RECENT DEVELOPMENTS OF HJT SCREEN PRINTING PROCESS AT CEA-INES WITH SILVER PASTE

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Purpose and approach of the work

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Currently the consumption of silver corresponds to about 15mg/W for PERC while it is around 25mg/W for HJT. The PV production could reach up to 1 TW in 2028 meaning the PV industry will use 100% of the global silver production. If PV industry wants to be sustainable there is need to reduce the silver consumption to less than 5mg/W not regarding the cell technology [3]. It is possible for instance to reduce silver content and introduce other metals in the paste, to replace screen-printing by copper plating and also to optimize metallization design by increasing the pitch and/or reducing the finger width. At CEA we address several of these strategies but in this paper we will focus on the reduction of finger width using small screen opening for HJT with silver paste. Mainly composed of a mesh and an emulsion, screen manufacturers made lot of progresses over the last years. With new materials and specific screen design, there is the possibility of silver reduction for HJT solar cells application thanks to narrow finger with low impact on cell performances.

Specific innovation and relevance

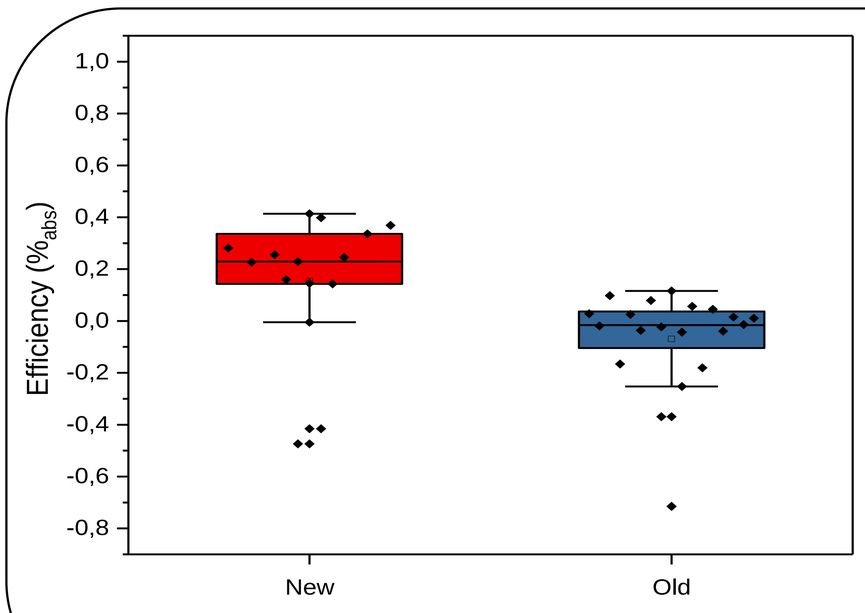

Figure 1: Efficiency comparison between New knotless screen (PI film) and Old knotless screen (emulsion)

Screen improvement

- *Tilted mesh screen* : Knots inside the opening ➔ large opening needed and so important deposit
- *Knotless screen with emulsion* : smaller opening, better cell performances and lower deposit
- *Knotless screen with PI film* : better paste transfer, lifetime, lower line resistance and better cell efficiency (+0,25%$_{abs}$)

Low screen opening

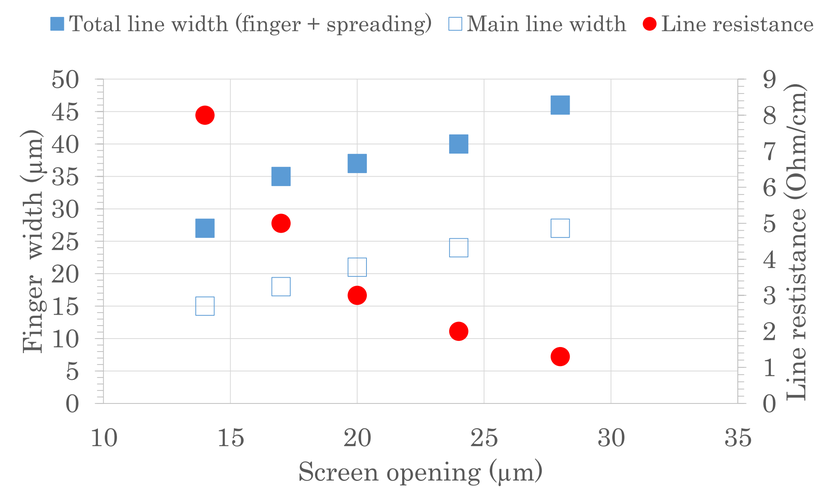

Figure 2: Finger width (blue) and line resistance (red) evolution according to the screen opening

Low silver consumption

- Performing the screen deposition process with these new knotless screens allow to avoid bad paste transfer that could lead to significant losses in efficiency. Silver paste has been used.
- Knotless screen + PI film / opening 24µm / M2-6 busbars format
- The deposit of silver : -34%$_{rel}$ compared to the CEA standard
- The efficiency of the cells remained at a good level: -0.08% vs reference

➔ The ratio of silver consumed per watt achieved was therefore 19.2 mg$_{Ag}$/W instead of 24.58 mg$_{Ag}$/W (ITRPV 2022) - which is the level of material consumption expected by the international community by 2026 for this technology

BS opening (µm)	FS opening (µm)	Total deposit (mg)	Total Ag deposit (mg)(93%)	BS line width (µm)	BS line resistance (Ohm/cm)	FS line width (µm)	FS line resistance (Ohm/cm)	Isc (A)	FF (%)	Eta (%)	mg$_{Ag}$ / W
Ref CEA											28,8
-9	-4	-34%$_{rel}$	-34%$_{rel}$	-20%$_{rel}$	+84%$_{rel}$	-6%$_{rel}$	+22%$_{rel}$	+0,24%$_{rel}$	-0,48%$_{abs}$	-0,08%$_{abs}$	19,2

Table 1: comparison of the standards screen at CEA and the low deposit screens (knotless)

- Using sliver paste, screens with opening 20µm, 17µm and 14µm have been designed and tested.

→ PI film screen optimization need to allow a good paste transfer and good cell performances

- Opening 17µm → finger width = 21µm
- Opening 14µm → finger width = 18µm
- High line resistance with opening 14µm → important losses in efficiency

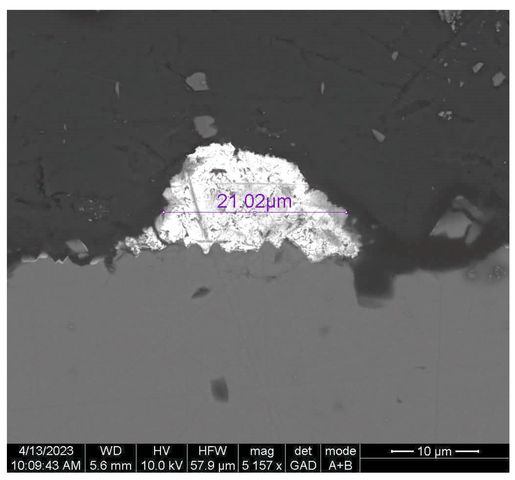

Figure 3: SEM image of finger printed with opening 17µm

Conclusion

- New screen allows to have small opening without a too much increase of the line resistance ➔ Good cell performances
- Important silver reduction : -34%$_{rel}$ with a silver paste
- Low ratio of silver consumed per watt with a silver paste : 19.2 mg$_{Ag}$/W
- Possibility to have very small opening

Perspectives

- The introduction of silver-coated copper paste or copper paste could allow a lot to reduce the ratio of silver consumed per watt : 15 mg$_{Ag}$/W already demonstrated without improved screen design
- Optimization of screens with very low opening in order to have good cell performances
- Other metallization like copper plating : fine line

[1] P. J. Verlinden, « Future challenges for photovoltaic manufacturing at the terawatt level », Journal of Renewable and Sustainable Energy, vol. 12, no 5, p. 053505, sept. 2020, doi: 10.1063/5.0020380 [5] A. Razzaq etal., Joule 6, 514–542, March 16, 2022
[2] Equipment, VDMA Photovoltaic. "International Technology Roadmap for Photovoltaic (ITRPV)."(2022)

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