Area: Crystalline and Thin Film Silicon PV

RELATIONSHIP BETWEEN LOCAL OXYGEN PRECIPITATION AND MINORITY CARRIER LIFETIME IN CZOCHRALSKI SILICON

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Oxygen precipitates have a negative impact on the minority carrier lifetime [1]. The impact of oxygen precipitates is often seen as a disk like structure with multiple striations in photoluminescence images [1, 2]. *Gaspar et. al*[2] showed that the higher oxygen concentration in the centre of the wafer leads to the observed disk-like structure of oxygen precipitates (millimetre scale features). However, the origin of the striations (in micrometre scale features) is less well understood. Indeed, observing the chemical structure of such striations require sub-millimetre spatial resolution.

In this work, n-type Electronic Grade (EG) Czochralski (Cz) silicon wafers with 1 Ω.cm resistivity were two-steps annealed at 650°C for 5 hrs followed by 11 hrs annealed at 1000°C to study the oxygen precipitation along the radial direction of the wafers. This long annealing at high temperature is not a standard step in solar cell fabrication. However, it represents a worst-case scenario for oxygen precipitation and forms a base to explore the relationship between precipitated oxygen and minority carrier lifetime with high sensitivity. The relative [O_i] concentrations of as grown and annealed samples were measured with a Fourier Transform Infrared Spectroscopy (FTIR) microscope with a spatial resolution of 160 µm. Minority carrier lifetime measurements were extracted from Photoluminescence (PL) images captured by a BT imaging tool with a spatial resolution of 160 µm.

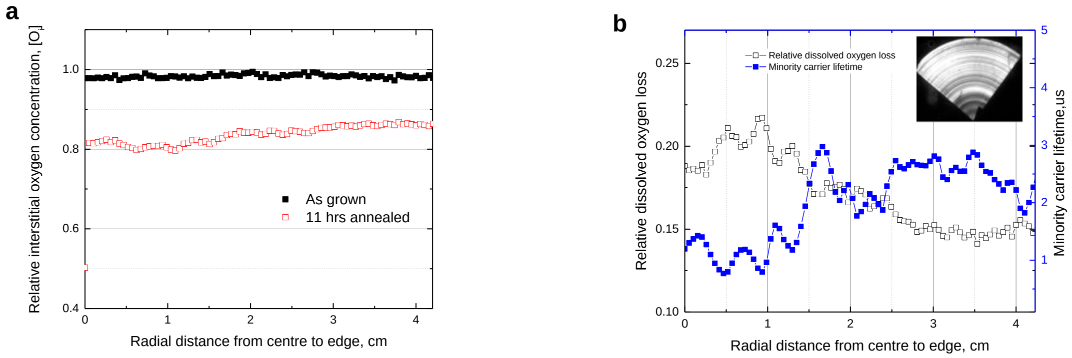

Figure 1: (a) Radial distribution of relative interstitial oxygen concentration for as-grown and two-steps annealed sample (b) Relative dissolved oxygen loss and minority carrier lifetime as a function of radial position from centre to edge, with corresponding PL image in the inset.

The minority carrier lifetime of the EG Cz sample is plotted with the dissolved oxygen loss along the radial position from centre to edge for two-steps annealed sample. In general the oxygen loss is high at the centre of the wafer but reduces towards the edge. There is clear global trend of lower minority carrier lifetime corresponding to higher oxygen loss. Furthermore, local crests of the minority carrier lifetime match with troughs of oxygen loss. Hence we have demonstrated that lifetime striations are due to non-uniform interstitial oxygen loss or oxygen precipitation. Interestingly, in our wafer this non-uniform oxygen loss is not related to a non-uniform as-grown oxygen distribution. This suggests that other factors, such as vacancy striations, may lead to the observed non-uniform oxygen loss and the subsequent lifetime rings.

Further work will be performed to investigate the relationship of oxygen loss and minority carrier lifetime for realistic solar fabrication process steps (such as phosphorous and boron diffusion temperature) for both EG and Upgraded Metallurgical-Grade (UMG) Cz silicon wafers.

Bibliography

1. Coletti, G., et al., *Removing the effect of striations in n-type silicon solar cells.* Solar Energy Materials and Solar Cells, 2014. **130**: p. 647-651.
2. Gaspar, G., et al., *Identification of defects causing performance degradation of high temperature n-type Czochralski silicon bifacial solar cells.* Solar Energy Materials and Solar Cells, 2016. **153**: p. 31-43.