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Influence of P gettering thermal step on light-induced degradation in Cz Si

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Abstract

It is well-known that B-doped Cz Si solar cells suffer light-induced degradation due to a boron–oxygen defect which is responsible of a reduction in lifetime and hence efficiency. In this paper, the influence of a P gettering thermal step on Cz material quality is explored. It is shown, in a range of resistivities and oxygen contents, that P gettering is able to recover lifetime, reducing both 'ingot growth-induced' and 'process-induced' impurities, and allowing also for a reduction of the defect concentration after the thermal step. A comparison among different thermal processes related to the reduction of this specific defect has also been carried out with the aim of evaluating the effect of self-interstitials injection during thermal processing. Although the reduction in Cz-defect concentration is mainly due to the thermal treatment, specific environmental conditions into furnace can modify in some extent the reduction of defects.

To evaluate the effect of the defect activation in the performance of solar cells, PC1D simulations of a specific P/Al structure have been performed, and results show that efficiencies in the range of 18% can be achieved in the degraded state, with a reduction of more than half a point of efficiency from the non-degraded state in the best case.

Keywords: Phosphorus gettering; Cz silicon; Light-induced degradation; Boron–oxygen defect; Lifetime degradation

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1. Introduction

Light-induced degradation of Cz Si solar cells was already detected in the 1970s [1], and the topic has recently received much attention in the context of high efficiency Cz solar cell research [2–4]. Cz Si solar cells experiment a decrease in efficiency after exposure to light, which is caused by lifetime degradation due to the activation of a defect related to the boron and oxygen contents. Degradation can also be caused by forward biasing the device. After a thermal step at low temperature (above 150 °C), the defect de-activates and lifetime is recovered.

Although this defect has been electrically characterized thanks to the development of new techniques, such as TDLS (temperature-dependent lifetime spectroscopy) or IDLS (injection dependence lifetime spectroscopy) [5], making possible to locate its energy level ($E_c - E_t = 0.41\,\mathrm{eV}$) and estimate that its electron capture cross-section is 9.3 times higher than the hole capture cross-section [6], its atomic composition keeps on being a controversial topic. Theories point out that the defect is related to a complex of substitutional Boron and interstitial oxygen. A model has been proposed in which the oxygen role is played by an oxygen dimmer (O_{i2}) [7,8], whilst for other authors, interstitial oxygen presents an indirect relation that could take advantage of other crystal defects such as vacancies and self-interstitials [6].

Ways to avoid the problem of degradation with light have been proposed, based in the reduction of boron and oxygen contents [9]; for example, by using magnetic controlled Cz or even FZ, where the oxygen content can be neglected, or by replacing boron doping with gallium one. Other alternatives can be the use of higher resistivity B-doped Cz, or even n-type material, but in this case changes in cell structure should also be implemented. In the case that standard B-doped Cz material is used, Glunz et al. propose a thermal process at high temperature (oxidation at 1050 °C in optimized conditions) to reduce the defect density [10], and studies on long time annealing at low temperature have demonstrated a reduction in the defect concentration of the material [11].

Since thermal treatments seems to have a positive effect reducing the light-induced defect concentration, and P gettering is an effective way of improving lifetime that is easily implemented in solar cell processing, it would be interesting to investigate to which extent lifetime recovered by the gettering step is affected by illumination, and whether degraded lifetimes are high enough so that cell performance is not limited by bulk recombination.

This paper evaluates the influence of an optimized P gettering step on light-induced degradation of B-doped Cz Si by lifetime measurements. Samples with different boron and oxygen concentrations are thermally processed, and lifetimes before and after light-induced degradation measured. Analysis of measurements leads to some conclusions. Besides, further experiments are designed to check whether the injection of self-interstitials associated to P gettering plays any role in the deactivation of the Cz-related defect.