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Temperature dependent degradation and regeneration of differently doped mc-Si materials

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Abstract

Light and elevated temperature induced degradation is observed for multicrystalline Si PERC-type solar cells, strongly limiting solar cell parameters under operation conditions. In this contribution, we investigate the effect of temperature on the degradation and regeneration kinetics of lifetime samples with different p-doping. While there is no fundamental difference visible between B- and Ga-doped materials, Ga-doped samples generally had a lower starting lifetimes and showed a slower degradation process. Ungettered Ga-doped samples did not regenerate within the applied time frame. For higher treatment temperatures (≥200°C) lifetimes after regeneration exceeded the initial values before degradation for both gettered materials. There are first indications that the degradation reaction is diffusion limited (following Arrhenius-like kinetics), while the observed regeneration kinetics might change for higher temperatures (≥150°C).

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Keywords: multicrystalline Si; lifetime; degradation; regeneration; illumination; temperature; PERC

1. Introduction

Light and elevated temperature induced degradation (LeTID) affects the performance of multicrystalline (mc) silicon passivated emitter and rear cell (PERC) solar cells [1-3]. The underlying effect or mechanism of LeTID is still unknown. The effect can also be observed on lifetime samples as already shown (*e.g.*, [3, 4]). The type of surface passivation [5], effective external gettering steps [6] as well as firing conditions [7, 8] strongly influence

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LeTID. Regeneration can be observed at longer timescales (after ~1,000 h) when treated at 75°C and 1 sun, a kind of standard conditions for LeTID experiments. It is known that the kinetics of the LeTID effect is influenced by illumination / carrier injection and temperature. Increasing the temperature accelerates the effect (*e.g.* [3]). Since the regeneration effect can be observed at 75°C only at longer timescales, an increase in speed by increasing the temperature would be interesting if the underlying effect is only accelerated but not altered otherwise.

This contribution presents a study of effective minority charge carrier lifetimes τ_{eff} to identify the temperature dependency of LeTID that might lead to a better modelling of the effect. It shows that even on equally processed sister samples with comparable grain structure the regeneration behaviour seems to change for temperatures above 200°C.

2. Experiment

For the experiment 5x5 cm² adjacent mc-Si wafers in ingot height (sister samples) with either B-doping (~1 Ωcm) or Ga-doping were used. By using sister wafers, a comparable material quality as well as very similar grain and defect structure can be achieved. All samples were etched to remove saw damage. To compare samples with and without P-gettering step, half of the samples received a $POCl_3$ diffusion step (55 Ω/□) and the created emitter was removed again by etching. All samples got a PECVD (plasma-enhance chemical vapour deposition) silicon nitride layer as surface passivation and were fired at 780°C measured peak sample temperature. The applied process sequences are also shown in Fig. 1.

For the degradation and regeneration treatment, an illumination of 0.9 ± 0.1 suns at various temperatures between 75°C and 250°C was used to investigate temperature dependent kinetics of the degradation and regeneration behaviour.

The minority charge carrier lifetime measurements of the samples were performed repetitively using TR-PLI (time resolved photoluminescence imaging [9, 10]) at room temperature. This is a fast, spatially resolved and self-calibrated way to obtain lifetime measurements.

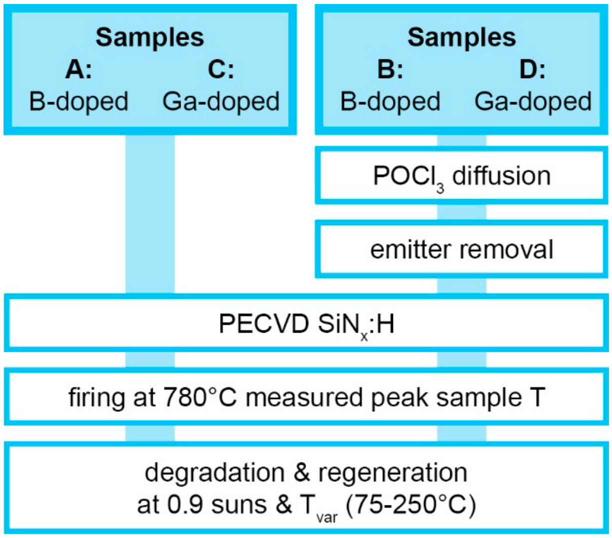

Fig. 1. Processing steps and treatment of the samples.

3. Lifetime measurements

The experiment results in many spatially resolved TR-PLI maps showing the lifetime after different treatment times for differently processed samples. So for every sample there are many lifetime maps to get an evolution of lifetimes during treatment. Fig. 2 shows exemplarily TR-PLI measured τ_{eff} maps of a Ga-doped, P-gettered sample