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Modelling of the Contact Resistance of Screen Printed Ag-contacts to Si emitters

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The Ag front contact of conventional Si-based solar cells accounts for around 10% of the direct efficiency losses of the cell. The fabrication of the Ag fingers is a well-established process based on screen printing and subsequent firing of a paste containing Ag particles and a glass frit. The macroscopic contact resistance of the Ag finger front contact is, however, up to 3 orders of magnitude higher than the microscopic contact resistivity of Ag/n-Si junctions [1]. Recent studies have shed light on the microstructure of the Ag/n-Si interface [2], including the mechanism of formation of the Ag crystals penetrating the n-Si emitter and providing the paths for conduction of electronic currents.

In this work, a detailed microstructural investigation of the Ag/n-Si interface was conducted, along with determination of doping profile, series resistance, macroscopic contact resistivity (by the TLM method), and fill factor of the samples. An example of a SEM picture of the contacting interface of a textured emitter is shown in Figure 1. Characteristic of this interface is the Ag crystallites penetrating the tip of the Si pyramid, as well as side walls, and the presence of the non-conducting glass phase from the paste. The microstructural characterization indicated further that around 25% of the Si-pyramids are in direct contact with the Ag fingers. Based on the microstructural characterization, a representative geometry of the interface was constructed, and implemented as a 3D model in the software COMSOL Multiphysics. The mathematical model included the experimentally obtained emitter doping profiles, corresponding to sheet resistances of 50, 65 and 95 Ohm/sq, respectively, as well as microscopic contact resistivities based on theoretical Schottky barrier models, including, however, ab initio calculated Schottky barriers [3]. The solution of these models provided the local current-voltage distribution around the Ag-crystallites as well as in the emitter layer, and based on these, the apparent macroscopic contact resistivity was determined. Experimentally observed etching of the emitter layer was also simulated by shifting the doping profiles.

Results were obtained for various doping profiles and geometries for temperatures in the range 70-350 K. The results clearly indicate that the conductivity of the emitter layer influences the macroscopic contact resistivity. Furthermore, the results indicate that the discrepancy between macroscopic and microscopic contact resistivity might be related to etching of the emitter. In fact, the model could reproduce the trend of experimentally obtained temperature dependence of the contact resistivity (Figure 3), which cannot be explained by Schottky barrier resistivity models alone.

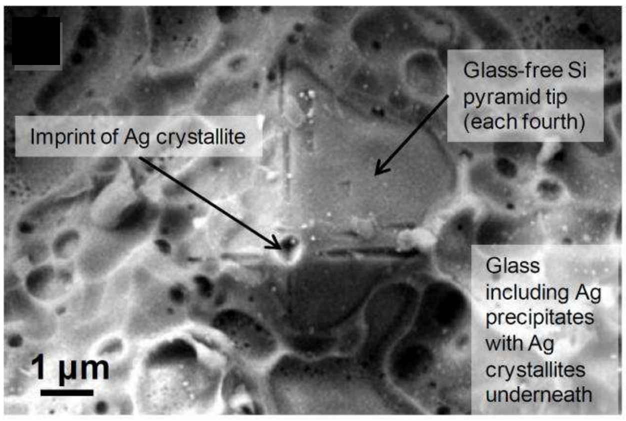

Fig. 1. SEM micrograph of Si pyramid underneath the Ag finger bulk showing the typical screen printed silver contact microstructure.

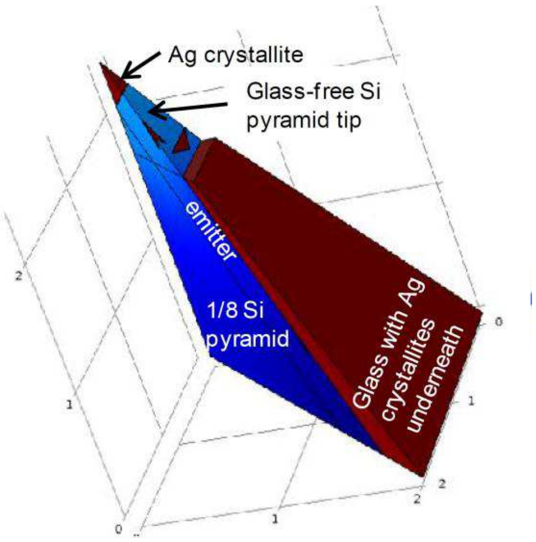

Fig. 2. Idealized 3D model geometry incorporating the detailed microscopic contact configuration.

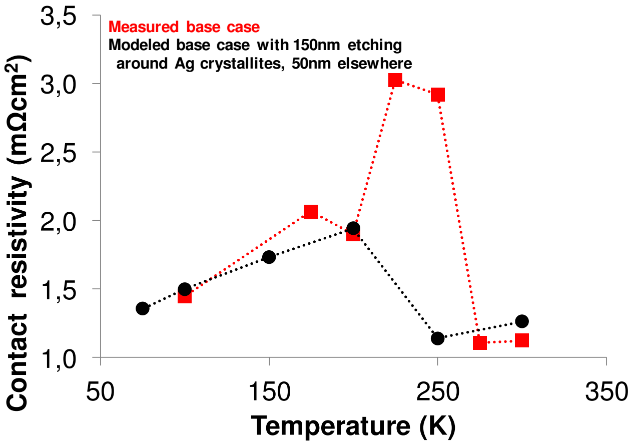

Fig. 3. Comparison of measured and modelled contact resistivity as a function of temperature.

References

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