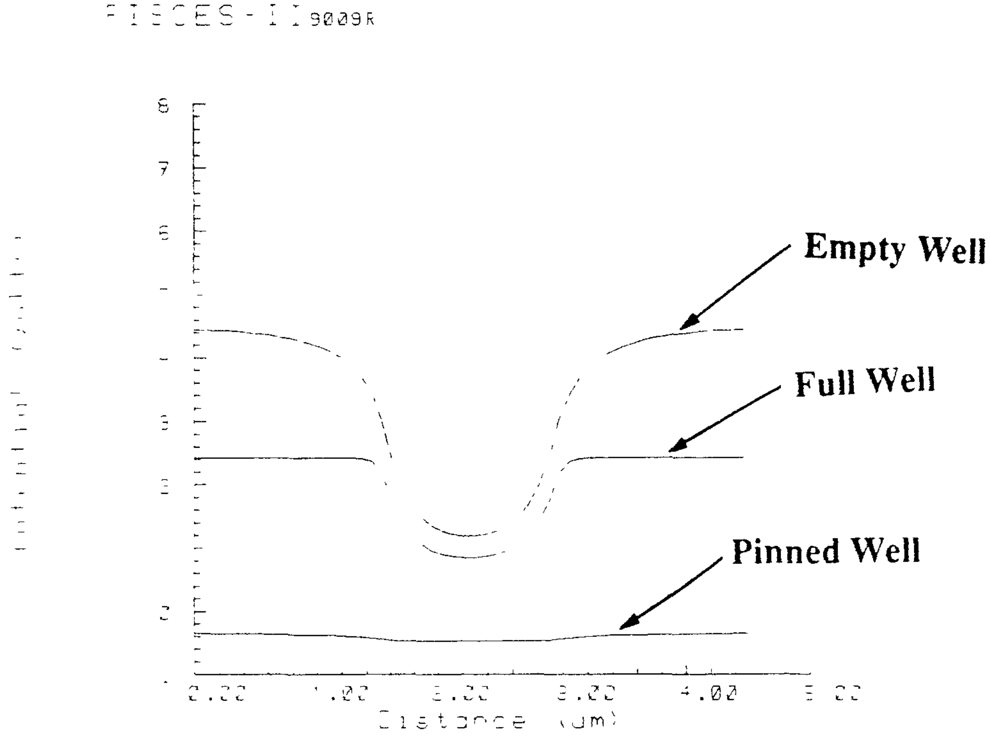
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



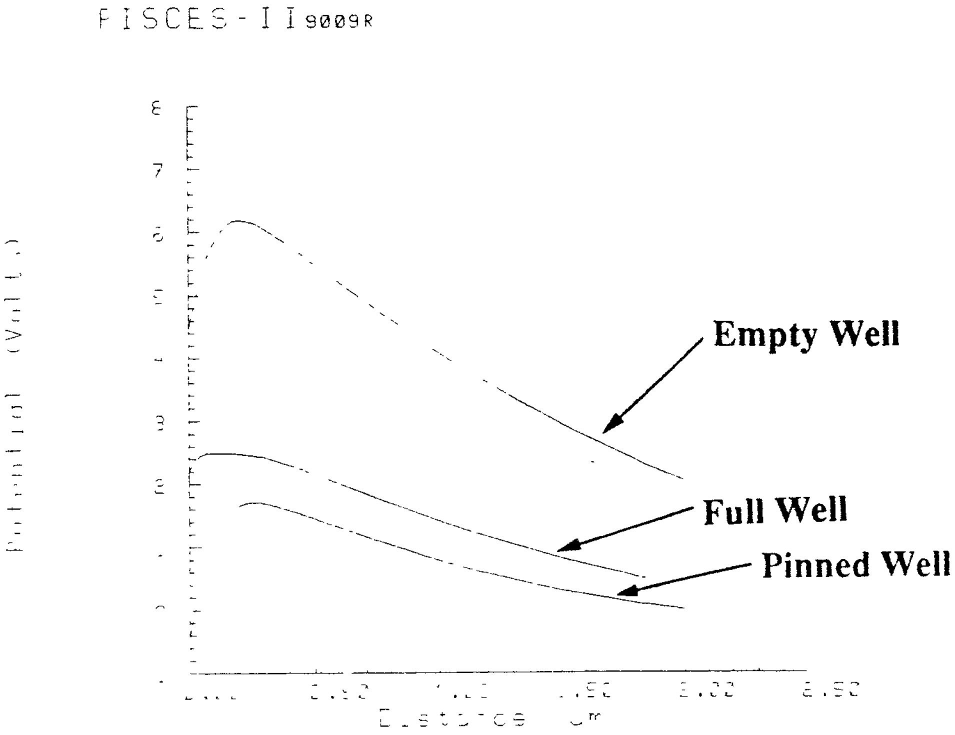
PISCES IIB Potential Profile for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



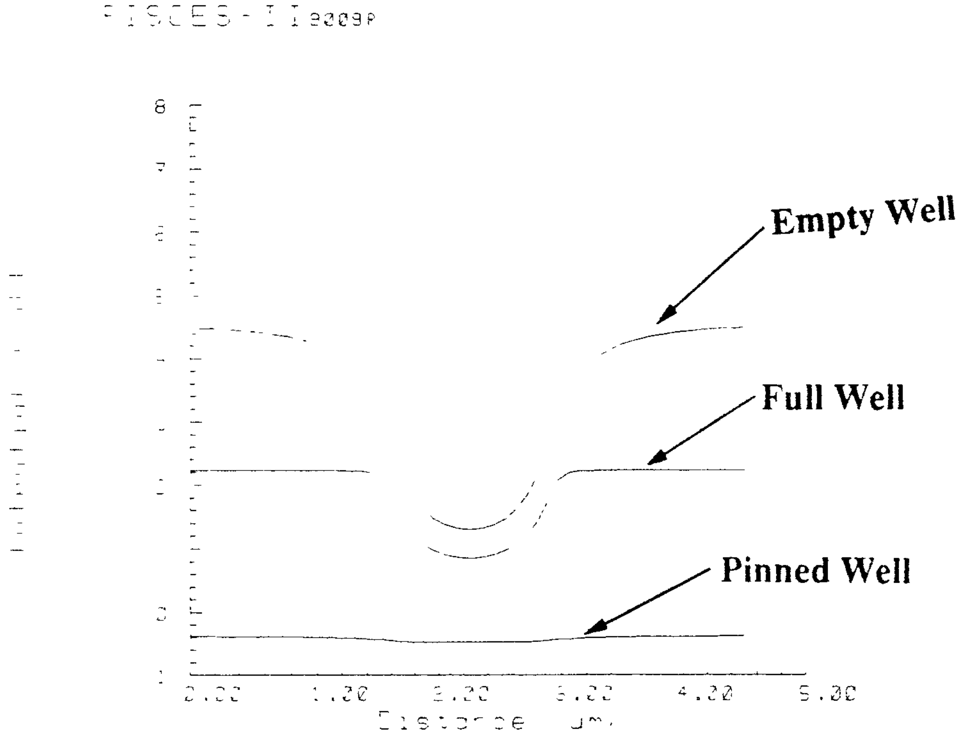
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



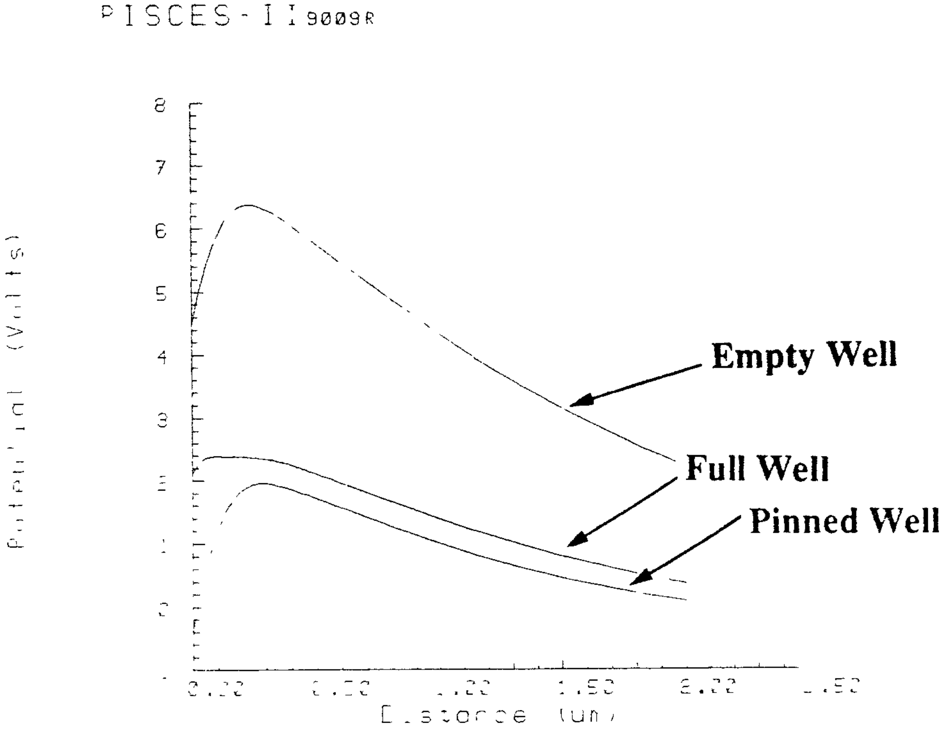
PISCES IIB Potential Profile for a Junction Depth of 0.50μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



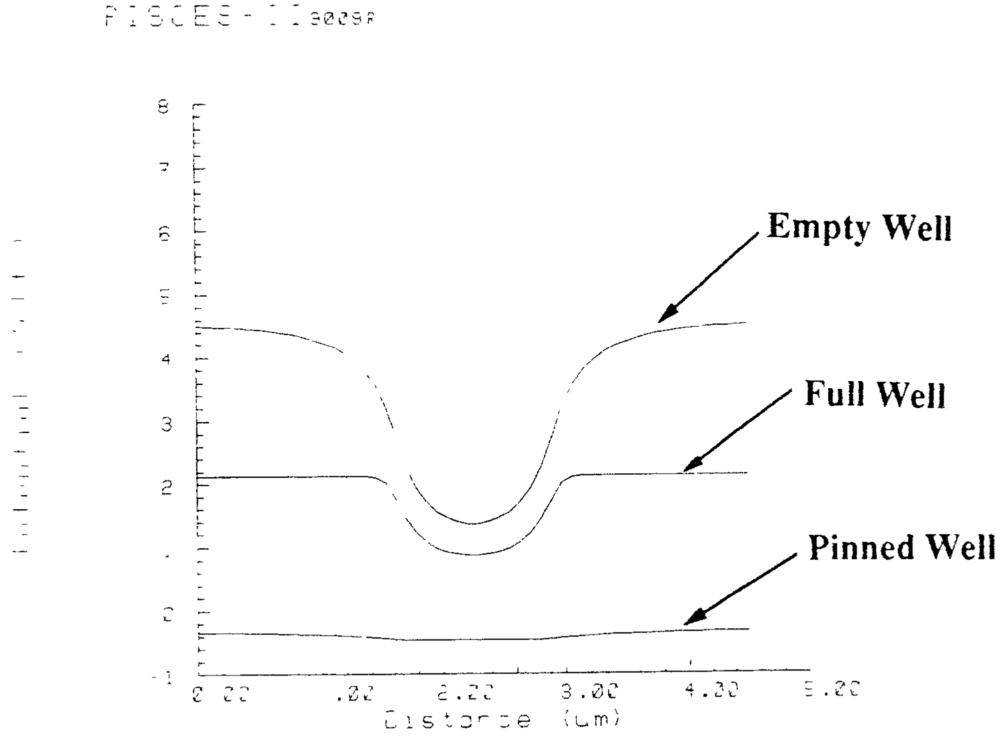
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.50μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



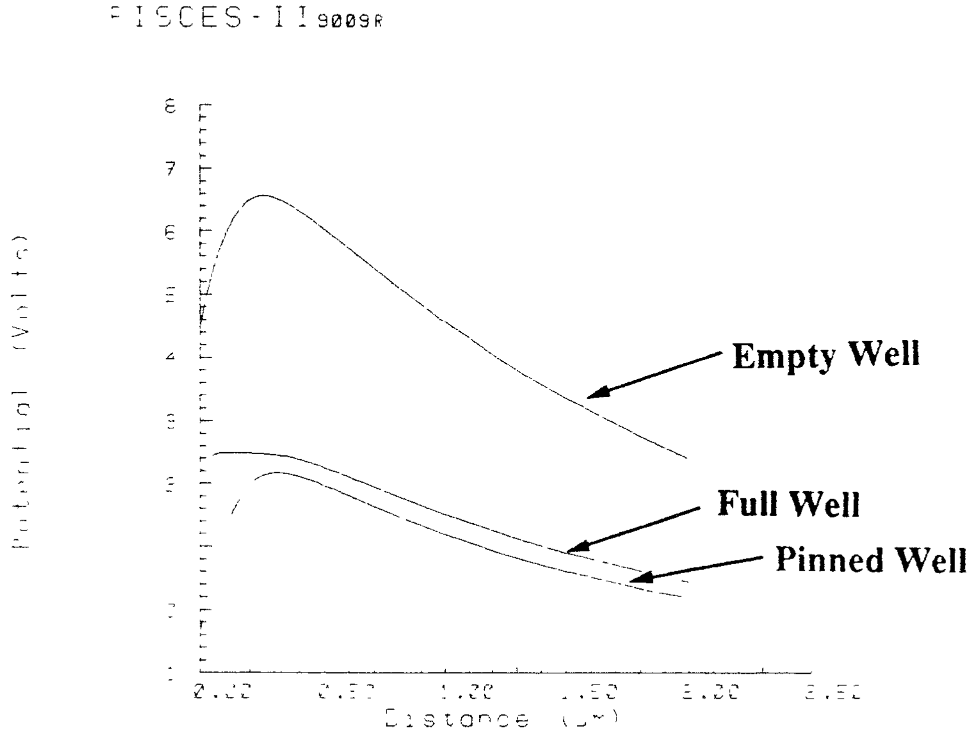
PISCES IIB Potential Profile for a Junction Depth of 0.55μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



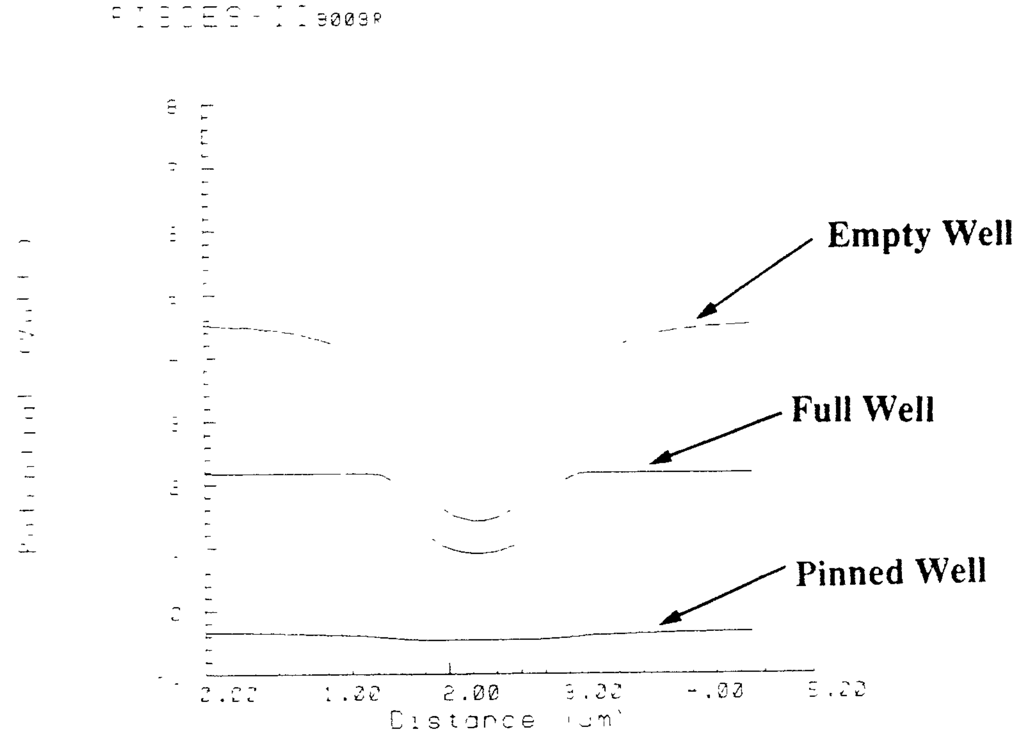
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.55μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



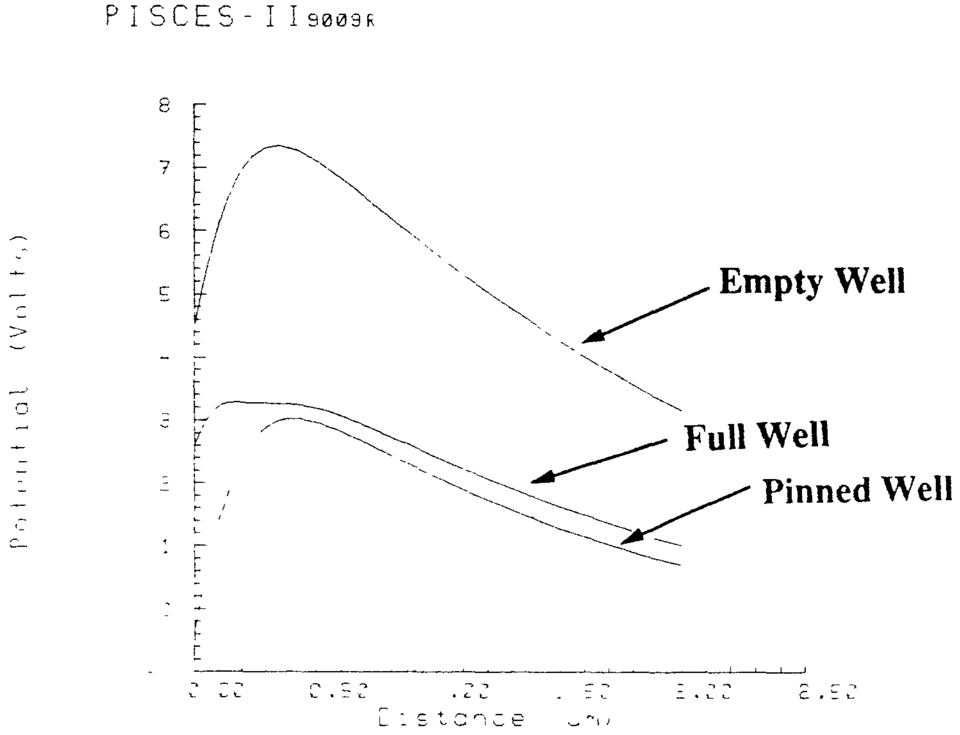
PISCES IIB Potential Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



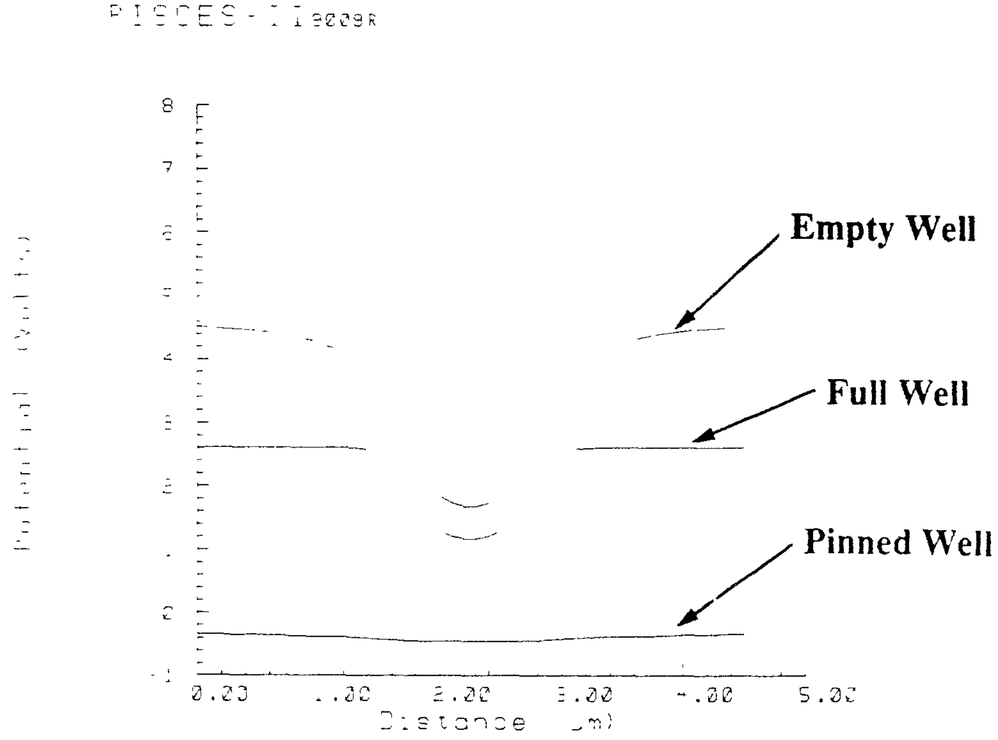
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



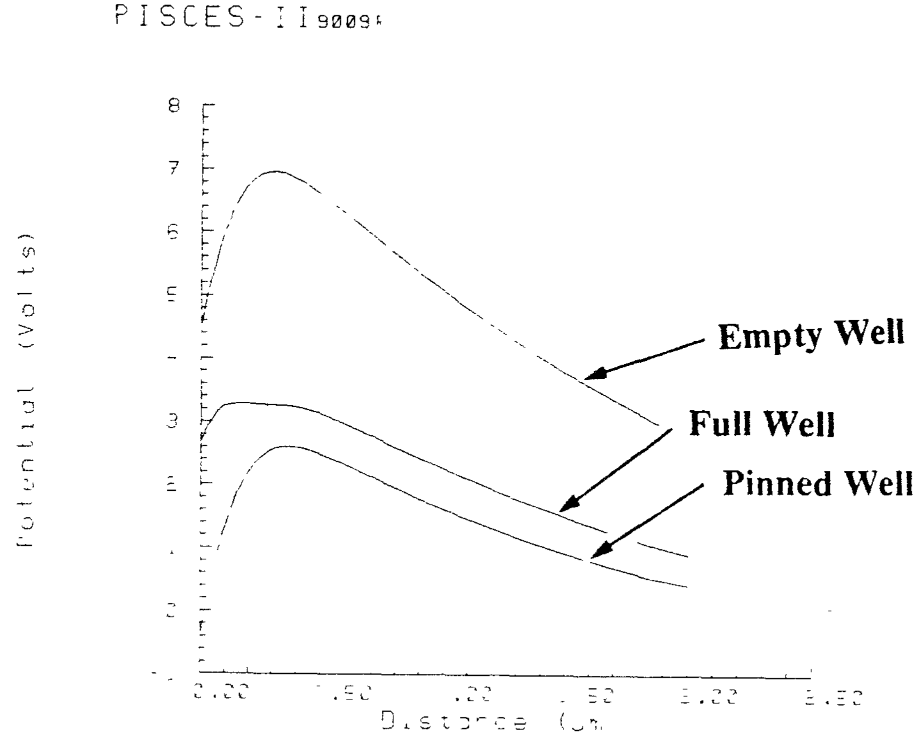
PISCES IIB Potential Profile for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



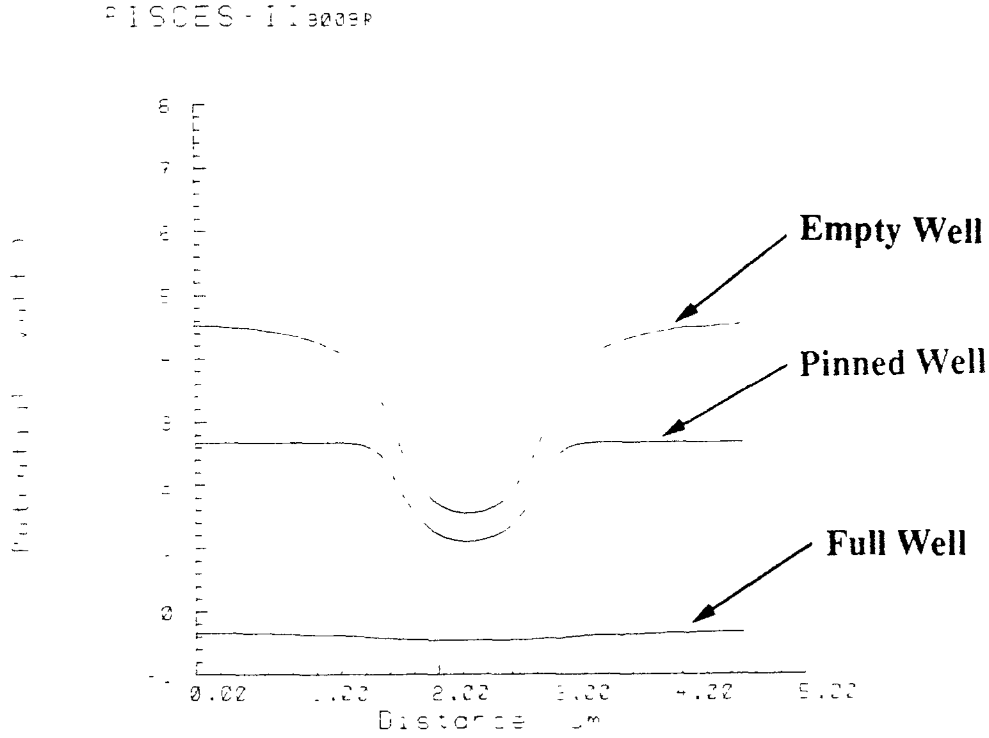
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



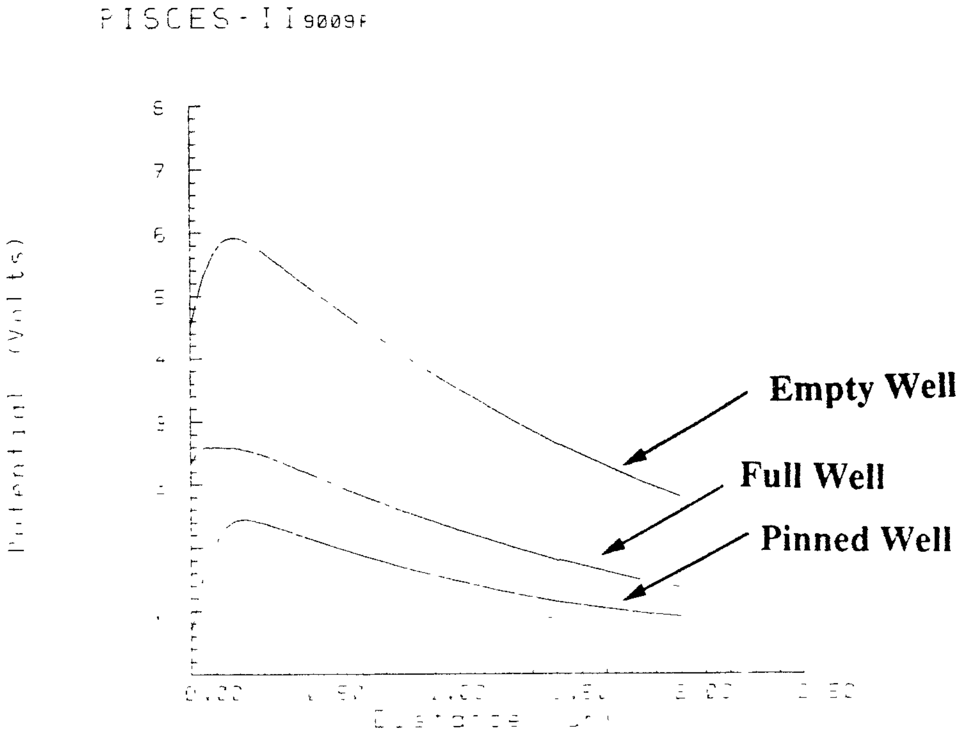
PISCES IIB Potential Profile for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



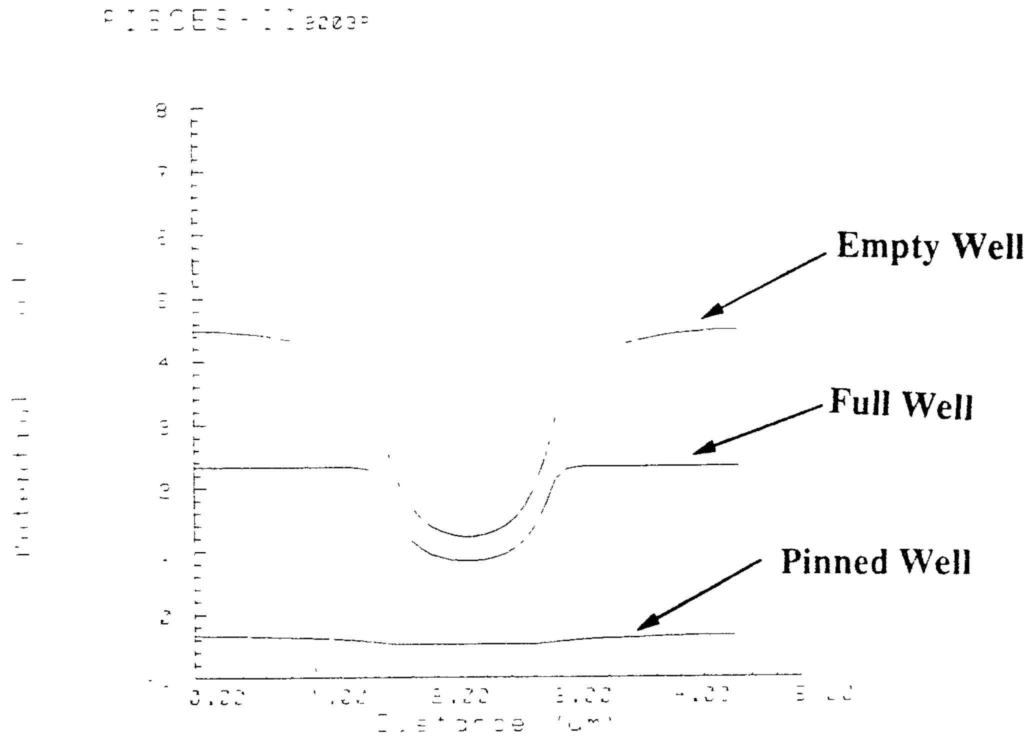
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



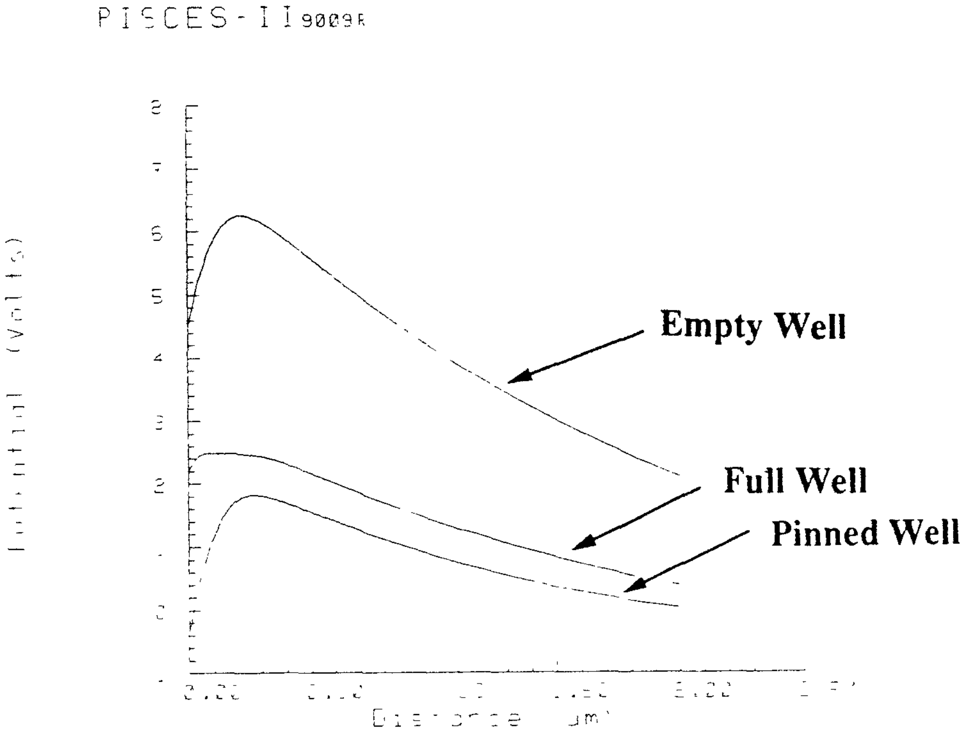
PISCES IIB Potential Profile for a Junction Depth of 0.40μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



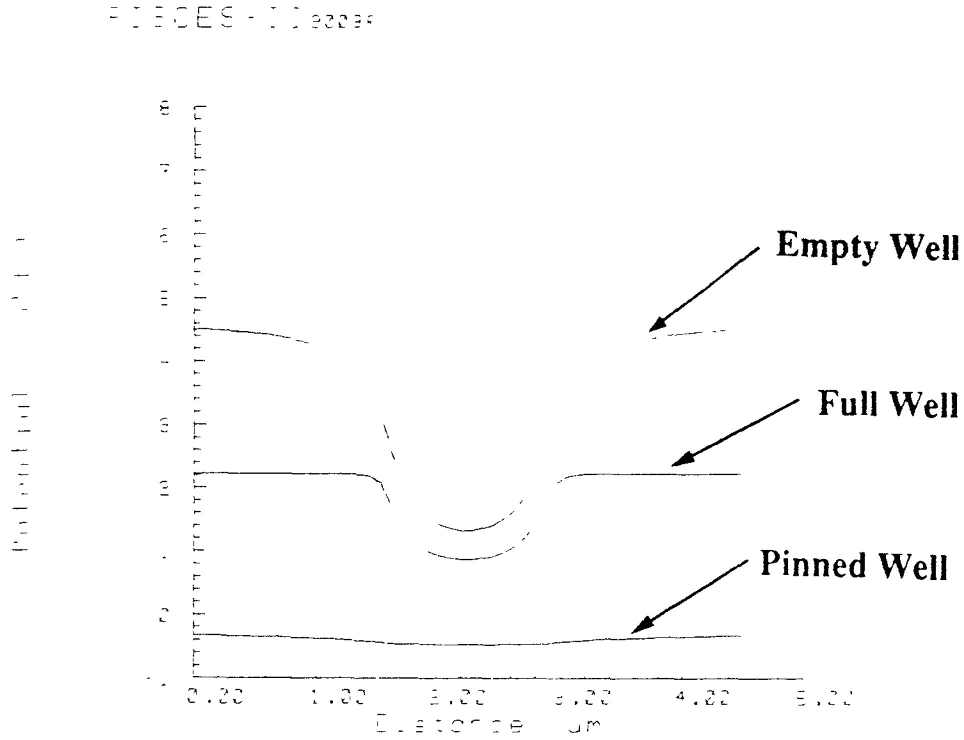
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.40μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



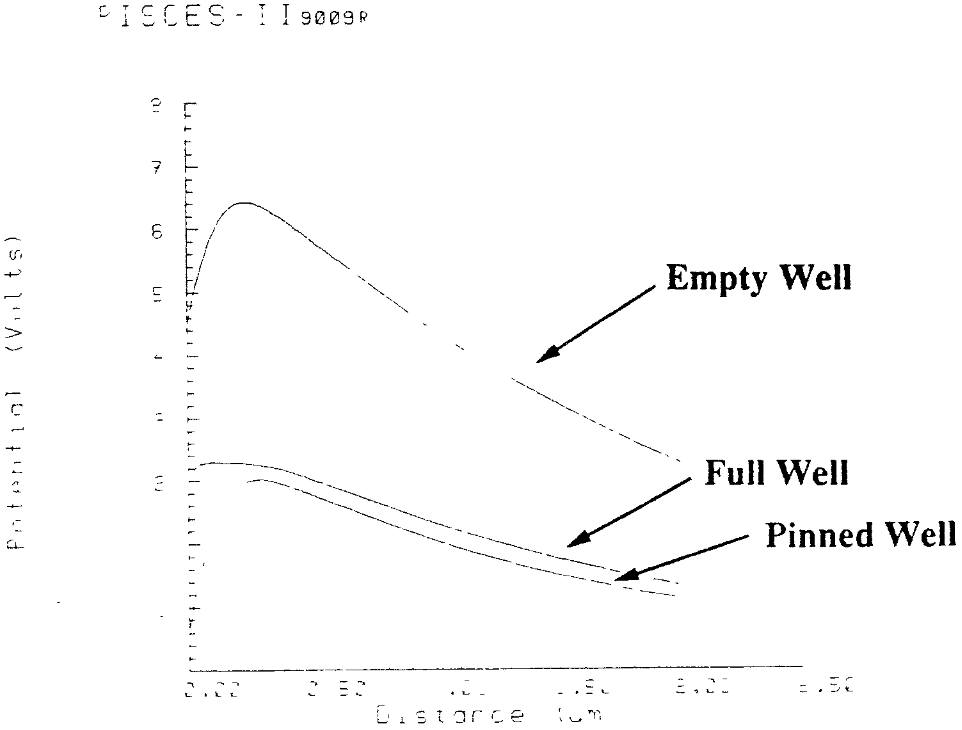
PISCES IIB Potential Profile for a Junction Depth of 0.50μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



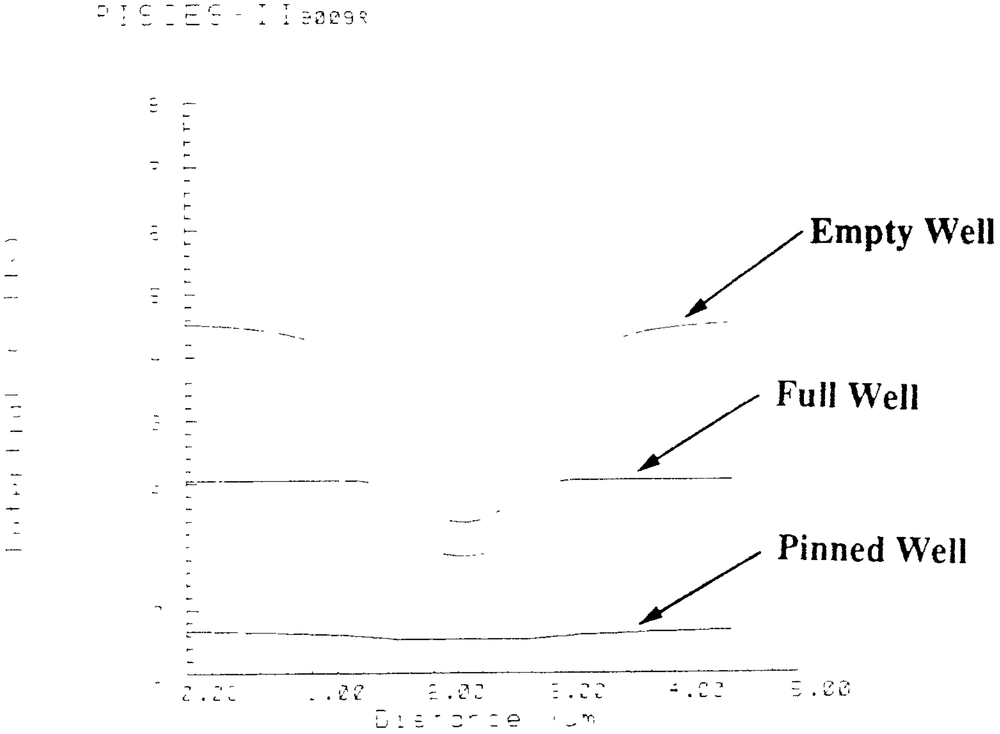
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.50μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



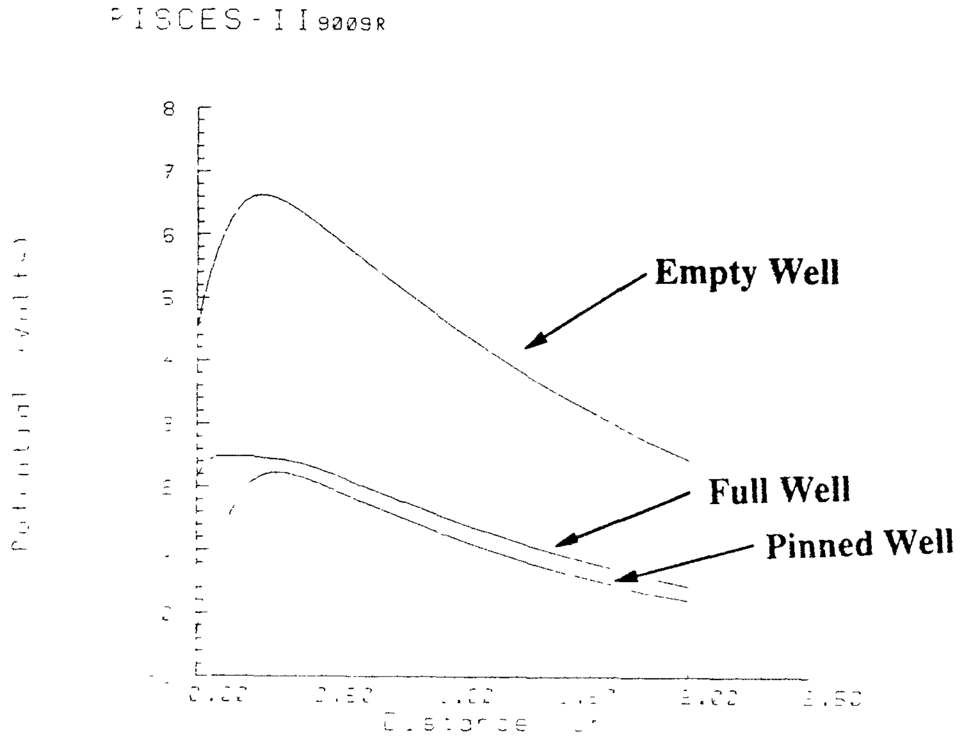
PISCES IIB Potential Profile for a Junction Depth of 0.55μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



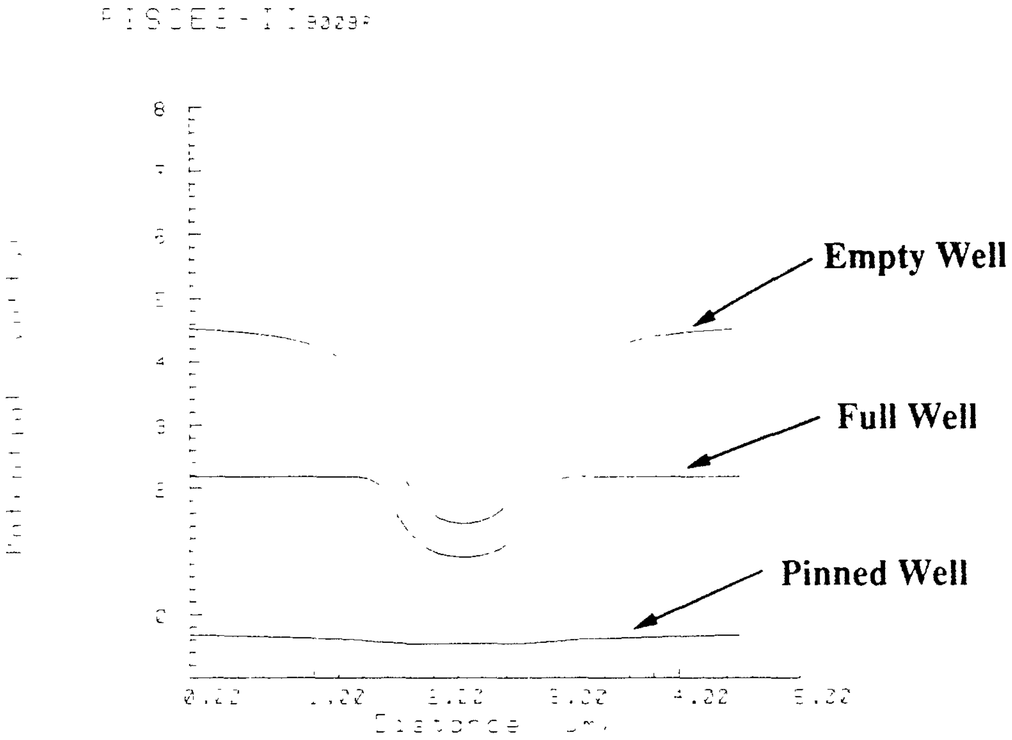
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.55μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



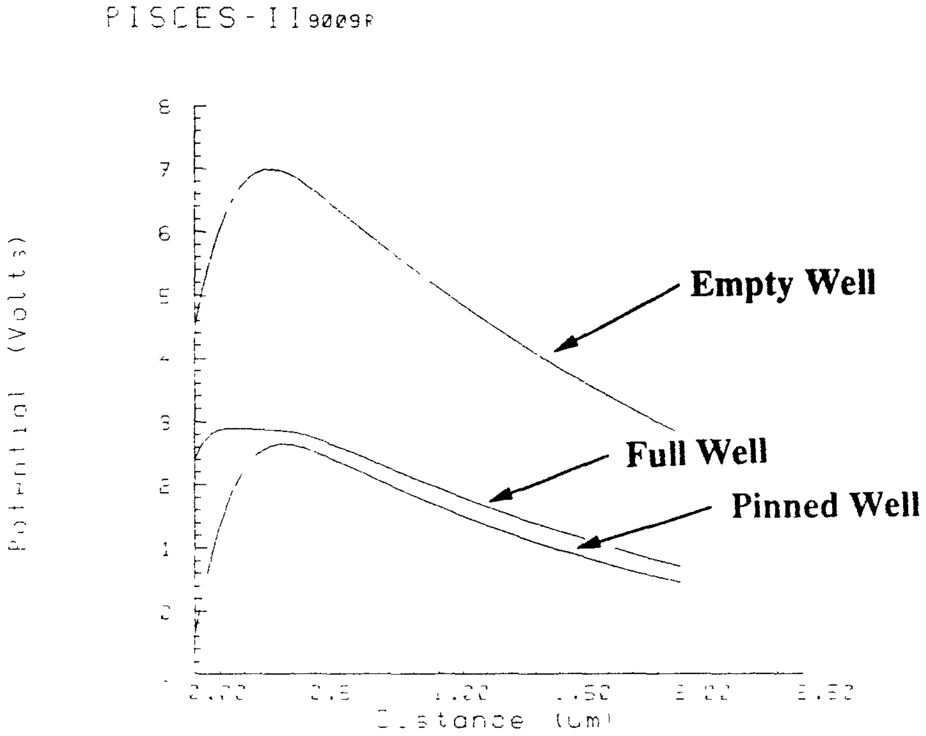
PISCES IIB Potential Profile for a Junction Depth of 0.60µm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



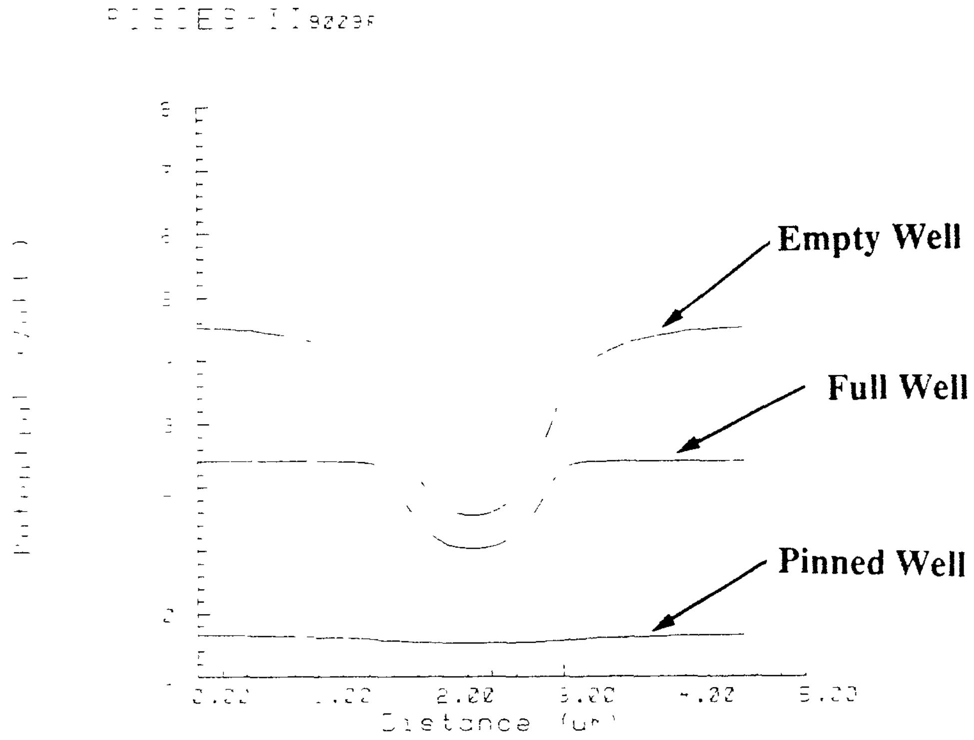
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.60µm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



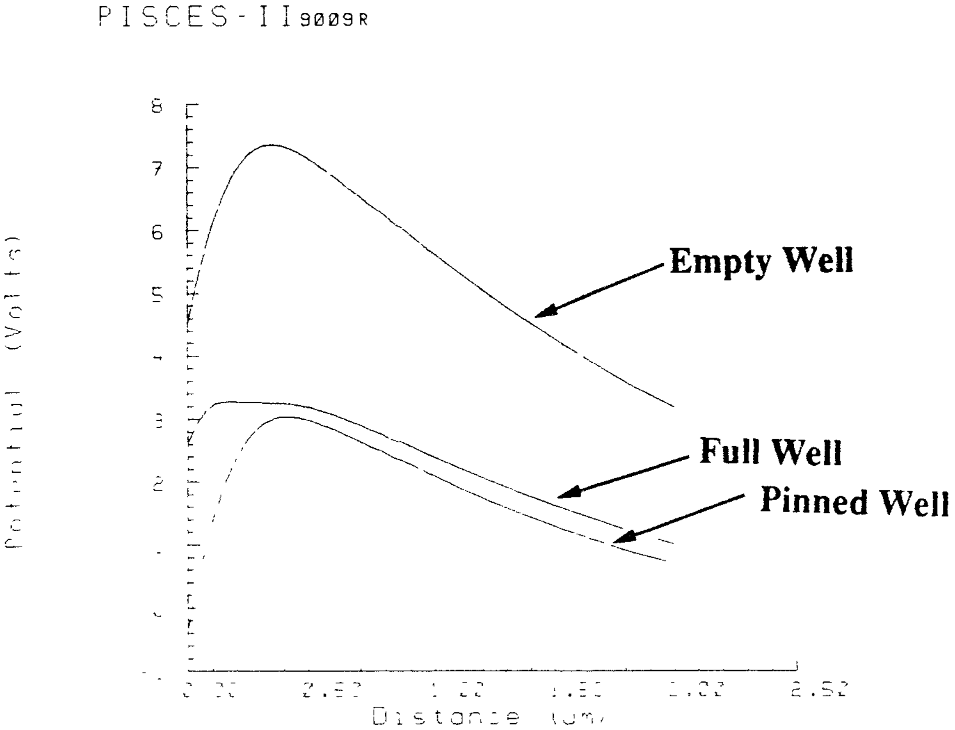
PISCES IIB Potential Profile for a Junction Depth of 0.70μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



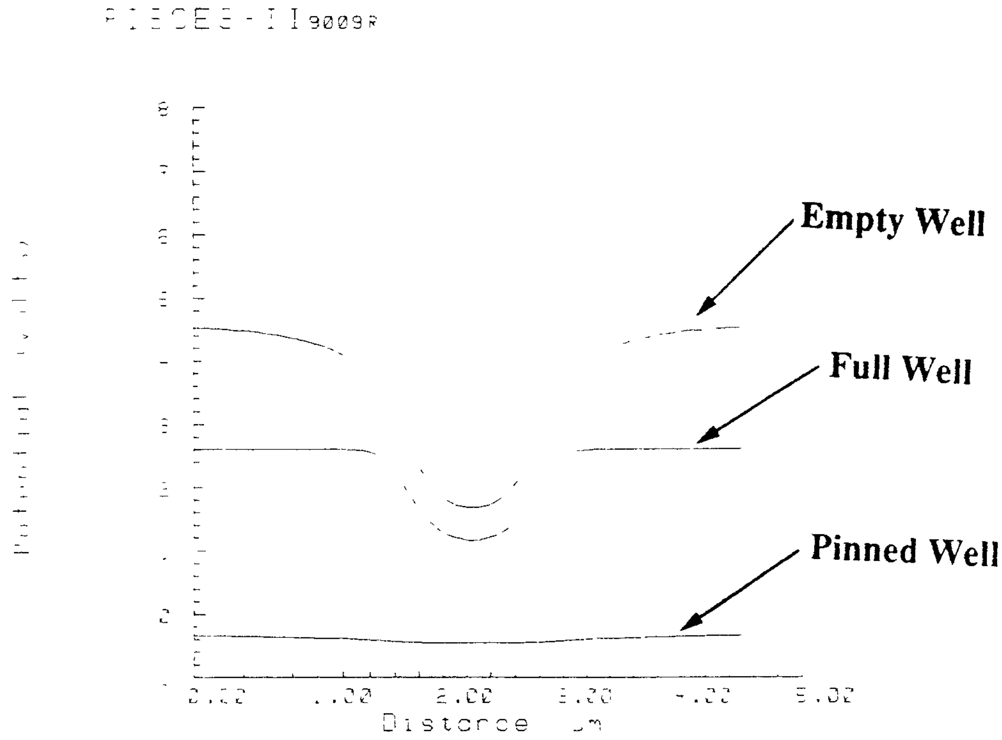
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.70μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



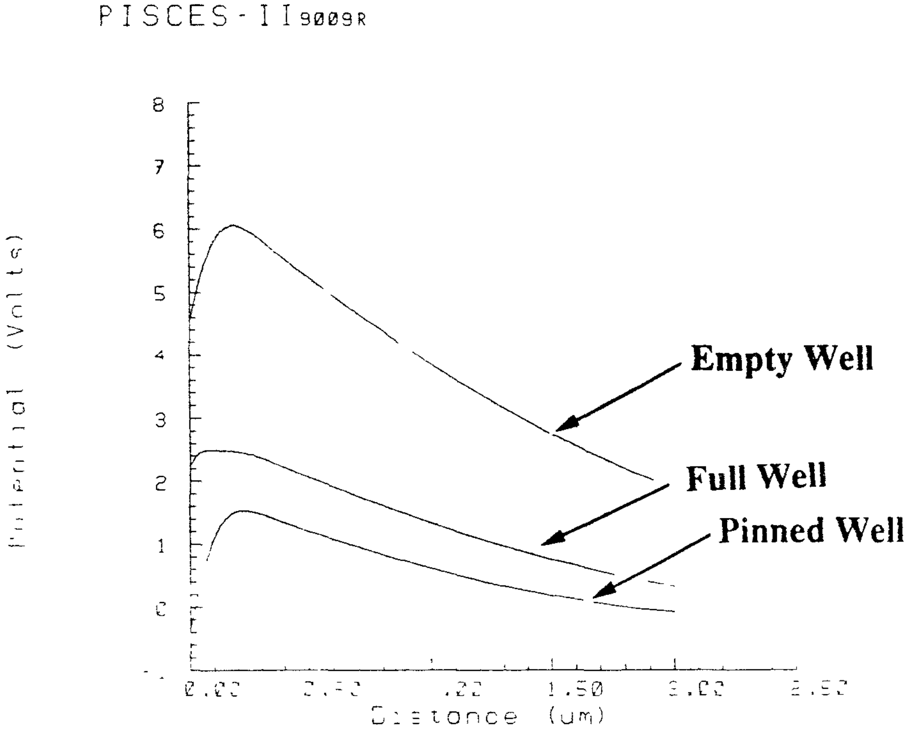
PISCES IIB Potential Profile for a Junction Depth of 0.80μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.80μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Potential Profile for a Junction Depth of 0.40μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2

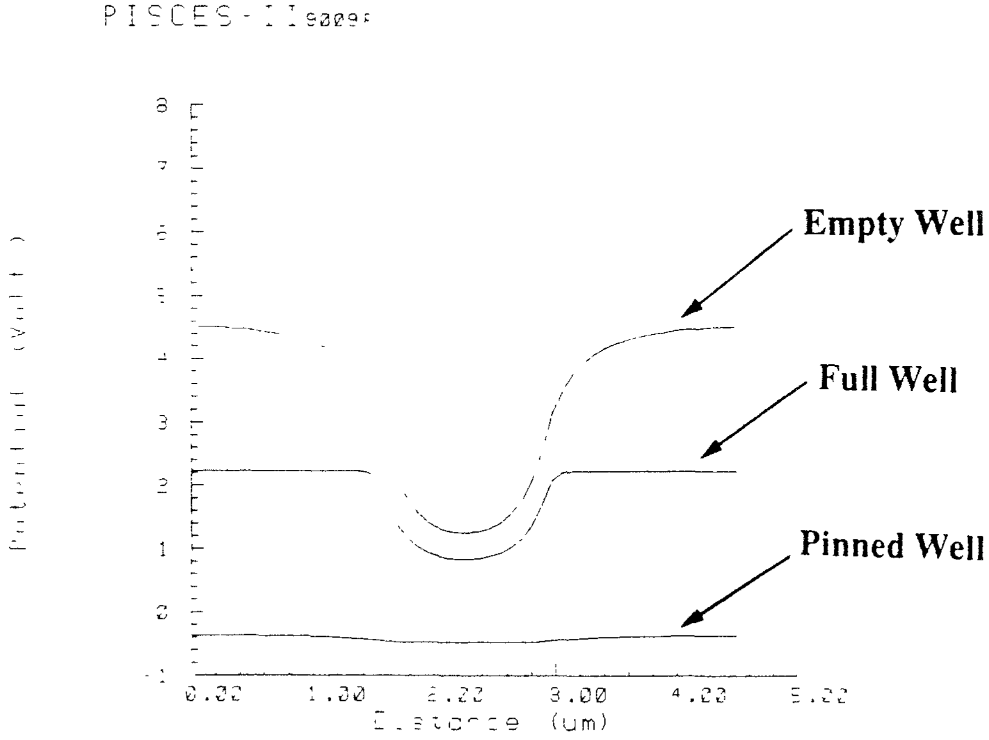


Empty Well

Full Well

Pinned Well

PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.40μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2

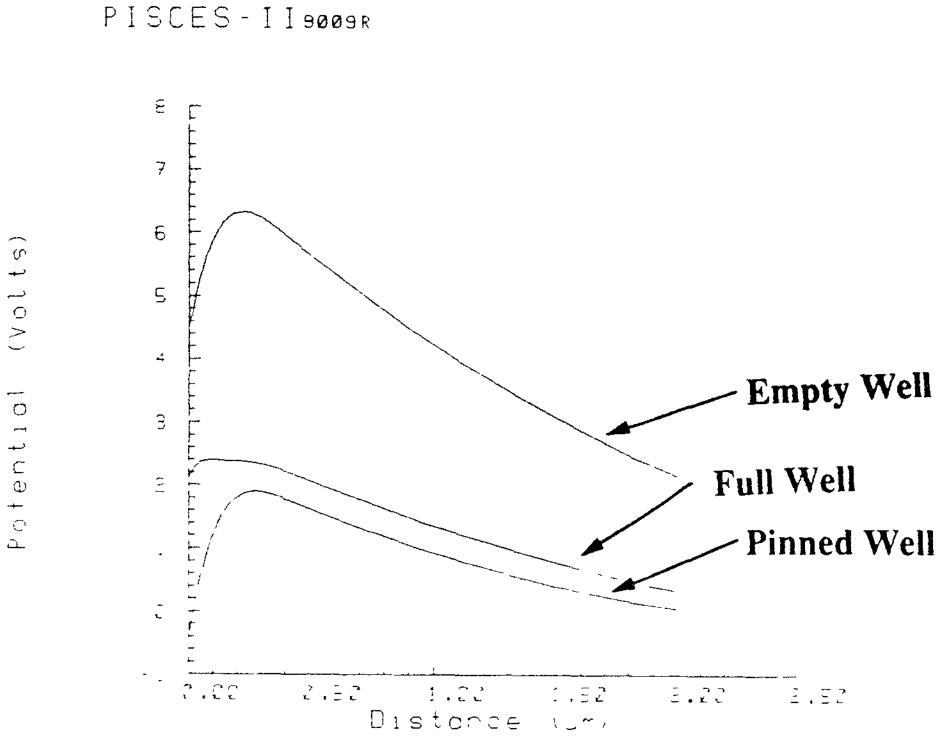


Empty Well

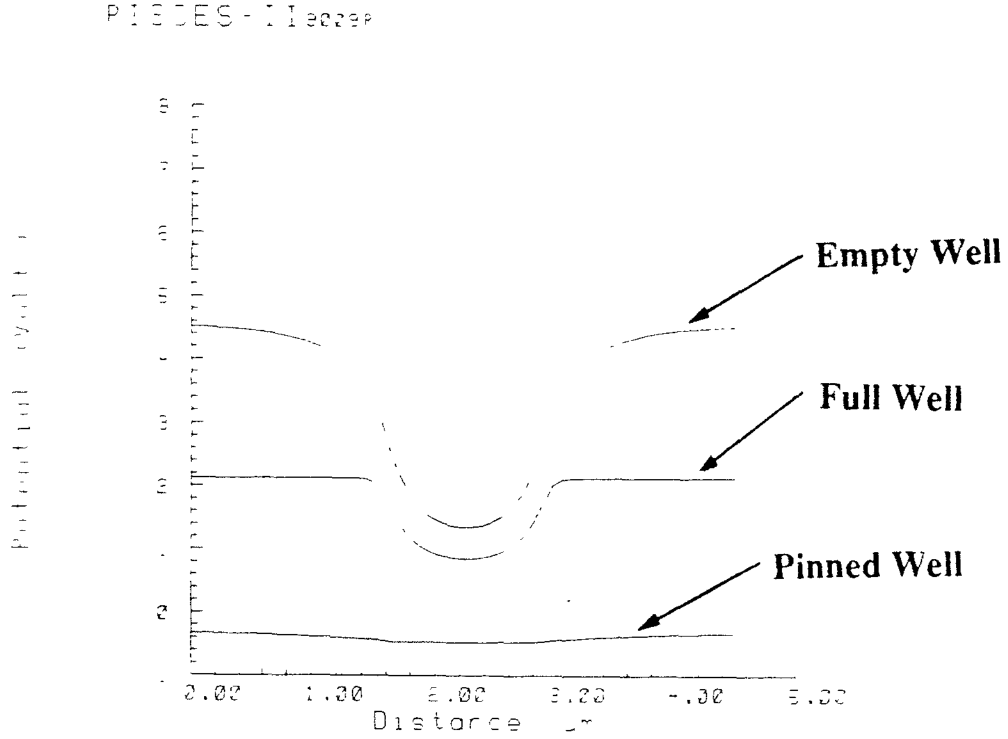
Full Well

Pinned Well

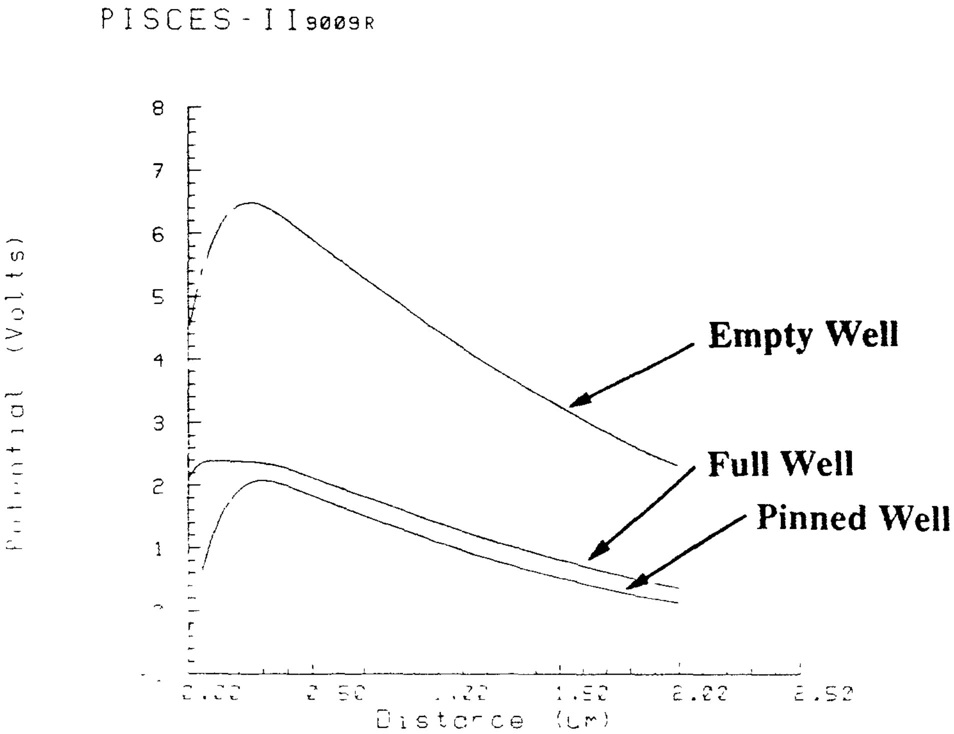
PISCES IIB Potential Profile for a Junction Depth of 0.50µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



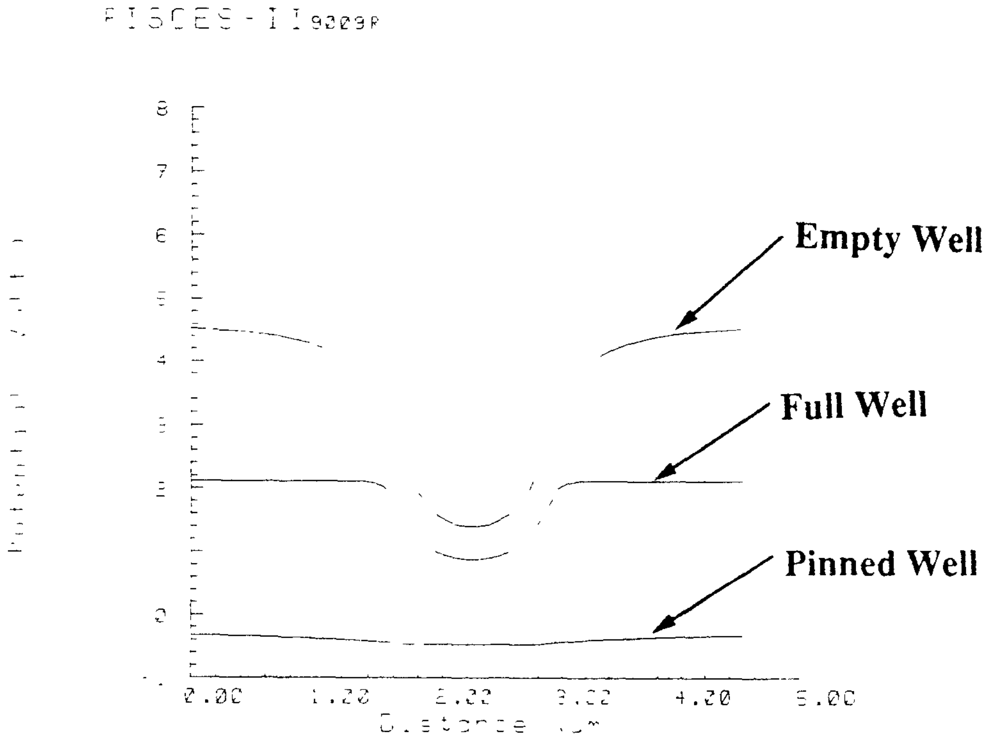
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.50µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



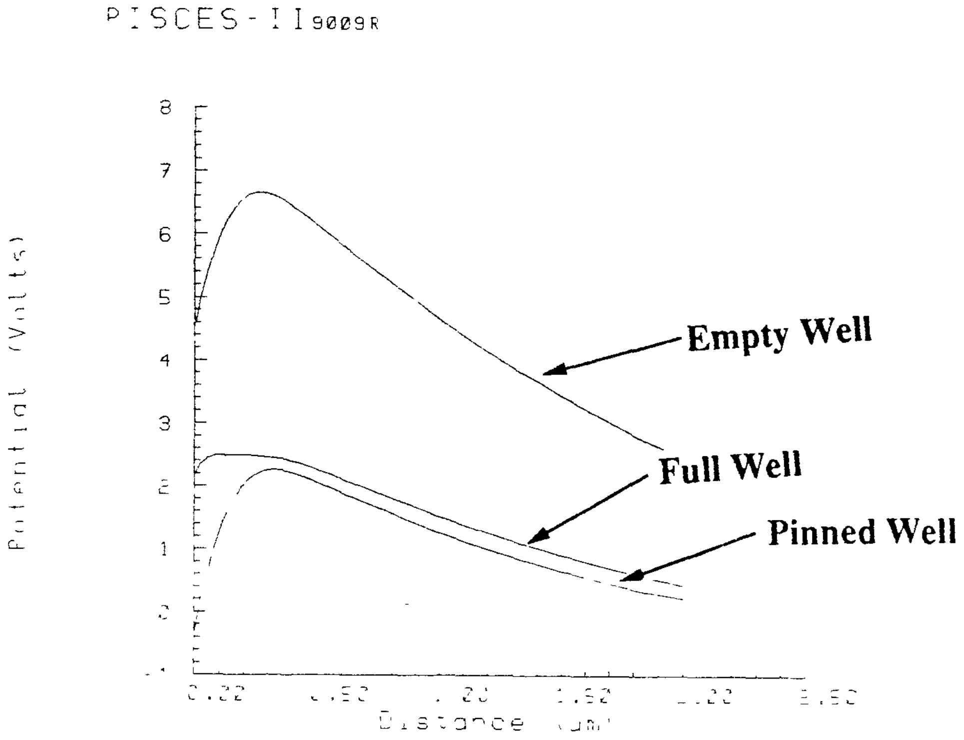
PISCES IIB Potential Profile for a Junction Depth of 0.55μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



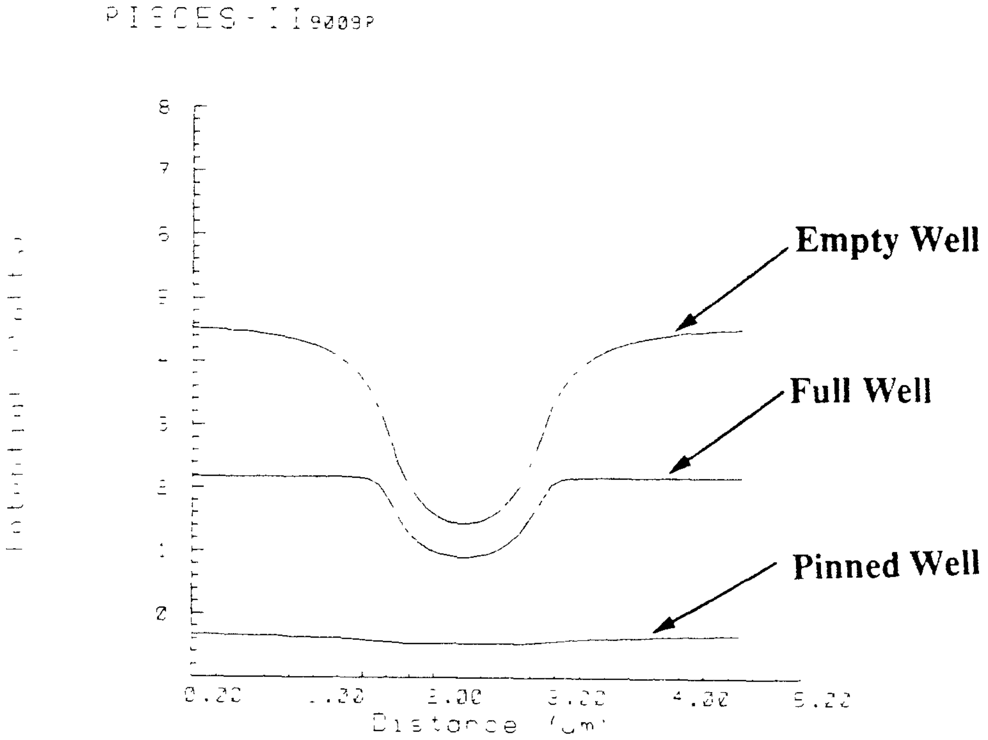
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.55μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



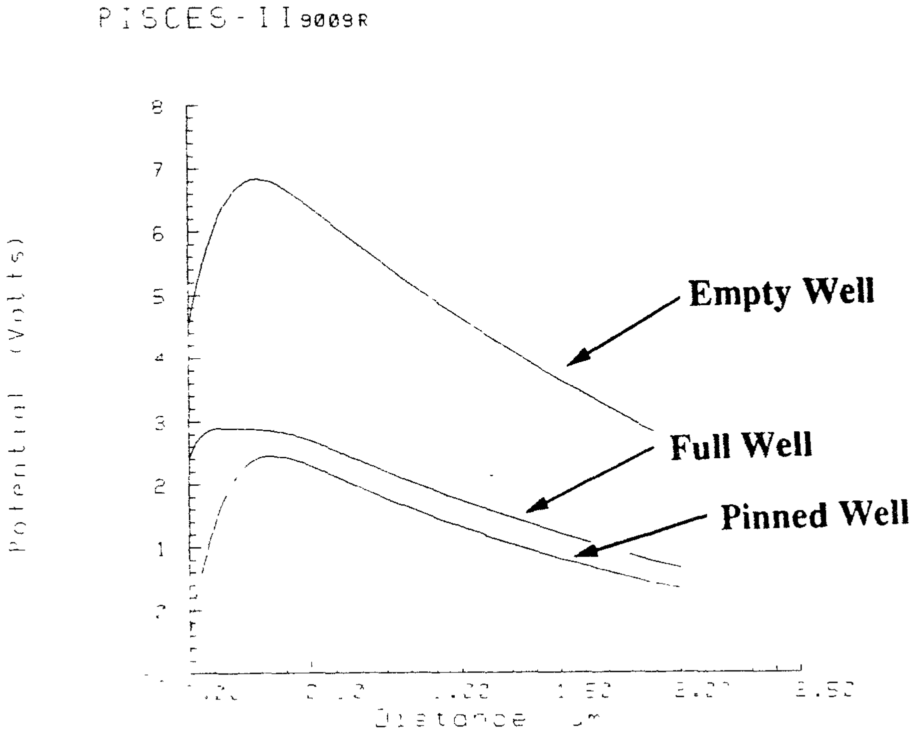
PISCES IIB Potential Profile for a Junction Depth of 0.60μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



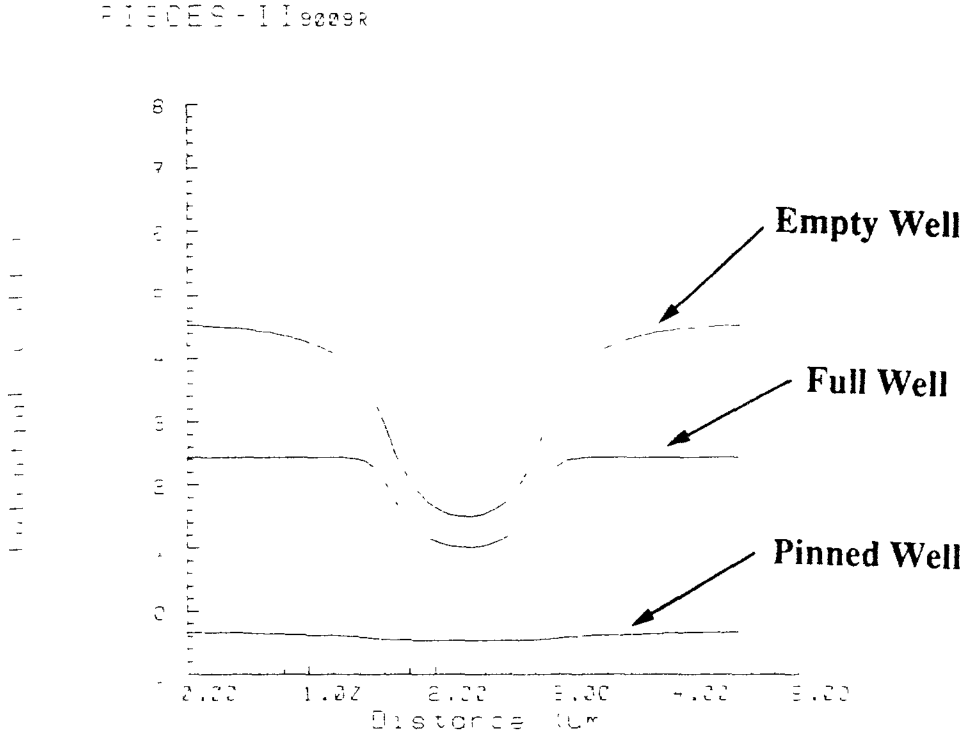
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.60μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



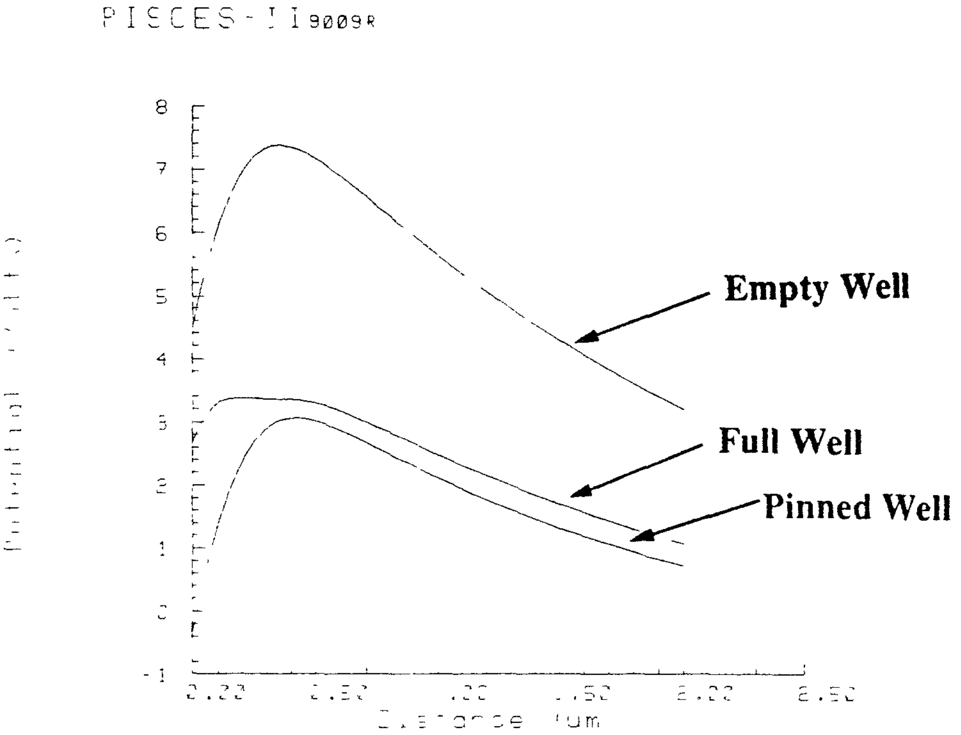
PISCES IIB Potential Profile for a Junction Depth of 0.70µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



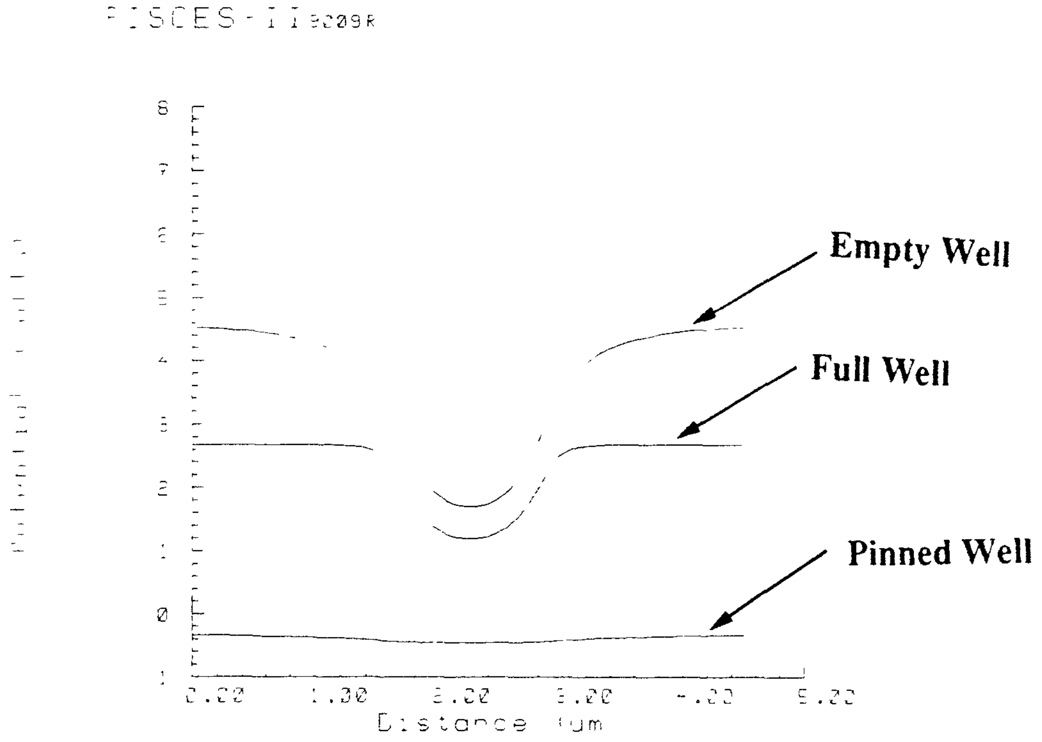
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.70µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



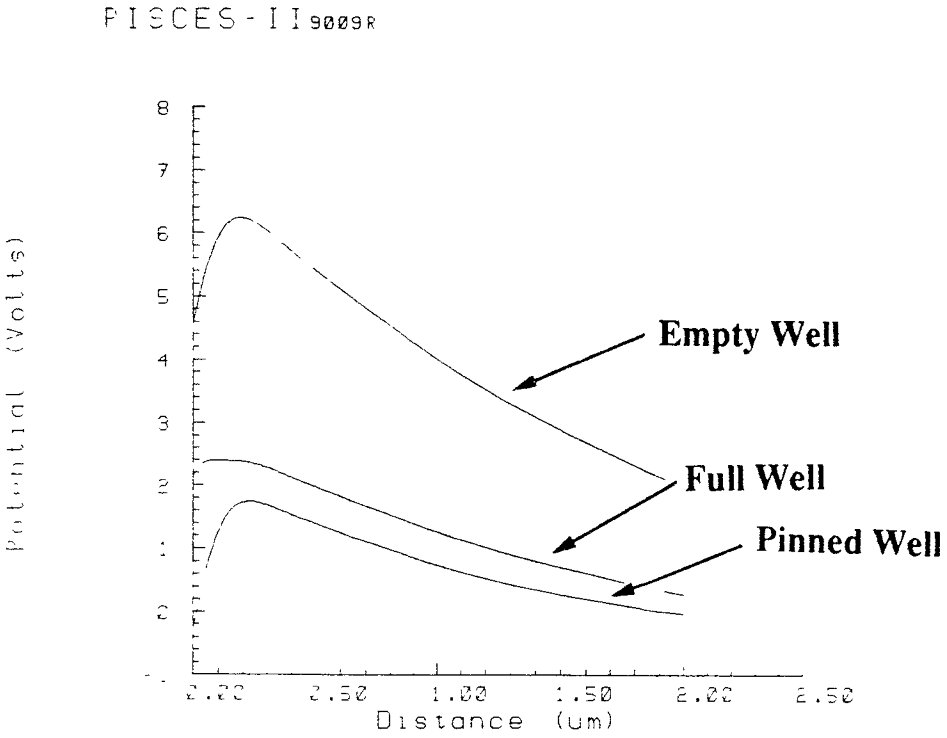
PISCES IIB Potential Profile for a Junction Depth of 0.80µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



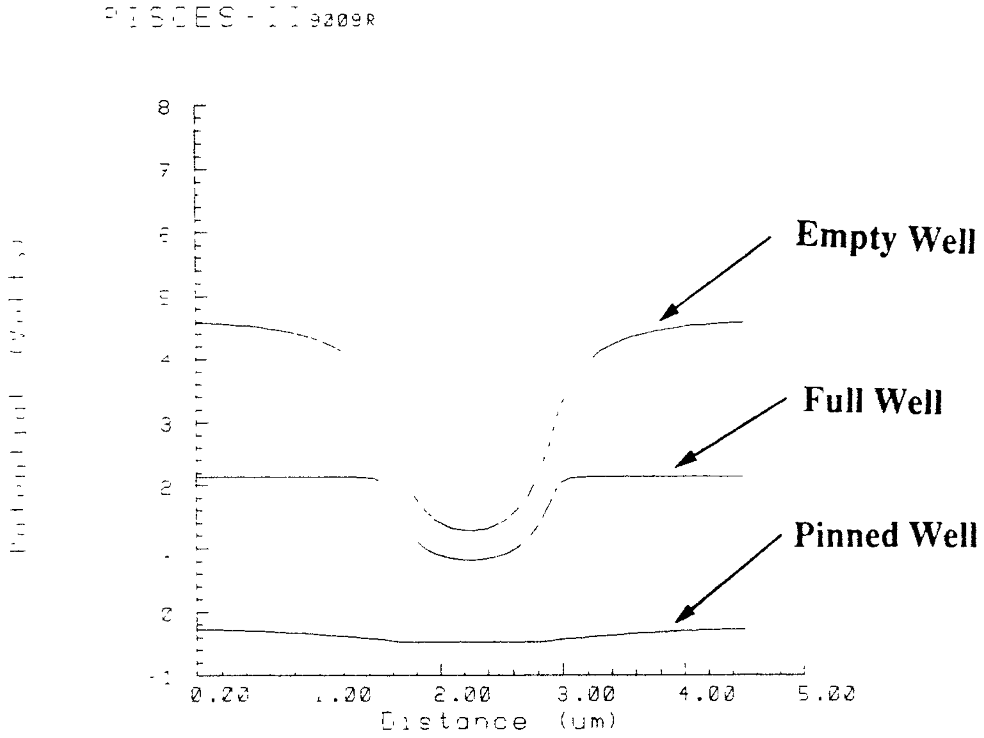
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.80µm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



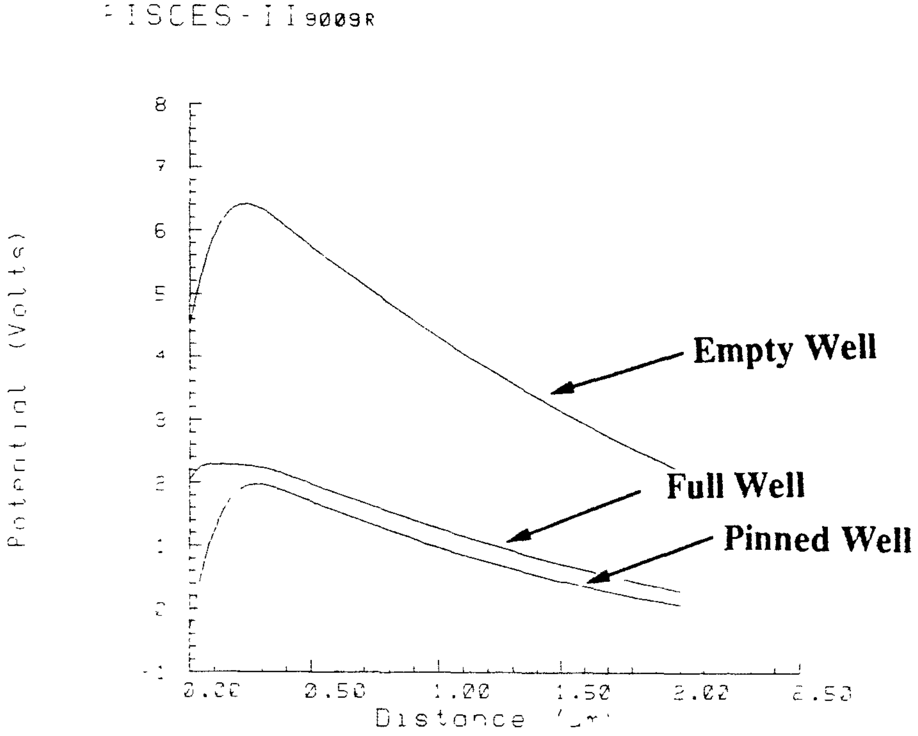
PISCES IIB Potential Profile for a Junction Depth of 0.40μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



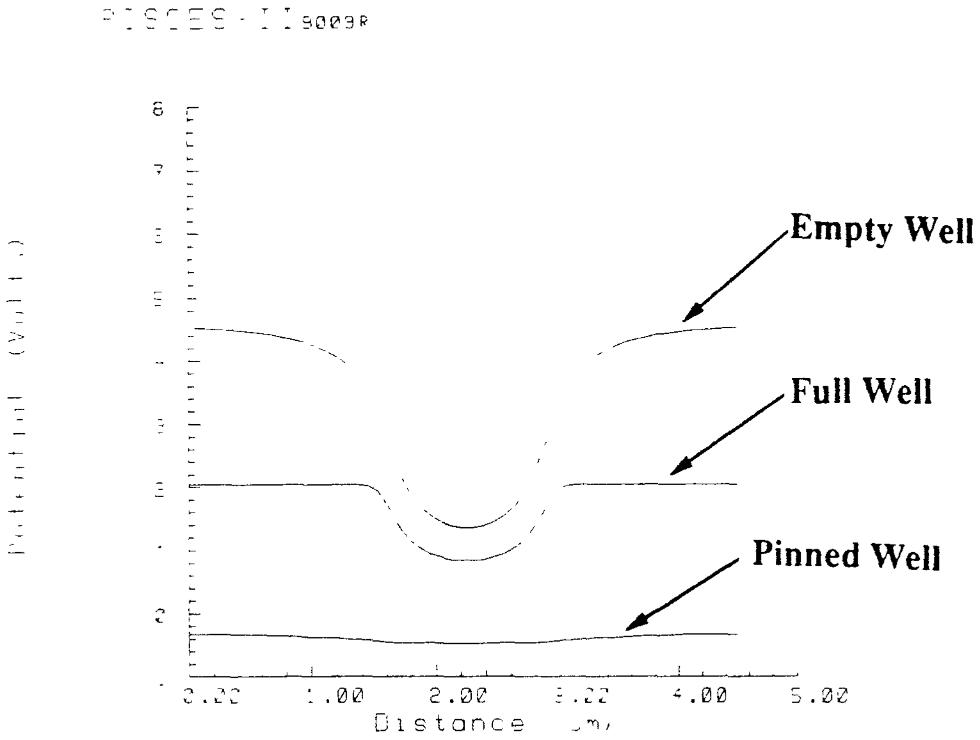
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.40μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



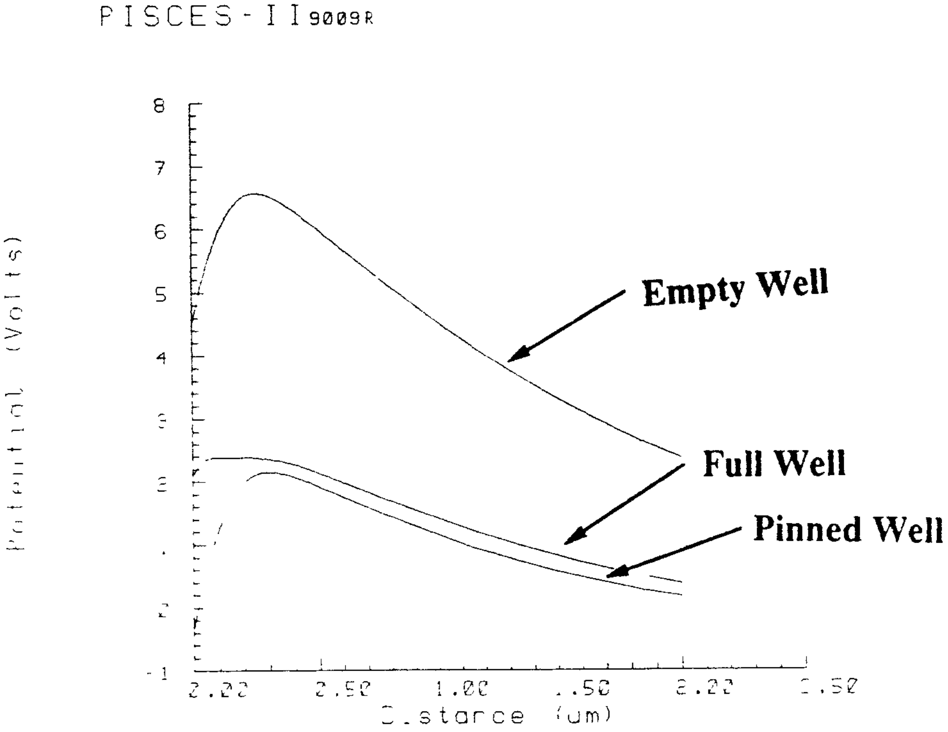
PISCES IIB Potential Profile for a Junction Depth of 0.50µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



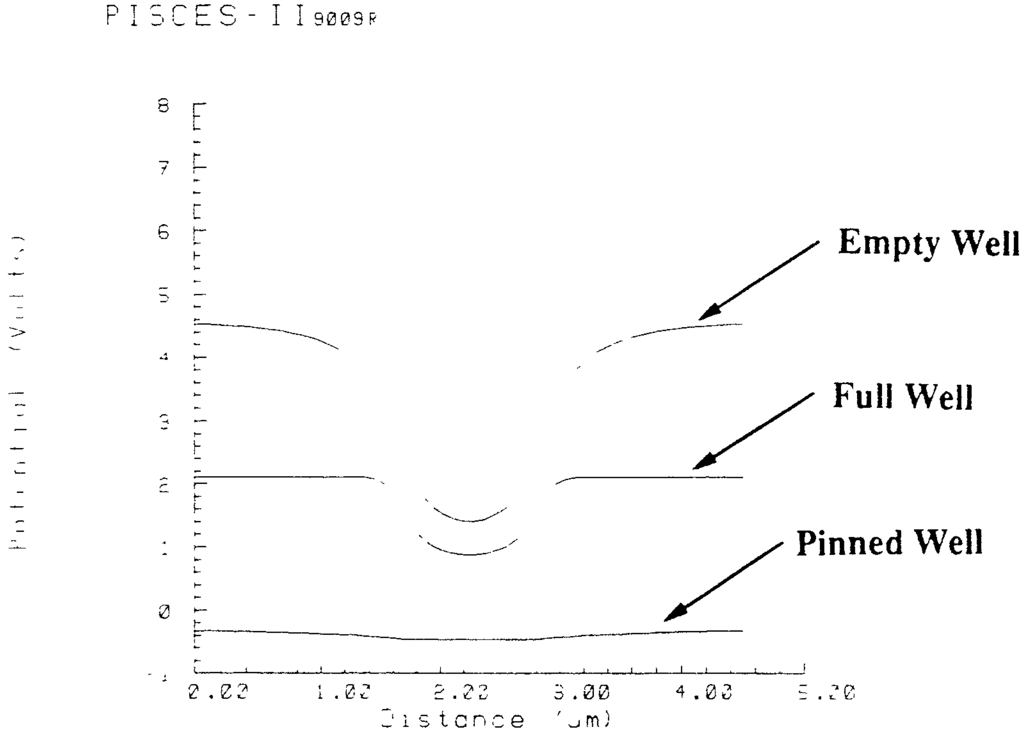
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.50µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



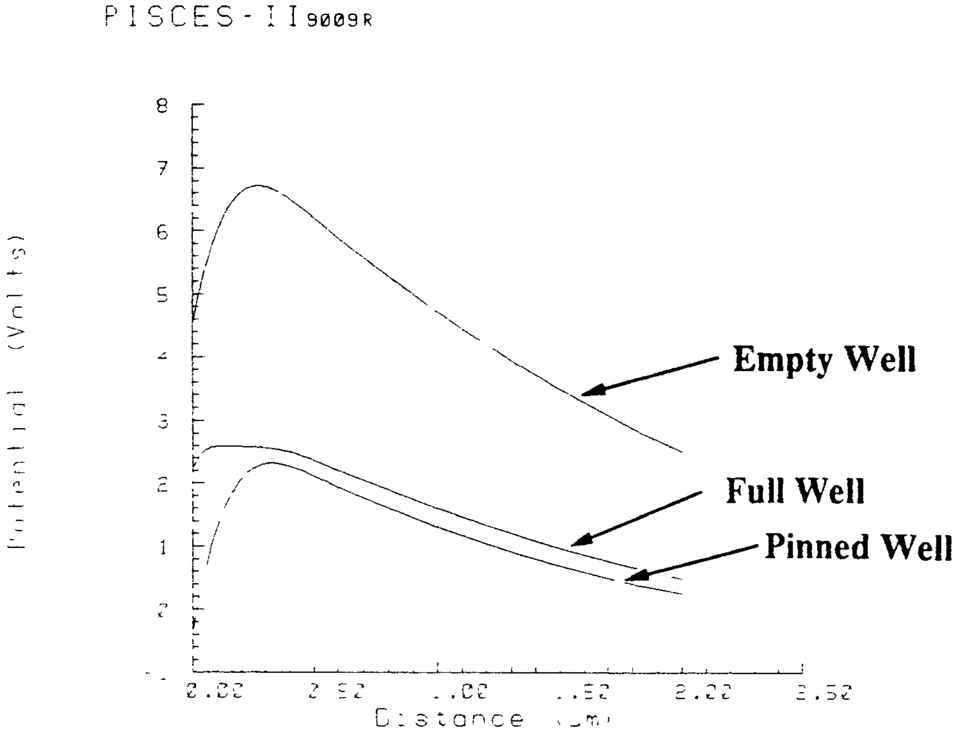
PISCES IIB Potential Profile for a Junction Depth of 0.55µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



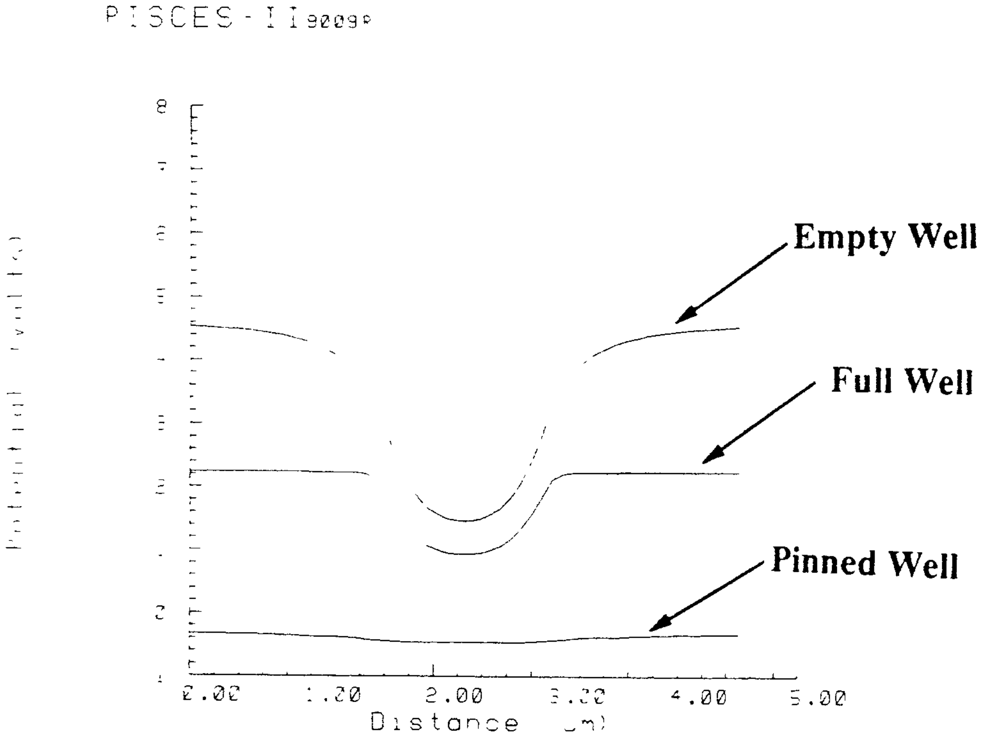
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.55µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



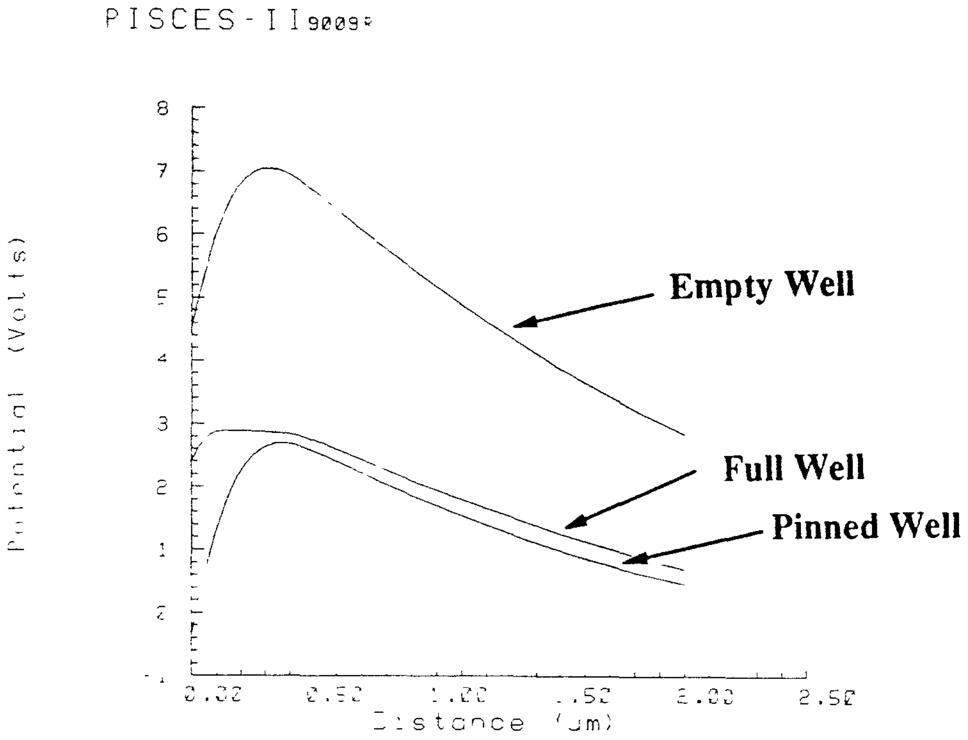
PISCES IIB Potential Profile for a Junction Depth of 0.60μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



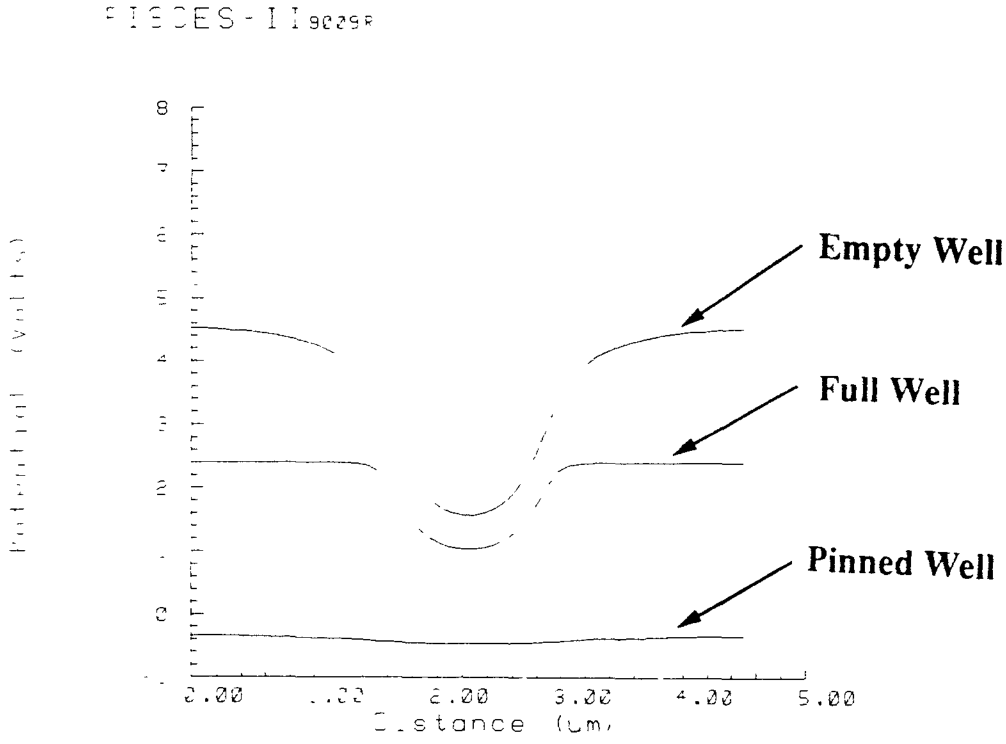
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.60μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



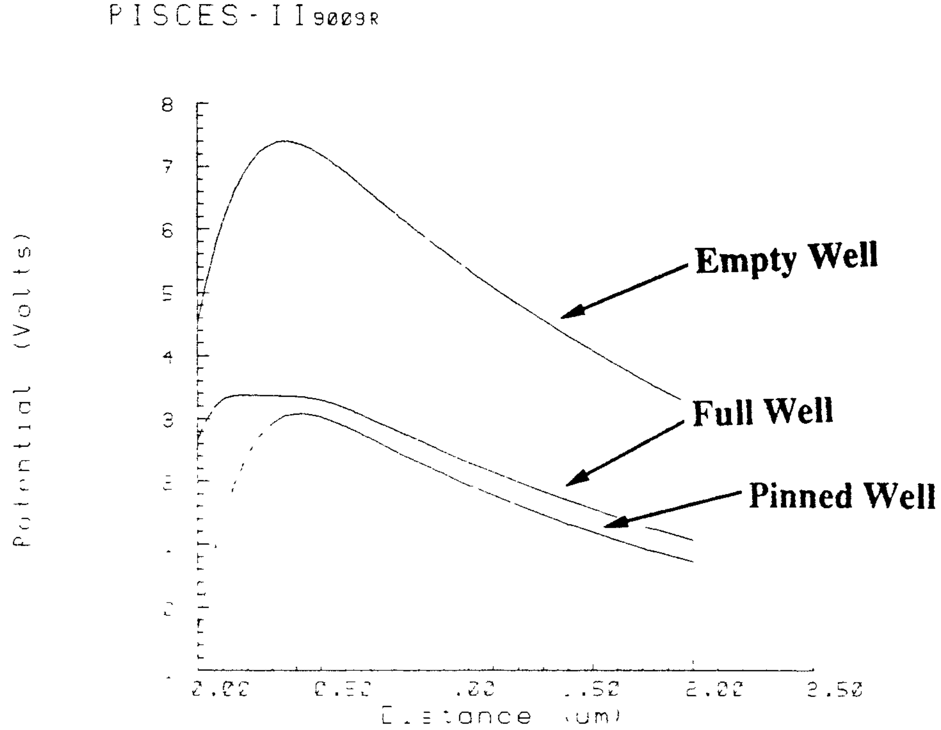
PISCES IIB Potential Profile for a Junction Depth of 0.70µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



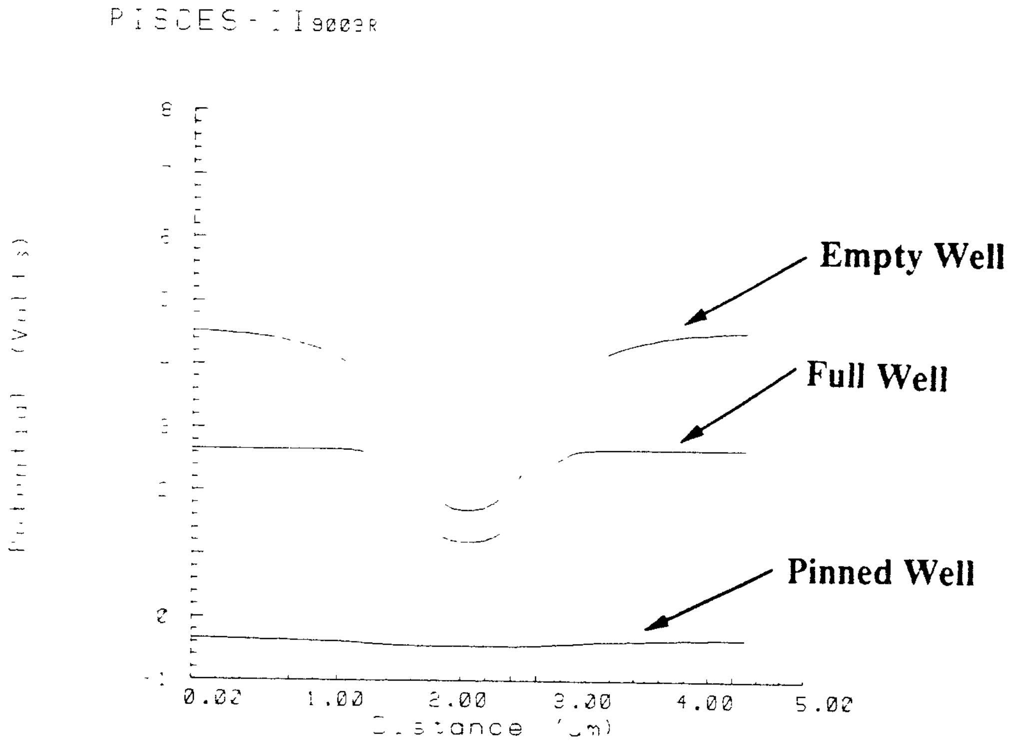
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.70µm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



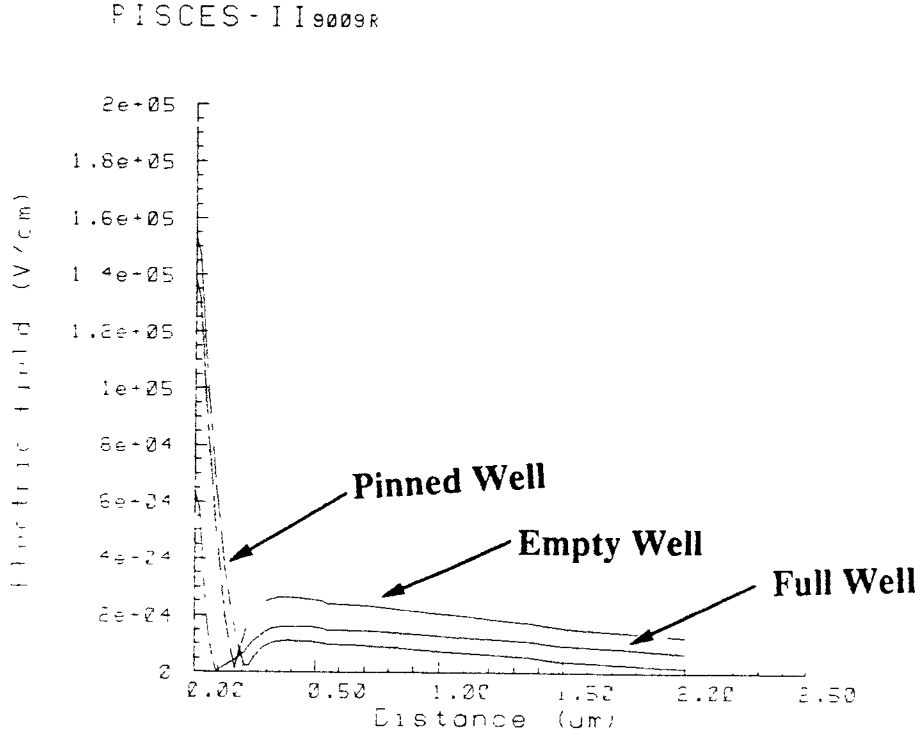
PISCES IIB Potential Profile for a Junction Depth of 0.80μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



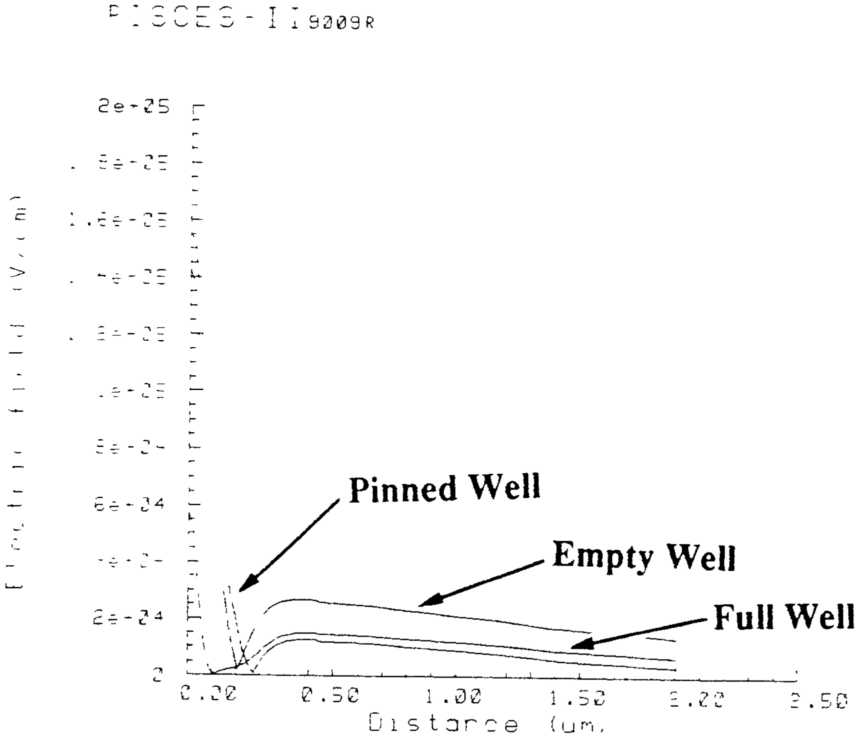
PISCES IIB Surface Potential Cross-Section for a Junction Depth of 0.80μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



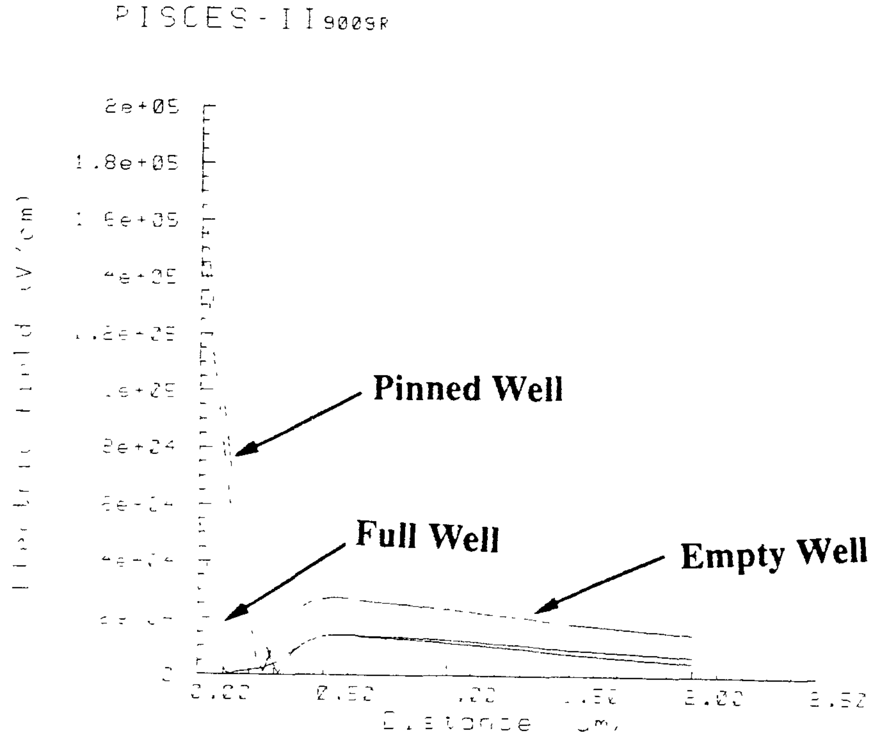
PISCES IIB Electric Field Profile for a Junction Depth of 0.40μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



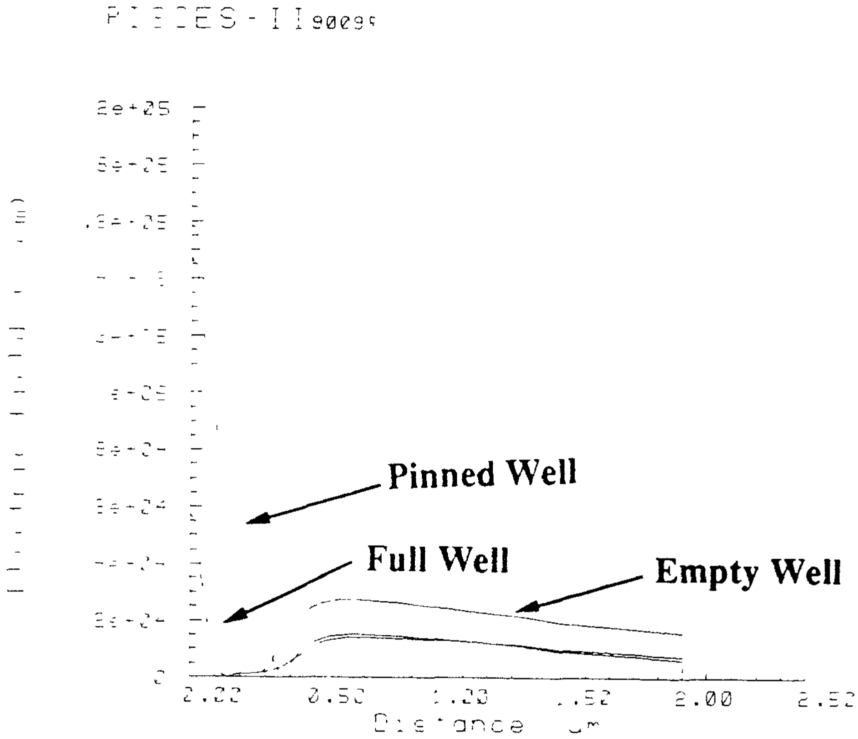
PISCES IIB Electric Field Profile for a Junction Depth of 0.50μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



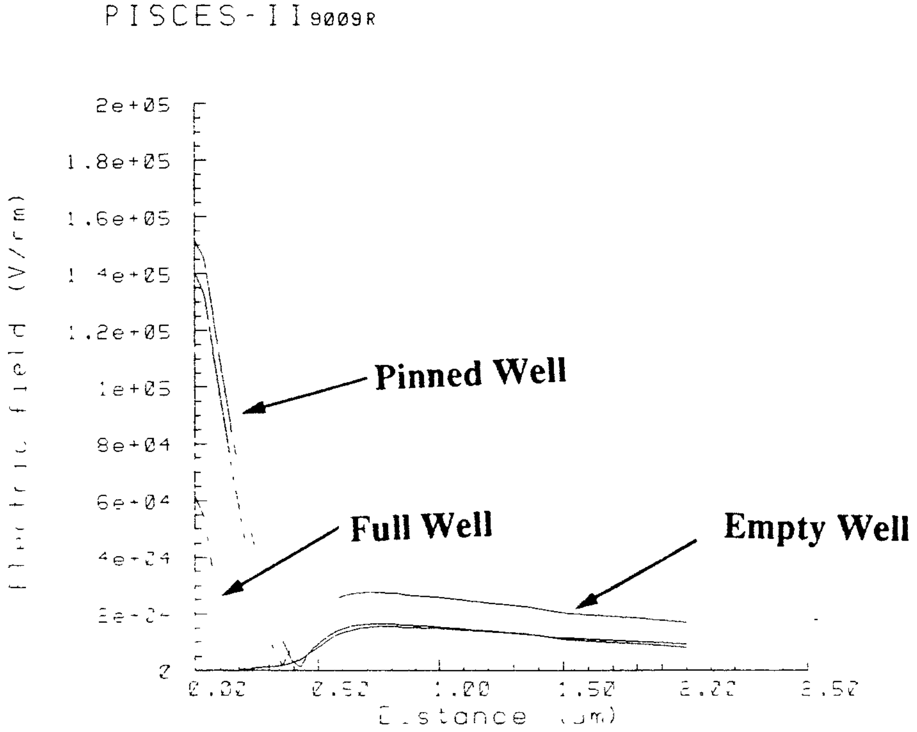
PISCES IIB Electric Field Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.70μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.80μm using a 100keV Arsenic Implant, Dose=1.3E12 ions/cm^2



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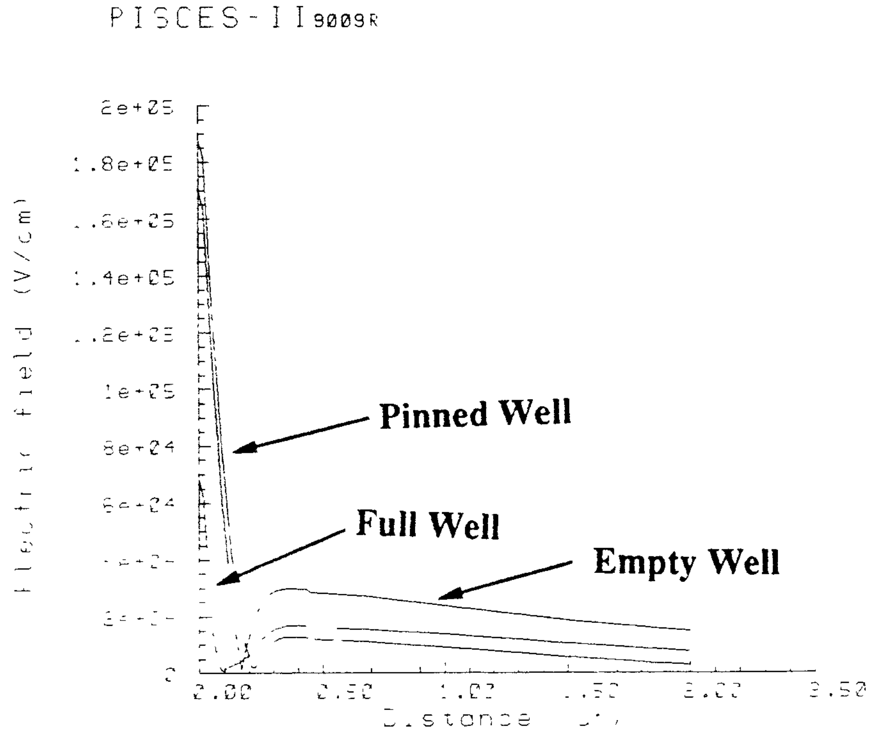

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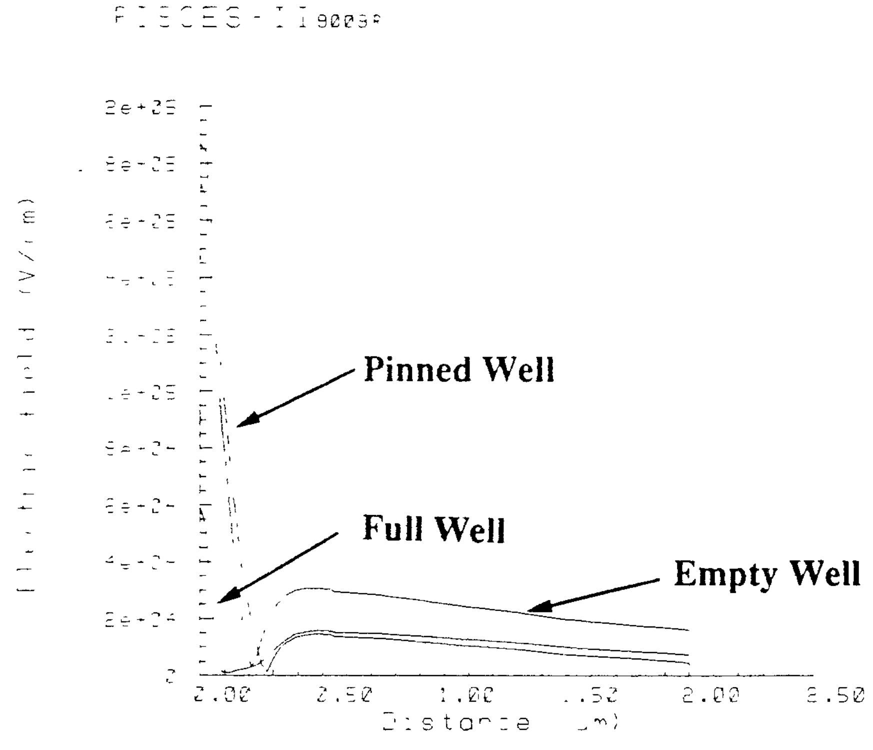
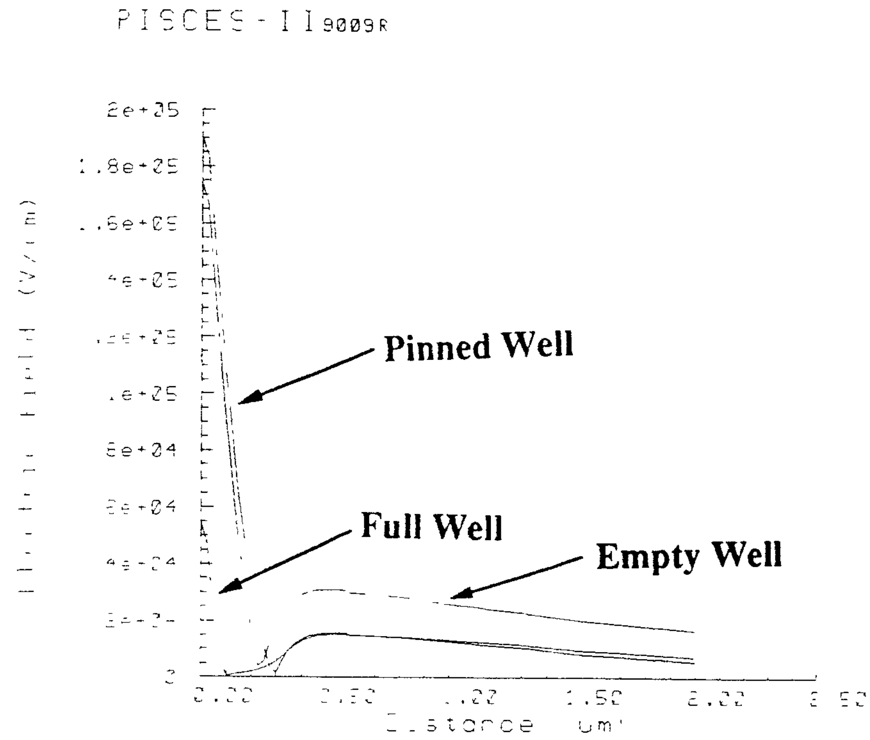
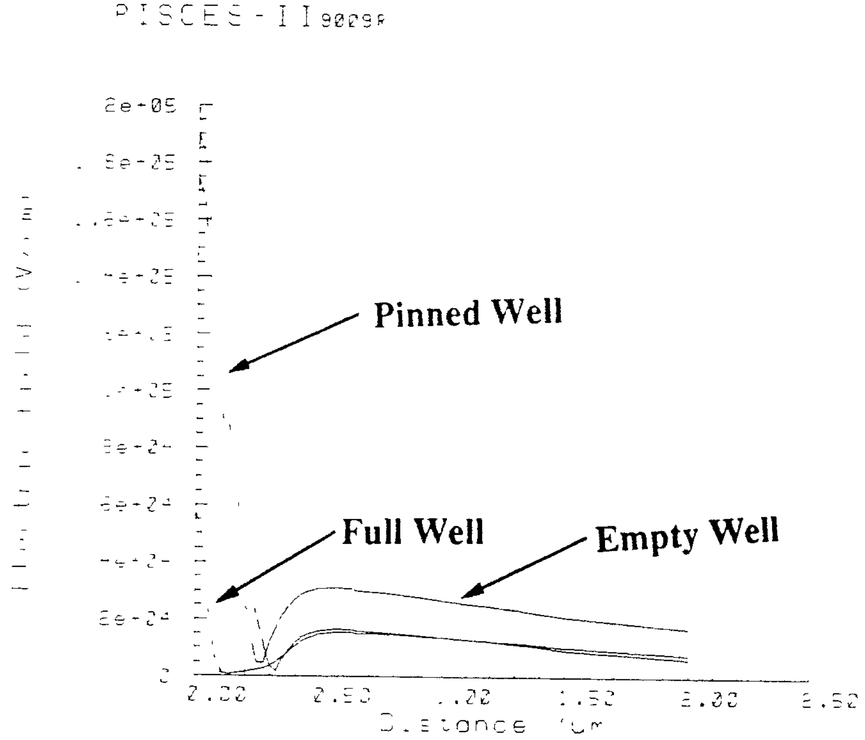


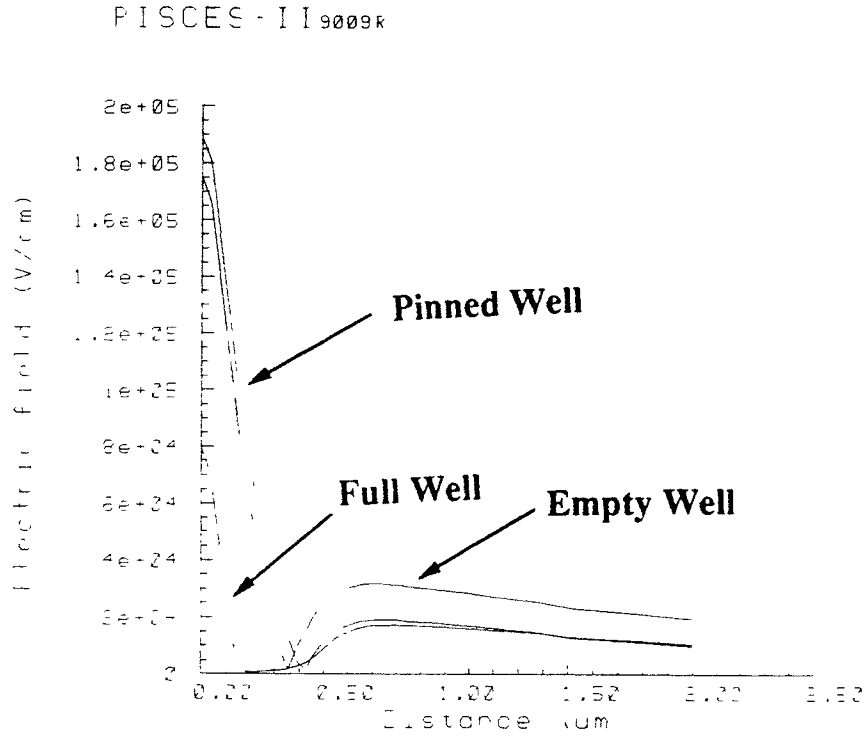
PISCES IIB Electric Field Profile for a Junction Depth of 0.55μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



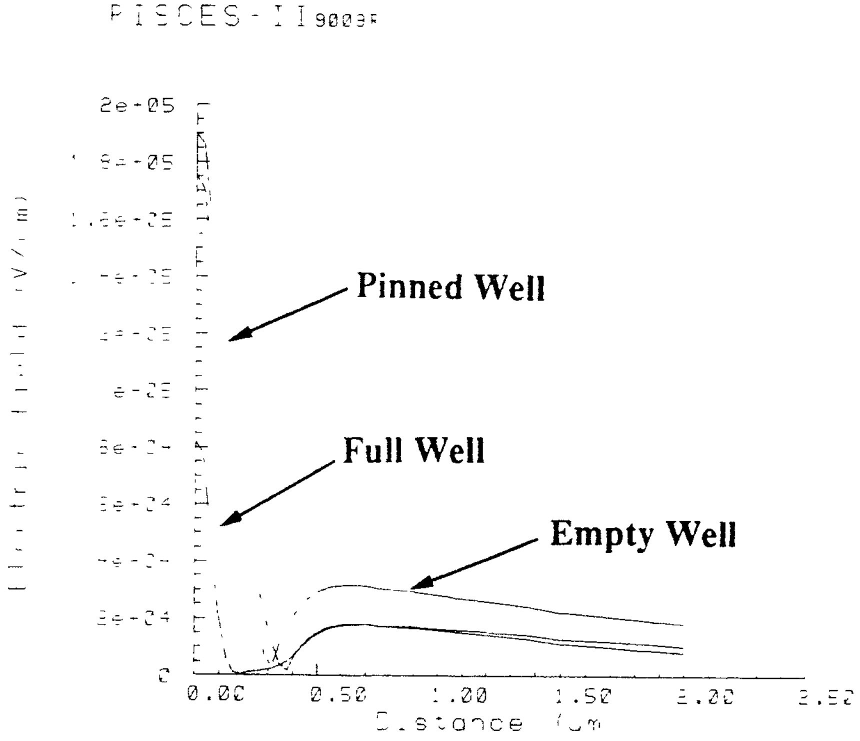
PISCES IIB Electric Field Profile for a Junction Depth of 0.60μm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



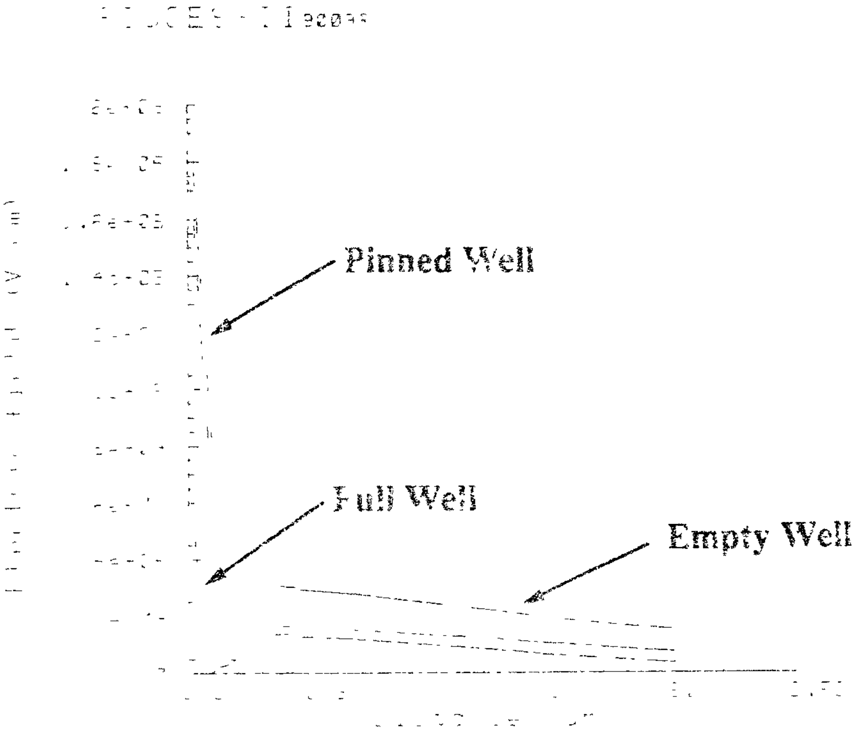
PISCES IIB Electric Field Profile for a Junction Depth of 0.70µm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



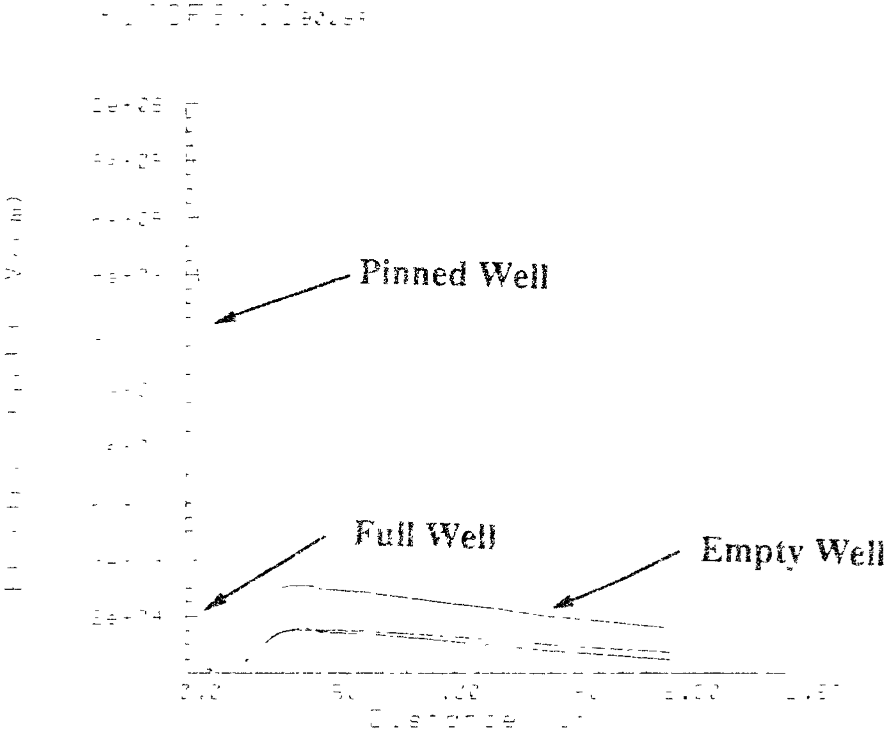
PISCES IIB Electric Field Profile for a Junction Depth of 0.80µm using a 100keV Arsenic Implant, Dose=1.6E12 ions/cm^2



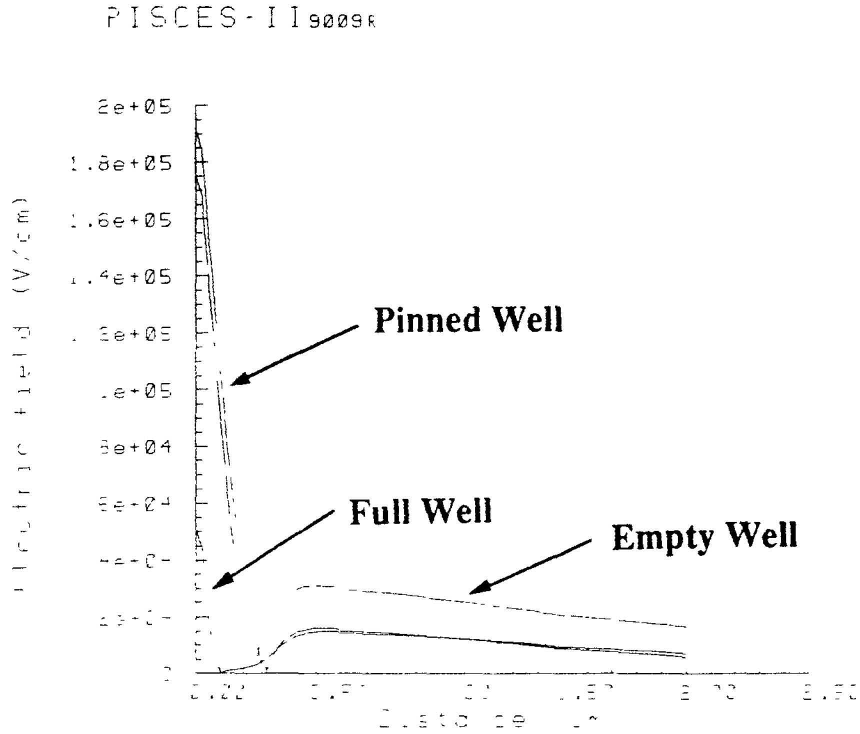
PISCES IIB Electric Field Profile for a Junction Depth of 0.40μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.50μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.55μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2

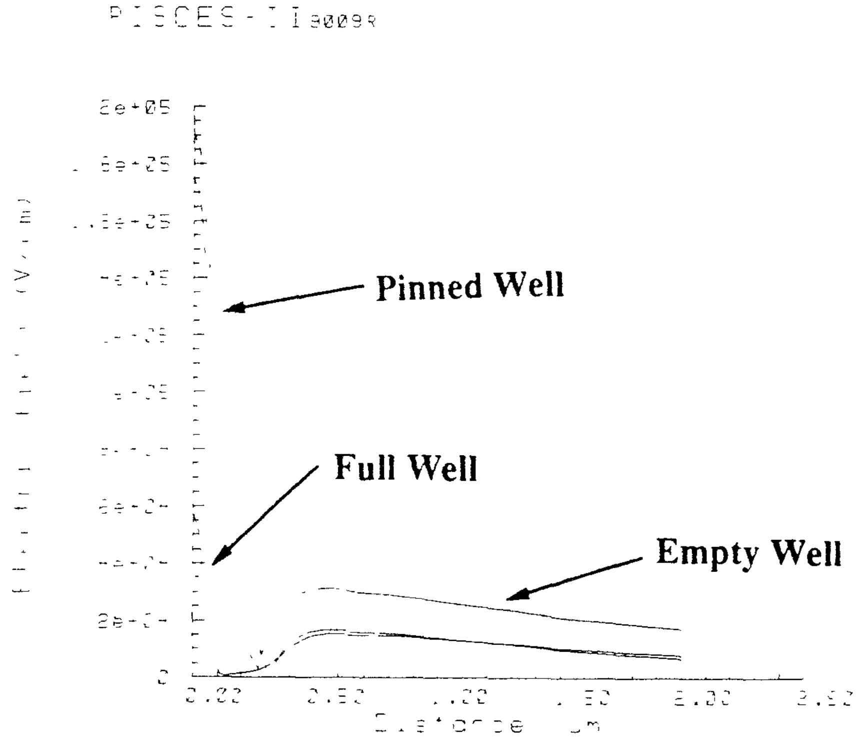


Pinned Well

Full Well

Empty Well

PISCES IIB Electric Field Profile for a Junction Depth of 0.60μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2

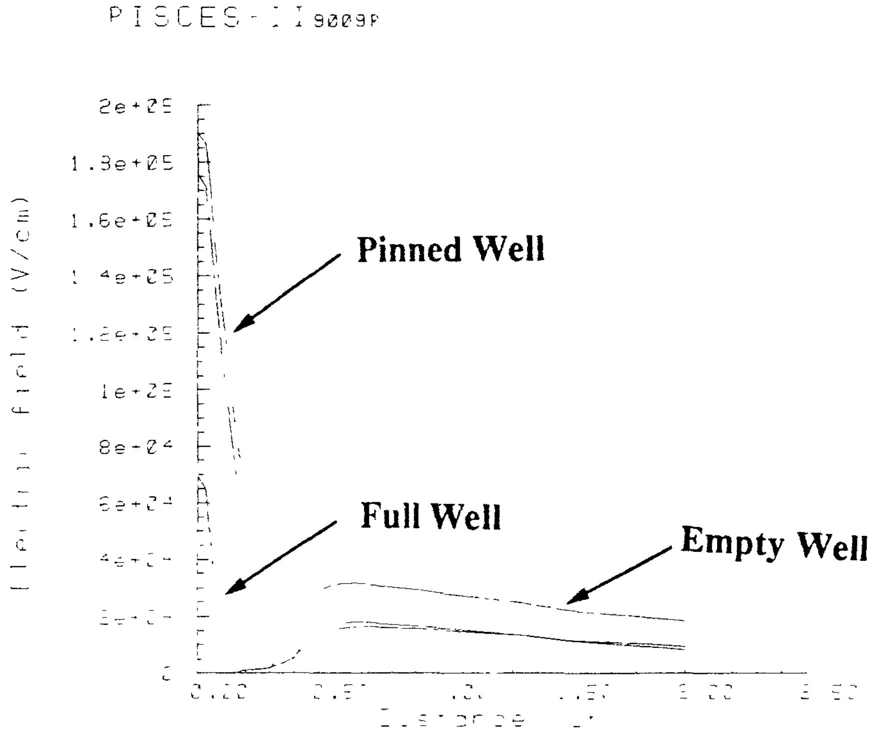


Pinned Well

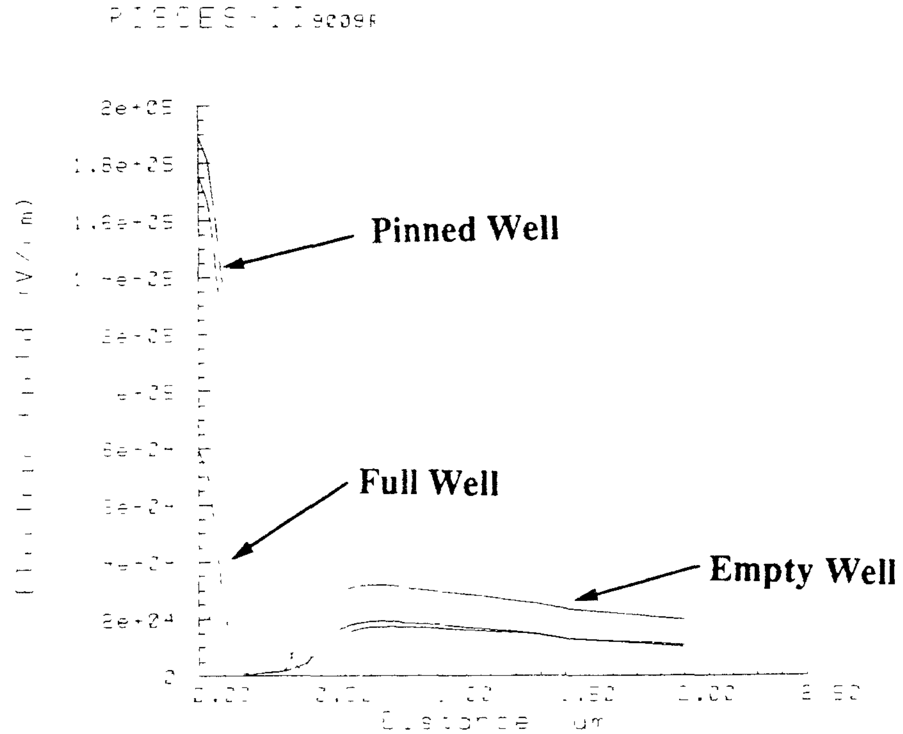
Full Well

Empty Well

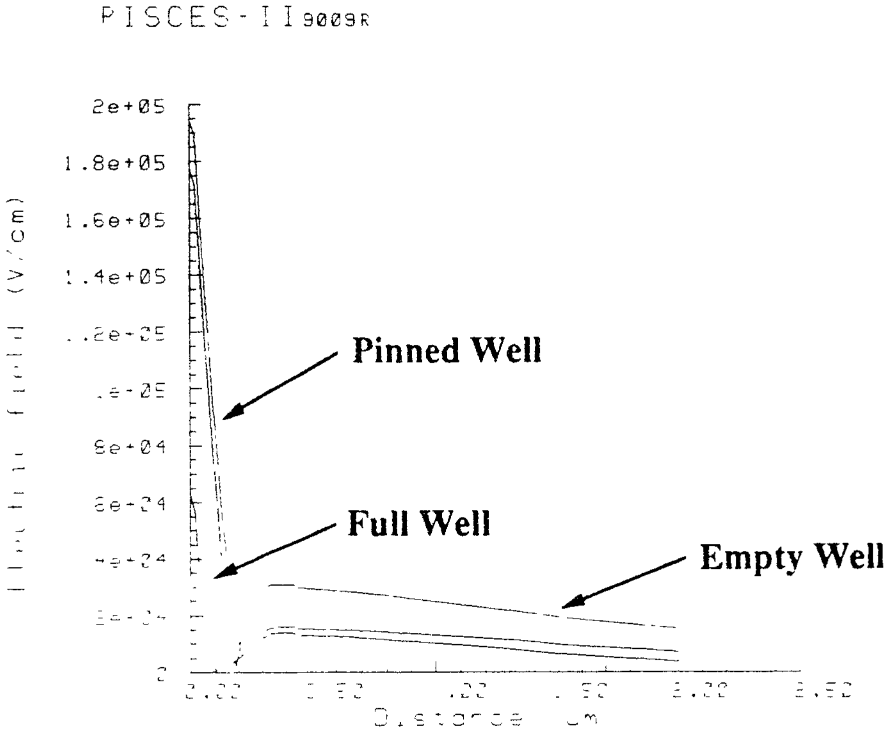
PISCES IIB Electric Field Profile for a Junction Depth of 0.70μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



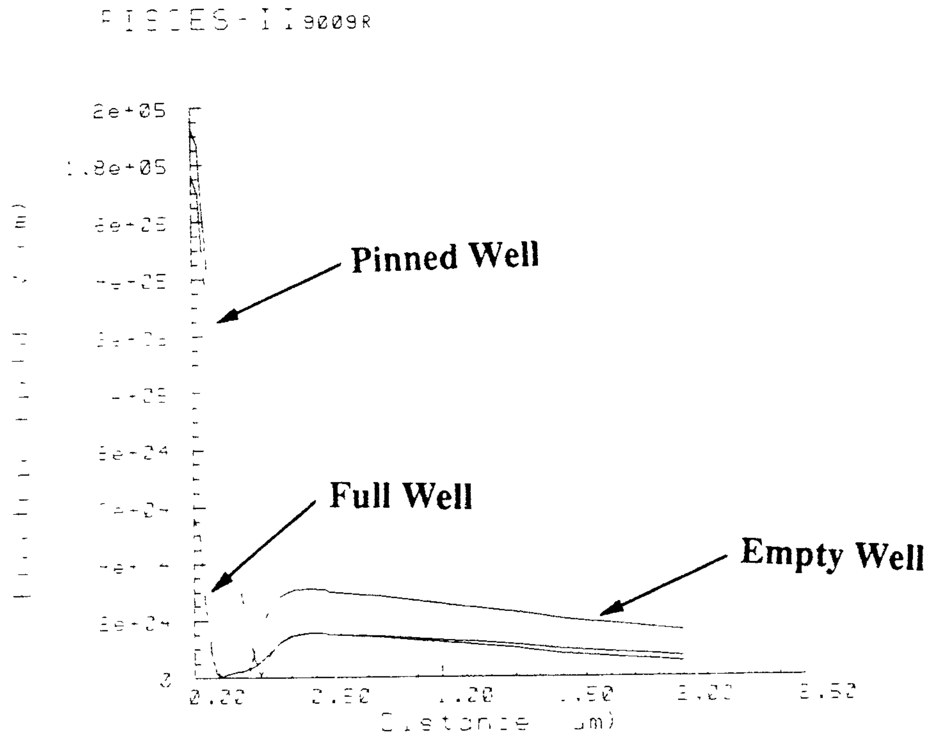
PISCES IIB Electric Field Profile for a Junction Depth of 0.80μm using a 150keV Arsenic Implant, Dose=1.6E12 ions/cm^2



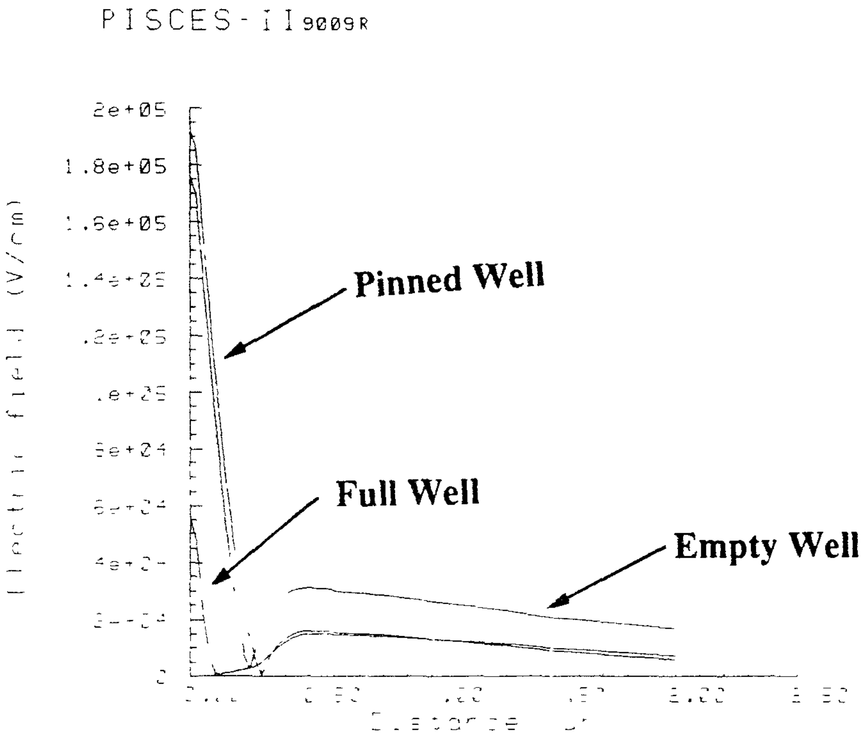
PISCES IIB Electric Field Profile for a Junction Depth of 0.40μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



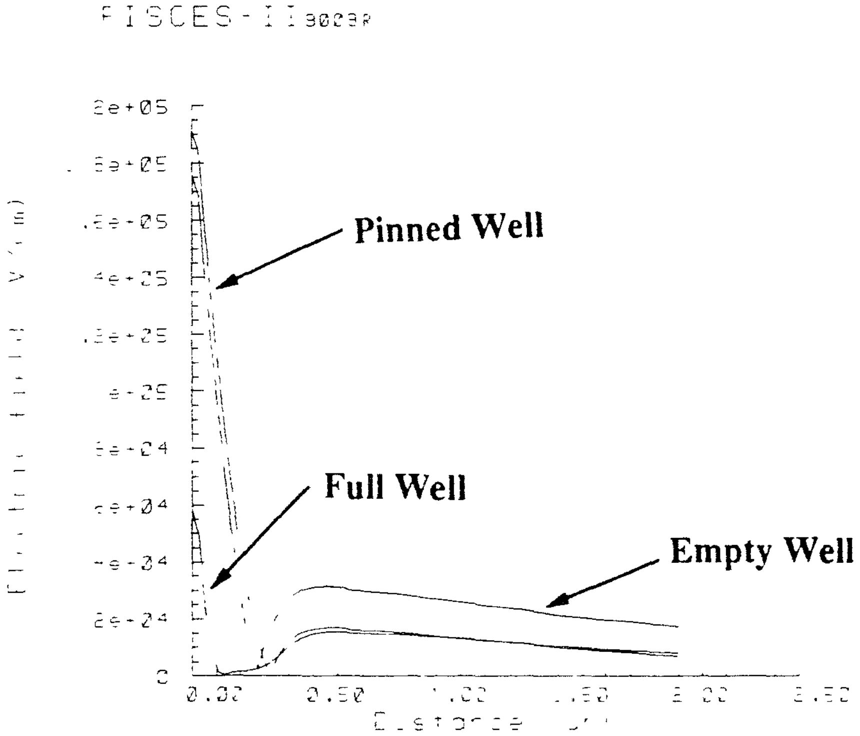
PISCES IIB Electric Field Profile for a Junction Depth of 0.50μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



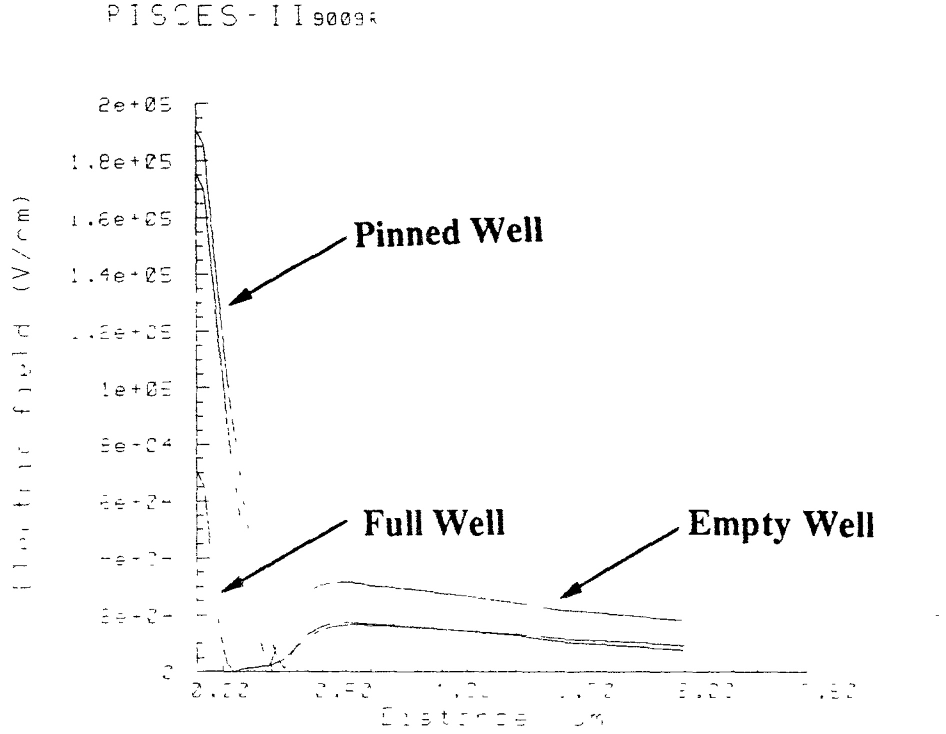
PISCES IIB Electric Field Profile for a Junction Depth of 0.55μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



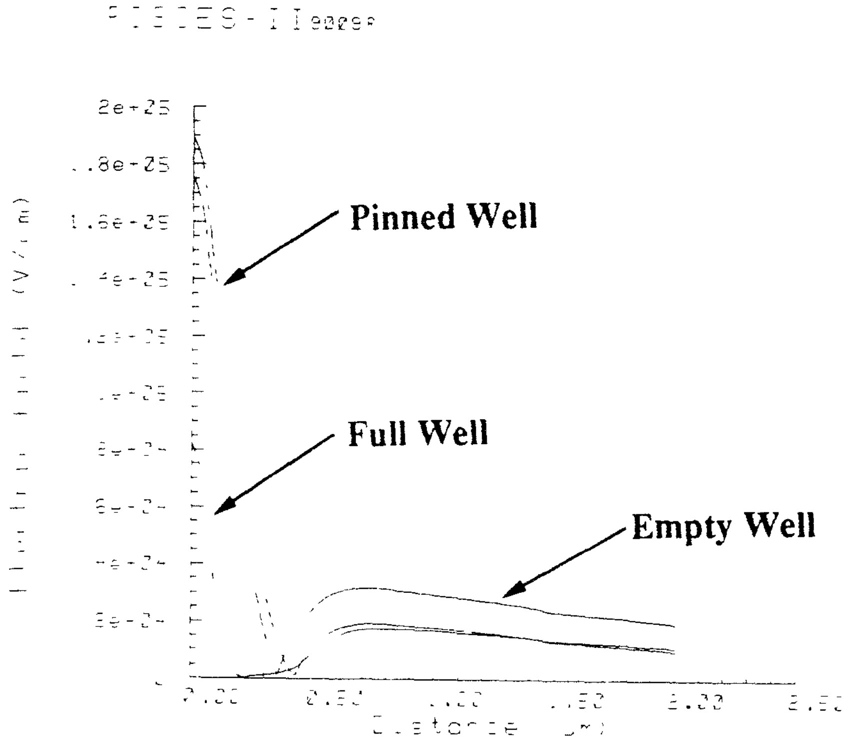
PISCES IIB Electric Field Profile for a Junction Depth of 0.60μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



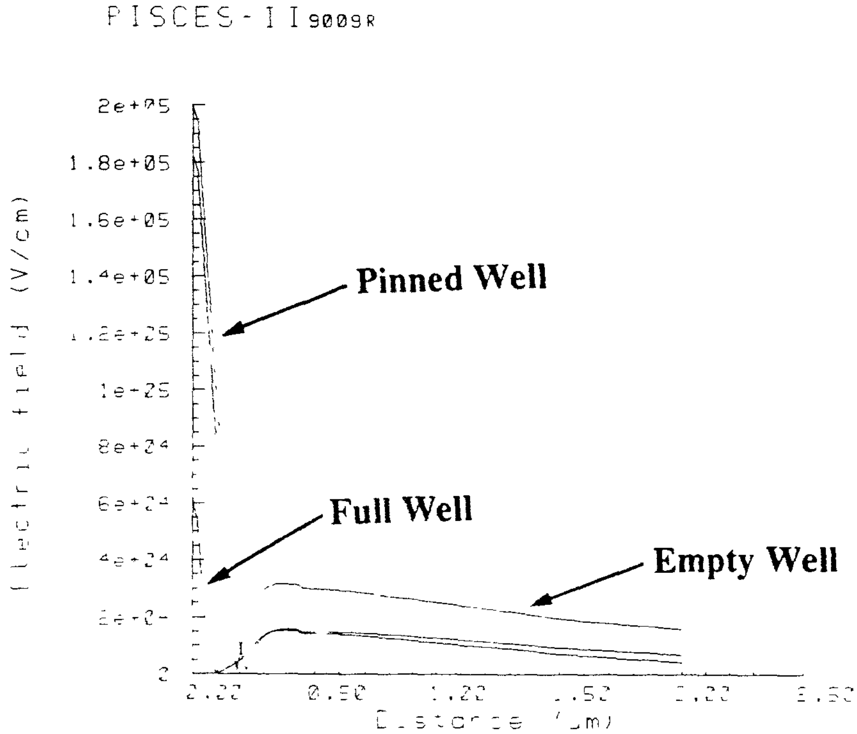
PISCES IIB Electric Field Profile for a Junction Depth of 0.70μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



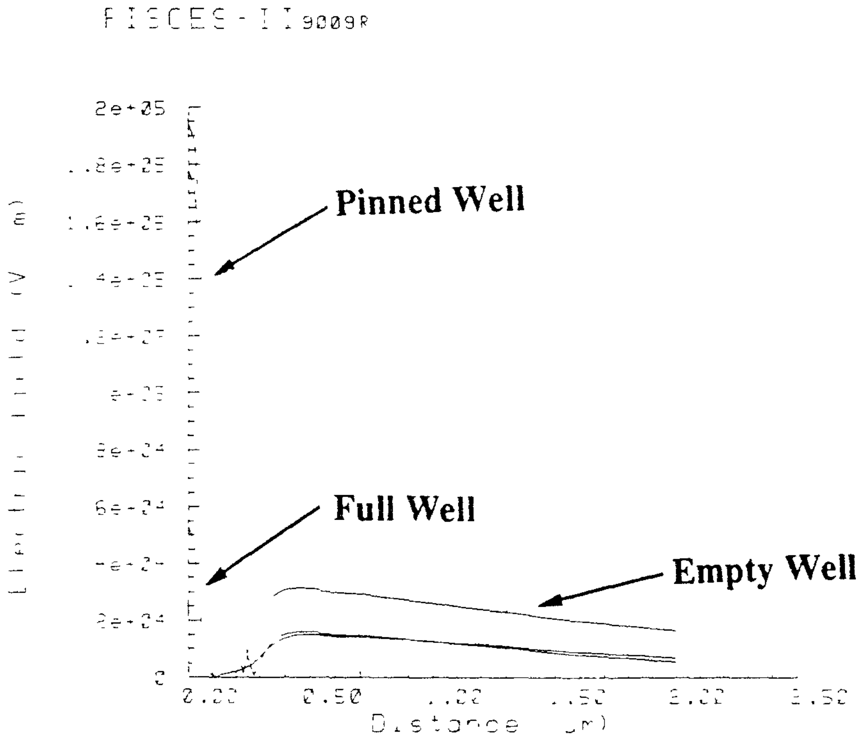
PISCES IIB Electric Field Profile for a Junction Depth of 0.80μm using a 175keV Arsenic Implant, Dose=1.6E12 ions/cm^2



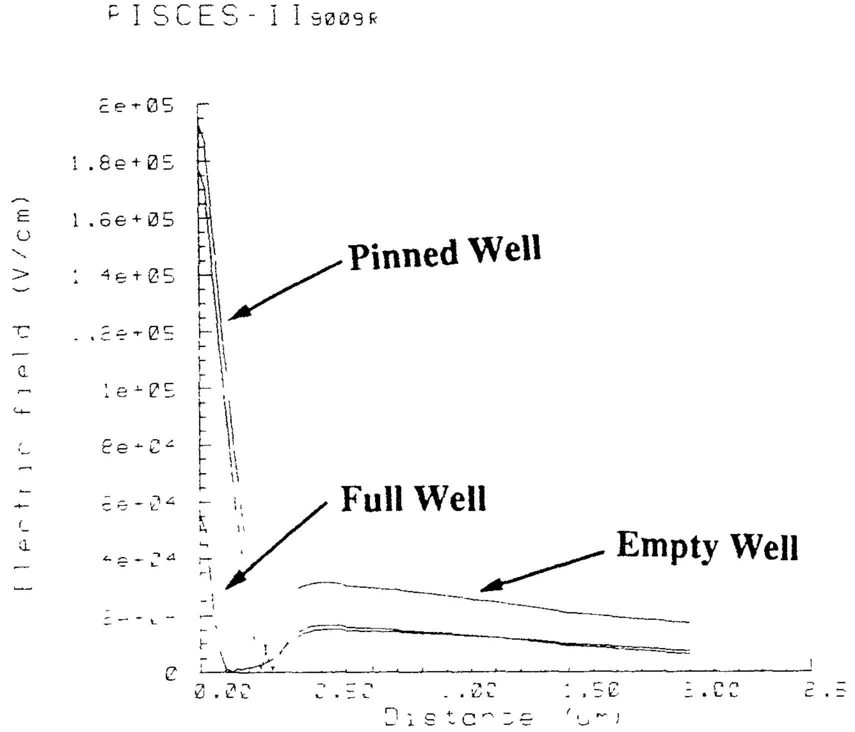
PISCES IIB Electric Field Profile for a Junction Depth of 0.40μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



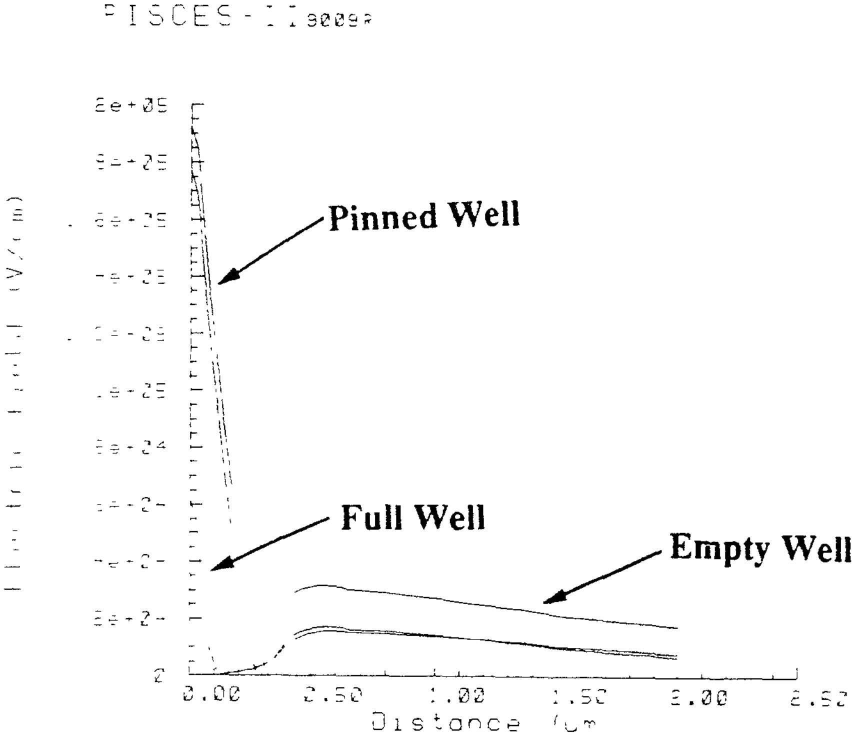
PISCES IIB Electric Field Profile for a Junction Depth of 0.50μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



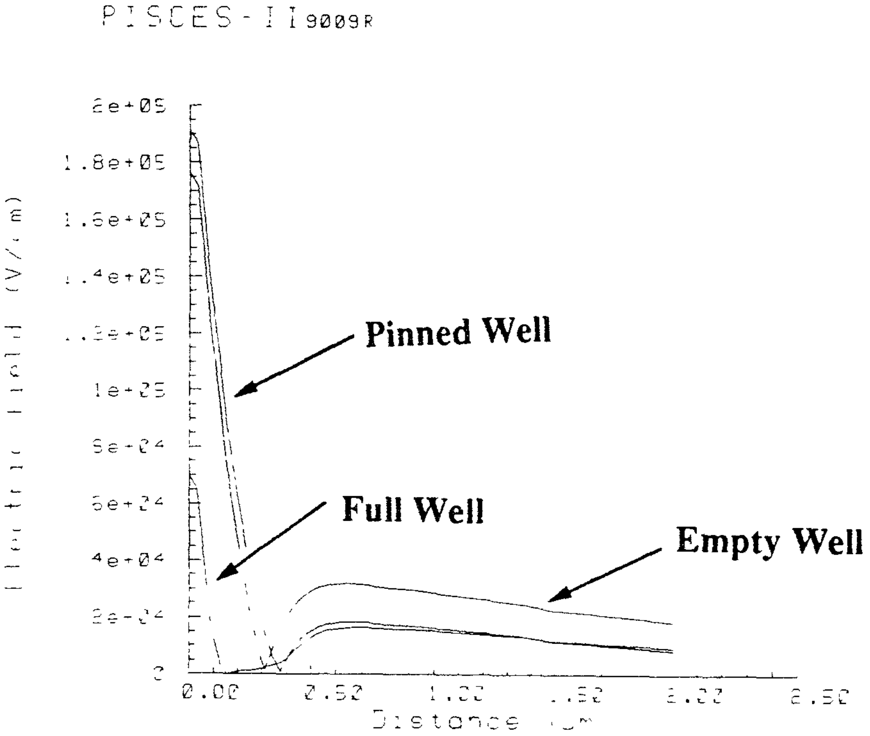
PISCES IIB Electric Field Profile for a Junction Depth of 0.55μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.60μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.70μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2



PISCES IIB Electric Field Profile for a Junction Depth of 0.80μm using a 200keV Arsenic Implant, Dose=1.6E12 ions/cm^2