Electrical characterization of silicon diodes formed by laser annealing of implanted dopants

L.K. Nanver[a], J. Slabbekoorn[a], T. Scholtes[a], R. Surdeanu[b], C. Ortiz[a], F. Simon[c], H.-J. Kalhert[c], J.W. Slotboom[a,b]

[a]*DIMES, TU Delft*
Feldmannweg 17, 2628 CT Delft, The Netherlands
[b]*Philips Research Leuven,*
Kapeldreef 75, B-3001 Leuven, Belgium
[c] *MicroLas Lasersystem GMBH, Robert-Bosch-Breite 10, 37079 Göttingen, Germany*

In recent years laser annealing has been identified as one of the few means capable of forming ultra-shallow junctions for future CMOS generations. A number of investigations have reported extremely abrupt n^+p and p^+n laser annealed junctions with sub-50 nm junction depths and dopant activation well above the solid solubility limit. Most often these reports are limited to SIMS, SPR and sheet resistance measurements on non-patterned wafers, and although such results demonstrate the large potentials of laser annealing, the fact remains that the challenges associated with actually incorporating laser annealing in integrated devices are enormous. Major issues include high pattern sensitivity, damage to masking layers, damage induced leakage, degradation during post-processing, and very often the resulting process window is very narrow to non-existant. While some successful applications of laser annealing for forming low-temperature, low-ohmic contacts have been demonstrated [1], the application to ultra-shallow junctions is still not evident.

This paper gives an overview of a number of novel electrical characterization techniques that make it possible to get a more complete view of the properties of laser annealed diodes. In particular the characterization of ultra-shallow p^+n diodes, fabricated by low-energy implantation and annealing with a 308 nm wavelength XeCl excimer laser, will be discussed. The most shallow of these junctions was originally developed using non-patterned wafers and is reported in [2] to have a depth of 20 nm, sheet resistance of 250 Ω/□, and an abruptness of 1.8 nm/decade. Measurements of the I-V characteristics of such laser annealed diodes show a very high sensitivity to diode size and both the thermal and masking properties of the diode surroundings. Perimeter current levels are often dominantly high and difficult to control, not only due to defect related leakage but also due to the very small extension of the junction past the contact window edge. The exact distance from the junction to the contact window will directly influence the ideal current density. Also, for ultra-shallow junctions, the bulk current level is very sensitive to the exact junction depth and contact quality. The interpretation of the diode characteristics can therefore be quite complicated and the following novel electrical test structures can add valuable information on the relationship to the laser anneal conditions:

- *CV profiling of the junction depth and abruptness.* The measurement technique described in [3] is used to profile the tail doping of the laser annealed diode, giving the depth and the abruptness of the junction. The results reported here show that the accuracy of this method is comparable to high resolution SIMS and moreover gives the added advantage of allowing rapid profiling over the whole wafer. An example of the measured profiles is given in Fig. 1.
- *Contact resistance.* Direct measurement of the contact resistance, rather than diode characteristics, is a much more straightforward method of determining whether an optimal melt and dopant activation has been achieved. The Kelvin test structures reported in [4] can be used down to contact resistivity values of about 10^{-8} Ωcm^2.
- *Polysilicon resistors for monitoring laser beam uniformity*. The laser beam uniformity is a critical parameter for the process window of a particular application. The resistance of polysilicon resistors, where the dopants are implanted and activated by laser annealing, is a sensitve monitor for laser energy density distribution over the beam spot. Low energy density regions, often found at the spot edge, can be readily identified. An example is shown in Fig. 2.

With this electrical analysis of the diodes and the laser annealing process the factors leading to for example high sensitivity to geometry and thermal properties of the surroundings can be quantified and methods of increasing the processing window can be identified.

References
[1] L.K. Nanver et al., BCTM'99, p.137 (1999)
[2] R. Suredeau et al., ECS '02 (2002)
[3] C. Ortiz et al., ICTMS'02, p.83 (2002)
[4] L.K. Nanver et al., ECS Proc. '99; p. 171 (1999)

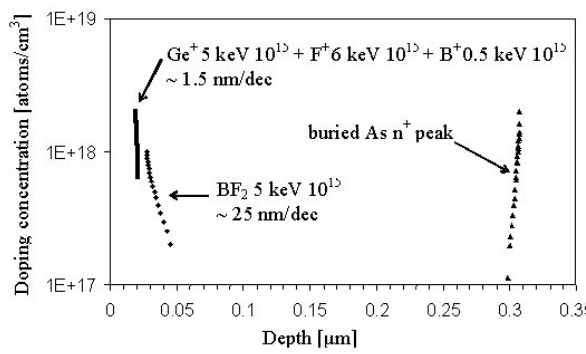

Fig. 1: CV profiles of two shallow boron implants laser annealed with 950 mJ/cm^2. They are profiled with respect to a buried arsenic n^+ peak, the depth and profile of which is measured by using a Schottky diode.

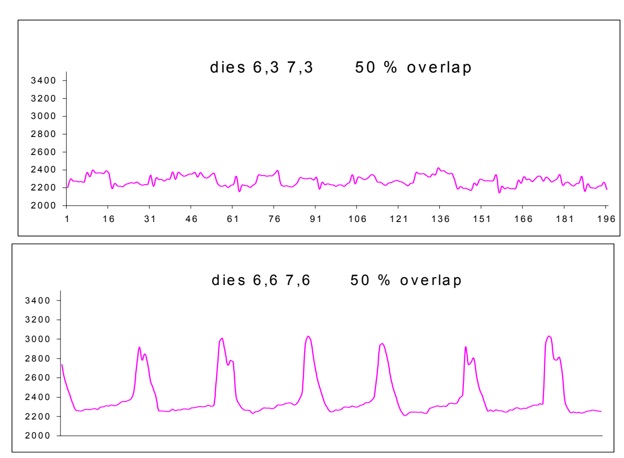

Fig. 2: Resistance versus position on die of laser annealed, implanted poly resistors for a MicroLas System (top) and XMR system (bottom). With advanced MicroLas optics the pulse edge has been made very abruptly and transition regions are not seen.