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Acceleration and Mitigation of Hydrogen Induced Degradation in *p*-type Cast-mono Silicon

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Low-cost silicon materials such as cast-mono and multi-crystalline silicon wafers degrade due to the formation of hydrogen induced degradation (HID) related defects [1]. This degradation is commonly known as light- and elevated temperature induced-degradation (LeTID) since the degradation requires elevated temperatures and excess carrier injection [2], [3]. The effect has been shown to be most detrimental to passivated emitter and rear cell (PERC) solar cells, and can cause up to 16% relative loss in power [4]. A recovery in minority carrier lifetime can be observed with extended light soaking under the same conditions that enable defect formation. However, the entire process of defect formation and recovery takes more than a decade in the field. Recent work demonstrated a method to accelerate the degradation and subsequent mitigation of the HID defects in mc-Si by subjecting a wafer to high illumination (laser) at elevated temperatures [5]. Through this laser process, HID was able to be suppressed, with the lifetime remaining stable after 100 hours of stability testing.

In this paper, we further conducted our investigation of acceleration and mitigation of HID in *p*-type cast-mono silicon. Lifetime structures were fabricated on neighbouring cast-grown boron-doped 1.7 Ω.cm 6-inch cast-mono wafers with a thickness of 180 µm. In addition, commercial grade 6-inch boron-doped Czochralski (Cz) and high performance (HP) multi-crystalline (mc-Si) wafers were processed in parallel as a reference. The as-cut wafers were subjected to a saw damage etch, RCA cleaning and $POCl_3$ diffusion. The cast-mono wafers were processed as PERC precursors with rear-side etch process followed by front side silicon nitride (SiN_x:H) passivated emitter and rear side AlOx:H/SiN_x:H stack. Cz and mc-Si wafers were symmetrically passivated with SiNx:H films deposited on both sides by PECVD. These wafers were then fired at a temperature of approximately 740 °C. All wafers were laser cleaved into tokens (3.9 mm × 3.9 mm) and cast-mono and mc-Si wafers sorted into identical 'sister' sets. For cast-mono wafers, three different 'sister' tokens were selected based on the composition of mono-like and dislocated regions. All selected lifetime samples were split into two testing groups, a) light soaking at 75 °C and 1 sun with a broadband halogen lamp, and b) accelerated degradation and regeneration under high illumination laser with temperatures between 130 - 190 °C.

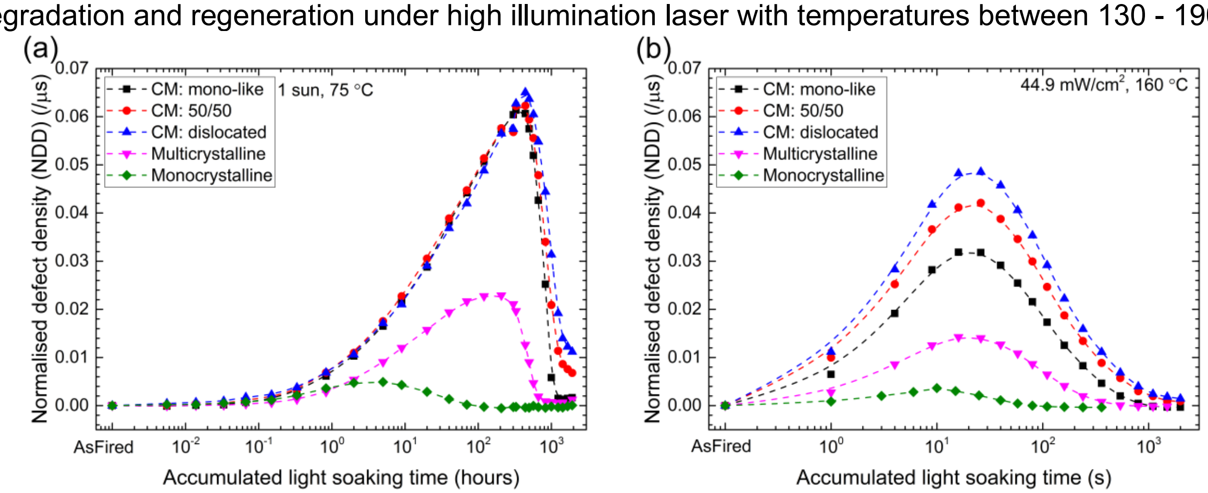

Figure 1. Normalized defect density of all types of wafers (a) under 75 °C, 1 sun test condition (b) under 160 °C and 44.9 mW/cm² of laser treatment. (CM represents cast-mono wafers)

Figure 1. shows the normalised defect density (NDD) for all types of wafers under standard light soaking (Figure 1a) and an example case of an incident irradiance of 160 °C and 44.9 mW/cm^2 under laser treatment (Figure 1b). No obvious difference in degradation extent was observed for the cast-mono samples soaked under standard conditions, while more severe degradation was found with laser treatment for samples with more dislocations. An example case for the analysed Shockley-Read-Hall (SRH) components of the defects with the most dislocated token in cast-mono silicon is shown in Figure 2a. A capture cross section ratio (*k*) of 29 ± 2 was determined based on the fitting of the lifetime data to the model. The fitted dark saturation current density (J_{0E}) indicated the degradation is more likely caused by defects in the bulk. Photoluminescence images for cast-mono silicon at different stages during the laser process are shown in Figure 2b. Comparisons were made by calculating the image ratio of the as-fired state with the degraded and regenerated state. At the degraded state, the sample had an average PL count 12 times lower than at the as-fired state. Regions with more dislocations degraded less compared to the mono-like regions. Whilst at the regenerated state, the regions near dislocations showed less recovery compared to the mono-like regions.

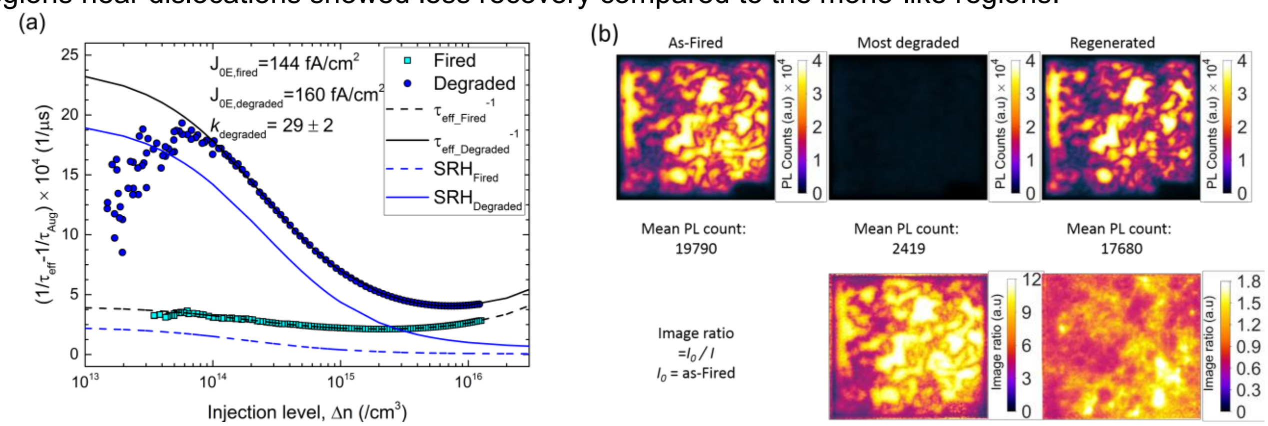

Figure 1. (a) Inverse lifetime curves and fittings of a cast-mono sample (contains more dislocations) before and after laser treatment (b) spatial analysis for a cast-mono sample (with more dislocations) at degraded and regenerated stage.

In the final presentation, we will be showing an accelerated formation of HID-related defects under different temperatures and illumination intensities. Stability testing has been conducted for all treated samples at both wafer and cell levels. A detailed Shockley-Read-Hall defect characterization as well as the spatial analysis on *p*-type cast-mono crystalline silicon will also be presented.

References

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