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ScienceDirect

Energy Procedia 92 (2016) 540 – 545

Energy Procedia

6th International Conference on Silicon Photovoltaics, SiliconPV 2016

Shade performance of a back-contact module assembled with cells featuring soft breakdown characteristic

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Abstract

We investigate the shade performance of modules assembled with interdigitated-back-contact (IBC) cells that consist of abutted p^+n^+ regions on the rear side. Because of the soft breakdown characteristic of these cells, the shade performance of such modules is different from the standard front-contact modules that exhibit high breakdown voltage. We fabricated IBC cells that feature early and relatively homogeneous breakdown characteristic, and then these cells were assembled into 60-cell modules. The module power was measured under illuminated and several shaded conditions, and the expected enhancement of module power under partial shading was verified. Further, a SPICE model was built to simulate the shade performance of cells with different breakdown voltages. We found that when the shaded area in the module exceeds a certain value, the dissipated power from the shaded cells is higher than the power generated by the non-shaded cells and hence the activation of bypass diodes is beneficial. Due to this reason bypass diodes are still necessary for such modules.

Peer review by the scientific conference committee of SiliconPV 2016 under responsibility of PSE AG.

Keywords: Back contact; partial shading; soft breakdown; shade performance; bypass diode

1. Introduction of soft breakdown

Partial shading is one of the major causes of energy losses in the photovoltaic (PV) system. Local hot spots can appear in partial shading condition and hence lead to local high temperature and possible irreversible damage on the

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Peer review by the scientific conference committee of SiliconPV 2016 under responsibility of PSE AG.
doi:10.1016/j.egypro.2016.07.138

modules. The shade performance is mainly defined by the reverse IV characteristic of the cells. Nowadays, the dominant front-contact crystalline silicon solar cells exhibit high breakdown voltage Vr (|Vr| > 10 V), while IBC cells that feature soft breakdown at reverse bias have been reported by several authors [1-5]. In this paper we define the breakdown voltage V_r as the voltage at which the reverse current reaches 2 A. A possible cause for the soft breakdown was reported to be the tunneling current across the abutted p^+n^+ regions on the rear side [6], e.g. as the one shown in Figure 1, leading to early breakdown at a low voltage (|Vr| < 6 V). And more importantly, the breakdown is uniform over the entire cell. This IBC cell architecture has two advantages: (1) simplified production process; (2) higher energy yield and improved module reliability in a PV system. The former advantage results from the fact that one masking step, which is used to form a narrow gap that separates the rear emitter and back-surface-field (BSF), can be eliminated [7]. The latter advantage is due to the low breakdown voltage and the uniform breakdown [2, 8-10].

In this work we study the energy yield and the role of bypass diodes in modules assembled with cells featuring soft breakdown characteristic in partial shading conditions. Firstly we fabricated such module and the module power was measured under illuminated and several shaded conditions. Secondly a SPICE model was built to simulate the module shade performance. Lastly we compare the shade performance of modules with high and low breakdown voltages.

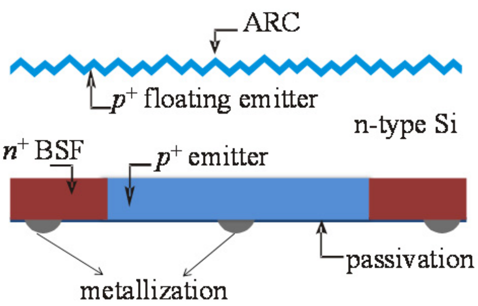

Fig. 1. IBC cells with abutted p^+ and n^+ regions on the rear side.

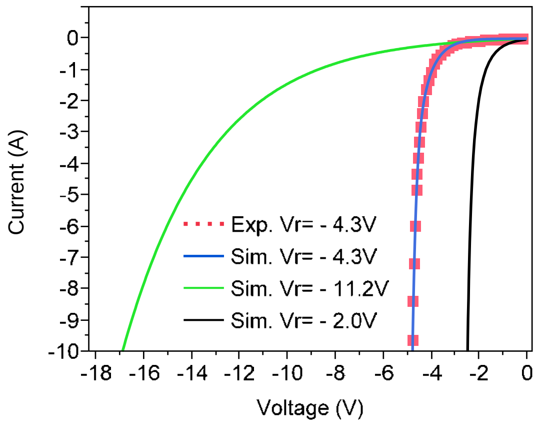

Fig. 2 Measured and simulated I-V curves of cells with different breakdown voltage at reverse bias.

Fabrication of cells and modules

Our IBC cells (Zebra), with no gaps between the emitters and BSFs as shown in Figure 1, were produced on 6-inch n-type Cz Si wafers by industrially feasible methods such as tube diffusion and screen printing metallization [11]. Eurotron BV supplied the assembly line for back contact module [12] and processed these cells into 60-cell modules with the application of conductive back sheets and low Ag content electrically conductive adhesive. Note that identical to standard front-contact modules, three bypass diodes were mounted on each module and each bypass diode was connected in parallel with 20 cells. For more details of module integration please refer to [13].

The reverse I-V curve from one cell (red squares in Figure 2) shows the typical soft breakdown characteristic. For the cell in Figure 2, it has a breakdown voltage of - 4.3 V. A reverse bias electroluminescence (ReBEL) measurement was performed, and the relatively homogeneous image implies homogeneous breakdown. One of our 60-cell IBC modules was calibrated by Fraunhofer ISE Callab and used for calibration of I-V measurements on other modules. Figure 3 depicts the I-V curve of the investigated 60-cell module under AM 1.5 spectrum and 25°C. The electrical parameters measured are as follows: Voc=39.12 V, Jsc=9.83 A, FF=76.4 %, and Pmpp=293.8 W.