THE BEHAVIOUR OF OXYGEN IN OXYGENATED N-TYPE HIGH-RESISTIVITY FLOAT-ZONE SILICON

E. Simoen[1], C. Claeys[1,2], R. Job[3], A.G. Ulyashin[3], W.R. Fahrner[3], G. Tonelli[4], O. Degryse[5] and P. Clauws[5]

[1]IMEC, Kapeldreef 75, B-3001 Leuven, Belgium

[2]KU Leuven, Electr. Eng. Dept., Arenberg Kasteelpark 10, B-3001 Leuven, Belgium

[3]University Hagen, Electr. Eng. Dept., Haldener Str. 182, D-58084 Hagen, Germany

[4]INFN, Sezione di Pisa, Via Livornese 1291, I-56010 Pisa, Italy

[5]Dept. of Solid-State Sciences, Ghent University, Krijgslaan 281 S1, B-9000 Gent, Belgium

Introduction. Recently, strong interest has developed in the use of oxygen-doped (or oxygenated) high-resistivity (HR) Float-Zone (FZ) silicon, as this can lead to the fabrication of radiation-hard detectors for nuclear-particle spectroscopy [1-3]. The presence of oxygen is believed to result in the formation of less harmful radiation defects, which better preserve the initial doping density. In addition, HR FZ substrates have shown potential for the development of RF and mm-wave CMOS technologies [4-5]. Doping with oxygen might improve the mechanical and gettering properties of the FZ substrates, in view of ULSI processing. However, to optimise the material, one should study the behaviour of oxygen, both in the as-doped state and after different thermal treatments. It is the aim of this work to present initial results of a spectroscopic study of oxygenated HR FZ silicon. The impact of a low-temperature hydrogen plasma treatment to promote the agglomeration of interstitial oxygen [6] will also be addressed.

Experimental. The starting material is n-type HR FZ silicon of resistivity ρ=2 or 5 kΩcm. Oxygen doping was performed by the following procedure: i) oxygen enrichment of the wafer surfaces by a 15 h dry oxidation at 1000 °C (the temperature ramps were driven in a N_2 ambient), ii) annealing at 1150 °C for 24 h. This 2-step annealing procedure was repeated three times in order to drive the oxygen as deep as possible in the 400 μm thick samples. The oxygen content was measured by SIMS and by Fourier Transform Infrared (FTIR) spectroscopy, using the 9 μm absorption band of interstitial oxygen (O_i). A concentration denoted by [O_i] of $1.0\pm0.05\text{x}10^{17}$ cm^{-3} was found from FTIR. Moreover, the FZ Si samples were hydrogenated by a RF hydrogen plasma exposure in a PECVD system. The plasma was applied for 1 h at 110 MHz frequency, a power of 50 W (≈ 0.35 Wcm^{-2}). During the plasma treatment the substrate temperature was about 250 °C. Post-hydrogenation annealing was carried out at 450 °C in air. The hydrogenated and subsequently annealed samples were characterized by Spreading Resistance Probe (SRP), Capacitance-Voltage (C-V) and Deep-Level Transient Spectroscopy (DLTS) measurements [6-7].

Results and Discussion. It will be shown that in the starting material, a whole variety of deep levels are present, which are probably oxygen related. At the same time, the initial resistivity is well preserved after oxygenation. The hydrogen-plasma treatment introduces shallow donors with a ten times higher concentration than the starting value. It is demonstrated, however, that they are not the expected oxygen thermal donors (OTDs), but a shallower species, most likely oxygen related. It will be argued that the N-O related shallow thermal donors (STDs) are good candidates for the unknown donors. From this also follows that most of the observed deep levels are probably nitrogen related. The presence of nitrogen could also explain the suppression of OTDs after the plasma treatment.

Conclusions. In conclusion, it is stated that HR FZ Si can be doped with oxygen to high concentrations in the range 10^{17} cm^{-3}, while preserving a high resistivity. At the same time, it is believed that nitrogen in the as-doped material could play a role in the agglomeration/precipitation of oxygen during cooling from high temperatures. A large number of deep-level traps was found, which can impact on the carrier lifetime of the material. It has finally been demonstrated that oxygen-related shallow donors can be introduced after a low-temperature hydrogen plasma treatment.

References.

[1] G. Tonelli, *Nucl. Instr. and Meth. A*, **386**, 129 (1997).

[2] A. Ruzin, G. Casse, M. Glaser and F. Lemeilleur, *Nucl. Instr. and Meth. A*, **426**, 94 (1999).

[3] B. Dezillie, Z. Li, V. Eremin, W. Chen and L.J. Zhao, *IEEE Trans. Nucl. Sci.*, **47**, 1892 (2000).

[4] J. Buehler, E. Kasper, P. Russer and K.M. Strohm, *IEEE Trans. Electron Devices*, **33**, 2047 (1986).

[5] D. Beck, M. Herrmann and E. Kasper, *IEEE Trans. Electron Devices*, **44**, 1091 (1997).

[6] R. Job, W.R. Fahrner, N.N. Kazuchits and A.G. Ulyashin, *MRS Symp. Proc. Series*, **513**, 337 (1998).

[7] R. Job, A.G. Ulyashin, W.R. Fahrner, E. Simoen, C. Claeys and G. Tonelli, *Proc. of the E-MRS Spring Meeting*, *Nucl. Instr. and Meth. B*.