CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter will be explaining and discuss the methodology used in this project. Basically, before a result can be obtained, a structure must be initially generated in the process simulation. So this chapter will firstly show and explain about the structure generation done in the process simulation. This will be followed by the methodology used in the characterization and analysis of the structure. The description of the step-by-step methodology will be based on the command, statement and parameters used in the input file. The process simulation tool used in this work is Taurus TSUPREM 4, which is one of the most accurate semiconductor process tools.

TSUPREM-4 is the industry-standard 1D/2D process simulation tool that is widely used by semiconductor companies to optimize IC fabrication processes. With the most advanced mode commercially available, TSUPREM-4 simulates the physical effects (e.g. transient enhanced diffusion and stress-dependent oxidation) found in leading-edge semiconductor processing.

The result is the generation of precise device structures that allow inexpensive what-if experiments through simulation, minimizing the need for processing test wafers. Thus, TSUPREM-4 can optimize device geometry to reduce product development cycles

and shorten product time to market. This software helps Design leading-edge MOS and bipolar manufacturing processes and devices, Investigate ion implantation processes, including the effects of arbitrary wafer tilt and dose, implant depth, shadowing, damage and ion channeling, Study impurity diffusion, including transient enhanced diffusion (TED), oxidation-enhance diffusion (OED), interstitial clustering and trapping of dopants at interface (dose-loss).Analyze stresses in all layers as a result of non-uniform oxidation, thermal mismatch, predict one- and two-dimensional device structure characteristics by accurately simulation ion implantation, diffusion, oxidation, solicitation, epitaxy, etching, deposition and photo resist processing[27].

In this work, two special structures will be generated in the simulation. This special structure generates will be labeled as structure A and structure B (refer figure 3.11 and 3.10). this special structure A and B is generated based on the bipolar junction transistor base region structure (show in figure 3.0).

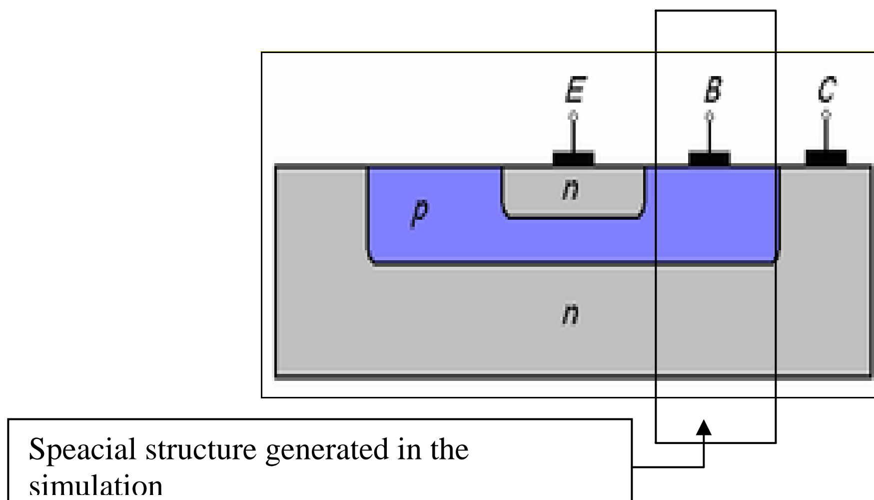

Figure 3.0: Speacial structure A & B generate from the BJT structure [7]

The discussion will be extended to the different between the special structure A and structure B. The difference between the special structures is the shape of the structures. The method and parameters used to produce both structure A and B is similar. This project is focused on structure A, because the special structure B is generated to observed the effect of the ion projection.

3.1 Structure Generation In Process Simulation

Both the special structure will be generated by using Taurus TSUPEM-4 TCAD. First, a special bare wafer is doped with arsenic to form a bare arsenic wafer. The arsenic concentration used is 1 x $10^{15}/cm^3$. Then, the process is followed by deposit silicon P-type doping underlying layer. This process is doping the underlying layer with P type material (boron) by using deposition method. The thickness of the underlying layer is 0.025 microns. The boron concentration in underlying layer is 2 x $10^{19}/cm^3$. Next, the process is deposit a silicon N-type doping layer. This process is deposit a thin layer silicon N-type material (arsenic) on the top of the silicon P-type underlying layer by using the deposition process. The thickness of the layer is 1 micron. The arsenic concentration used is 1 x $10^{15}/cm^3$.

Then, will proceed with oxidation process. Grow or deposit a thin layer silicon oxide on the top of the N-type material (arsenic) using the deposition method. The thickness of the layer is 1 micron thick. After the oxidation process, the silicon oxide layer will be etching to form the shape that need to perform the boron implantation in later work. Some of the oxide layer will be etch away to form the surface.

Next is the implantation process. The boron will be implanted into the structure. The structure will be implant with boron with dose of 1 x $10^{15}/cm^3$ at 120kev of implantation energy. Then, the process is followed by implantation of fluorine. This process will implant the fluorine into the structure with the dose of 1 x $10^{15}/cm^3$ at 20kev of implantation energy. The process diffusion (annealing process) is the last step of the process. The structure will have preceded the diffusion process with the temperature of 900^oC for 30 second. Repeat the step for implantation of fluorine by change the parameter fluorine energy for 35kev and 50kev. The doses of the fluorine implant are maintaining (1 x $10^{15}/cm^3$).

For the structure B, the same method is used for the structure A. The different between the structure A and B is the etch area of the silicon dioxide where the structure A will be reflected to the left. The commands used in the input files are shown in the appendix

B. The parameters used under ion implantation, diffusion and diffusion coefficient are shows in table 3.0, 3.1 and 3.2.

Table 3.0: Parameter values used under the fully coupled model PD.FULL in TSUPREM-4

Parameter	Models	Ref	Value	
			Pre-exp. term	Activation energy
Diffusivity if *I* in Si (cm^2s^{-1})	Lever *et al*	19	$D.0 = 1.55 \times 10^6$	D.E = 3.22
Equilibrium conc. Of *I* in Si (cm^{-3}) C_I^{eq}	Boit *et al*	20	$Cequil.0 = 3.11 \times 10^{19}$	$Cequil.E = 1.58$
Surface recomb. Velocity of *I* at Si / O_2 interface(cm^{-1})	Crowder	21	$Ksurf.0 = 7.33 \times 10^3$	$Ksurf.E = 1.88$
Surface recomb. Velocity of *I* at Si / ambient interface(cm^{-1})	Crowder	21	$Ksurf.0 = 7.33 \times 10^3$	$Ksurf.E = 1.88$
Equilibrium conc. of vacancies in Si (cm^{-3}) C_V^{eq}	Law	22	$Cequil.0 = 4.77 \times 10^{18}$	$Cequil.E = 0.71$
Diffusivity of V in Si (cm^2s^{-1}) Dv	Law	22	$D.0 = 6.34 \times 10^3$	$D.E = 3.29$
Surface recomb. Velocity of *V* at Si / O_2 interface(cm^{-1})	Law	22	$Ksurf.0 = 1.12 \times 10^4$	$Ksurf.E = 2.48$

Surface recomb. Velocity of V at Si / ambient interface(cm^{-1})	Law	22	$Ksurf.0 = 1.12 \times 10^4$	$Ksurf.E = 2.48$
Bulk recomb. rate of I in Si (cm^{-3})	Law	22	$Kb.0 = 1.4$	$Ksurf.E = 3.99$
Diffusivity of B with I in Si (cm^{2}s^{-1}) D_i^o	Default	23	$Dix.0 = 3.5 \times 10^{-2}$	$Dix.E = 3.46$
Diffusivity of B with I^+ in Si (cm^{2}s^{-1}) D_i^o	Default	23	$Dip.0 = 0.648$	$Dip.E = 3.46$
Diffusivity of B with V in Si (cm^{2}s^{-1}) D_v^o	Default	23	$Dvx.0 = 1.85 \times 10^{-3}$	$Dvx.E = 3.46$
Diffusivity of B with V^+ in Si (cm^{2}s^{-1}) D_v^o	Default	23	$Dvp.0 = 3.6 \times 10^{-2}$	$Dvp.E = 3.46$

I – Interstitial V - Vacancy

I^+ - Positively charged interstitial V^+ - Positively charged vacancy

Table 3.1: Parameter values used in the dislocation loop model of Huang and Dutton under fully couple model PD.FULL in TSUPREM-4 [24]

Parameters	Values
Initial volume density of loops (number/cm^3)	L.DENS = 5×10^{14}
Radius of the loop (cm)	L.RADIUS = 5×10^{-6}
The lower limit of interstitial conc. where loops are produced	L.DMIN = 5×10^{20}

Table 3.2: Parameter values used in the transient clustering model of Solmi *et al* under fully coupled model PD.FULL in TSUPREM-4 [25]

Parameters	Values
The factor by which the intrinsic conc. is multiplied to obtain the minimum activation level at which the 'kink' will occur	ACT.MIN = 2
The prefactor for the time constant for the activation of dopant (s)	T.ACT.0 = 4.1×10^{-15}
The activation energy for the time constant for the activation of dopant (eV)	T.ACT.E = -3.7

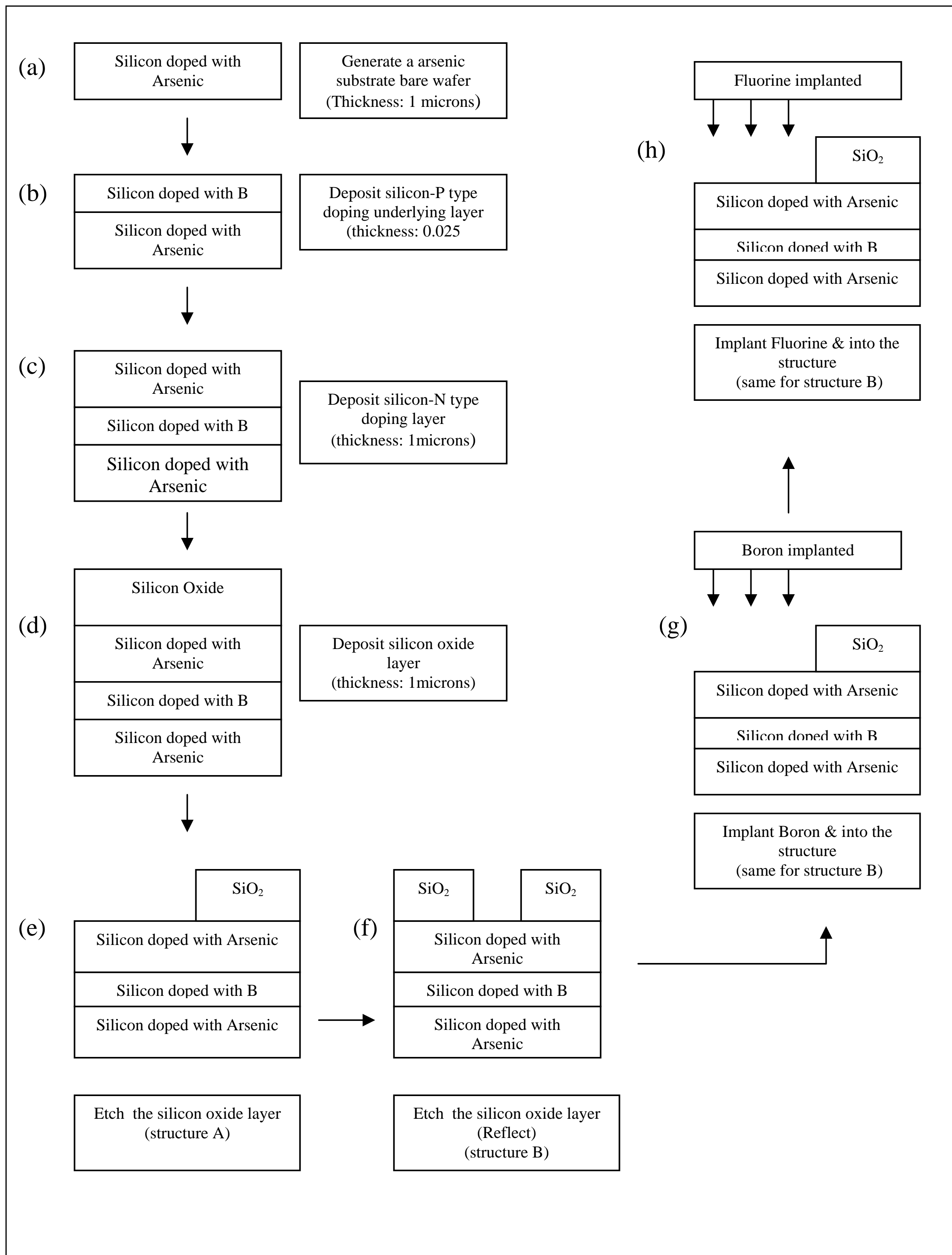

Figure 3.1: Process flow of structure generation in the process simulation. (e) SiO_2 etched left. (f) The structure is reflected before Boron and BF_2^+ implanted can be performed

3.2 Characterization And Analysis

Ones the structures are generated (as shown in figure 3.1); the structure will be analyzed and characterized. The all characterization is done by obtaining the profiles of dopant and point defects in the structure. The point defects to be observed are interstitials, vacancies and clusters. The parameters used under fully coupled model, clustering model and dislocation loop as shown in table 3.0, 3.1, 3.2 are included to ensure that the simulation done will activated transient enhanced diffusion since the default model in the simulation only take into account normal diffusion. A significant difference in the structure geometry is in the structure A and B as shown in the figure 3.1(e) and 3.1(f) where different opining is done before implantation of Boron and BF_2^+ is performed. This is implanted to observer the effect of ion trajectories during implantation and what are the effect that would occur during diffusion. The results will be calibrated after implantation (without diffusion, after diffusion and evolution during the interstitial start of diffusion until the end of diffusion. All the result will be discussed in the following chapter 4 in detail.