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Ultra-Shallow p+/n Junction Prepared by Low Energy BF_3 Plasma Doping(PLAD) and KrF Excimer Laser Annealing

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1. Introduction

As the dimension of devices is becoming smaller, size and junction depth have to become shallower, ion implantation with boron which has short channel behavior and transient enhanced diffusion(TED) faced the limitation to make shallower junction.[1]~[4] So many research has been done to make more shallower junction.

Plasma doping(PLAD) has been studied as a replacement of conventional ion implantation.[5] However, at a low doping energy of 1kV or less, TED during activation annealing is inevitable.[6]~[7] To reduce the enhanced diffusion and to obtain a highly activated dopant profile, excimer laser annealing(ELA) has been studied.[8] And it has been previously reported that fluorine can suppress boron TED and it can improve the electrical characteristic of junction.[9]~[11]

During device fabrication, post-annealing process is accompanied with deactivation of dopant. Y. Takamura et al.[13] have shown that the deactivation of boron in laser annealed silicon is stable.

In this study, we achieved P^+/n ultra-shallow junction with low energy BF_3 plasma doping (PLAD) and excimer laser anneling (ELA). We investigated their activation and deactivation behavior of boron due to fluorine effect.

2. Experimental details

The dopant boron atoms were implanted with BF_3 Plasma Doping at Samsung electronics. Wafer bias of 1kV and targeted dose of $5 \times 10^{15}/cm^2$. The wafers were cut into 5×5 mm^2 followed by ELA. Excimer Laser Annealing was conducted by a KrF excimer laser with 248 nm wavelength. The laser energy was 300~ 600mJ/cm^2 at 1 pulse. Post-annealing was done by rapid thermal annealing (RTA) at 400~800℃ for 10min. We performed Hall measurements with Van der Pauw geometry and indium electrodes. Time-of-flight secondary ion mass spectrometry (SIMS) was performed to investigate dopant depth profile. Cross-sectional transmission electron microscopy (X-TEM) analysis was done to confirm the crystalllization of samples and Plane-view transmission electron microscopy (Plane-view TEM) was used to analyze the condition of surface.

3. Results & discussion

Figure 1 depicts sheet resistance and active carrier concentration versus laser energy of low energy BF_3 PLAD junctions at 1 pulse. The sheet resistances of samples show a value of ~1000Ω/sq. at laser energy of 600mJ/cm^2 and a-

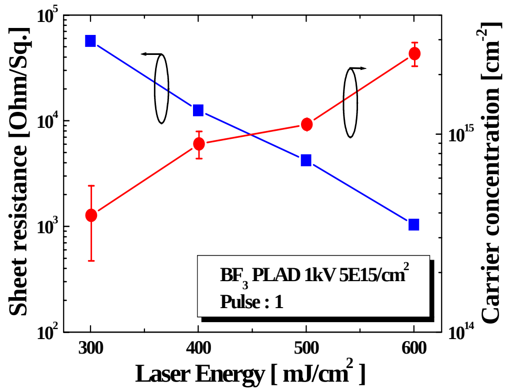


Fig. 1 sheet resistance and active carrier concentration versus laser energy of BF_3 PLAD junctions at 1pulse.

ctive carrier concentration shows a value of $2 \times 10^{15}/cm^2$ at the same energy.

ELA at 600mJ/cm^2 for 1pulse resulted in diffusion-less activation of boron dopants (Fig. 2 (a)) with a junction depth of 28 nm (at 5×10^{18} cm^{-3}). But the depth is deeper than our expectation. It can be explained like when BF_3 is implanted into the substrate, it dissociate into boron and fluorine and shows boron-like-profile. Fig. 2(b) shows the fluorine SIMS depth profile. In this case, the depth profile moved toward left side significantly due to the post-annealing. G. Impellizzeri.[12] have shown the fluorine segregation toward the surface after annealing in a preamorphized silicon. As fig. 2(b) shows, fluorine segregates toward the surface and this might cause boron depth profile to move toward left side due to the post-annealing.

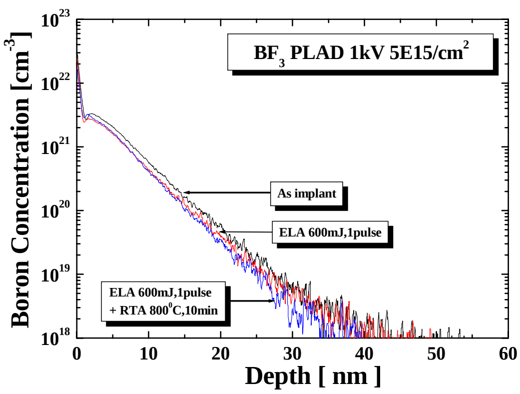


Fig. 2 (a) Boron SIMS depth profile of 1kV, $5\times10^{15}/cm^2$ BF_3 PLAD junctions

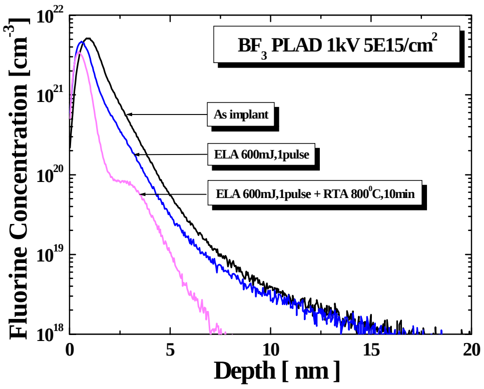


Fig. 2 (b) Fluorine SIMS depth profile of 1keV, 5×10^{15} cm^{-2} BF_3 PLAD junctions

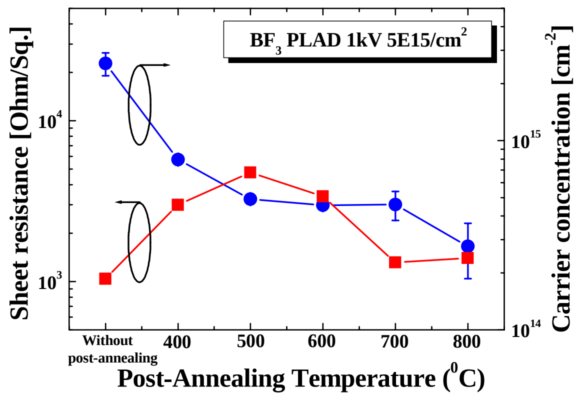
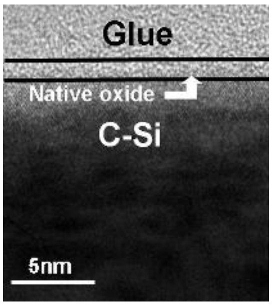
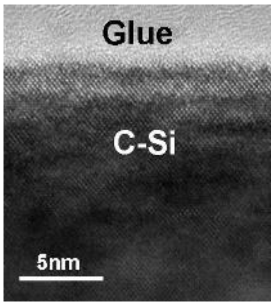


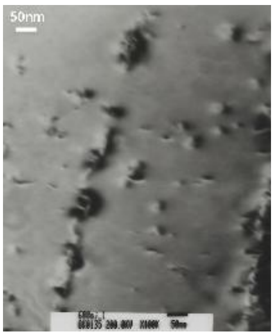
Fig. 4 Sheet resistance and active carrier concentration versus thermal budget of BF_3 PLAD junctions after the post-annealing



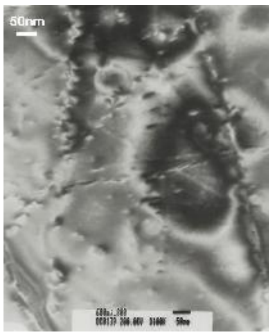
(a) As-implanted



(b) 600mJ/cm^2, 1pulse



(c) 600mJ/cm^2, 1pulse



(d) 600mJ/cm^2 + 800℃

Fig. 3 (a), (b) X-TEM image (c), (d) Plane-view TEM image of 1kV BF_3 PLAD junctions

According to cross-sectional TEM images, as implant of BF_3 PLAD junction didn't make the amorphous layer (fig. 3(a)). Fig. 3(b) shows that defects due to boron or fluorine or other complexes are occurred near the surface after ELA at 600mJ/cm^2 for 1pulse and it shows very rough surface. The plane-view image after ELA 600mJ/ cm^2 for 1pulse (fig.3 (c)) shows some clusters on the surface. Fig. 3(d) illustrates after ELA at the same condition followed by RTA at 800℃ for 1min. This figure shows more clusters and the number and size of clusters are increased comparing to fig. 3(c). In other words, boron and fluorine segregate toward the surface after annealing and segregation is increased following the additional heat treatment so this figures can support the result of SIMS depth profile.

Fig. 4 demonstrates sheet resistance and active carrier concentration after excimer laser annealing at 600mJ/cm^2 for 1pulse followed by RTA at 400~800℃ for 10min. As expected from previous results, active carrier concentration is significantly decreased (~89%) following the post-annealing. Compared with this, sheet resistance is not much increased below 500℃ but decreased from 500℃. This phenomenon is due to the increasing mobility of dopants.

4. Conclusions

In summery, activation and deactivation of shallow P^+/n junction was investigated using low energy BF_3 PLAD and excimer laser annealing. We could achieve sheet resistance of ~1000Ω/sq and junction depth was(~28nm) and we confirmed that low energy BF_3 PLAD didn't make the amorphous layer by X-TEM image. Boron and fluorine moved toward the surface following the annealing confirmed by SIMS profile and plane-view TEM image. We proved that deactivation rate of boron due to the post-annealing after ELA is increased due to fluorine.

Acknowledgements

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