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Elimination of Metal-Sputtering Contamination in Ion Implanter for Low-Leakage-Current pn Junction Formation

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Metal contamination caused by high-energy ion-beam sputtering of metal components and chamber walls of ion implanters is one of the major contamination sources. In this paper, such contamination has been quantitatively evaluated, and it was found that metal atoms as much as 0.05% of the total dose are incorporated into ion implanted wafers. Furthermore, it was demonstrated that the reverse-bias current in low temperature (450~500°C) annealed pn junctions is able to be reduced by suppressing such metal-sputtering contaminations.

1.INTRODUCTION

implantation is one of the most Ton essential processes in fabricating present day ULSI devices. Low temperature annealing of ion implanted silicon is quite essential establishing fabrication processes for in future ULSI devices. However, reduction in annealing temperature causes a severe the in the reverse-bias current, increase typically by several orders of magnitude [1,2]. The contaminant atoms incorporated into the amorphous layer formed by ion implantation enhances the defect generation during solid phase epitaxy of the amorphous layer, resulting in the increase in the reverse-bias current[3]. Especially, metal contamination caused by the high-energy ionbeam sputtering of metal components and chamber walls within the ion implanter is thought to be one of the major contamination sources.

In this paper, metal contamination occurring on wafers during ion implantation has been quantitatively evaluated by SIMS measurements. As a result, it was found that metal atoms as much as 0.05% of the total dose are incorporated into ion implanted wafers. Furthermore, it was demonstrated that the reverse-bias current in low-temperature (450~500°C) annealed pn junctions is able to be reduced by suppressing such metalsputtering contaminations.

2. EXPERIMENTAL

An ultrahigh-vacuum (UHV)[4,5,6] mediumcurrent ion implanter was used in the experiment. The vacuum chambers as well as internal components of the system are almost all made of Al-alloys. Stainless steel components are also partially utilized. Wafers were held by electro-static chucks[7] at the reverse side.

Arsenic implantation was carried out to bare silicon surfaces at the energy of 25 keV with the dose in the range of $10^{14} \cdot 10^{16} \text{cm}^{-2}$. The annealing of the ion implanted layer was performed in N₂ ambient at temperatures of $450 \cdot 700^{\circ}$ C.

Contamination brought into wafers were measured using secondary ion mass spectroscopy (SIMS).



Fig.1 Numbers of aluminum atoms incorporated into arsenic implanted wafers as a function of arsenic dose.



Fig.2 Dose dependence of leakage current density in low-temperature (500°C) annealed pn junctions at a reverse bias voltage of 5V.

3.RESULTS AND DISCUSSION

Figure 1 shows the concentration of aluminum atoms in arsenic implanted wafers as a function of the dose, exhibiting linear relationship between these two quantities. The fact clearly indicates that the Al contamination is caused by the ion beam. Ion beam sputters the aluminum alloy which construct the chambers, and the sputtered Al atoms are incorporated into wafers. other atoms contained in the Therefore. aluminum alloy like Fe, Mg, Cr and so forth must have been also incorporated into wafers. which form deep-level traps in the silicon band gap.

Figure 2 shows the reverse-bias leakagecurrent density in pn junctions as a function of the dose. The reverse current is also proportional to the ion dose. A good correlation is observed in the data shown in Fig. 1 and those in Fig. 2. The data shown in these two figures indicate that the metallic contamination brought into wafers degrades pn junction characteristics.

In order to monitor the metal contamination, we placed several pieces of Si wafer in the ion implanter. close to the These test pieces were evaluated after several months of operation. Arsenic ions implanted were more than 70% of the total dose. As it is shown in Fig. 3, the data well fit to the line extraporated from the data shown in Fig. 1. The results again confirm that such contamination is caused by high-energy ion-beam sputtering of chambers and component materials of the ion implanter. The amount of contamination is as large as 0.05% of the implanted dose. Therefore, the suppression of ion-beam-induced contamination



Fig.3 Al contamination level observed on test pieces of silicon left in the ion implanter for several months (\blacksquare , \blacktriangle). The data exhibit an excellent fit to the line extraporated from data shown in Fig.1 (\bigcirc).







Fig.4 The most serious sputtering occurs at the X-Y scanner apertures where we installed sputtering protection boards made of Si.

i.e., to protect chambers and components from being sputtered by the ion beam is essential to improve implanted pn junction characteristics.

By carefully observing portions where the most serious sputtering occurs in the ion implanter, we installed sputtering protection boards made of Si as shown in Fig. 4. In



Fig.5 Comparison of contamination levels(a) and pn junction leakage currents(b) before and after the installation of sputtering protection boards.

Figs. 5 (a) and (b), the effect of installing these sputtering protection boards are demonstrated. Figure 5(a) shows the Al concentration incorporated into implanted wafers before and after the installation. The concentration of metallic contamination is reduced by a factor of about 1/3. Figure 5(b) shows the reverse-bias current in pn junctions before and after the installation. of 450~700°C, At all annealing temperatures implanted pn junction characteristics are improved. These two figures clearly indicate that sputtering protection boards very effectively suppress the generation of metalsputtering contamination during ion implantation and have improved the pn junction characteristics as well.

4. CONCLUSIONS

Metal-sputtering contamination caused by the high-energy ion beam during ion implantation has been experimentally studied. was found to be contamination The ion dose. proportional to the Such contamination severely degrades the characteristics of low-temperature annealed pn junctions. By installing sputtering protection boards made of Si, the metal successfully contamination has been the pn junction suppressed and have been improved. characteristics Therefore, we conclude that one of the most important issues for low temperature pn junction formation is to completely eliminate of metal-sputtering the generation contamination in the ion implanter.

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