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Controlled introduction of cracks into crystalline silicon solar cells and subsequent acoustic excitation

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Abstract

Due to the high cost pressure in solar module manufacturing over the last years the need for investigation of module quality (reliability, lifetime, security) has become more important. To investigate the long time behavior of solar modules both in the field or in the lab it can be beneficial to simulate typical defects in components of solar modules. In this work two different methods are presented to introduce artificial mechanical defects into standard silicon solar cells. Furthermore the dynamic behavior of cracks is investigated during strong acoustic excitation using a self-made excitation setup and photoluminescence techniques.
In the first method a steel ball is dropped in a controlled way on a mounted solar cell leading to a reliable introduction of a cross-shaped crack. In the second method a pendulum is used to introduce mechanical edge defects in solar cells which always leads to chipping of silicon but not necessary to crack introduction. By investigation of over 100 samples it can be shown that mc-cells have a higher probability of breaking if initial mechanical defects are present at the edge compared to Cz-cells. Furthermore no evidence was found that the edge isolation method (chemical or laser) could influence the breaking of solar cells with damaged edges. Also it is shown that cracks close to the edge lead to a higher chance of breakage compared to cracks in the center of the solar cell.

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Keywords: Defect; Crack; Durability; Acoustic excitation; Sonic treatment; Photoluminescence

1. Introduction

For the last years the competition in the solar module market is strongly increasing with steadily dropping module prices. For solar module manufactures this high cost pressure leads to the need for a more efficient module production. But the high cost pressure holds the risk of lower module quality because of cost savings in quality assurance and material quality. For this reason testing of solar modules both in the field and in the lab has become

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more important over the last years. In this work we try to simulate typical defects of components of solar modules in order to later build test modules and use them in long-term tests. Here it is important to establish defect simulation methods that are reliable and reproducible. We present two techniques that aim to introduce cracks in standard silicon solar cells, in the first method a steel ball is dropped on the sample and in the second method a pendulum is used for edge defect introduction. In addition the damaged samples are acoustically excited in a way that the samples oscillate in resonance. In photovoltaics acoustic excitation to examine wafer defects is already known [1]. The sonic treatment allows us to gain general information about the dynamics of mechanical defects like cracks in solar cells. Further we use it to be able to better estimate whether cells with simulated defects can be handled in module production processes, e.g. unwanted module defects could occur or certain module processes could become impossible at all. This work is about cracks because cracks are a common defect in solar modules that can lead to more severe damage over time which affects the security and performance of the module. Known ways of common introduction of cracks are for instance transportation [2] or heavy loads like snow or wind [3]. To investigate the crack propagation we use photoluminescence (PL) techniques.

2. Experimental setup

The ball-drop setup is imaged in Fig. 1 (a), it is built similar as described in [4]. The cell sample is mounted on a brass chuck using vacuum suction. The steel ball has a diameter of 6.4 mm, a mass of 1 g and was taken from a ball bearing. The ball is hold by a magnetic coil, the height of the coil and the position relative to the cell sample can be adjusted. A drop height too low does not reliably introduce cracks while a drop height too high leads to multiple cracks as the ball bounces from the sample. It was found that a drop height of 70 mm is optimal to introduce cracks reliable and reproducible. In Cz-samples always cross-shaped cracks occur while in mc-samples the cracks are star-shaped with three or more arms. The crack diameter lies between 3…10 mm. In the experiment described later in this document a constant drop height of 70 mm was chosen. For both Cz- and mc-samples two different crack positions were investigated. The first position (center) lies in the center of the cell around 10 mm next to the busbar in the middle. The second position (edge) is also next to the middle busbar but 3…9 mm close to the cell edge.

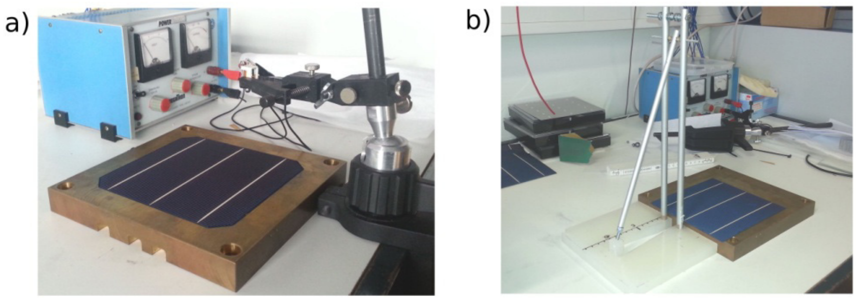

Fig. 1. (a) ball-drop setup; (b) pendulum setup.

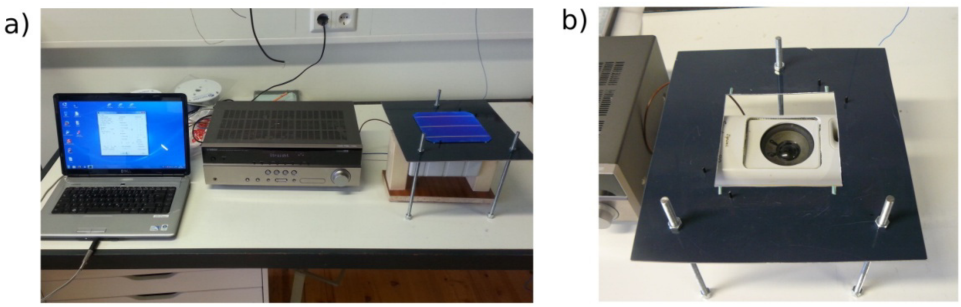

Fig. 2. (a) complete acoustic excitation setup with laptop, HiFi-amplifier, loudspeaker and sample holder; (b) sample holder in detail.