Implanted Layer Characterization

Adharul Muttaqin, Irman Idris

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^-2 dose of phosphorus on a silicon wafer type N<111>. For all measured area, pn-junction diode has junction depth Xj = 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^{12} 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.

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 BF₃ gas source and figure 4 from PH₃ gas. Referring to manual handbook, figure 3 was BF₃ 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 PH₃ 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].

Manuscript received May 20, 2007.

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Jurnal EECCIS Vol. 1, No. 1, Juni 2007
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.

\[ V_{bi} = \frac{kT}{q} \ln \left( \frac{Na.Nd}{n_{i}^{2}} \right) \]

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

\[ Na = 6x10^{18} \]

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}.

Profile concentration was also measured using four point probe measurement. From this measurement resistivity dopant \( \rho_i = 1.2x10^{-2} \) ohm-cm was obtained. This value has the correlation with dopant concentration of 3x10^{18} [5].
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>
<thead>
<tr>
<th>No</th>
<th>Method</th>
<th>Doping Concentration</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>SUPREM3</td>
<td>3 x10^{18} cm^{-3}</td>
</tr>
<tr>
<td>2</td>
<td>I-V</td>
<td>6x10^{18} cm^{-3}</td>
</tr>
<tr>
<td>3</td>
<td>C-V</td>
<td>5x10^{18} cm^{-3}</td>
</tr>
<tr>
<td>4</td>
<td>Sheet Resistance</td>
<td>5x10^{18} cm^{-3}</td>
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</tbody>
</table>

TABLE II COMPARISON OF PN JUNCTION PARAMETER BETWEEN MEASUREMENT AND SIMULATION

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Measurement</th>
<th>Simulation</th>
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<tbody>
<tr>
<td>Xj</td>
<td>1 mm</td>
<td>0.9 mm</td>
</tr>
<tr>
<td>VB</td>
<td>-45 V</td>
<td>≈-45 V</td>
</tr>
<tr>
<td>Vbi</td>
<td>±0.8 V</td>
<td>±0.8 V</td>
</tr>
<tr>
<td>Concentration</td>
<td>5x10^{18} cm^{-3}</td>
<td>3x10^{18} cm^{-3}</td>
</tr>
</tbody>
</table>

V. REFERENCES