Implanted Layer Characterization

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***Abstract*—In modern semiconductor process technology, ion implantation has become the most important technique to introduce dopant atoms into semiconductor materials. The main advantage of ion implantation technique is its high controllability of process parameters, which influencing dopant distribution profile. This research was intended to characterize the product of ion implantation machine NV-3204. Ion implantation characterization successfully produced and evaluated pn-junction diode characteristics. PN-junction diode was fabricated using 100 keV energy and 5x10^{13} cm^{-3} dose of phosphorus on a silicon wafer type N<111>. For all measured area, pn-junction diode has junction depth X_j = 1 um, breakdown voltage -45V, built-in voltage 0.8V, and dopant concentration 5x10^{18} cm^{-3}. Comparing the simulation, this result exhibited that output of ion implantation machine was well controlled.**

***Index Terms*— characterization, controllability dopant, implanted layer, installation, ion implantation**

I. INTRODUCTION

Ion implantation is introduction of ionized dopant atoms into a wafer substrate with enough energy to penetrate beyond the surface. The most common application is substrate doping. The use of 3 keV to 500 keV energy for phosphorus, boron, or arsenic dopant ions is sufficient to implant the ions from 100 Å to 10,000 Å below the silicon surface. These depths place the atoms beyond any surface layers, and therefore any barrier effect of the surface oxides during impurity introduction is avoided. The depth of implantation, which is proportional to the ion energy, can be selected to meet a particular application [1] [2].

Implantation offers a clear advantage over chemical deposition techniques. The major advantage of ion implantation technology is the capability of precisely controlling the number of implanted dopant atoms. Upon annealing the target (heating to elevated temperatures of approximately 600-1000 degrees C), precise dopant concentrations between 10^{14} to 10^{21} atoms/cm^3 in silicon are obtained. Furthermore, the dopant's depth distribution profile can be well-controlled. [3]

This paper describes the characterization of ion implanter product.

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II. NV3204 ION IMPLANTATION MACHINE CHARACTERISTICS

According to functional characterization experiment, several gases have been fed as source to determine that different gas source would produce different ion beam spectrum. Figure 3 was obtained from BF_3 gas source and figure 4 from PH_3 gas. Referring to manual handbook, figure 3 was BF_3 beam current. The maximum current was found at AMU 10 as the value for B^{+11} ion that will be used for implantation of p type impurity. Figure 4 was shown as PH_3 spectrum after manual handbook. The dominant current was found between 26 – 28 AMU, the maximum current was for P+ ion that will be implanted as N type impurity [3].

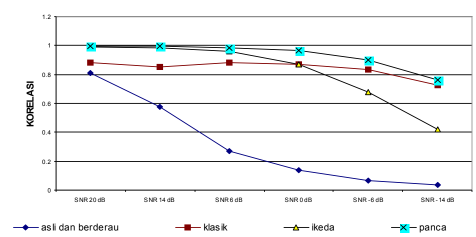

Figure 1 Current beam-spectrums for PH_3 source gas

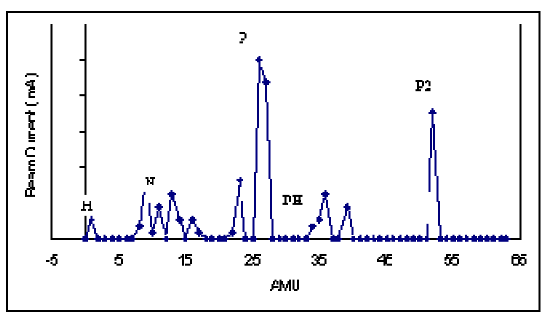

Figure 2. Current beam-spectrum for BF_3 source gas

Both fig. 1 and fig. 2 show several possibilities of ions can be produced from different gases. Those figures indicate that NV3204 machine has been work properly.

III. IMPLANTED LAYER CHARACTERIZATION

Implanted layer characterization was done to determine the successful of ion implantation technique for impurity doping. It would also indicate the advantage implant technique could achieve using

NV3204 machine. The advantage is the controllability of impurity profile.

The various experiments to analyze implanted layer have been developed . Based on the measurement instrumentations available at our laboratory, the analyzing method was the measurement of implanted pn junction diode. Parameter extraction from this measurement would be used to determine implanted layer characteristic. The extraction result would be compare with SPICES2B and SUPREM3 simulation.

PN junction diode has been fabricated using the following process parameter:

- Implant Energy: 100 KeV
- Ion Dose: 5 x 10^{13} cm^{-2}
- Wafer type: P <111> 10^{15} /cm^3
- Gas Source: PH_3 (N type doping)
- Annealing and followed by five hours drive-in.

The simulated profile implanted layer using SUPREM3 was shown on figure 5. The junction depth is 0.95 um and the maximum concentration was $3x10^{18}$ cm^{-3}. Using grooving method, junction depth is 1 um.

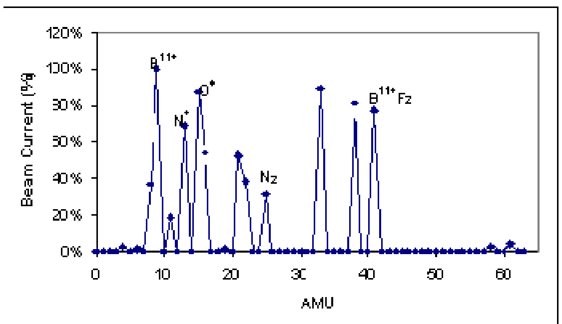

Figure 3 Profile of implanted p type silicon, P dopant at 5x1013 cm-2 at100 KeV

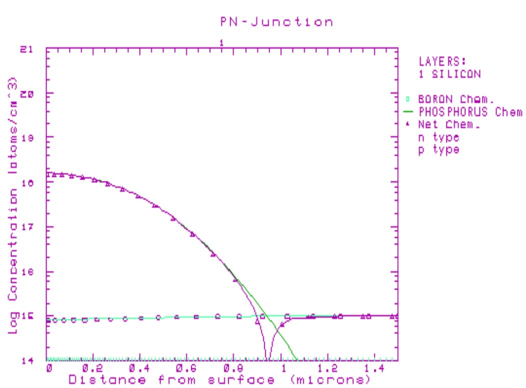

Figure 4 I-V Characterization of Implanted Diode

The I-V characteristic of fabricated pn junction was shown on figure 6. Breakdown voltage was –45 V and $V_{built\text{-}in}$ was 0.8.

Then, derived from $V_{built\text{-}in}$:

$$V_{BI} = \frac{kT}{q}\ln\left(\frac{Na.Nd}{n_i^{\,2}}\right)$$

$$0.8 = 0.0258x\ln\left(\frac{Na.10^{15}}{2.1x10^{20}}\right)$$

$$Na = 6x10^{18}$$

The concentration of implanted layer is $6x10^{18}$ cm^{-3}.

Figure 7 shows the curve of $1/C(V)^2$ have been obtained form breakdown C(V) measurement. This curve was used to find layer profile using C-V techniques [4]. For limited measurement area, layer profile using this technique was shown at figure 8. The concentration value was at the range of 10^{18} cm^{-3}.

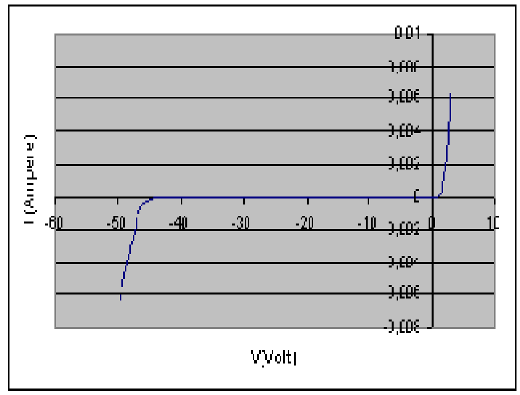

Figure 5 $1/C^2$ curve

Profile concentration was also measured using four point probe measurement. From this measurement resistivity dopant $\rho_s = 1.2x10^{-2}$ ohm-cm was obtained. This value has the correlation with dopant concentration of $3x10^{18}$ [5].

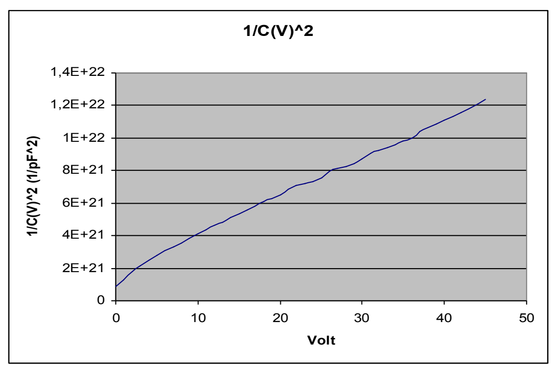

Figure 6 Layer Profile, derived from C-V Measurement

IV. Conclusion

Table 2 and table 3 show the resume of characterization. From the various methods of measurement, we have got the same value within the range of doping concentration. Table 3 also shows the comparison between the pn junction measurement and simulation. It indicate ion implanter machine have operated and the output of NV3204 ion implantation was well controlled.

TABLE I COMPARISON OF DOPING CONCENTRATION HAVE BEEN OBTAINED FROM VARIOUS METHODS

No	Method	Doping Concentration
1	SUPREM3 Simulation	3 x10^{18} cm^{-3}
2	I-V	6x10^{18} cm^{-3}
3	C-V	5x10^{18} cm^{-3}
4	Sheet Resistance	5x10^{18} cm^{-3}

TABLE II COMPARISON OF PN JUNCTION PARAMETER BETWEEN MEASUREMENT AND SIMULATION

Parameters	Measurement	Simulation
Xj	1 mm	0,9 mm
VB	-45V	≈-45 V
Vbi	≈0,8 V	≈0,8 V
Concentration	5x10^{18} cm^{-3}	3x10^{18} cm^{-3}

V. References

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