> 0,4% ABSOLUT EFFICIENCY GAIN BY FAST NI-CU-SN ELECTROPLATING OF SOLAR CELLS WITH FINE LINE PRINTED CONTACTS BY A SINGLE SIDE WET TREATMENT TECHNOLOGY

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ABSTRACT: The front grid of screen printed solar cells strongly limits the efficiency in terms of shading and resistive losses. Main focus of this work was to provide an alternative two-step front contact process consisting of fine printing followed by an adapted plating stack of Ni/Cu/Sn. Results on improved fine line printing as well as a new plating technique will be presented for the first time.
Optimized parameters for printing with newly developed techniques as well as adapted plating techniques will be shown. Solar cells using the new developed front metallization have been characterized and compared with standard screen printed solar cells. Efficiency gain of more than 0.4% has been achieved so far.
Keywords: Metallization, Electrodeposition, Screen Printing

1 INTRODUCTION

Integration of light induced silver plating (LIP) is considered to be the next step to improve industrial solar cell production efficiencies [1]. However, the spread of this technology is mainly limited by integration challenges and high consumable costs which become only visible on the second glance.

Achieved tool uptimes are mainly limited by metallization of contact wheels if no continuous demetallization is available. Also a full immersed process requires special back contact properties while parasitic plating of expensive silver on the back is always present as side reaction. Besides this undesired plating the sponge like behavior of Al back contact paste causes a high drag out losses of the silver plating bath which easily amounts 30-50% of the overall chemical costs. Further the economical and technical discussion on using high energy consuming light sources to reach reasonable plating rates make this process less attractive.

The presented plating technique shows how to overcome the economical and technical issue of using high energy consuming light sources to reach reasonable plating rates. The RENA fountain plating principle was adjusted to reach a single side wet processing set up with a continuous demetallization of contacts. A direct contact to the front grid without electrolytes on the aluminum rear side of standard solar cells allows to introduce a fast copper plating as a cost saving alternative for pure silver process (-70%). The established barrier layer function of nickel combined with tin as a solderable finishing is proofed as a reliable stack system for solar cell applications. These benefits were demonstrated on an industrial machine platform which fulfills all requirements of a modern solar cell mass production. The presented process solution confirmed in combination with an innovative fine line finger print efficiency gain above 0.4% absolute compared to standard solar cell production. We believe that this metallization is a solution for decreasing the cost in Euro per Wp compared to the state of the art technology of crystalline silicon solar cells.

1.1 Fine Line Print

The front side metallization of a standard solar cell is a strongly limiting factor of the series resistance Rs. Due to a compromise of different parameters (contact resistance, adhesion, solderability etc.) the specific resistance is quite low compared to bulk metal values. Thus reducing in an industrial production the resulting printed finger width down to 50µm and plating up with compact copper is a low cost way for increasing efficiency.

While standard screen printing technology is limited to dimensions of 80-120µm a new stencil technology for standard PV screen printing device is presented in this paper. The main advantage is a homogeneous and reproducible print of <60µm over the whole stencil life time. Due to unique technique only locally openings at busbar and finger sites are produced which combine high paste transition (>55%) with a flexible and robust stencil performance (Fig.1). These properties keep the silver paste consumption in a production time over the stencil life time constant and guarantee highest benefits in combination with a plating process like Ni/Cu/Sn.

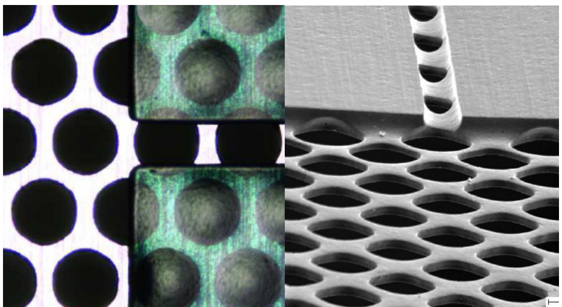

Fig.1: sunstence® *uni* for R&D => sunstence® *me* for industrial mass production

1.2 Electrodeposition of Ni/Cu/Sn

Copper integration for solar cell application requires a good barrier function like electroplated Ni. This first layer is followed by a conductive copper layer which needs to be finished by a solderable metal like tin. All processes need to be carefully adjusted to reach best performance on fine line printed solar cells [2].

2 EXPERIMENTAL

Mono- and multicrystalline solar cells from industrial production (Fig.2) were used for these experiments. After PECVD SiN_x deposition a standard screen printed back metallization combined with screen printed fine line print was co-fired. The subsequent plating Ni/Cu/Sn on silver paste structures was carried out on single side plating tool which correspond to a RENA industrial production platform.

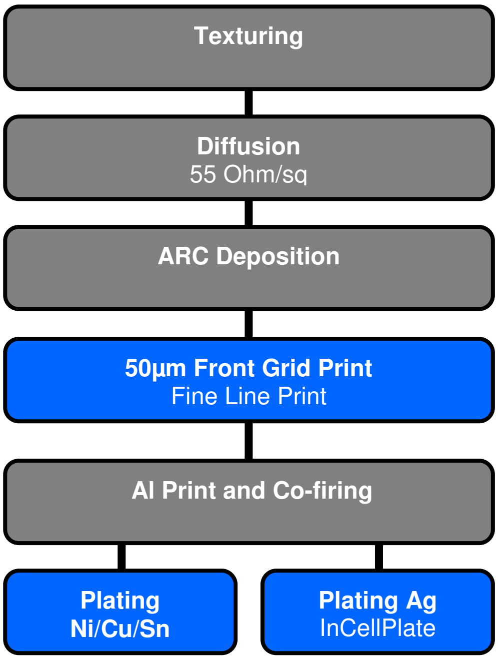

Fig.2: Process scheme for solar cell fabrication with Fine Line Print followed by RENA plating technology

2.1 Machine platform

The applied plating process for Ni/Cu/Sn is adjusted to run on the pseudo inline plating tool – CupCellPlate (Fig.2). This equipment enables to run all required process steps via a single side wet chemical treatment while a demetallization technology provides a continuous process flow without down times.

Fig.3: RENA *CupCellPlate* – R&D platform at RENA Technology Center Freiburg/Germany

The main benefit of RENA plating machine platform - *CupCellPlate* for Ni/Cu/Sn - is a single side processing of crystalline solar cells and thus no chemical attack of the aluminium and low chemical drag out to subsequent rinsing steps. This feature allows plating Cu on solar cells with a finished back contact without any metal contamination of electrolytes or solar cells by aluminium or Cu. For the *CupCellPlate* tool power consuming light sources obligatory for the LIP method is replaced by a direct wet chemical contact arrangement with continous demetallization.

For this paper up to 1000 mc-Si and >500 mono-Si solar cells were used to demonstrate and evaluate the Ni/Cu/Sn plating technology on fine line printed Ag paste. All plating steps were processed at RENA *CupCellPlate* platform, which is available for customer sampling at the RENA Solar Technology Center in Freiburg/Germany.

The capacity of this R&D tool is limited to 150wafer/h due to the flexibility of different single side processes for wet chemical treatments. A possible configuration for Ni/Cu/Sn plating at the R&D tool is shown in Fig.4.

Fig.4: RENA *CupCellPlate* - single side pseudo inline tool for cleaning and Ni/Cu/Sn plating

2.2 Deposition process Ni/Cu/Sn

For the Ni/Cu/Sn process the following sequences were applied:

Dry input – Ni electroplating - rinsing – Cu electroplating – rinsing – Sn electroplating – inline rinsing – drying incl. output.

While all rinsing steps between chemical steps run single sided only the last step runs full immersed.

To form a diffusion barrier, Ni was deposited by a standard PV electrolyte. Plating parameter setups up to 5 ASD to push the plating time down to 3 minutes were used. This barrier layer is necessary to encapsulate the porous Ag paste and protect it against the high acidic Cu plating solution.

In the next step Cu was deposited from a standard industrial electrolyte as a main conducting metal in order to increase the finger conductivity. This in turn lowered the series resistance of the cell. The Cu bath was designed to work with current densities up to 10ASD to reduce the plating time down to 4 minutes.

The final plating step used a standard Sn-electrolyte to generate the solderable material on top. At 3ASD a plating time of 2 minutes was sufficient to deposit 3µm Sn.

3 RESULTS AND DISCUSSION

After the fine line print a fast Ni/Cu/Sn plating step was performed.

To confirm the deposited plating thickness and metal layer structure a cross section of a finger was prepared.

Estimated deposition targets could be confirmed to Ni (1.7 µm), Cu (9.1 µm) and Sn (2.8 µm).

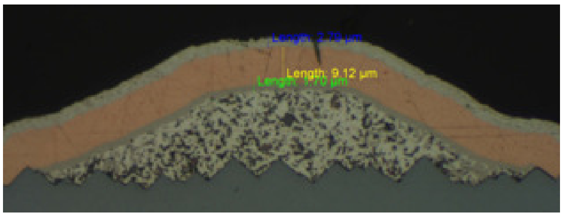

Fig.5: cross section Ni/Cu/Sn stack on Ag paste

3.1 Electrical results

Figure 6 shows the efficiency gain and increased line conductivity after plating on multi crystalline silicon solar cells. As the fine line print was 85 µm, only an efficiency gain of 2% relative to the reference group was achieved. The low performance of the fine line print limited the possible efficiency gain.

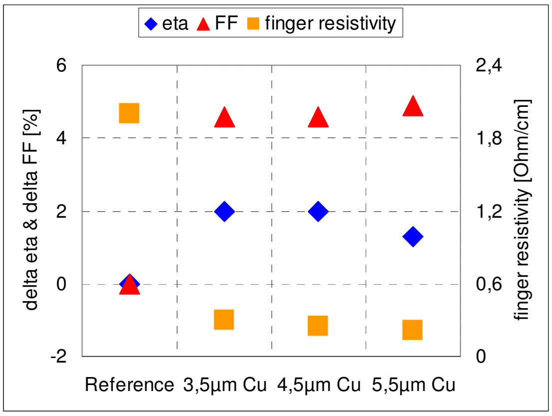

Fig.6: mc-Si, ~85µm insufficient Fine Line Print plated with Ni/Cu/Sn

In figure 7 fine line printed mono crystalline silicon solar cells electroplated with Ni/Cu/Sn are compared with standard screen printed solar cells. The deposition thickness of the Cu is 8 µm and 10 µm. Even with the thinner Cu deposition thickness a low finger resistivity of 0.2 Ohm/cm was reached. The low fill factor of the cells before plating is caused by the high series resistance of the fine line print. The series resistance is dramatically reduced by the plating process. Due to the much lower finger resistivity the cell efficiency and the fill factor increases up to 0.5% compared to the standard cells. We expect that less copper than in the experiment is sufficient for a high increase in cell efficiency.

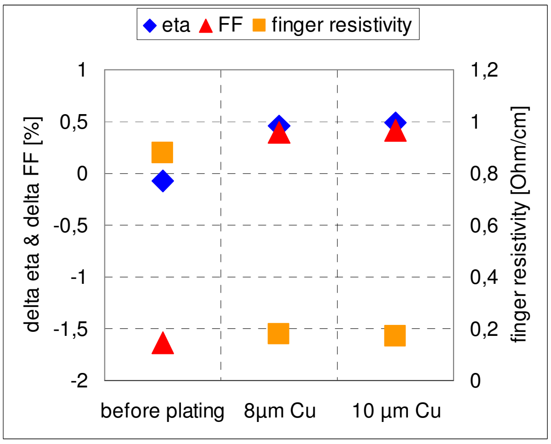

Fig.7: mono-Si, ~75 µm Fine Line Print plated with Ni/Cu/Sn

4 CONCLUSION

In this paper, RENA presented fast Ni/Cu/Sn electroplating of fine line printed solar cells by single side wet treatment technology. An efficiency gain of 0.5% on standard mono crystalline solar cells was realized. We showed the industrial feasibility of replacing cost intensive silver by copper.

The cells were fabricated to modules. The modules passed successfully a module test, conformal to DIN EN 61215, which verify that no copper diffusion into the silicon is occurred.

First estimations about the CoO demonstrate that Fine Line Print and RENA plating technology is an important step towards grid parity.

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