

Evaluating depth distribution of excimer laser induced defects in silicon using micro-photoluminescence spectroscopy

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Laser Thermal Annealing (LTA) has been demonstrated to be an effective method to create heavily doped regions required for ultra-shallow junctions, in which dopants are typically introduced by ion implantation. More generally, laser annealing is very attractive due to the localised nature of the annealing process (both on the wafer surface and in depth), allowing dopants to be activated while preserving the integrity of the surrounding areas. Similarly, it is generally accepted that the laser induced damage, if any, is also localised and is reduced when using ultrashort pulses. However, the depth distribution of the laser induced damage has been rarely investigated in detail, with few works reporting on the subsurface doping and damage in laser-doped Si solar cells [1, 2].

In a preliminary study [3], we investigated the penetration of oxygen (O), from the surface native oxide, occurring during melt laser annealing of *in-situ* doped epitaxial Si layers. Depending on the laser anneal conditions, we found that the O in-diffusion could also result in the formation of O precipitates, while the presence of defects and their evolution was qualitatively monitored by micro-photoluminescence spectroscopy (μ PL).

In this work, we present a more precise investigation both in terms of defect localization and formation mechanism. To this aim, we have used SIMS and temperature-controlled μ PL (with a defect detection limit as low as 10^6 defects/cm² [3]) to evaluate the laser-induced damage on samples submitted to various LTA conditions (fluence in the range 1.7 to 8 J/cm² and various numbers of pulses). In addition, a phase-field continuum model has been used for the simulation of the temperature, phase and impurity fields, necessary for the interpretation of the experimental results.

Firstly, we have obtained useful information about the spatial distribution of defects at various depths by varying the μ PL excitation wavelengths. Depending on the depth, optical defects known as G- and D-lines, related to O, carbon and/or dislocations are observed, whose behaviors are correlated with the LTA conditions.

Secondly, to further improve the defect depth location, a controlled etching process was implemented in combination with the μ PL measurements so that, for a given sample, several μ PL measurements are available as a function of the removed silicon thicknesses (determined from the corresponding SIMS O profiles). This approach provided a better localization of defects and allowed a more detailed specification of their formation in relation to LTA parameters.

The results obtained in this work are expected to improve the available knowledge on the laser induced damage formation mechanisms and eventually contribute to the optimisation of this advanced annealing process.

[1] P. Gundel *et al.*, IEEE Trans. Electron Devices 58, 2874 (2011)

[2] Y. J. Han *et al.*, Appl. Phys. A, 122:420 (2016)

[3] R. Monflier *et al.*, Nanotech. Mat. & Dev. Conf. (NMDC), 2016 IEEE, 2016, pp. 1–2