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Analysis of activation energies and decay-time constants of potential-induced degraded crystalline silicon solar cells

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Abstract

A laboratory type PID-test system was used to measure degradation curves of the shunt resistance during the stress test. It was found that these curves feature typically an initial plateau without significant changes and a mono-exponential decay, both having temperature depended time constants: The plateau length as well as the decay time constant behave Arrhenius-like. Performing these degradation measurements under various temperatures enable the identification of PID relevant activation energies. A solar module compound made of industrial-type crystalline silicon solar cells was investigated and an activation energy of the decay was determined to (0,95 ± 0,14) eV.

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Keywords: PID, PID-test, activation energy

1. Introduction

Potential induced degradation by the shunting type (PIDs, further referred to as PID) of crystalline silicon solar cells is still a not fully described phenomenon. The effect can be reduced or even avoided on cell level, module level or system level. Many manufacturers have decided to produce already PID free solar cells. To check the PID resistance of a certain solar cell architecture a supplement of an already existing quick PID test procedure [1] is suggested. This PID test on cell level measures the reverse characteristic parallel resistance R_{shunt} and gives a good

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correlation to PID in the module and system level [2]. Although this type of PID testing was introduced to the community several years ago, so far no activation energy measurements were done using it. Nevertheless, activation energy measurements were published so far by Raykov et al. [3], Taubitz et al. [4] and Hacke et al. [5] for temperature dependent leakage current measurements in solar modules. These values are in the range of 0,4 eV/0,7 eV [3], 0,73 eV [4] and 0,86 eV [5].

The complex system of materials and interactions makes it very difficult, to give a physical interpretation of the origin of this activation energy. So far it is commonly accepted, that the PID effect is correlated with

- the composition of anti reflection coating made of silicon nitride and the interfacial properties to the silicon surface underneath [6,7], and
- sodium occurrence in silicon: Stacking faults are decorated with a huge amount of sodium [8].

In this contribution the temperature dependent analysis of solar cell R_{Shunt} degradation curves is developed and applied to measure the activation energy E_A of the degradation mechanisms to give access to an important measure related to PID.

2. Experimental

Industrial type crystalline silicon solar cells were fabricated using 3-6 Ohmcm Cz-wafers. The process sequence is based on industrial features, having an alkaline texture, a phosphorus diffusion, a PECVD SiN_X-Antireflection Coating (ARC) and screen printed metallization based on silver on the front and aluminum on the rear. A certain type of solar cell was used in the experiments, which were known to be PID-prone. Such solar cells were locally degraded in a laboratory apparatus as pictured in Fig. 1: On the front side of the cells a stack of EVA and a TCO coated glass were mounted (TCO on the upper side). To investigate the cells, the EVA foil used must be PID prone, hence not to suppress PID. This stack was placed onto aluminum foil and further on a precision hot plate. Between the front-glass TCO and the solar cell base, a high voltage of 1000 V was applied, the minus polarity on the cell base contact. This high voltage can cause a potential induced degradation to the solar cell. Since not all the solar cell area was covered with EVA and glass, the front contacts of the solar cell were partly free. The high voltage stress was applied for several temperatures between 54 and 82 degree Celsius (°C). During the degradation, the shunting resistance of the solar cell was measured by applying a low reverse voltage of 100 mV and measuring the corresponding current (see Fig. 1 a). The PID stress was applied for several hours until a significant R_{shunt} degradation was observed. The cells were characterized prior to and after the PID-stress test by means of light IV (under STC), electroluminescence (EL) and Dark Lock-In Thermography (DLiT). Such measurement results were shown in Fig. 1 b) as an example indicating the typical PIDs related degradation phenomena: Reduction of parallel resistance R_{shunt} followed by a decrease in fill factor *FF*, efficiency *Eta* and later open circuit voltage V_{OC}. In the EL

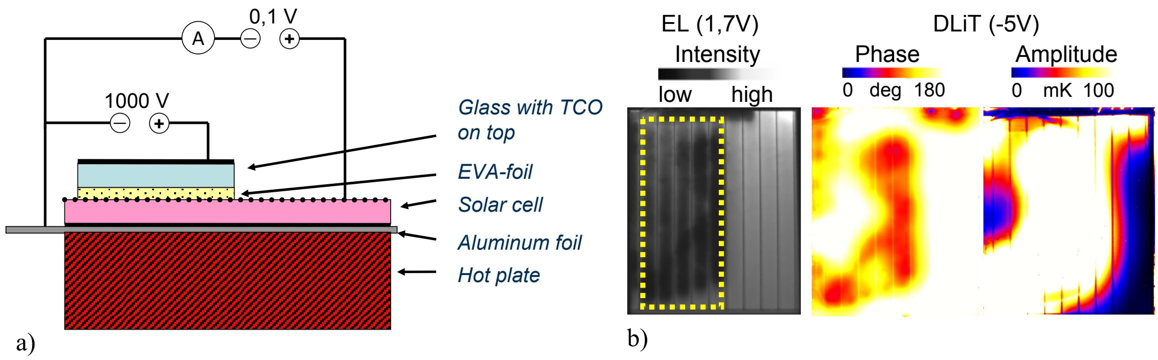

Fig. 1. Simplified cross section of experimental setup (a). Representative EL and DLiT pictures of a PID-affected solar cell after PID-degradation are shown in (b). PID occurs in area of the solar cell which was covered by the EVA and glass (yellow frame in EL). Sample sizes are 20x25 mm², PID-area ~10x20 mm².