Subject: Solar Cells and Auxiliary Materials

Title: Dispensing, Enabling High Throughput Metallization for SHJ Solar Cells

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Introductive summary

Fine, homogeneous front contacts as achievable by using dispensing technology enable to reduce silver consumption along with a further increase in solar cell efficiency. With a gaining market share of bifacial solar cells, a similar effect arises from the rear side, especially when thinking of tomorrows solar cell concepts that contain silver electrodes on both surfaces. When taking the ITRPV roadmap [1] as general guideline, SHJ solar cells especially suffer from high silver consumption (>200mg) as well as rather low printing speeds (~180mm/s) in pilot production lines up to date. Dispensing here could play a key role to increase throughput rates at the same time decreasing silver consumption and breakage compared to conventional screen printing solutions. Furthermore, busbarless approaches would even enable metallization lines without screen printing.

Aim and experimental approach

Along with further efficiency increases and a reduction of material consumption, the achievement of higher production throughput rates is a major goal of metallization lines these days. Parallel dispensing offers substantial improvements regarding all three aspects and further requires only limited investment costs to improve existing metallization lines based on screen printing technology. The ability to apply commercial available screen printing Ag-pastes further reduces the risk of unwanted cross impacts along the PV value chain and ensures robustness and long lifetimes of manufactured solar modules.

Scientific innovation and relevance

Fraunhofer ISE's dispensing technology is on the way to commercialization. Core feature is its 6" parallel print head allowing for intermittent operation with speeds up 300mm/s with commercial available low temperature Ag pastes applied on SHJ solar cells. This study gives an overview of current printing results and a perspective to future applications.

Results and conclusions

Within the last experiment [2], three different low temperature paste systems were compared on industrial HJT precursor material using the dispensing process. In order to indicate the efficiency potential, an all screen printed reference group was added, printed with a 40µm opening and Ag16 on the front surface, N_f = 120 contact fingers and 5 busbars and a wet paste laydown of Δm_{Ag} = 65mg. The rear surface (also Ag16) contains $N_{f,r}$ = 150 contact fingers respectively hence adding another $\Delta m_{Ag, r}$ = 120mg of Ag paste ending up at $\Delta m_{Ag, cell}$ = 185mg in total for both sides.

The all dispensed groups contain only N_f = 100 contact fingers on each side and respectively contain Ag16 paste version on the rear. On the front surface, a paste variation was conducted including an AgCu paste with coated copper particles, Ag16 version and Ag19 that allows for processing with D = 35µm nozzle openings, compared to 40µm with the previous pastes.

Looking at the solar cell results (Figure 3), a clear increase of efficiency is visible from AgCu to Ag16 and Ag19, reaching top values of η_{max} = 22.2% for the last group, dispensed with Ag19 on the front. This significant difference between the groups is mainly caused by FF and j_{sc} influences. The FF is lowest for AgCu paste and even Ag16 does not reach the level of the screen printed reference when dispensed. However, Ag19 reaches a high level despite the fact that Ag laydown was reduced by 30% to Δm_{Ag} = 2 x 65mg for Ag19 compared to Δm_{Ag} = 65mg+120mg for the SP reference. This reduced Ag laydown is caused by the rear side grid – on the front side, the number of contact fingers is reduced for the dispensed groups although the Ag consumption remains the same due to the increased contact aspect ratio (AR).

Key for all industrial applications is the 6” dispensing print head that is equipped with up to 150 nozzle aligned in parallel and hence requires only one stroke to process a whole solar cell. Here, the focus is on printing stability and precise line end positions during intermittent operation (Figure 2). Although, outstanding printing results with Ag19 paste are achieved, solar cell processing has to be proponed until a solution for pseudosquare substrates is available. Latest cell results on SHJ solar cells produced by dispensing will be presented on the conference as well as a roadmap to introduction of this technology to PV industry.

Explanatory pages:

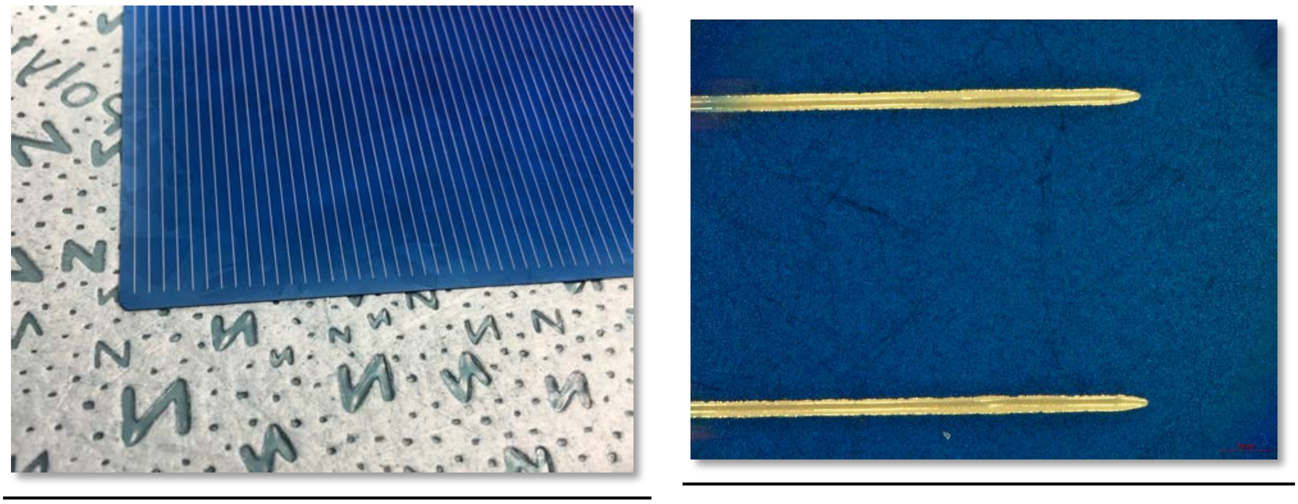

Figure 1: Precise line ends on a solar cell achieved by intermittent parallel dispensing. Process control further prevents bone shaped line ends hence enabling homogeneous grid lines at minimum paste consumption.

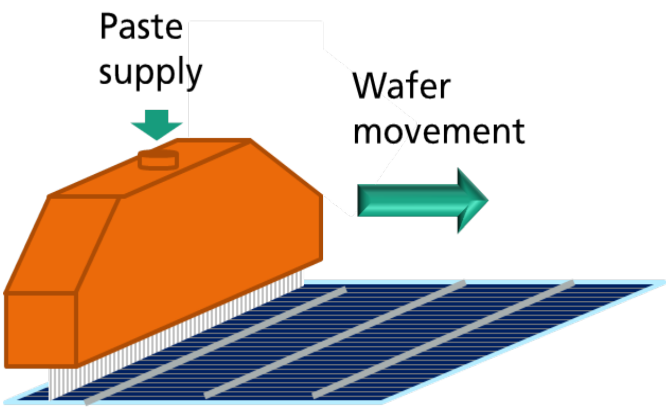

Figure 2: Schematic illustration of a continuous operating parallel dispensing system. The parallel print head is placed above the solar cell ensuring a contactless metallization without the need to interrupt cell movement. With this setup, the throughput bottleneck hence is shifted to automation technology.

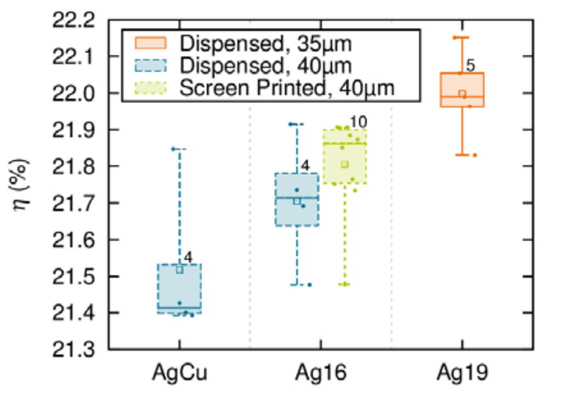

Figure 3: Comparison of screen printed and dispensed samplings on SHJ solar cells. The advantage of dispensed contact fingers of group Ag19 is subject to a significantly reduced finger width along with decent contacting behaviour of the applied paste. The AgCu paste could be successfully applied but requires an improved electrical behaviour in order to be competitive.

References

[1] VDMA, *ITRPV Roadmap 2019.* [Online] Available: https://itrpv.vdma.org/.

[2] M. Pospischil, et al., “Applications of parallel dispensing in PV metallization,” in *AIP Conference Proceedings*, 2019, p. 20005.