Advanced High Efficiency Silicon Solar Cells Employing Innovative Atomic Scale Engineered Surface and Contact Passivation Layers

Project results and lessons learnt

Lead organisation:	UNSW
ARENA ID:	2017/RND007
Project commencement date: 7 December 2017	**Completion date:** 31 August 2021
Date published:	28 August 2019
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This project received funding under the Australian Renewable Energy Agency (ARENA) Solar Research & Development Program (Round 3).

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Executive Summary

The objective of this project is to develop ultrathin films which can be used to improve the performance of current or next-generation solar cells in a cost-effective way. Just before the halfway point of the project, we are very excited that we have already been successful in the development and subsequent transfer of a new application of an ultrathin film to the photovoltaic industry. We have also been able to upgrade a pilot-scale atomic layer deposition (ALD) reactor to a versatile R&D enabled reactor which will be housed in Sydney and be used to accelerate our future R&D and commercialisation efforts. We have identified a wide range of promising materials at the laboratory-scale, which will be further investigated in the remaining two years of this project in close collaboration with our academic and industry partners.

Project Overview

Project summary

Silicon solar cells are dominating the photovoltaic market, and this dominance is expected to continue in the next decade(s). The most efficient way to achieve further cost reduction for silicon solar cells is to increase the solar cell efficiency. This project brings together the Australian academic leaders in the fields of atomic layer deposition (ALD) and novel passivated contacts, with both a leading industrial equipment manufacturer and consumable supplier. This partnership is ideally suited to ensure rapid transfer of project results to the industry. The first part of this project will focus on exploiting the benefits of bifacial ALD on improved majority carrier transport, which simultaneously results in a significant cost reduction and increase in solar cell efficiency. The second part of this project focusses on exploiting the intrinsic merits of ALD for the development of novel tunnel oxide layers and extreme work-function materials, which will allow the realisation of innovative dopant-free passivated contacts. The final part of the project will focus on the development of bifacial transparent conductive oxide deposition using ALD, again offering significant cost and efficiency potential.

Project scope

The photovoltaic industry is currently undergoing a transition to the PERC (Passivated Emitter and Rear Cell) solar cell architecture, which has a significantly higher efficiency potential compared to the incumbent technology. One of the key enablers of the higher efficiency afforded by the PERC solar cell is the application of ultrathin films at the rear of the solar cell. It is generally accepted that future industrial solar cells will rely even more heavily on the application of novel thin films in order to achieve higher efficiencies at lower costs. This project focusses on the development of multifunctional thin films which can be used as a critical building block in future high-efficiency solar cells.

We have traditionally used thin films to improve the optical properties of solar cells, for example, by applying them as an antireflection coating. From the year 2000, silicon nitride thin films were also used to reduce electronic losses at the front surface of a solar cell. In the PERC solar cell, a thin film stack consisting of aluminium oxide and silicon nitride is used to reduce electronic losses at the rear side of the solar cell as well. The next-generation of solar cells will use thin films to simultaneously reduce electronic losses and extract the solar-generated electricity via so-called carrier selective contacts. Extraction is currently achieved by introducing impurities into the solar cell using high temperature diffusion processes. These impurities limit the efficiency potential of industrial solar cells to approximately 25% and by changing to thin films, the efficiency potential increases to well above 27%.

In order to maximise the performance of a solar cell using carrier selective contacts, it is critical that the properties of the thin films can be controlled at an atomic scale. It is for this reason that we synthesize films using atomic layer deposition (ALD); the technique enables 'digital' control of the film thickness and layer-by-layer composition. ALD is already used in high-volume solar cell manufacturing to grow the key layer for PERC solar cells, which ensures that the outcomes of this project can be readily commercialised.

We aim to develop various new thin films in this project, which can be used as “building blocks” in future high-efficiency solar cells. We will gain significant fundamental knowledge and skills by first optimising processes on laboratory-scale reactors that allow for real-time analysis of the film properties and growth dynamics. Our project team members will subsequently work on the integration of the thin films in solar cell devices, as well as upscaling the process to the pilot-scale level on our in-house pilot line. The project will also focus on the commercial aspect of the developed processes at a very early stage, to identify potential roadblocks and rapidly assess their industrial potential.

Outcomes

The project is currently not even halfway, yet it has already achieved some remarkable results. We have been successful in transferring one of our processes from the laboratory into a high-volume manufacturing line, resulting in higher efficiency industrial solar cells at a lower cost, therefore attacking the cost per watt from both sides. This work was carried out in collaboration with our industry partner Leadmicro and one of their main customers. In addition, we have developed processes for over 10 new materials, of which some will be investigated further throughout the remainder of this project. In particular, our work on doped metal oxides is very promising and this allows us to significantly expand our parameter space from binary to tertiary compounds in order to identify the most promising materials. We have also filed for two new patents related to processes with a commercial appeal, which will be further investigated.

Overall, our project is tracking very well and is well ahead of schedule in terms of impact, with both a process commercialised and two patent applications in the first half of the project. In the next few weeks, we will receive the R&D-enabled pilot-scale ALD reactor, which has been developed as part of this project. To the best of our knowledge, this acquisition is a world-first for a university, which we look forward to announcing to the wider community and ideally use in new collaborations in Australia and beyond.

Transferability

We designed our project with intrinsic transferability by teaming up with industry partners. The most promising processes developed in this project will be transferred from the laboratory to a pilot scale reactor and consequently be commercially available. The other processes developed in this project will be communicated to the broader community via news articles, conference presentations, and peer-reviewed publications. The pilot-scale ALD reactor developed in this work is, in principle, available to be used in new collaborations with industry and academia. It should be noted that the processes/designs with the highest commercial potential will be patented and commercial agreements will subsequently govern their wider use.

Conclusion and next steps

The project outcomes are already resulting in cheaper, in terms of A$/Wp, photovoltaic modules available to Australia using one of the processes developed in this project. The project is also heavily used in the training of 8 under- and post-graduate students and thus supporting the Australian Education Export. The project will result in a globally unique capability in terms of atomic layer deposition, which is expected to support research contracts as well as Education Export further.

We expect to be developing various new processes in the final two years of the project and look forward to further contributing to lowering the cost of photovoltaics in Australia and around the world.

Lessons Learnt

Lessons Learnt Report: Impact of bifacial deposition on PERC solar cells

Project Name: *Advanced high-efficiency silicon solar cells employing innovative atomic scale engineered surface and contact passivation layers*

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

Key learning

We learned how the excellent laboratory-scale results related to bifacial deposition of aluminium oxide can be exploited in high-volume manufacturing.

Implications for future projects

We learned that we should design our experiments from the onset with the final application in mind. This, in particular, relates to all the processes, and their correlation, involved in solar cell manufacturing. We are currently exploring home-built and commercials solutions to address some of these correlations very early in the development.

Knowledge gap

We are currently mainly investigating the long-term stability of the thin films investigated in this project

Background

Objectives or project requirements

We found that an additional aluminium oxide layer on the front a PERC solar cell could improve its performance by lowering the contact resistance between the silver front metal grid and the emitter after contact firing. The objective was to apply this additional layer in high-volume production without increasing manufacturing costs or complexity.

Process undertaken

We designed a way to integrate this additional layer into the PERC process flow by changing the atomic layer deposition process from monofacial to bifacial. This change reduced process complexity *for the ALD process and increased its throughput and thus decreased the costs of the PERC production.*

Supporting information (optional)

We show production data for the bifacial aluminium oxide process in Figure 1, and it is clear that the process transfer was successful, even delivering higher performance than its monofacial aluminium oxide counterpart at a lower cost.

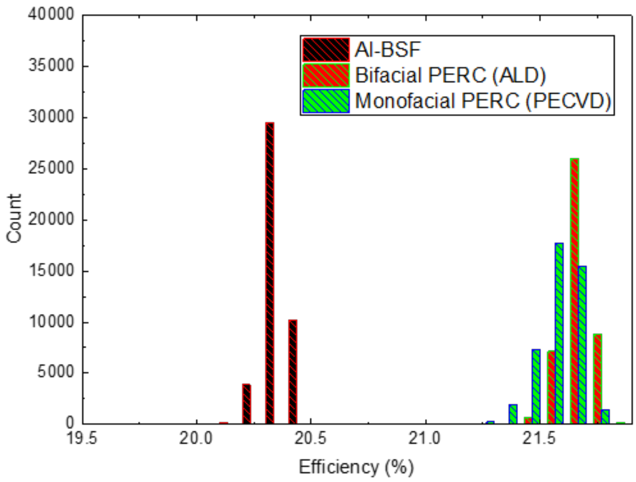

Figure 1: High-volume production data for the incumbent Al-BSF technology and PERC solar cells with a monofacial and bifacial aluminium oxide layer. It can clearly be seen that the solar cells with the bifacial aluminium oxide layer show a better performance compared to the monofacial aluminium oxide layer while the production costs of the bifacial aluminium oxide are lower.