

ELECTROLYTIC NICKEL DEPOSITION FOR THE FRONT SIDE METALLIZATION OF SILICON SOLAR CELLS

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ABSTRACT: In this work the formation of a nickel seed layer for the front side metallization of silicon solar cells based on light induced plating (LIP) is presented. Nickel is plated from a Nickel Watts electrolyte. The influence of LIP parameters like the intensity of the incident light and the applied potential to the rear side of the solar cell has been investigated. After generating the nickel seed layer the contacts were thickened by a cyanide-free silver LIP step. First promising results were obtained producing industrial solar cells with a cell efficiency of 16.8 %.

Keywords: Contact, electrodeposition, metallization; light induced plating (LIP)

1 INTRODUCTION

The future of solar cell structures includes the use of emitters with a higher sheet resistance, a lower surface doping concentration and very thin substrates. This is definitely a challenge for the standard metallization concept, which is based on screen-printing of a silver metal paste. Alternative technologies should allow the formation of contacts with low contact resistivity, a high line conductivity and also a reduction of shading losses. Additionally, they should work at a high through-put, low costs and exhibit a stable processing performance.

Electrolytic nickel plating is an ideal answer for these requirements. The contact properties provided by this metal allow the contact formation on lowly doped surfaces with a low contact resistance. Since no mechanical pressure is applied during processing, it is compatible with thinner substrates. Another advantage is the low-temperature processing. This offers the implementation of passivation layers which are not compatible with the firing step required by silver pastes [1]. However, a structured antireflection coating (ARC) is mandatory for this process. This can be achieved, for example, by an inkjet printing of an etch resist and wet-chemical etching of the SiN_x - layer [2], laser ablation [3] or laser chemical processing (liquid guided jet) [4,5].

1.1 Electrolytic Nickel deposition

Figure 1 shows the experimental setup of the Ni LIP process, which is comparable to the Ag LIP process [6].

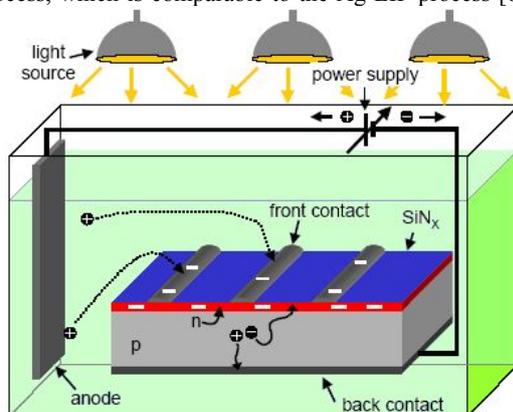


Figure 1: Functional principle of the nickel seed layer light induced plating (LIP) process.

The solar cell is immersed into the electrolytic nickel

plating bath and irradiated to its front side. A voltage is applied between the rear side of the solar cell and the anode to avoid the dissolution of aluminium. Several process parameters were investigated as e.g. rear side potentials, the light intensity and the composition of the plating bath.

The electrolytic plating has some advantages over the electroless plating. The bath lifetime is much higher since no by-products like sulfate and orthophosphate are accumulated as in the case of electroless plating processes. The window of process parameters for the electrolytic plating path is wider and requires less control. Furthermore, the plating thickness can be easily controlled by the plating time. Using adequate parameters a very homogenous deposition with a good mechanical adhesion can be achieved.

If required phosphor [7] or other metals can be easily co-deposited by changing the plating solution. This can be advantageous for electrical contact and adhesion properties.

2 EXPERIMENTAL

Solar cells were manufactured from $1 \Omega \cdot \text{cm}$ p-type Cz-Si with an alkaline texture. A phosphorus-doped emitter with a sheet resistance of $55 \Omega/\text{sq}$ was used. After removal of the PSG glass, a PECVD SiN_x layer was deposited on the front side of the wafer as the ARC. Structuring of the ARC was performed by printing a structured inkjet etch resist and selectively opened with HF as described in [2]. The wafers were screen-printed with aluminum paste at the back and fired to create a back surface field. The opened areas were electroplated with nickel using the LIP process to form the seed layer. A subsequent silver LIP step was carried out in a cyanide-free silver plating bath to obtain highly conductive fingers. The adhesion of the electroplated nickel was strong enough to plate more than $20 \mu\text{m}$ Ag and to perform an annealing step afterwards. This annealing step was made to improve the contact resistance as well as the adhesion by nickel silicide formation.

3 RESULTS AND DISCUSSION

The main focus of this paper is the evaluation of the Ni-LIP regarding the nickel seed layer formation. An evaluation of the influence of the metal concentration, intensity of illumination and the applied voltage between the rear side of the solar cell and the anode on the

adhesion and the nucleation of the plating process is performed.

3.1 Ni ion concentration

The optimum of the Ni concentration of the electrolyte depends on the intensity of light and the claimed plating kinetics. On the one hand a low Ni concentration is needed to keep the light absorption of the electrolyte low in order to achieve an optimal front side potential. On the other hand the Ni concentration influences the plating time, i.e. a high concentration increases the plating velocity and is therefore more interesting for industrial production.

3.2 Incident light

Contrary to the Ag-LIP, in the Ni-LIP the intensity of incident light has to be very homogenous all over the cell to get a uniform distribution of the potential at the front side of the solar cell. This is caused by the fact that no high conductivity material leveling the potential distribution is present.

In the case of Ag-LIP the photovoltage caused by the light is distributed by the seed layer which can be for example the nickel seed layer or a fine line print. Without full optimization of the plating parameters, an inhomogeneous deposition with great grains is observed on SEM measurements (see fig. 2).

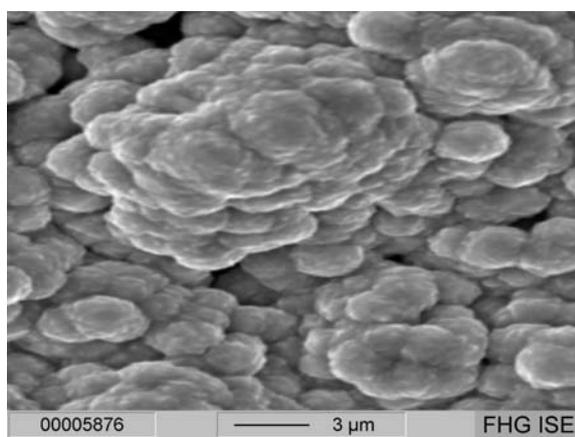
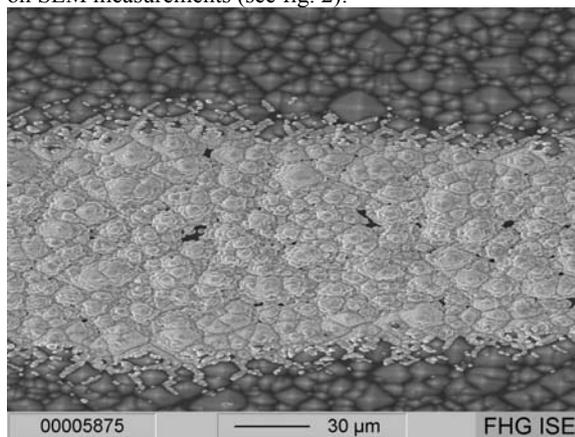


Figure 2: SEM images with different magnifications of electroplated nickel fingers with bad plating conditions.

With optimal plating parameters a homogenous nickel layer can be achieved. These affect the nucleation of nickel, enabling the deposition of very small grain sizes with a good adhesion (see figure 3).

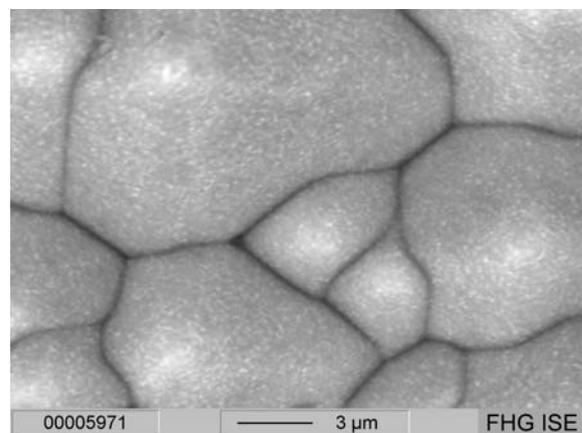
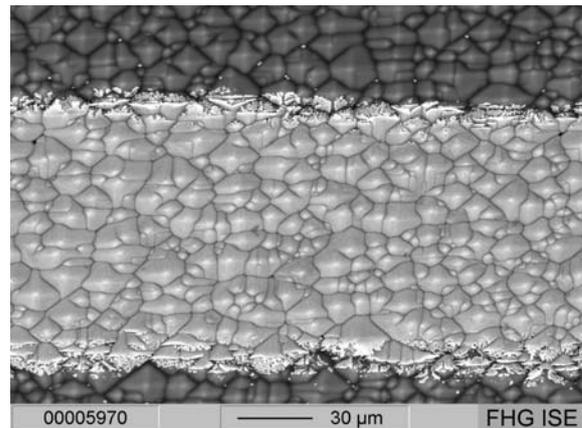


Figure 3: SEM images with different magnifications of electroplated Nickel fingers with good plating conditions

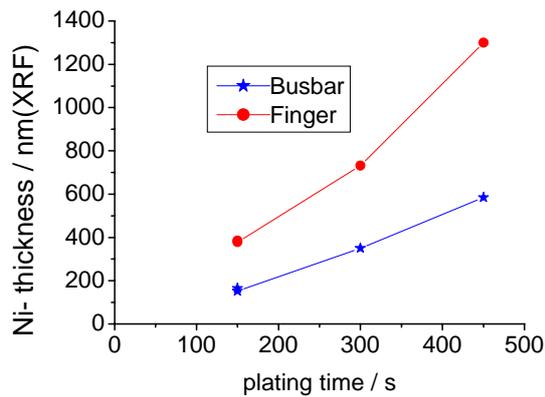
3.3 Rear side potential

The rear side potential is the main parameter affecting the process, since it determines the front side potential. The latter one is correlated to the total current density. Too negative rear side potentials are disadvantageous. They lead to the deposition of non-adherent Ni layers as a consequence of the high current densities.

3.4 Local current density

The overall current density is correlated to the total area of the opened domains. However, the fingers and busbars are separated leading to a corresponding local current density.

X-ray fluorescence spectrometer measurements showed that the thickness of the Ni layer along the busbars was thinner than on the fingers, as a result from a lower local current density (see Figure 4). Since the deposition rate is directly related to the current density, we assume that this effect becomes more relevant with reducing finger width. However, during the X-ray fluorescence (xrf) measurement, the minimal spot size is limited to 100 µm, i.e. the reliability of the results for the thickness of finer fingers is questionable.



Photovoltaics Specialists Conference, San Diego (2008)

[5] Kühnlein et. al; this conference

[6] Bartsch et al; this conference

[7] F. Winkler, M. Gutmann; Galvanotechnik; 1948-1945; (2005)

Figure 4: Thickness of plated Nickel measured with XRF of the busbar and finger over different plating times.

Although the process and the chemistry of the plating solution are currently under development, the first results observed on industrial solar cells are very encouraging.

Table 1: IV results of the first processed cells

V_{OC}	J_{SC}	FF	η	pFF
[mV]	[mA/cm ²]	[%]	[%]	[%]
619.6	36.4	74.6	16.8	79.0

4 OUTLOOK

Since nickel is known as a diffusion barrier for copper our intention is using copper as conductive material substituting silver. The central issue is how to prevent an overlapping copper growth in a LIP process as is it observed in the Ag- LIP process.

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