[HYDROGENATED BIFACIAL PERL SILICON PV CELLS WITH LASER DOPING AND PLATED CONTACTS]

[RND004]

Project results and lessons learnt

Lead organisation: UNSW	
Project commencement date: 6 December 2017	**Completion date:** 31 December 2021
Date published:	
Contact name: CheeMun Chong	
Title: Professor	
Email: cm.chong@unsw.edu.au	**Phone:** 02 9385 4563
Website: www.unsw.edu.au	

Acknowledgement: This project received funding under the Australian Renewable Energy Agency (ARENA) Solar Research & Development Program (Round 3).

Table of Contents

Executive Summary

This project will build on the successful outcomes of three ARENA projects to develop the next generation high-efficiency solar cell, based on the three key technologies developed in these projects: laser doping, advanced hydrogenation, and simultaneous bifacial plating. It will address the performance and cost limitations of the current Passivated Emitter and Rear Contact (PERC) technology by enabling the transformation of industrial p-type solar cells to a Passivated Emitter and Rear Locally diffused (PERL) structure using proven technologies. Record 22.6% efficient PERC solar cells use screen-printing, requiring expensive silver and aluminium pastes. PERC cells also have significant metal/silicon interface recombination, high metal shading losses and are generally plagued by light-induced degradation (LID), which significantly affects performance and therefore increases costs. Transforming PERC into PERL in the lab through improved metal/silicon interface doping, increased efficiencies from 22% to 25%. The aim of the project is to develop a breakthrough low-cost, high-efficiency PERL cell technology and innovative, high-throughput commercial production processes and equipment.

The work in the first 18 months of the project has focused on the development of integration of the three technologies. This includes the development of an AlOx based p-type laser doping process, the following metal plating process, the incorporation of advanced hydrogenation at different cell process steps for the passivation of laser-induced and light-induced defects, and PERL cell fabrication using commercial grade p-type wafers.

The technical work in the second 18 months of the project has focused on optimizing the fabrication processes of plated bifacial PERL solar cells integrating the three technologies. A 20.4% efficient bifacial plated PERC cell integrating the three technologies and a 21.5% PERL cell has been made using 6-inch commercial grade wafers. A working bifacial module of bifacial plated PERC cells has been fabricated.

Project Overview

Project summary

The first stage is to integrate the three technologies and fabricate laser doped and hydrogenated PERC and PERL cell devices with plated contacts.

One of the focuses is to implement the selective laser doped emitter technology on both the front and rear surfaces to create a bifacial PERL cell structure for optimum current generation and collection. Different lasers have been tested to develop suitable conditions for the selective laser-doping process. Smooth laser doped lines with minimal laser-induced damage have been achieved after optimization.

Plating has been developed together with the laser doping process for metal deposition. To avoid using expensive silver and aluminium screen-print paste, low temperature metal deposition by light induced plating for laser doped bifacial PERL cell has been developed. The laser doping and self-aligned plating form closely placed narrow fingers with significantly reduced shading losses. Smooth and uniform metal deposition on both the n-type surface and p-type surface has been achieved.

Advanced hydrogenation technology, which controls the charge state of hydrogen, has been integrated into the cell fabrication process. It improves the quality of commercial grade silicon wafers, eliminates LID and passivates laser induced defects introduced during the laser doping process.

Project scope

Record 22.6% efficient PERC solar cells use screen-printing, requiring expensive silver and aluminium pastes. PERC cells also have significant metal/silicon interface recombination, high metal shading losses and are generally plagued by LID, which significantly affects performance and therefore increases costs. Transforming PERC into PERL in the lab through improved metal/silicon interface doping, increased efficiencies from 22% to 25%. This project will address the performance and cost limitations of current PERC technology by enabling the transformation of industrial p-type solar cells to a PERL structure using proven technologies. The aim of the project is to develop a breakthrough low-cost, high-efficiency PERL cell technology and innovative, high-throughput commercial production processes and equipment.

Outcomes

We have successfully integrated the three technologies with ongoing optimization to fabricate hydrogenated bifacial PERC and PERL solar cells with laser doping and plated contacts. These cells have been fabricated using 6-inch commercial silicon wafers. The cells have been light soaked to test for LID. Using an industry standard light soaking process, the cells lose less than 1% relative efficiency due to LID. A working bifacial module of bifacial plated PERC cells has also been made.

The promising result indicates we are well on track to develop a breakthrough low-cost, high-efficiency PERL cell technology and innovative, high-throughput commercial production processes and equipment.

Transferability

The PV industry is shifting toward the PERC technology, while the top manufacturers are exploring the possibility of bifacial cells. Plating is a preferred approach for bifacial solar cells due to the narrow line-widths achievable, and the avoidance of silver consumption. With the main hurdle of access to high throughput plating equipment resolved by this project, it is expected manufacturers will have great incentive to licence the technology for the fabrication of bifacial solar cells.

Metal plating has many advantages over traditional screen-printing techniques. It is capable of forming narrower metal fingers to reduce shading loss and does not require expensive silver. It is expected that future high-efficiency cell technologies will employ plating to form metal contacts. The availability of commercial plating equipment at the conclusion of this project will facilitate the commercialization of future generations of high-efficiency solar cells using plating technologies.

Conclusion and next steps

We have successfully achieved the goal of the second stage of the project of incorporating the three key technologies. Promising initial cell efficiency and working module results have been achieved. The next step is to further develop the cell technology, analyse the cell efficiency losses, optimize each fabrication process to improve cell efficiency, and to fabricate bifacial modules using these cells with plated contacts.

Lessons Learnt

Lessons Learnt Report: Hydrogenation of solar cells with plated contacts

Project Name: HYDROGENATED BIFACIAL PERL SILICON PV CELLS WITH LASER DOPING AND PLATED CONTACTS

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW

Key learning

We have learnt that the laser doping process critically influences plated contact properties. In plated contact formation, removing surface dielectrics and simultaneously heavily dope the silicon are the main purposes of the laser doping process. The surface geometry and doping effect introduced by laser can affect the plating process greatly. This is because metal plating prefers initializing at the point of lowest chemical potential, which is largely affected by the surface morphology. The surface roughness will induce electric filed non-uniformity and different doping profile will have different resistance distribution. Therefore, a uniform laser doping surface is preferred to facilitate uniform metal deposition during plating. To achieve excellent plated contact properties and high efficiency solar cells, a careful selection of laser focus, power, and doping time is necessary and different plating strategies are needed for different wavelengths laser doped cells.

Implications for future projects

Laser doping is the most efficient way to create electrode patterns on cell precursors for plated contacts formation. A clear understanding of laser doping effects on plating and corresponding strategies will greatly reduce researchers' and manufacturers' efforts on identify processing failure thereby effectively focusing on the optimization of plated contacts and cell performance.

Knowledge gap

Currently, laser doping effects have been mainly discussed in plating metallization. We will research how other processes might also be influenced by laser doping and develop a series of processing strategies and baseline procedures for simplifying the plated cells' fabrication and promote the efficiency.

Background

Objectives or project requirements

The technical work in the second stage of the project has focused on optimizing the fabrication processes of plated bifacial PERL solar cells integrating the three technologies. A 20.4% efficient bifacial plated PERC cell integrating the three technologies and a 21.5% PERL cell has been made using 6-inch commercial grade wafers. A working bifacial module of bifacial plated PERC cells has been fabricated.

The aim of the second 18 months is focusing on optimizing the fabrication process of plated bifacial PERL solar cells integrating the three technologies. These objectives include:

- Demonstration of bifacial plated PERC cells incorporating the three new technology areas with efficiency > 20% in the lab or 19-20% efficiency using industrial or prototype industrial tools
- Achievement of 21.5-22.5% efficiency (Cz) or 20.5-21.5% efficiency (multi) for a PERL cell fabricated using industrial equipment in UNSW SIRF
- Achievement of <3% LID efficiency loss using standard industry testing on a cell with plated contacts
- Fabrication of a working module of bifacial plated PERC cells in industrial partner facilities

Process undertaken

For the hydrogenation process, at this first stage we needed to see:

- If the standard advanced hydrogenation for screen printed cell can work on the bifacial PERL cells with laser doping and plated contacts
- How well it can passivate laser induced defects and eliminate LID
- At which stage of the cell fabrication it should be incorporated in
- Identify if there's a more efficient way of applying the advanced hydrogenation technology and optimize it for the bifacial PERL cells with laser doping and plated contacts

For the laser doping processes, at this stage we needed to know:

- What surface geometry and doping profile can provide the best plating and cell efficiency results
- Which laser doping processing parameters are the most critical
- Identify the origins of laser doping effects on plated contacts and what plating strategies should be utilized in different laser doping surfaces for achieving reliable contact properties and high cell efficiency.

We have systemically studied the effects of key laser doping processing parameters (e.g. focus, power, wavelength etc.) on plated contacts. Laser doping can efficiently create electrode patterns on the precursor surface for contact formation, which is widely favoured in mass production. However, a careful selection of the processing parameters and utilizing correct plating strategies are necessary to avoid problems such as poor adhesion, ghost plating and high contact resistance. We have successfully determined the key parameters and developed a baseline procedure in laser doping and plating. In the next stage, we will also look into the laser doping effects on other processing such as nickel sintering, and then optimizing those processes for furthering enhancing the cell efficiency.