Australian National University

Interim Public Dissemination Report

ARENA R&D Project 2020/RND009: Advanced multifunctional dielectric layers enabling simplified production of high-efficiency silicon solar cells

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Acknowledgement and Disclaimer

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.

Project Details

Project title	Advanced multifunctional dielectric layers enabling simplified production of high-efficiency silicon solar cells
Lead organisation	The Australian National University
Project partners	Eindhoven University of Technology (Netherlands), SunPower Corporation (USA)
Commencement date:	21 September 2020
Completion date:	1 October 2022

Executive Summary

This Project aims to investigate the application of novel multifunctional dielectric layers based on phosphorus oxide (PO_x) to reduce surface recombination and simplify processing of high-efficiency silicon solar cells.

Key findings of the project so far include:

- Excellent performance of PO_x-based dielectric stacks on textured and n+ diffused silicon surfaces has been shown, as well as compatibility with standard SiN_x capping and high-temperature firing processes
- Investigations of the chemical structure and composition of PO_x-based stacks have revealed substantial structural changes occurring at elevated temperatures, which help to explain the origins of their unique electrical properties
- The ability to form local electrical contacts via laser processing of silicon surfaces coated with PO_x-based dielectric stacks has been experimentally demonstrated, opening the way for applications in devices

Two journal articles enabled by this project have so far been accepted for publication. The project has created one full-time-equivalent postdoctoral researcher position and is paying part of the salary of a research technician.

The next steps in the research will be to demonstrate the investigated POx-based dielectric stacks at a device level in proof-of-concept solar cells.

Aim of the Project

This Project aims to investigate the application of novel multifunctional dielectric layers based on phosphorus oxide (PO_x) to reduce surface recombination and simplify processing of high-efficiency silicon solar cells.

Key Findings

While previously demonstrated on planar (flat) silicon surfaces, PO_x-based dielectric stacks have now been shown also to be suitable for application to textured silicon surfaces, with or without a heavily doped phosphorous emitter, like those which are present on the front side of commercial silicon solar cells. On such surfaces the PO_x-based stacks have been found to reduce surface recombination losses to levels significantly below those of the standard SiO_x/SiN_x passivation stacks which are currently used in most commercial cells. Compatibility with a standard SiN_x capping layer and high-temperature firing process have also been demonstrated

Investigations of the chemical structure and composition of PO_x-based stacks have revealed significant intermixing which occurs between the PO_x layer and Al_2O_3 capping layer during annealing treatments at elevated temperatures. These treatments are used to activate the beneficial electrical properties of the stacks, and the observed structural changes help to explain the microstructural origins of these properties.

The ability to form local electrical contacts via laser processing of silicon surfaces coated with PO_x-based dielectric stacks has been demonstrated. Optimised laser processing allows simultaneously removal of the dielectric stack while driving in phosphorus to the silicon substrate. Since phosphorus is an n-type dopant in silicon, this allows the formation of local n+ emitter regions which are self-aligned with the laser-processed contact openings and facilitate the formation of contacts with low electrical resistance. While previously hypothesised, this has now been demonstrated experimentally. This opens up exciting possibilities for simplification of manufacturing processes for high-efficiency silicon solar cells.

Lessons Learnt

Having all personnel and facilities ready to go at the commencement of a short (2 year) project like this is critical. This is particularly the case during a period when international borders are closed and recruitment, shipping and supply chains are severely constrained.

Outputs

Two journal articles enabled by this project have so far been accepted for publication:

J. Melskens, R. J. Theeuwes, L. E. Black, W.-J. H. Berghuis, B. Macco, P. C. P. Bronsveld and W. M. M. Kessels, "Excellent passivation of n-type silicon surfaces enabled by pulsed-flow plasma-enhanced chemical vapor deposition of phosphorus oxide capped by aluminum oxide", physica status solidi RRL 15, 2021. (https://doi.org/10.1002/pssr.202000399)

R. J. Theeuwes, J. Melskens, L. E. Black, W. Beyer, D. Koushik, W. J. H. Berghuis,† B. Macco,† W. M. M. Kessels, "PO_x/Al_2O_3 stacks for c-Si surface passivation: Material and interface properties", ACS Applied Electronic Materials, In press.

Next Steps

The next steps will be to demonstrate the investigated POx-based dielectric stacks at a device level in proof-of-concept solar cells. Here we hope to demonstrate how their outstanding properties and multifunctional potential can translate into improvements in energy conversion efficiency and simplified manufacturing flows.

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