



Comprehensive study of light induced plating of nickel and its effect on large area laser doped crystalline solar cells



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ABSTRACT

Light-induced plating (LIP) as one of alternative metallization technologies has been widely investigated for solar cell metallization, especially for laser-doped selective emitter (LDSE) silicon solar cells. Plating of nickel layer is very crucial in the whole metallization process because nickel is the initial layer on the laser doped area, acting as both contact and barrier layer. The negative effect of poor nickel layer on performance degradation was initially evaluated on LDSE solar cells. Several parameters of light induced nickel plating were then investigated via a laboratory scale plating bath to understand the mechanism of light induced nickel plating directly on the laser doped silicon. Finally, the effect of nickel plating improvement on the performance of large area laser-doped multi-crystalline solar cells was studied via an industrial plating system. By optimization of the applied voltage in the plating nickel, the operation window of laser power was enlarged. At last, an independent confirmed cell efficiency of 17.8% was achieved on large area (243.4 cm²) LDSE multi-crystalline silicon.

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1. Introduction

Screen-printing is the preferred metallization technique today for industrial crystalline solar cells production [1,2]. However, standard screen-printing technology has so many challenges for cost-efficient solar cell development due to the requirement on surface concentration, alignment accuracy for selective emitter, finger width to height ratio, shadow loss and silver consumption etc. Light induced plating (LIP) technology which can minimize the limitations of current screen printing technology has drawn lots of attention recently [3–6]. In addition, because of its advantage on self-alignment, it can be employed in the cells with laser doped selective emitter (LDSE) leading to cost-efficient Si solar cells [7–11].

The structure of LIP fingers often include a thin contact layer which is nickel and a thick conductive layer which is silver or copper. Recently studies show that conductive layer plating is significantly affected by the electrolyte composition [12,13], plating condition, seed layer and surface morphology [14–16]. However, the contact nickel layer plating directly on the exposed silicon has not been widely investigated. The quality of plated

nickel layer is very important in the whole metallization process because nickel layer acts not only as contact layer but also as barrier layer when the conductive layer is copper [17,18]. A poor plated nickel layer on laser doping area will considerably impact on the conductive layer plating, leading to significant performance deterioration [19].

This paper aims to comprehensively study the light induced nickel plating on laser doping solar cells and its effect on cell performance. The negative effect of improper nickel layer on performance degradation was initially evaluated. Several parameters of light induced nickel plating were then investigated via a laboratory scale plating bath to understand the mechanism of light induced nickel plating directly on the exposed silicon. Finally, the effect of nickel plating improvement on the performance of large area LD multi-crystalline solar cells was studied via an industrial plating system.

2. Experimental

Commercial p-type 5' mono-crystalline and 6' multi-crystalline Si with resistivity of 1 Ω cm and the thickness around 200 μm were used to prepare the solar cells. The standard LDSE solar cell fabrication process is as follows: The wafers were acid-textured

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and phosphorus-diffused to $90 \Omega/\text{square}$ in tube furnace. Edge isolation was carried out with an industrial rear-etching process. A SiN_x antireflection coating with a thickness of 88 nm and a refractive index of 2.07 was deposited on the front surface. Aluminum (Al) paste was screen-printed on the rear surface followed by a firing step in a belt furnace in order to form the back surface field (BSF). Diluted phosphoric acid was spin-coated on the front surface followed by a laser process with dielectric layer ablation and patterning of n^+ contacts. A 532 nm, Q-switched Nd:YAG laser was employed in the laser process.

For fast investigation on the effect of nickel plating parameters such as plating time, applied voltage and light intensity, some of experiments on mono-crystalline Si wafers with the size of 4 cm^2 which were cut from those 5' mono-crystalline cells were carried out via a laboratory scale plating bath. Before plating, a buffered fluoroboric acid pretreatment solution was applied to remove the oxide on the laser-doped region. An electrochemical workstation (660D, CH instrument) was used to provide the voltage between anode and backside of the cell. The LDSE solar cells on 6' multi-crystalline Si wafers were parallel prepared by plating nickel (Ni) and silver (Ag) in an industrial RENA LIP system followed by sintering at 350°C to form nickel silicide, which provides a low-resistance contact.

The morphology of the plated nickel layer was investigated by a Hitachi 4800 scanning electron microscopy (SEM) system. Cell efficiency was measured under standard testing conditions (AM 1.5 G, $100 \text{ mW}/\text{cm}^2$, 25°C).

3. Results and discussion

3.1. Analysis of impact of plated nickel layer in solar cell performance

Impact of plated nickel layer in solar cell performance was investigated on cells with different nickel layer quality, prepared

by decreasing plating time. Samples used here are small size mono-crystalline wafers (4 cm^2). Fig. 1 shows SEM images of electroplated nickel layer at different plating time when keeping constant current density value of $0.46 \text{ A}/\text{dm}^2$. The reduction of plating time will result in the insufficient covering of nickel on the laser doped area. Only some individual metal islands can be seen when the plating time is 1 min. As the deposition time increased, more nucleation generated and the size became larger and larger. At last, the nickel seeds start to merge leading to a continuous layer. As a contact and barrier layer, a discontinuous nickel layer on top of the exposed emitter region may result several problems. Firstly, it's hard to form Ag–Si alloy at such a low sintering temperature (350°C), which may lead to a large contact resistance and a Schottky contact barrier. Secondly, if copper is used as the conductive layer, direct contact between copper and silicon makes the cell performance decline rapidly due to the diffusion copper into silicon. Thirdly, the direct contact of silver or copper electrodes on emitter may lead to “burning-through” during the annealing process because of the penetration of metal in the silicon.

Table 1 shows the cell performance with different nickel plating time. As the nickel plating time decreases from 6 min to 1 min, the open circuit voltage (V_{oc}), fill factor (FF) and cell efficiency (η) drops from 629 mV, 75.8% and 17.2% to 626 mV, 57.3% and 12.9%, respectively. As seen from Fig. 1, when the plating time is short, the plated nickel layer is insufficient to cover the entire laser doped

Table 1
Comparison of cell performance with different nickel plating time.

Plating time/min	V_{oc} (mV)	J_{sc} (mA/cm^2)	FF (%)	η (%)
6	629.3	35.9	75.8	17.2
3	629.3	35.9	74.9	16.9
2	628.2	35.9	70.0	15.8
1	625.8	35.8	57.3	12.9

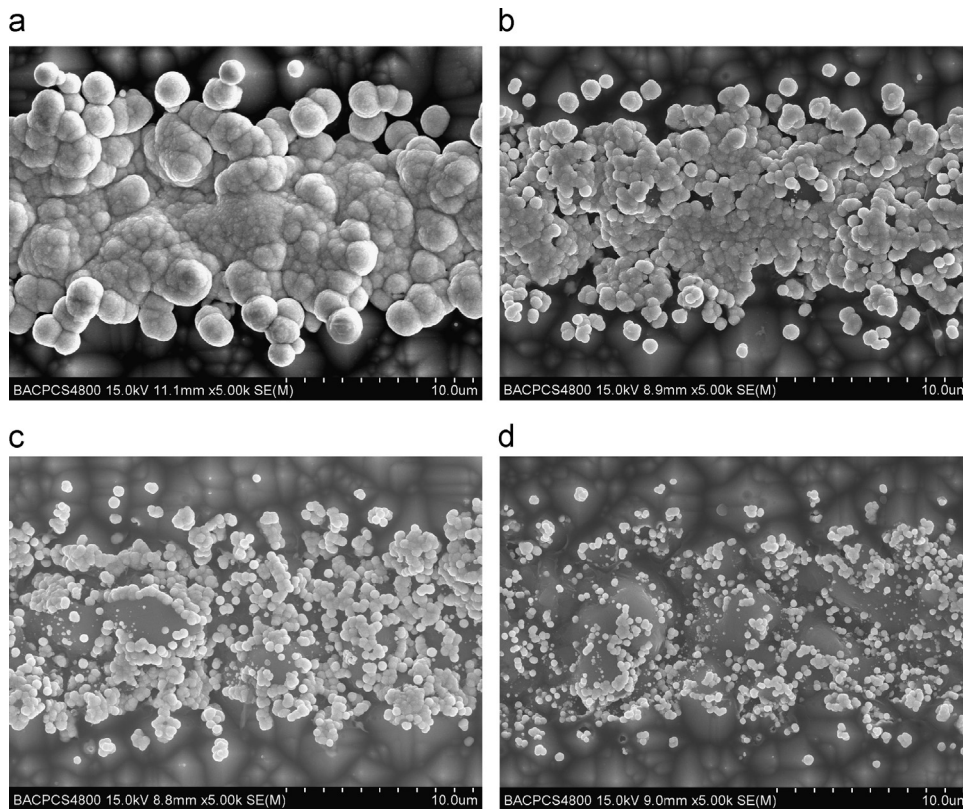


Fig. 1. SEM images of plated nickel layer at different plating time when keeping current density constant at $0.46 \text{ A}/\text{dm}^2$ (a) 6 min, (b) 3 min, (c) 2 min and (d) 1 min.

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