Ion implanter and Activation Annealing for SiC devices

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Abstract—Ion implanter process for SiC devices needs much longer time compared with Si process. Therefore implantation process optimization is important to reduce cost. In this paper, implantation temperature that affects process time is discussed. And activation conditions after implantation is also discussed.

Keywords—box profile, high temperature implantation, room temperature implantation, activation annealing, capping

I. INTRODUCTION

Ion implantation process time for SiC devices is long, because it needs several times implantation to create box-profile due to dopant hardly move even if activation annealing.

Figure 1. is the 300nm depth box-profile. To get this profile, Four(4) times Al+ implantations are carried out at the beam energy 30keV, 70keV, 150keV and 300keV respectively (Table 1.). Figure 2. is the SIMS profile after activation annealing, it shows SIMS profile does not be affected by the annealing temperature so much, it means implanted dopants hardly move in SiC.

In order to optimize implantation temperature, fundamental experimental results are discussed.

II. IMPLANTATION TEMPERATURE

Mr. Watanabe et al., investigated the effects of implantation temperature on electrical properties of heavily Al-doped 4H-SiC layer formed with Al implantation [1]. The multi-step-implanted Al had a box profile with a concentration of about 2E20/cm³. They said that the implantation temperature above 175deg.C. is needed.

This implies the possibility of reducing the implantation temperature to about 200-250deg.C. from 500deg.C. Therefore ion implanters are required to operate these temperature range. Ion implanter throughput improves with a decrease of implantation temperature. Because wafer pre-heating time is also can be decreased.

We investigated the implantation temperature dependence at the Al concentration 5E18 cm⁻³ and 2E20 cm⁻³ respectively.
Fig. 2. Implantation temperature dependency at Al concentration 2E20/cm³

| DOSE  | Implantation Temperature |
|-------|--------------------------|
| 2E20/cm³ | 500°C                   |
|        | Room Temp.               |

4H-SiC epiwafers were used. Fig. 2, Al concentration 2E20/cm³, shows amorphous layer (3C poly-type) after annealing in RHEED pattern at the room temperature implantation condition. It means that high temperature implantation is necessary at the relatively high Al concentration.

Fig. 3, Al concentration 5E18/cm³, shows 4H poly-type after annealing in RHEED pattern at the even room temperature implantation.

| DOSE  | Implantation Temperature |
|-------|--------------------------|
| 5E18/cm³ | 500°C                   |
|        | Room Temp.               |

Summary is following based on these results above.

1. High temperature is necessary at the Al concentration is 2E20/cm³ (Relatively high dose).
2. Room temperature implantation is possible at the Al concentration is 5E18/cm³ (Relatively low dose).

3. 200-250deg.C. not 500 deg.C. may be possible for high temperature implantation.
4. Room temperature implantation or reducing implantation temperature have benefits of improving throughput.

On the other hand, the device electrical properties improvement is reported when implantation temperature is increased to 600deg.C. [2].
III. ACTIVATION ANNEALING

Activation annealing after ion implantation is important, because high annealing temperature causes SiC surface’s roughness that leads to deterioration of the electrical characteristics.

We investigated the surface roughness dependency on annealing temperature and time. We also compared the difference between carbon cap and photo resist cap as a protect film during annealing.

Fig. 7 shows the surface roughness deteriorates with the increase of annealing temperature and time.

Fig. 8 shows that the surface roughness in Fig. 8 is described by Ra (nm). It shows that the annealing time less than three(3) minutes, less than twelve(12) minutes, and less than thirty (30) minutes are necessary at the annealing temperature 1900 deg.C., 1700 deg.C., and 1650 deg.C. respectively.

IV. SUMMARY

The implantation temperature conditions for SiC devices are discussed. To improve throughput for implantation process, it is important to optimize the implantation temperature. Activation conditions after implantation is also discussed.

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