Enabling the potential of plated contacts on carrier selective contact solar cells for mass production

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**Topic: Silicon Solar Cell Improvements and Innovation**

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1. Relevance and Approach

The efficiency potential of PERC solar cells is estimated to be in the range of 24% [1]. Passivated contact solar cells such as tunnel oxide passivated contact (TOPCon) [2] and silicon heterojunction (SHJ) solar cells are promising candidates for enabling solar cell efficiencies in mass production beyond the efficiency limit of PERC. Various research institutes and solar cell manufacturers already demonstrated solar cell efficiencies beyond 24%. This technology change would most likely come with a migration from p-type to n-type mono wafers. Passivated contact solar cells are already achieving high cell efficiencies and are proven for many years in mass production at different solar cell manufacturers (Sunpower, Panasonic, Sunpreme, …). However, one major developing task is to further decrease production costs. Back-end processes are a significant cost driver for TOPCon and SHJ solar cells. Screen printing is the established and well understood metallization technology for PERC solar cells and is also typically used for metallizing TOPCon and SHJ solar cells. The bifacial grid design which is common for these solar cell types significantly increases the material costs due to the fact that now silver (Ag) or silver-aluminum (AgAl) pastes have to be printed on front and rear side of the solar cell to achieve also on the rear side low grid resistances. Forecasting increasing PV growth up to TW market scale the silver consumption turns out to be a massive cost driver (1 TW would use 100% of today’s annual worldwide Ag production [3]) for solar cell production. Replacing Ag with copper (Cu) would enable a reduction in raw material costs by a factor of 100. Plating of Cu or stacks of Ni/Cu/Ag is a well-known technology in PV industry. This article shows in the following that plated Cu contacts align well with all back-end technology requirements of TOPCon and SHJ solar cells. Plating technology holds the potential to significantly reduce production costs for passivated contact solar cells. The main advantages of plated Cu contacts for these solar cell designs are:

* Low cost of ownership
  + Low material costs
  + Enabling synergetic cost reductions such as TOPCon thickness reduction
* Compatible with existing mass production back-end tool equipment
* Potential for efficiency gain
  + Narrow contact width
  + Highly conductive finger at low process temperatures
  + Low contact resistance and contact recombination

1. Experimental

The process sequence shown in Figure 2 is an industrially feasible approach to integrate plated Ni/Cu/Ag metal contacts in i-TOPCon solar cells. The contact metallization can either be a Bifacially plated contact design or a combination of plated and screen printed contacts. Table1 shows three back-end sequences with either plated metal contacts on the boron emitter, on the TOPCon or on both sides. Hybrid designs refer to combinations of screen printed and plated contacts on either side of the solar cell.

Table 1: Testes Back-End Designs on n-PERT cells with a TOPCon backside. NiCuAg plating is replacing Ag screen printing only on front and rear and on both sides.



The precursors are taken out of the regular mass production line and are optimized for screen printed metallization. There were no specific changes in design or processing for all precursors before metallization. The reference group with bifacially screen printed metal contacts was fully processed at the manufacturer’s site. For the hybrid approaches, the screen printing and firing/TOPCon activation was also covered by the manufacturer. The plating metallization for all process groups with plated metal contacts was realized on the RENA InCellPlate platform.

The TOPCon activation of the bifacial plating precursors was performed at Fraunhofer ISE. Since the FFO/TOPCon activation process at Fraunhofer ISE was not optimized for these precursors the implied Voc (cell’s Voc potential before metallization) was about 5-10 mV below the optimized FFO/TOPCon activation process at the manufacturers site.

Table 2 shows measured IV parameters of the fabricated i-TOPCon solar cells. The measurements were performed using a 145x145 mm² shadow mask because of edge artifacts due to shipping and manual handling. All process groups reach mean cell efficiencies between 22.3-22.7%. The screen printed reference achieves a best solar cell efficiency of 22.7%. The back-end groups with combinations of screen printing and plating Hybrid 1 & 2 show best cell efficiencies of 22.4% and 22.7%, respectively. The more detailed analysis in the following sections reveals that even for the hybrid groups lowering of contact recombination and narrowed contact width seem to enable improvements in Voc and Jsc. However, these improvements are statistically not significant in this experiment due to small sample/group size and large spreading of the results in each group. The bifacially plated group demonstrates a best cell efficiency of 22.7%. The decreased shading fraction due to narrow contact width of 25 μm leading to inceased Jsc compared to the process groups with screen printed front side contacts.

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| Table 2: Cell efficiencies of differnt BackEnd designs of the i-TOPCon cells. | Figure 1: CoO comparison of bifacial plating cluster and bifacial screen printing cluster |

1. Conclusion and Outlook

Bifacial and hybrid (plating / screen printing) TOPCon solar cells with laser defined and plated Ni/Cu/Ag contacts demonstrate efficiencies up to 22.7% and open paths to further reduce resistive, recombination and optical losses of i-TOPCon solar cells. Low contact resistance and low finger line resistivity allow finger width below 25 μm. Low contact recombination enables TOPCon thickness reduction below 100 nm. Future work will have to estimate the minimum TOPCon thickness which allows low contact recombination for laser defined plated Ni/Cu/Ag contacts. Cost calculations show (´Figure1) that the introduction of plated contacts especially as bifacially plated grid enables to reduce back-end processing cost for TOPCon solar cells. Further cost savings can be achieved by reducing TOPCon layer thickness due to shallow laser damage depths of ultra-short pulse laser ablation.