Public Dissemination Report

Advanced Silicon Solar Cells by DESIJN (Deposited Silicon Junctions)

(2017/RND016)

September 2021

Lead organisation: The Australian National University

Project partners: Zhejiang Jinko Solar Co. Ltd

Project commencement: 1st December 2017

Project completion: 30 September 2021

within this document. This project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program

Executive Summary

The project has focussed on the development and deployment of a new silicon solar cell technology in collaboration with our industry partner Jinko Solar, one of the top three PV manufacturers globally. Specifically, we have developed industrial processes for the fabrication of high efficiency n-type silicon solar cells using phosphorus-doped poly-silicon passivating contacts on the rear side of the device (sometimes referred to as TOPCon cells). This has led to several world record large-area cells made with this new technology, including most recently a 25.25% efficient solar cell fabricated in the pilot lines at Jinko Solar, with screen-printed metallisation and industrially-compatible processing. Jinko Solar intend to move this technology to mass production in the near future.

Project Summary

This project has developed new solar cell technologies based on poly-silicon layers, which simplify the solar cell design and fabrication process, whilst enabling higher efficiencies to be achieved in production. The poly-silicon layers provide two functions simultaneously – they allow electrical contact to be made to the solar cell with low resistive losses, and they also block charge carriers within the solar cell from reaching the defective surfaces, where they could otherwise be lost. We have worked with Jinko Solar to develop cost effective and industrially compatible ways to make solar cells with this new type of poly-silicon contact.

Project scope

The April 2021 edition of the International Technology Roadmap for Photovoltaics (ITRPV) Report gives a detailed assessment of the likely future trends in the PV industry, as seen by leading industry players. One of the key questions for industry is which technologies will take over from the current industry standard p-type PERC technology, and over what time frames. A major driver here is the reduced impact of cell fabrication costs as a fraction of total module costs. From 2018 to 2020, the proportion of total module costs attributed to the transformation of wafer to cells, dropped from 28% to 12% for mono-crystalline silicon wafers. This means that more can be spent on cell fabrication to increase both cell and module efficiency, whilst having little impact on total module costs. This in turn drives down the cost of solar electricity in terms of $/W.

This continued push for higher efficiencies has led to the emergence of several technology candidates to take over from p-type PERC cells in the coming years. The key candidates are silicon heterojunction cells (SHJ), poly-silicon passivated contact cells (often referred to as TOPCON), and inter-digitated back contact cells (IBC). In their current form, they are all based on n-type wafers, although they may also be viable with p-type wafers in the future if the wafer properties can be improved sufficiently.

IBC cells have held a small share of the market for many years, but they are more complex to fabricate than SHJ or poly-silicon cells. Similarly, SHJ cells have been present in the market at a small scale for decades, but have failed to increase market share significantly, partly due to their higher capital costs compared to PERC. On the other hand, the similarity of poly-silicon processing technology to PERC technology, coupled with the potential for significantly improved cell performance, have made poly-silicon contacts an attractive candidate to replace PERC. This is reflected in the ITRPV predictions, which expect IBC cells to account for 5% of global market share by 2031, SHJ for 15%, poly-silicon passivated contacts for 35%, and p-type PERC for 35%, with the latter declining.

A key question then is which fabrication methods for poly-silicon passivated contact cells will be the most suitable and cost-effective for industry to adopt. This project aimed to address this question, through the development of poly-silicon fabrication methods at ANU, and their transfer to pilot lines at our industry partner Jinko Solar. The project has been very successful, and has developed industrially-compatible methods to create high quality poly-silicon contacts, leading to certified efficiencies of over 25% on full-sized solar cells made at Jinko Solar.

Outcomes

The project has successfully developed a range of suitable methods for creating poly-silicon contacts, for both p-type and n-type solar cells. The key components of poly-silicon passivated contacts are the formation of the interfacial oxide layer, the deposition of the silicon films, the method for doping the silicon films, and the metallisation of the contacts. In this project, various methods for forming these key components have been explored in detail, and optimised in terms of their electronic and optical properties. Their potential in terms of device performance has been quantified via 3D cell simulations using Quokka3, and their transferability to industry has also been assessed. The most promising were implemented in small-area devices fabricated at ANU, and in large-area cells at Jinko Solar.

The most significant outcome of the project has been the successful development and implementation of a complete process for phosphorus doped poly-silicon passivating contact technology for high efficiency n-type cells in pilot production at our industry partner, Jinko Solar. The methods developed are compatible with standard production tools and can be applied at high throughout, including the screen-printed metallisation. The project has led to a string of world-record large-area solar cell efficiencies using this technology, including certified values of 24.8% in July 2020, and most recently 25.25% in May 2021. Jinko Solar intend to move this technology into full scale production in the near future. This new technology will help to further drive down the levelised cost of solar electricity for Australian consumers.

Conclusion and next steps

The project has successfully developed industrially-compatible technology for the fabrication of n-type silicon solar cells with efficiencies over 25%. The next step will be to move this technology from the pilot lines to mass production at Jinko Solar. This project has demonstrated the value of collaboration between Australian research teams and the PV industry. Australian PV R&D capabilities are world-class, and highly sought after by industry partners. By working together, we are able to accelerate the development of PV technology, for the benefit of consumers in Australia and around the world.

Contact for further information

Prof. Daniel Macdonald

The Australian National University

daniel.macdonald@anu.edu.au