

Intermetallic Formation in Photovoltaics Modules

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Keywords: Photovoltaics, Soldering, Intermetallics, EDS Mapping.

Abstract: Besides the lamination process, photovoltaic modules reliability depends on the quality of the metallurgical bond between the solder coated copper ribbon and the Ag busbar and, consequently, on their intermetallics formation. In this study, we show how the ultra-thin layer between 60Sn-40Pb and Ag can be identified by using field emission scanning electron microscopy and energy dispersive spectroscopy. We also assess the effect of the manufacturing equipment on the inter-connection reliability. Although not visible through ordinary cross-section and imaging, we observe Ag diffusion into the solder matrix as individual particles as well as in solid solution with Sn.

1.0. Introduction

The photovoltaics (PV) industry is expected to deliver products with lifespan that is considerably longer than in most consumer electronics. Although the manufacturing costs of PV modules have been falling in recent years, high reliability expectations of solar panels put additional strain on the fast expansion of solar energy usage. Higher reliability of PV modules comes from adequate soldering during stringing process and optimized process parameters during their lamination.

In the stringing process a solder coated copper ribbon, also known as PV ribbon, is soldered to the Ag busbars of the Si module using an appropriate flux. A good soldering is given by the quality of the metallurgical bond, which in this case is defined by the formation of an intermetallic compound (IMC) at the interface between the PV ribbon and the solar cell metallization. Consequently, the IMC formed is an indication of good electrical and mechanical bonding [1].

In this work we study the effect of the manufacturing equipment on the quality of the PV module soldering. Sn40Pb coated copper ribbon was assembled on PV modules using either a fully automatic or a semi-automatic equipment. Their respective cross-sections were prepared, imaged and analyzed using microscopic techniques for evaluation of their soldering quality.

2.0. Methods

2.1. Samples. Sample A was assembled using a fully automatic stringing equipment, in which there is no intervention of the operator during the soldering of the PV ribbon on the module, whereas in sample B the operator has to add the flux manually.

2.2. Sample Preparation. PV module samples were cut and cold mounted. The metallographic preparation of these cross-sections included grinding and polishing using SiC abrasive pads to flatten the sections and remove damage from cutting. However, as mechanical polishing alone is not enough to remove the residual damage from mechanical polishing, we used ion milling for final preparation of the area of interest. An argon ion polisher (Hitachi made) was used in its flat milling mode. For these particular samples, we found that setting the milling at an angle of 90 degrees, and 10 reciprocations per min for 15 minutes, at an operating voltage of 4V, gave the most optimal result for imaging and analysis.

2.3. Microscopic Analysis. We used a field emission scanning electron microscope (FESEM) from JEOL (model 7800F PRIME) for imaging, whereas the qualitative identification of the IMC composition was done using energy dispersive spectroscopy (EDS) analysis. Imaging was carried

out using a BSED Deben detector, at 10 KV and 10 mm working distance, whereas the EDS analysis used a Bruker QUANTAX EDS with 30 mm² X flash detector.

3.0.Results

Routine characterization by metallographic sample preparation and scanning electron microscopy did not reveal any intermetallic layer, although the samples showed good mechanical peel strength indicating good bonding [2]. After mechanical polishing and ion milling the samples were imaged and analyzed using FESEM and EDS [3]. A systematic analysis of the cross-sections was carried out to verify the presence of bond formation and identify the intermetallics phase [4]. Using these combined techniques of mechanical etching and surface smears removal, and high resolution imaging helped visualizing the various particles in the solder matrix, which were identified using EDS mapping.

Cross-sectional analysis of sample A does not show any IMC layer at the Ag/solder interface. Despite the absence of a visible layer between the Ag busbar and the PV ribbon, EDS mapping was used to verify the elemental distribution of the soldered area. Fig.1 shows that Ag particles diffused into the solder region. Additional area scan on the Ag layer close to the Sn40Pb solder did not reveal any Sn present in this region. A further spot scan on the Ag rich region observed in the EDS mapping showed presence of Sn, Pb and Ag. Thus we can assume that the Ag particles dispersed into the solder are starting to combine with Sn. However, due to the very short duration of heating during soldering, the time and temperature were not enough to ensure the formation of an actual intermetallic phase. Imaging of another area of the same sample confirmed these observations, as shown in Fig.2. EDS mapping showed areas of inter-diffusion of Ag and Sn, but no evidence of an intermetallic phase.

Similarly, the cross-section analysis of sample B did not show presence of intermetallics formation, but EDS mapping of the Ag busbar/solder interface showed presence of a thin layer containing Sn and Ag. This was also confirmed by additional individual EDS mapping (Fig.3). An area scan determined that this thin layer has 85 wt.% Ag and 11.6 wt.% Sn. From the Ag-Sn phase diagram, we conclude that this layer was Ag and Sn in solid solution, and not the eutectic Ag₃Sn phase. Although we did not see formation of a clear intermetallic compound, we observed several areas with Ag-Sn inter-diffusion (Fig.4).

4.0.Summary

Despite showing good mechanical strength, no evidence was found that the soldered PV ribbon forms an intermetallic with the Ag busbar of the PV module. However, using high resolution imaging and EDS analysis we observed Ag diffusion into the solder matrix as individual particles as well as in solid solution with Sn.

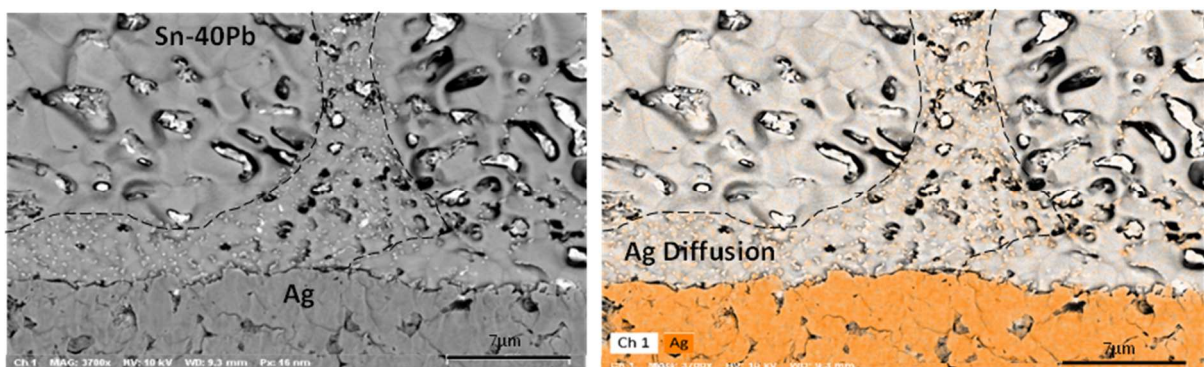


Fig.1 Sample A cross-section (x3700) shows dispersion of particles (left) identified as Ag diffusing into the solder matrix (right).

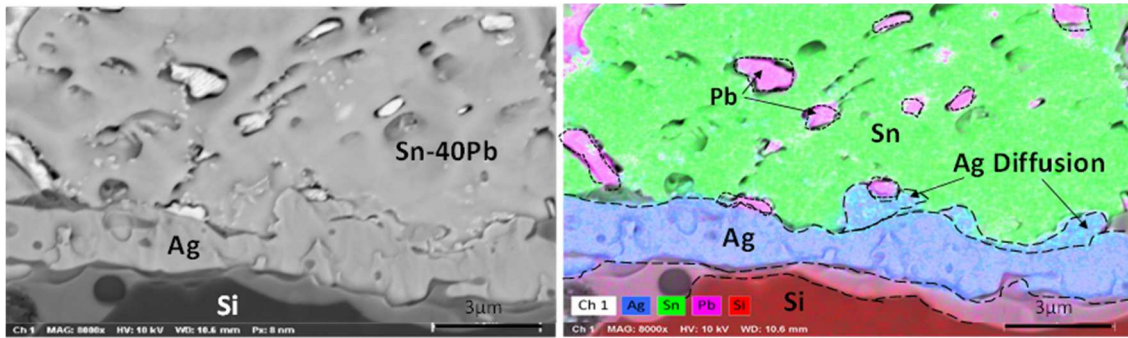


Fig.2 Sample A cross-section (x8,000) microstructure (left) indicates Ag-Sn inter-diffusion on the Ag busbar/solder interface (right).

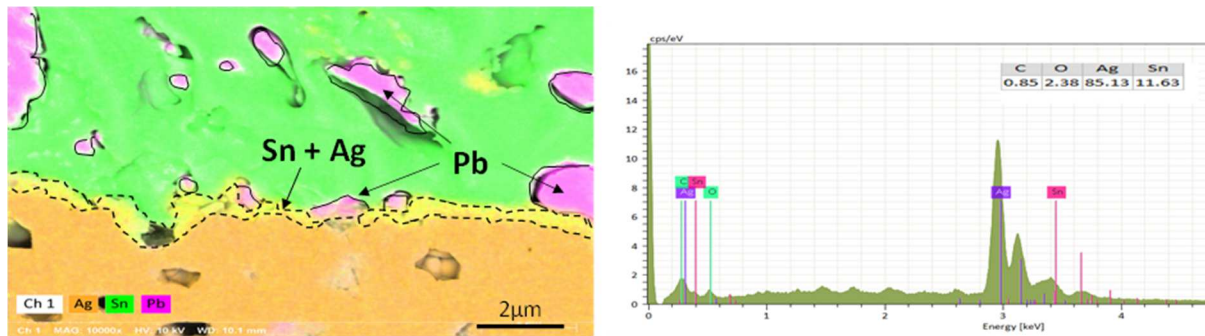


Fig.3 Sample B cross-section (x10,000) EDS mapping (left) shows presence of Sn in solid solution with Ag (right).

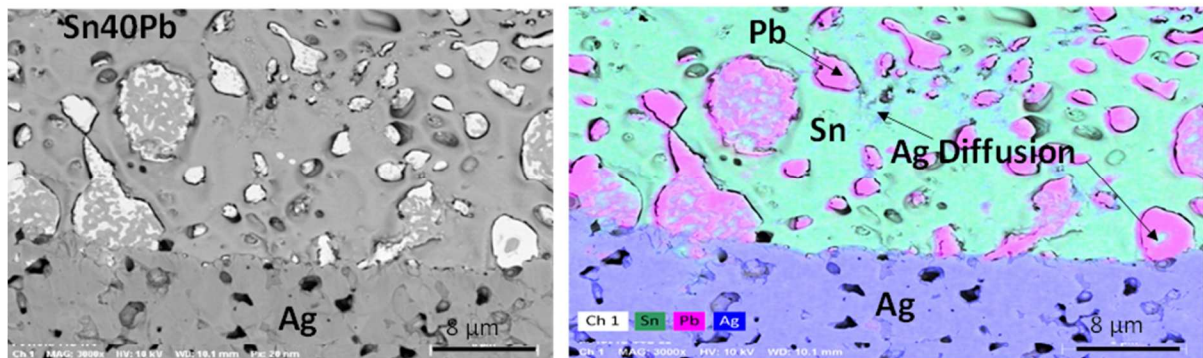


Fig.4 Sample B cross-section (x3,000) microstructure (left) indicates Ag diffusion on the Ag busbar/solder interface (right).

References

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