Room temperature migration of B implanted in laser irradiated Si

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The dimensions of shallow junctions formed in future semiconductor devices are expected to decrease at a rate as predicted in the semiconductor roadmap [1]. Annealing procedures alternative to conventional RTP processes are currently under investigation in order to achieve high electrical activation whilst maintaining very shallow and abrupt doping profiles. With respect to the issues associated with the enhanced diffusion, electrical activation and profile abruptness, a process procedure, originally developed in the 1970's has been recently revisited, namely Excimer Laser Annealing (ELA) [2].

Normally ELA replaces conventional RTP and therefore is used after the implant process in order to activate the dopant. However, during the fabrication of innovative devices based on the use of ELA, the entire device area is irradiated, even those regions where dopant is not yet implanted but it will subsequently be. Moreover, the specificity of laser irradiation makes an hard task the effective masking of the overall surface being, for example, SiO_2 well transparent to laser light. Although a perfect crystalline Si layer is generally obtained after ELA the resolidification process might, in principle, alter the physical properties of the Si lattice as a matter for dopant diffusion.

In view of these considerations we used the implantation and diffusion of B as a marker able to testify the chemical modifications of Si after ELA.

The process consists of irradiating the implanted Si with a laser beam (1.3 J/cm^2), such that the surface layer is melted to a depth governed by the laser pulse energy profile. After laser processing, the irradiated layer is implanted with B (5keV 1×10^{13}/cm^2). As-implanted and diffused samples have been studied by chemical (SIMS), electrical (SRP) and structural (TEM) techniques.

Figure 1a testifies the modification that occur in Si when irradiated with laser (it is shown only the case of maximum energy irradiation corresponding to a melt depth of about 150nm). The implanted B distribution, assumes, at room temperature, a shape significantly different from what measured on the same sample, but out of the laser spot (solid line). In fact, a small percentage of B is able to freely migrate just until it reaches the original liquid/solid interface [3].

The deactivation profiles measured by SRP (Fig. 1b) reveal that the irradiated material allows a deactivation similar to that reported in literature for very pure Epi-Si (also shown as + in Fig. 1c) that stops in correspondence of the liquid/solid interface. In contrast the deactivation depth measured outside the irradiated region is not correlated with laser melt depth and depends only on the substrate purity (Fig. 1c) [4].

After having treated these samples by conventional RTP processes (900°C and 1100°C 30), we did not observed any significant difference regardless of the pre implant irradiation. Of course the RTP-diffused profiles however have shapes totally different due to different as-implanted profile.

Further measurements have been performed changing the melt depth, the implant energy and the substrate purity.

Our data point out that the interaction of high energy bean with the matter has still to be deeply investigated before to finally asses the effectiveness of laser technology.

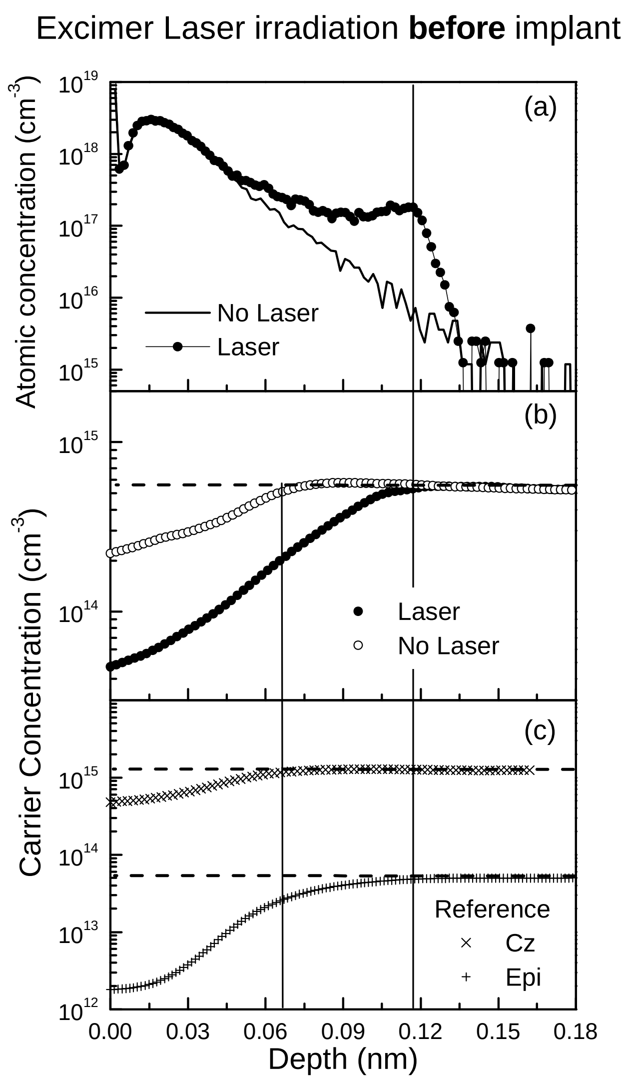

Figure 1 *(a) SIMS profiles of B (5keV, 1x10^{13}/cm^2) measured in Si irradiated with laser **before** implant (solid line measurement outside the irradiated area, symbols measurement corresponding to the maximum energy density of 1.3J/cm^2 – melt depth of about 150nm); (b) SRP depth profiles of deactivated carriers outside the irradiated area (open symbols) and measurement corresponding to the maximum energy density (filled symbols); (c) SRP depth profiles of deactivated carriers in as-implanted (5keV B 1x10^{13}/cm^2) Czochralsky and Epitaxial Si used as reference to measure defect migration at room temperature.*

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