Development of a localized electrochemical copper metallization process for high-efficiency and sustainable industrial photovoltaic cells

G. Rodrigues Lopes [(1)], W. Favre [(1)], J. Jourdan [(1)],
S. Bastide [(2)]

[(1)] CEA, LITEN, Campus INES, 73370 Le Bourget du Lac, France
[(2)] CNRS, ICMPE, UMR 7182, 94320 Thiais, France
gustavo.rodrigueslopes2@cea.fr

SHJ (silicon heterojunction) technology, recognized for its high efficiency, has joined the mass production in the recent years together with TopCon. However, the large-scale deployment of the SHJ device architecture necessitates a substantial reduction, or even complete elimination, of critical materials like silver (Ag) and indium (In), which are presently essential in their manufacturing processes. Currently, the industry-standard metallization procedure involves depositing pure Ag conductive pastes using a screen-printing technique. In 2022, the PV industry accounted for the consumption of 4,365 tons of Ag, representing 14% of the annual global Ag supply, with PV installed capacity continuing to increase significantly year after year [1].

One approach to reducing Ag consumption in PV is to replace Ag with copper (Cu), as they have similar electrical properties, and Cu is approximately 10 times less expensive than Ag and has greater reserves and resources. However, Cu is more prone to oxidation [2]. To overcome copper's lower oxidation resistance, Ag/Cu conductive pastes are composed of Cu particles coated with Ag [3], [4]. This technology is expected to become mainstream in the near future [5]. Nevertheless, Ag/Cu pastes do not eliminate the use of Ag entirely. The complete replacement of Ag by pure Cu conductive pastes remains challenging due to the higher electrical resistivity of screen-printed Cu contacts compared to pure bulk Cu [6]. Moreover, the thermal annealing required to cure the paste can result in potential oxidation of the contacts, which affects their electrical conductivity and, hence, the cells' performance.

In this context, a promising alternative for achieving an Ag-free metallization process in PV cells is Cu electroplating. CEA is collaborating with an industrial partner to deposit and grow metallization through electrochemical methods. This collaboration aims to enable localized growth of Cu metallization on silicon SHJ cells, leveraging a technology that is industrially compatible and offers lower costs and higher throughput than standard plating processes. This presentation will mainly focus on the initial results of the on-going PhD thesis on the topic and will present: (i) identifying the main challenges of screen-printing metallization applied to SHJ devices with full Cu pastes currently available on the market, and propose strategies to improve this route, and (ii) results of Cu plating on SHJ devices, along with a discussion about the associated challenges.

REFERENCES

[1] *World Silver Survey*, 33rd Ed. Washington D.C.: Silver Institute, 2023.

[2] J. Perelaer *et al.*, 'Printed electronics: the challenges involved in printing devices, interconnects, and contacts based on inorganic materials', *J. Mater. Chem.*, vol. 20, no. 39, p. 8446, 2010, doi: 10.1039/c0jm00264j.

[3] J. Li *et al.*, 'Ultrahigh Oxidation Resistance and High Electrical Conductivity in Copper-Silver Powder', *Sci. Rep.*, vol. 6, no. 1, p. 39650, Dec. 2016, doi: 10.1038/srep39650.

[4] Y. Zeng *et al.*, 'Review on Metallization Approaches for High-Efficiency Silicon Heterojunction Solar Cells', *Trans. Tianjin Univ.*, vol. 28, no. 5, pp. 358–373, Oct. 2022, doi: 10.1007/s12209-022-00336-9.

[5] A. Lachowicz *et al.*, 'Aging tests of mini-modules with copper-plated heterojunction solar cells and pattern-transfer-printing of copper paste', *EPJ Photovolt.*, vol. 15, p. 11, 2024, doi: 10.1051/epjpv/2024008.

[6] A. Lachowicz *et al.*, '2021_Lachowicz_Patterning Techniques for Copper Electoplated Metallization of Silicon Heterojunction Cells', in *2021 IEEE 48th Photovoltaic Specialists Conference (PVSC)*, Fort Lauderdale, FL, USA: IEEE, Jun. 2021, pp. 1530–1533. doi: 10.1109/PVSC43889.2021.9518493.