Investigation of Oxygen Precipitation in Photovoltaic Polycrystalline Sheet Silicon

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The positive internal gettering action of oxygen precipitates and associated extended defects in IC silicon devices is complicated in polycrystalline solar cell materials due to the presence of grain boundaries and the need for a long minority carrier diffusion length. Since all these defects can act as both beneficial gettering sites[1] and as detrimental minority carrier recombination centers[2, 3], it is of some value to optimize their interaction with metallic impurities specifically for polycrystalline sheet silicon[4]. We have used FTIR, DLTS, microwave-PCD, SEM/EBIC, and etch pit/optical microscopy following a solar cell process which included an intentional high temperature gettering step. Following processing, the concentration of interstitial oxygen and substitutional carbon decreased from 14.4 to 3.2×10^{17} cm^{-3} and from 3.3 to 2.3×10^{17} cm^{-3}, respectively, see Fig. 1. To investigate the gettering effect on background transition metals, the samples were analyzed by DLTS before and after cell processing. As shown in Fig. 2, the virgin wafer contains four prominent traps, corresponding to Fe-B, Fe-Al, Cr-B and Fe_i, respectively; however, only a single broad peak, at much lower concentration, appears in the annealed samples. Since complementary SEM/EBIC images did not show any obvious correlation between the decrease in the Fe and Cr concentration and the grain boundary electrical activity, we conclude that defects related to oxide precipitation are the dominant gettering mechanism. Comparison with PCD lifetime measurements indicates that decreasing the concentration of the transition metals does not improve the minority carrier lifetime to a value expected from such a final trap level. Evidently, a lifetime degrading entity is formed during the gettering process which is not evident as a specific DLTS trap. In addition to the obvious precipitate related recombination, another candidate defect was found, see Fig.3, where optical etch pit microscopy following preferential etching shows that a high concentration of stacking faults form during annealing, while there are only dislocations in the virgin sample.

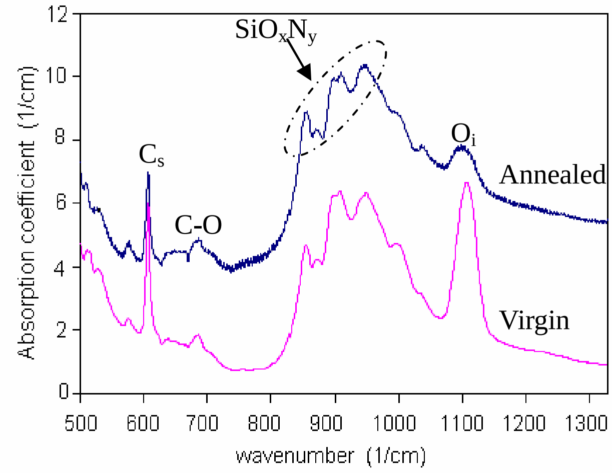

Fig. 1 Room temperature FTIR spectra of the sheet silicon wafers before and after the annealing processes.

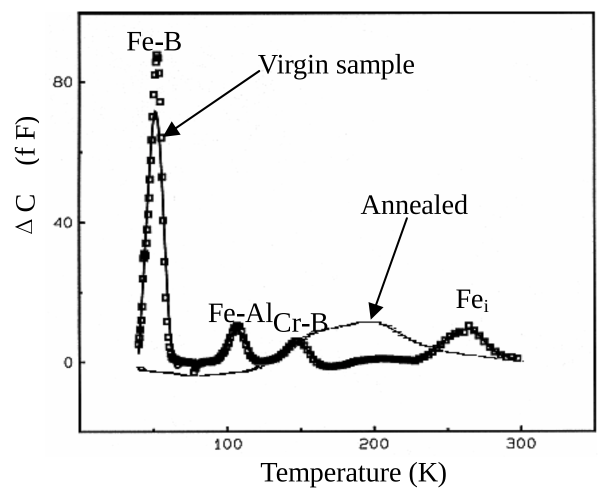

Fig. 2 DLTS spectra measured before and after solar cell processing.

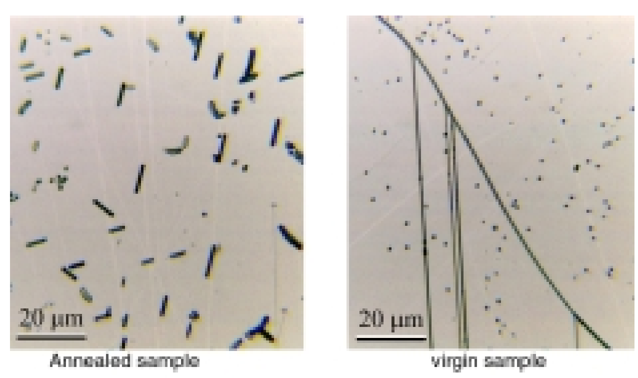

Fig. 3: Optical micrograph of the virgin and annealed samples following a 45 second Secco etch.

[1] T. Y. Tan, E. E. Garner, and W. K. Tice, Appl. Phys. Lett., **30**, 175 (1977)
[2] D. H. Hwang, B. Y. Lee, H. D. Yoo and O. J. Kwon, J. Cryst. Growth, **213**, 57 (2000)
[3] S. Kusanagi, T. Sekiguchi, B. Shen, and K. Sumino, Mat. Sci. & Tech., **11**, 685 (1995)
[4] R.B. Hall, A.M. Barnett, et al, pg. 117 in MRS **PV 426**, 1996 Spring Symposium, San Francisco, CA, USA