Laser-Doped Bifacial Plated Silicon Solar Cells: Conceptual Design, Prototype and Implementation

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This paper reviews the process development of bifacial plating for laser-doped bifacial PERL silicon solar cells. Ni/Cu plated contacts can replace the expensive silver paste during manufacturing to save more than 30% of cell manufacturing cost. However, this technology becomes diminished among photovoltaic manufacturers because of the limited availability of high-throughput commercial production processes and equipment for metal plating. Developing cost-effective plating equipment will become more important in the coming decade for commercialising high-efficiency passivated contact solar cells, such as heterojunction solar cells, which is not compatible with conventional high-temperature screen printing process and requires much more expensive low-temperature silver paste. ITRPV has predicted that copper applied with plating technologies is the envisioned substitute provided that appropriate equipment and processes are made ready.

UNSW's unique bifacial plating technology metallises n-type and p-type surfaces simultaneously using the world's only inline bifacial plating prototype tool developed by A.Prof Ji. Using commercial grade 6-inch p-type CZ wafers, 19.8% solar cell conversion efficiency has been achieved on a laser doped PERL cell with bifacial plated contacts. No performance degradation has been observed after industry standard light soaking test. All the cell fabrication processes are done using industrial equipment in addition to the bifacial plating prototype tool, which can be easily scale-up to a full size industry equipment.

This paper discusses the process and equipment development for simultaneous Ni/Cu bifacial plating, including three phases: phase 1 - conceptual design and proof-of-concept; phase 2 – prototyping and process development; and phase 3 – tool implementation and technology transfer to industry. We will discuss the challenges encountered at each phase of the development, using PERL solar cell as an example, together with the solutions and learnings as the technology was demonstrated.

Topic area: crystalline silicon solar cell metallisation

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Introduction

Today, at least 90% of commercial silicon solar cells have screen-printed electrodes [1]. Screen printing contacts exhibits robust conductance and reliability on Al-BSF and PERC solar cells. However, it becomes challenging for high-efficiency solar cell structures, such as silicon heterojunction solar cells, where the low-temperature cell processing is not compatible with conventional high temperatures. The reason is that the hydrogen within amorphous passivation layer will effuse out, and the passivation layer will crystallise at standard firing temperature (approximately 700℃), reducing the passivation effect[2]. HIT/HJT solar cells uses twice the amount of silver compared to PERC solar cells. In addition, only low-temperature silver paste is compatible, making them 30-40% more expensive than PERC solar cells. Replacing the screen-printed contacts with plated contacts will significantly reduce the manufacturing cost.

Laser doping and plating has been successfully commercialized and won numerous world records for commercial grade mono-facial p-type CZ silicon material (Roth & Rau, Centrotherm, Shinsung, Hyundai, and Suntech). However, the market is moving towards bifacial solar cells. ITRPV predicts bifacial cells will gain share from 15% in 2019 to 60% in 2029 [3]. It is necessary to investigate the functional low-temperature metallisation process and equipment to incorporate bifacial solar cells.

This paper uses bifacial PERL solar cell as an example, to review the challenges and solutions during process and equipment development for laser-doped bifacial solar cells with plated contacts. Solar cells achieved 19.8% conversion efficiency using industrial processing equipment, indicating promising potential for the bifacial plating technology.

Challenges and solutions

Phase 1 conceptual design

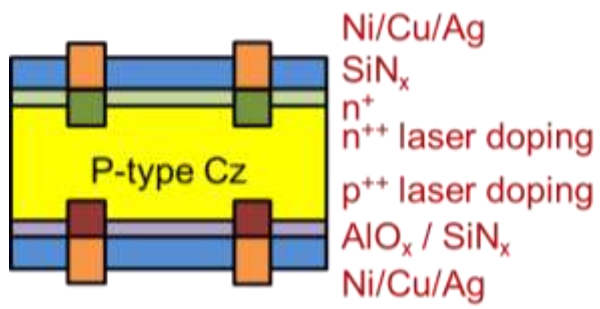

Figure 1 shows the schematics of the laser-doped bifacial plated PERL solar cells. Selective heavy doping shields the active cell region from the high recombination metal/silicon interface. Bifacial structure generates 30% power compared to current PERC structure.

Figure 1 Schematics of laser-doped bifacial plated PERL solar cells

Phase 2 prototyping for tool and process development

Light induced plating is commonly used to plate copper on the front side of p-type LDSE solar cells; however, uniform p-type plating remains technically challenging because electroplating requires a point of contact on the solar cell [4]. Prof Ji is a world-leading expert on plating and tool design and development. Ji has developed Suntech's plating baths for their exclusive use that facilitated the mass production of the Pluto cells. He has invented the bifacial plating technology, which deposits metal to both cell surfaces simultaneously. A prototype bifacial plating tool has been successfully developed. Photos in Table 1 demonstrate the prototype tool in operation and the resulted Cu plating on both surfaces. This is the only tool that can plate both cell polarities without electrodes contacting the surfaces being plated. Its inline characteristics increase yield significantly and can be easily scaled up into a full commercial production tool.

Figure 2 shows the inline prototype tool in operation. With the inline bifacial plating tool, the cell fabrication becomes much simplified, as shown in Figure 3.

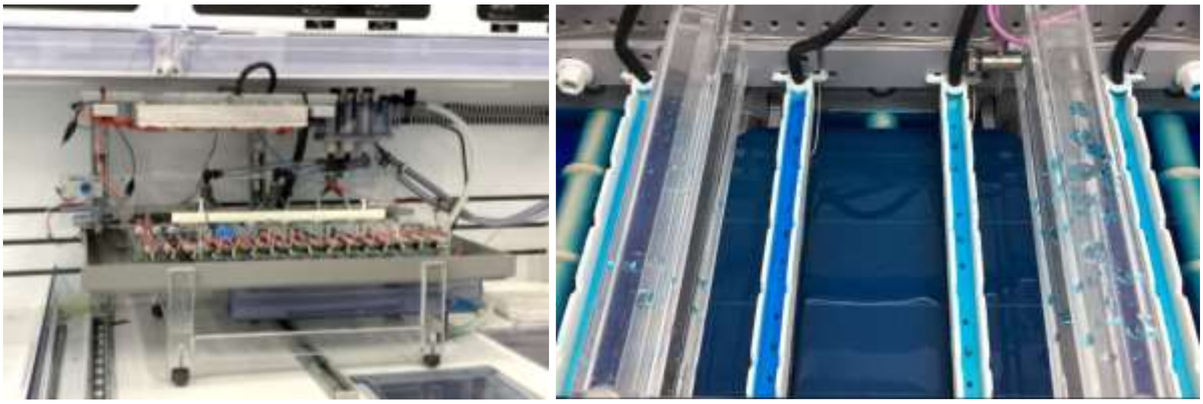

Figure 2 Prototype inline bifacial plating tool

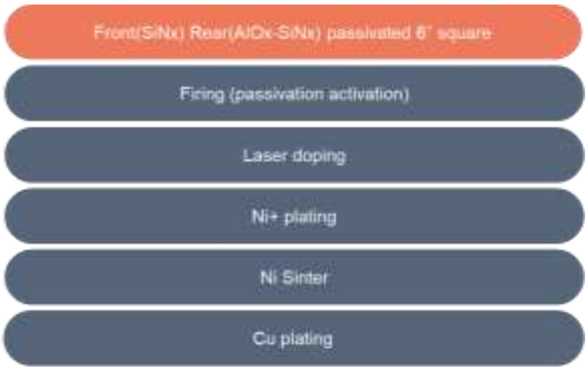

Figure 3 Bifacial plated solar cell processing sequence

Achieving uniform plating has been the challenge of this phase. The point of contact has much lower resistance, while the resistance increases as the current distributes to other regions of the solar cell (i.e. the region without direct contact). Tool modification has been implemented to significantly improve the uniformity. A second generation prototype is being commissioned at UNSW, which is made from industrial equipment components. This makes scaling up to full size production equipment simple and straight forward. Figure 4 shows a bifacial plated solar cell. This solar cell achieves 19.8% efficiency, as shown in Figure 5.

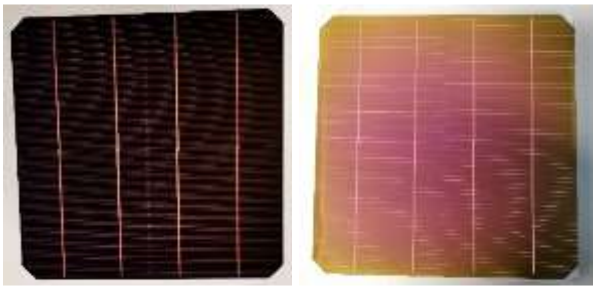

Figure 4 Front (on the left) and rear (on the right) side of the bifacial plated solar cells.

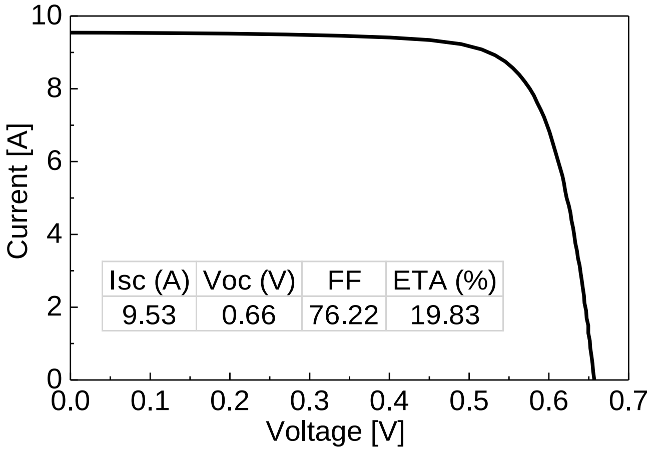

Figure 5 Light IV curves for the bifacial plated PERL cells.

Phase 3 Technology transfer to industry (ongoing)

With the lessons learnt in the design and prototyping stage, pilot-scale inline bifacial plating tools for p-type high efficiency solar cells are being designed. We will report further insights during phase 3 in the final paper.

Reference

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