Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 77 (2015) 346 – 355

Energy Procedia

5th International Conference on Silicon Photovoltaics, SiliconPV 2015

Reduction of thermomechanical stress using electrically conductive adhesives

Torsten Geipel[a],*, Li Carlos Rendler[a], Manuel Stompe[b], Ulrich Eitner[a], Lutz Rissing[b]

[a] *Fraunhofer Institute for Solar Energy Systems, ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany*
[b] *Institute of Microproduction Technology, Leibniz University Hannover, An der Universitaet 2, 30823 Garbsen, Germany*

Abstract

We compare the thermomechanical stresses in solar cell interconnections based on electrically conductive adhesives (ECA) with soldered joints by using bending experiments and finite element analysis (FEA). Additionally, the influence of an increasing number of busbars is studied. The FEA is validated by measuring the bending of cell strips after cooling down from a single-sided interconnection process. The material parameters are determined by tensile tests, microscopy and nanoindentation. The comparison of ECA and soldering shows that an elastomer with a Young's modulus of below 0.5 GPa is capable of reducing the thermomechanical stress effectively resulting in, approximately, a mean tensile stress in the ECA of 5 MPa, 110 MPa in the ribbon, and a maximum compressive stress in the silicon of 75 MPa. Increasing the number of busbars from three to five leads to a reduction in compressive stresses in the silicon and a slight increase of the peak tensile stress in the busbars.

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG

Keywords: Photovoltaic Module; Interconnection; Electrically Conductive Adhesives; Thermomechanical Stress; Finite Element Model

---

1. Introduction

New high-efficiency cell concepts such as heterojunction solar cells reach efficiencies well above 24% [1]. These concepts require a low temperature interconnection process to manufacture modules due to the temperature sensitivity of the involved cell layers. Lead-based solders, as the present standard interconnection technology, need

---

* Corresponding author. Tel.: +49-761-4588-5023; fax:+49-761-4588-9193
E-mail address: torsten.geipel@ise.fraunhofer.de

Peer review by the scientific conference committee of SiliconPV 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.07.049

to be processed at temperatures above 200 °C which is not suited for the interconnection for temperature sensitive high-efficiency solar cells. Instead, glueing with conductive films [2] and conductive adhesives in form of pastes [3] have proven to be alternative solutions thanks to their low processing temperatures of below 180 °C. ECAs have become the key interconnection technology for the fabrication of metal-wrap-through solar modules [4]. Still, using ECAs as a replacement for soldering is mainly confined due to the higher material costs and lacking long-term experience

The interconnection process induces thermomechanical stress on the interconnection and the solar cell. This is due to the different contraction of the metal components of the interconnection as compared to the silicon wafer caused by the differences in coefficients of thermal expansion (see Table 1). As a result of their lower processing temperatures, using ECA can reduce the thermomechanical stress after the interconnection process [5].

Until present, the simulation work on crystalline silicon H-pattern solar cells focused on soldered interconnections with a successive refinement of model parameters and complexity [6–9]. The interest in thermomechanical stress analysis of ECA was driven by the development of long-term stable backcontact modules [10–13]. Due to the availability of a large variety of ECAs with widely differing material properties it is important to question which material properties are important in order to reduce the thermomechanical stress effectively.

There is a trend to increase the number of interconnections per cell in order to reduce the series resistance [14]. However, it has not been investigated so far which changes in thermomechanical stress will arise due to the introduction of more than three busbars.

Thus, it is our goal to understand the effects of the mechanical properties of ECAs for the reduction of thermomechanical stress on the solar cell interconnection and compare the effects with standard leaded soldering. Additionally, we want to understand the thermomechanical stress for an increasing number of busbars. Therefore, we want to establish and validate a finite element model with appropriate material parameters for the interconnection with different interconnection technologies.

Nomenclature

CTE	Coefficient of thermal expansion
E	Young's modulus
E_x	Young's modulus (with x the respective layer)
E_t	Tangent modulus in plastic region
σ	Stress from tensile stress-strain curves
σ_{ys}	Yield strength
σ_I	1st principal stress
σ_{II}	3rd principal stress
σ_x	Normal stress in x-direction
σ_y	Normal stress in y-direction
v	Displacement in y-direction
z	Depth
ε	Strain from tensile stress-strain curves
t_x	Layer thickness (with x the respective layer)

2. Approach

The approach for the investigation is to create a finite element model (FEM) of single-sidely interconnected cell strips and calculate the cell bending for the case of two different adhesives: a thermoset adhesive (Young's modulus $E \approx 5$ GPa) and an elastomer adhesive ($E \approx 9$ MPa) and two different processing temperatures (130 °C and 160 °C) as well as interconnection by leaded solder with a solidification temperature of 179 °C. The dimensions of the components are obtained using optical microscopy and scanning electron microscopy. The mechanical parameters of