METAL CONTACTS OF THE CRYSTALLINE SILICON SOLAR CELLS

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Introduction

Electrical contacts of silicon solar cells are still developed because the solar cell based on crystalline silicon are the most commonly used type of solar cell in the industry. Currently, there are many approaches for producing photovoltaic cells and thus many types of metallic contacts allowing current to flow from the cell to the external electric circuit where the cell works. The most popular and still the most commonly produced type of cell is a cell based on crystalline silicon. The most popular technology of front metal contact of this type of cell is screen printing using pastes based on silver. Despite the progress in this domain, the screen printing has some limitations and it is not possible today to print electrical paths narrower than 80 um. In practice, counter electrodes have usually the width of about 100 µm [1]. There exist some publication reports [2] that by heating of the substrates it is even possible to lower the width of paths to 60 µm, however reduction the width of the electrodes is not the only one problem. Another problem is connected with lateral intersection of the metal electrode.

As a consequence development of new materials and techniques designated for elaboration of new types of electrodes for photovoltaic structures are strongly required. The most often meet in the literature resources, are ink-jet printing methods of metal inks, aerojet-printing of metals [3,4]. Such investigations correspond with increase in silver price. That's why in the literature one can find information about the need for replacement of silver with other metal. One of the most popular candidate is copper [5,6]. The share of metals used for contact formation predicted to be used in future is consistent a steady decrease of silver consumption and increasing use of copper (Fig. 1). Some experts expect copper based pastes for screen printing [7].

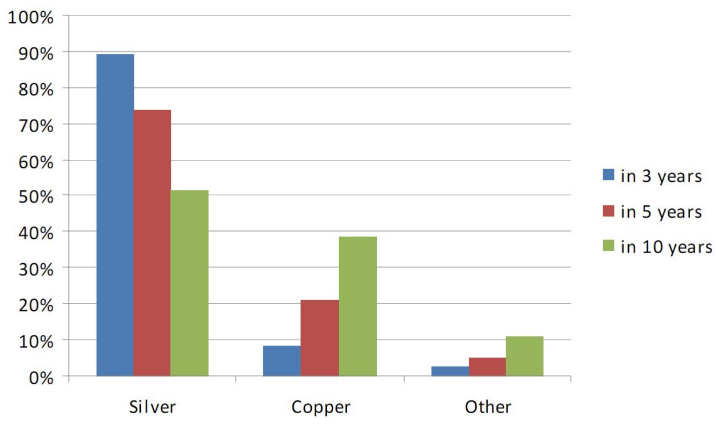

Fig. 1. Share of the metals used for front grid in solar cell production

However, successful application of copper in the construction of metal electrodes in solar cells yet requires elaboration of interlayer deposited directly on the surface of silicon, which will play the role of effective buffer layer that will protect the silicon substrate from the copper migration. Therefore, in the article main directions of research of copper covered front electrodes conducted in Photovoltaic Laboratory of PAS are presented.

The works conducted in the Photovoltaic Laboratory IMMS of PAS

The silicon cells and printed paths were prepared at semi-automated, experimental line at the Photovoltaic Laboratory of IMMS PAS. The screen printing was done with a KEKO P-200B screen printer using commercially available, silver based paste. The finger paths were deposited in double step process consisting of screen printing method followed by electrodeposition of thin metal layer. In the first step, the thin paths of 80 µm in width were screen printed with the use of conventional silver-paste. Then the metallic (Ag or Cu) coating layer was deposited on the printed substrate to the maximum width of 130 µm [8]. The silicon substrates were <100> oriented, p-type, monocrystalline Si (mono-Si) wafers of the resistivity of 1 ⍰cm, the thickness of 200 ⍰m and size 5x5 cm. The emitter was generated at temperature of 825°C for 25 min. in an open quartz tube using liquid POCl3 as the doping source.

The thickening of the electric paths was performed by copper electrodeposition (works at the in the ICSC PAS). The substrate sheet was immersed in the plating bath stirred vigorously. The aqueous plating bath containing 200 gdm-3 of $CuSO_4$ and 50 gdm-3 of H_2SO_4 was used at room temperature. The plating bath was intentionally free of additives to avoid contamination of the substrate surface by organic additives. In the potentiostatic mode of -0.5 V, the mercury/mercurium sulfate saturated electrode (MMSE) was applied as a reference electrode and the copper rod as a counter one (CE). The printed paths were used as the working electrodes (WE) by connection with the copper stickers. The SEM images of plane view of screen printed finger before and after copper electrodeposition were shown in Figure 2. The finger shown in this figure was printed using the screen with a width of finger paths of 80 µm and intentionally thickened to 100 µm by electrodeposition. The width of the printed finger path after the drying process was around 90 µm i.e. broader of about 12% than scheduled. The electrodeposition of copper resulted in the width increase ranging from 110 to even 130 µm. The non-sharped edge, flattened on the top and broad of approximately 10 µm, was observed on copper coated finger path as indicated by the yellow arrow in Figure 2 (right) [8].

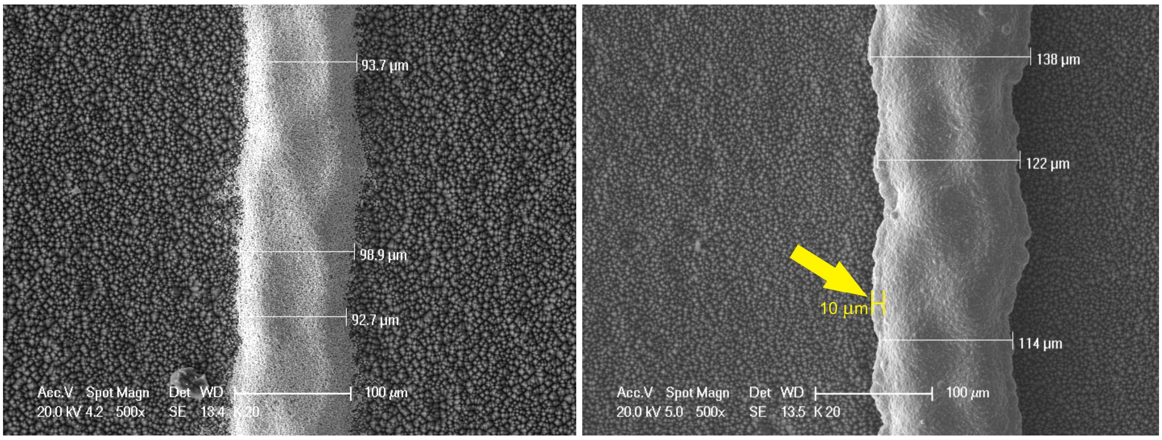

Fig. 2. SEM micrographs showing plain view of finger path after silver path printing using 80 µm screen (left) and the same finger path after copper electrodeposition (right) [8].

The cross section of the copper plated finger path was shown in Figure 3 (left). This image shows 10 µm nominal thickening. The thickness of the deposited layer was approximately 11 µm and it was uniform over whole cross section of the printed path. Moreover, the edge area of the screen printed substrate was not sharp but diffused (see left part of the path).

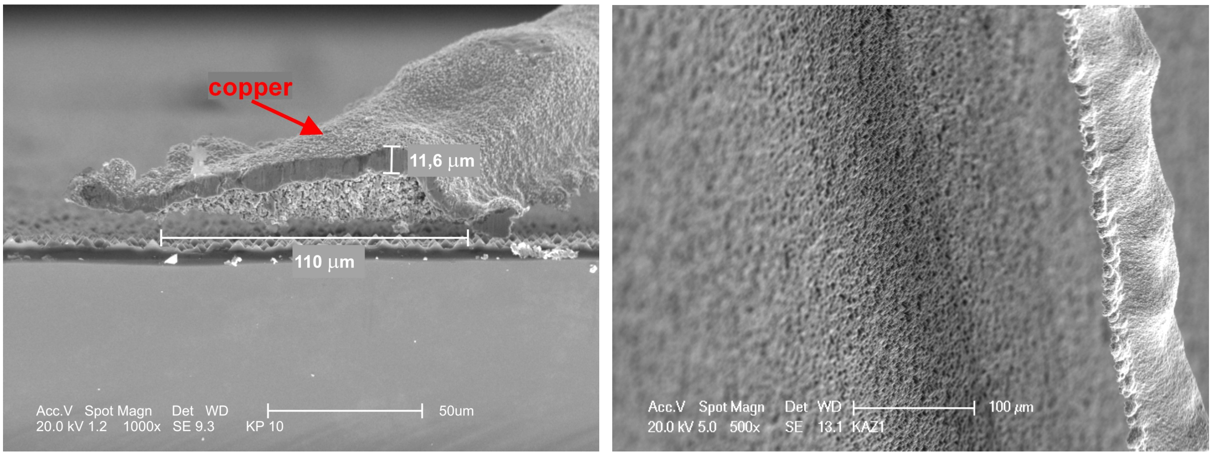

Fig. 3. SEM micrographs of cross section of the finger path obtained by silver path printing using 80 µm screen followed by copper electrodeposition (left) and the mechanically delaminated copper coated path (right) [8].

The microscopic analysis of the thickened finger paths showed some disadvantages of the presented method. The most important problem is related to the adhesion of the prepared path to the silicon base plate that is low. The Figure 3, right, showed the finger path coated with copper and delaminated form silicon substrate. On the other hand, the adhesion of copper coating to the printed substrate and mechanical strength of the coated path can be an advantage of the overall product. It is worth mentioning that all the disadvantages were related to the screen printed part of the path fabrication process and they need to be solved to obtain good substrates for copper deposition.

Conclusion

The method of copper deposition on the finger paths screen printed with conventional paste was shown. The metallic thin film was obtained by simple two stage method of deposition. The problem with mechanical stability of the covered paths leading to delamination was indicated. The method needs to be optimized to approach thicker copper layer as well as larger adhesion to the cell surface.

References

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