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Ribbon interconnection of 6” BC-BJ solar cells

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Abstract

This work presents an interconnection approach for 6” back-contact back-junction (BC-BJ) solar cells by using conventional solder-coated copper ribbons with implemented wave structures for thermomechanical stress relief. We developed a process for production and advanced mechanical and electrical characterization for these interconnectors. In our study, mechanical stress is reduced up to 96.6 % (for ribbons) and up to 81 % (for wires) compared to non-structured interconnectors. In electrical terms, the relative effective resistance of the interconnector is increased by 3.1 % (for ribbons) and by 6.4 % (for wires). In general both, ribbons and wires, are suitable for the interconnection of 6” BC-BJ solar cells.
A 4-cell module with 19.94 % efficiency in a standard module setup with 21.09 % - 21.18 % 6” BC-BJ ZEBRA cells (CTM_{power} = -3.8 %) is manufactured. For interconnection 8 modified ribbons (1.5 x 0.2 mm²) are used on the rear side. The cells feature a multilayer metallization with a low temperature paste. The module passes TC-200 according to IEC 61215 without degradation. Our cost analysis shows that such a stress relief structure can be realized with additional material costs of lower than 0.2 € for a 60 cell full size module.

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*Keywords:*BC-BJ; IBC; Solar cell; PV solar module; Wave-shaped ribbon; Wave bending process; Ribbon interconnection; Busbar; IV; EL; Mechanical analysis; CTM; Temperature cycling;

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1. Introduction

Nowadays, back-contact back-junction (BC-BJ) PV modules feature an edge interconnection with 5” cells and are commercialized by SunPower [1-3]. The interconnection of 6” BC-BJ solar cells is still a technical challenge. The electrical current path in the finger is longer, resulting in an unacceptably high series resistance for an edge interconnection. Thus, the use of ribbons or wires for the interconnection enables a strong decrease of the series resistance. Cells that feature a multilayer metallization, consisting of an isolation layer and a busbar with a low temperature paste (LTP) [4-8], can be used for this approach. A solution to avoid the undesirable cell bow caused by the asymmetric single-sided interconnection with standard ribbons is presented in this paper.

2. Experimental

2.1. Mechanical behavior of structured interconnectors

The undesired cell bow of an interconnected back contact solar cell is mainly driven by the different temperature coefficients (CTEs) of copper ($\alpha_{Cu} = 17.0 \cdot 10^{-6}\ K^{-1}$) and silicon ($\alpha_{Si} = 2.6 \cdot 10^{-6}\ K^{-1}$). The approach, to measure the cell bow, introduced by Rendler et al. is used [9] (Fig. 1). A confocal sensor measures the difference between the horizontal line and the cell bow.

In order to define ideal specifications for the ribbon’s mechanical compliance we use the following consideration. The relative displacement Δl between two materials of length l after a homogeneous temperature change ΔT can be calculated by $\Delta l/l = \varepsilon_{th} = \Delta T \cdot (\alpha_{Si} - \alpha_{Cu})$. With $\Delta T = 219$ K for a SnPbAg solder (lowest temperature in TC of -40°C to solidus temperature of solder at 179°C) the thermal strain ε_{th} is -0.315 %. Aiming at a stress-free state of the silicon solar cell after soldering and in TC tests the ideal ribbon features highest compliance (lowest stiffness) in the strain range up to 0.315%.

We therefore induce strain relief structures into conventional ribbons and perform tensile tests to access the stress-strain-curves of the structured ribbons. Since the curve measured by tensile tests differs from a typical stress-strain curve (Fig. 8), and in order to enable the comparison between interconnectors with and without a stress relief structures, we introduce a new σ-parameter, i.e. $\sigma_{0.315}$ for SnPbAg. The definition of the σ-parameter allows the compliance specification for any solder alloy and can be extracted from measured stress-strain-curves of any interconnector structure. The lower this stress value the lower becomes the resulting cell bow and in consequence the thermomechanical stress level in the cell after soldering.

The determination of the σ-parameter is done in three steps. (1) Measure the original stress-strain-curve commencing at almost 0 MPa. (2) Plot a tangent through the first inflection point, analogous to linear elastic regime characterization. (3) Shift the measured curve so that the tangent passes through the origin, and determine the σ-parameter of the corrected curve for the specific solder alloy (table 1 and Fig. 2).

Table 1. σ-parameter for different solder alloys.

Solder alloy	σ parameter
Sn62Pb36Ag2	$\sigma_{0.315}$
Sn60Pb40	$\sigma_{0.325}$
Sn43Bi57	$\sigma_{0.258}$

To display both the wave-shaped interconnector (Fig. 7) and the non-wave-shaped interconnector in one chart, we have to rename the axis labels. From a physical perspective, a change in the material’s cross section occurs when the material gets stretched. However, since we use a material with a stress relief structure the material does not follow this rule. To emphasize this difference we use “effective stress” and “effective strain” for the axis labels. From the cell (technical) perspective, the given stress is a comparative value which gives an idea of the mechanical stress applied to the solder joints, and which affects the cell bow. Please consider in case of