SHALLOW JUNCTION FORMATION BY RAPID THERMAL ANNEALING OF BORON IMPLANTED SILICON WITH FLUORINE PREAMORPHIZATION

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In this paper, we demonstrate that shallow junctions can be formed without ultra-low energy ion implantation machines. Preamorphization of silicon wafers with fluorine ions and rapid thermal annealing, can produce boron (10 keV implant) junctions shallower than 100 nm. Fluorine ions played a major role in this scheme. Alongside channeling suppression by the amorphous layer, fluorine interaction with vacancy-type defects during annealing, leads to uphill boron diffusion effect, shrinking the junction depth.

Ultra-low energy (sub keV) boron implants have been intensively studied to produce shallow junctions. However, most commercial ion implanters currently in use were not designed to operate in this range of energy. An alternative approach is to combine substrate amorphization, prior to boron implant, to suppress ion channeling, and rapid thermal annealing (RTA) to reduce diffusion. With this scheme, shallow junctions could be produced with energies that are not so extreme, so that conventional implant machines can be used.

Several species of ions were used or Si preamorphization, mainly Si, Ge and F [1-4]. In this work, the process of p-type junction formation by the utilization of F preamorphization, boron implantation and rapid thermal annealing are studied, in order to establish the optimal conditions to achieve shallower junctions, without ultra-low energy implantation.

Single crystal, phosphorous doped (2-10 Ω cm) n-type 100 silicon wafers were preamorphized with F ions at 50 keV and 2×10^{15} ions/cm^2. Boron implants were performed at 10 keV and 5×10^{14} ions/cm^2. All implants were 7^o tilted away from the ion beam. Ion implants were performed in a medium current, medium energy Eaton GA 4020 machine. RTA were done at 960^{o}C for 10s, 20s and 30s in N_2 atmosphere.

Fluorine preamorphization had a noticeable effect in boron profiles. Secondary ion mass spectroscopy (SIMS) depth profiles showed that the higher annealing time (30s) produced a shallower than as-implanted boron profile (~70 nm), figure 1. Boron diffusion suppression was explained [3] by the interaction of F ions with excess mobile interstitial Si, that otherwise are responsible for the boron enhanced diffusion. Probably, the formation of thermodynamically stable SiF_x complexes, would immobilize this interstitials. However, we still don't have a conclusive answer to the boron profile shrinkage. It is thought that a high vacancy-type defects concentration at the under-surface would be responsible for this effect. The shallower junction obtained by the highest annealing temperature indicates that fluorine diffusion towards the surface increased, capturing boron ions. Although unexpected, junction shrinkage after thermal annealing already was observed in Mg-implanted GaAs [5]. This "uphill diffusion", was explained by the substitutional-interstitial diffusion mechanism. In the region of uphill diffusion, the dopants diffuse from areas of excess interstitials toward areas of excess vacancies. Also, it was observed [6] that fluorine tends to accumulate around the maximum vacancy region in Si. So, this model could be a reasonable explanation of the observed junction shrinkage.

Sheet resistance measured in a four-probe setup obtained the electrical activation value of 258 Ω/sq, for the 30s annealing.

Fluorine preamorphization has a remarkable effect, showing junction shrinkage after rapid thermal annealing and good electrical activation. Although some authors previously reported shallow junctions obtained from fluorine pre-implants, as far as we know, it is the first time that an uphill diffusion mechanism was observed in boron-implanted silicon. Our present knowledge about the mechanisms responsible for the thermal stability of defects created by ion implantation is still limited, in spite of its great technological importance, this subject is still open to discussion. Also, it was demonstrated that available commercial ion implantation machines are still useful to shallow junctions production.

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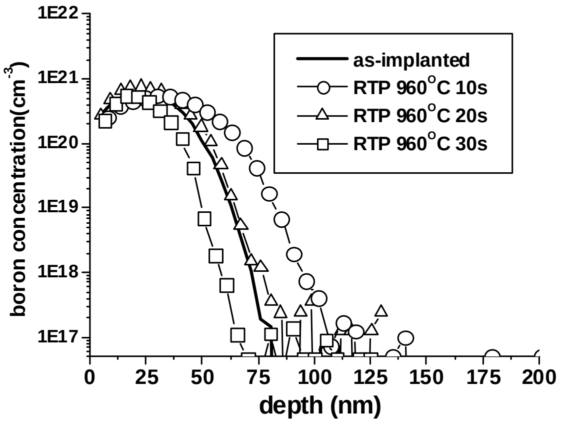

Figure 1 – Boron depth profiles, for as-implanted and annealed samples, showing junction reduction with annealing time. Rapid thermal annealing was done at 960^{o}C for 10s, 20s and 30s.