Australian Government
Australian Renewable Energy Agency

ARENA

Advanced Surface and Contact Technologies for Industrial Silicon Photovoltaics (2014/RND003)

Project results and lessons learnt

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Executive Summary

Project: *Advanced Surface and Contact Technologies for Industrial Silicon Photovoltaics* (2014/RND003)

Public dissemination report

The Australian National University (ANU) and the University of New South Wales (UNSW) have completed a three-year project with one of the world's leading commercial solar cell manufacturers, TRINA Solar, and solar cell equipment manufacturer, Tempress.

This work comprised development activities across an important suite of processes which are critical to the manufacture of silicon solar cells including:

- Novel coatings to improve the quality of the surfaces of the solar cells so electricity is delivered to an external load rather than being lost to defects on the surface
- Cutting-edge patterning techniques using lasers to locally remove these coatings with high precision
- New processes for replacing the expensive silver used in the metal contacts for current solar cells with cheaper copper and characterisation methods to testing the adhesion of the metal to the solar cell

The project looked at identifying promising technology advancements developed in the Australian universities and undertake proof of concept testing of small batches of solar cells with a range of outcomes. The technologies that passed this proof of concept testing with the most potential for commercialisation were then tested in larger quantities to determine if they were suitable for pilot scale manufacturing trials.

Highlights of the project include:

- Demonstration of interdigitated back contact (IBC) solar cell efficiencies of greater than 24.1% in solar cells manufactured on large area industrial silicon wafers. This efficiency approaches the best results (24.4%) produced by the ANU on small IBC devices in the laboratory. TRINA is now conducting a pilot production of IBC cells.
- Identification of two alternative metal oxide coatings by ANU that provide surface quality improvements similar to current state of the art. These findings have led to three patent applications with TRINA.
- Development of a metal adhesion testing method and tool at UNSW and successful transfer of the tool to TRINA for testing the quality of the silicon to metal contacts which is critical to long term reliability.

ARENA's support of this project has enabled Australian research to be successfully trialled and transferred from the laboratory to commercial manufacture. It has also exposed the researchers to mass manufacturing of solar cells to enable better understanding of the challenges of improving performance and reducing cost of solar cells in an industrial setting.

Project Overview

Project summary

The ANU and UNSW have worked with TRINA Solar and Tempress on a range of technologies related to the surfaces of silicon solar cells in attempt to transfer university developments into the commercial environment.

Project scope

The ANU and UNSW have extensive knowledge and experience in silicon solar cell research. This project was an excellent opportunity for these institutions to work with leading solar cell and equipment manufacturers to transfer this knowledge into commercial outcomes.

The learning curve of silicon requires continued improvement in silicon device process to enable further cost reductions. The technologies that the teams worked on were identified as areas of opportunity for manufacturing improvements that could deliver these savings.

This work comprised development activities across an important suite of technologies, which are critical to the manufacture of silicon solar cells including:

- Novel coatings for solar cells to improve the quality of the surfaces so electricity is collected by the solar cell rather than being lost to defects on the surface;
- Cutting-edge patterning techniques using lasers to remove these coatings; and
- New processes for replacing the expensive silver used in the metal contacts for current solar cells with cheaper copper and characterisation methods to testing the adhesion of the metal to the solar cell.

Outcomes

The initial work was focused on demonstrating that the three key technologies of interest were of a standard that warranted their testing on working devices and this was demonstrated in the first phase of the project as planned.

The second phase of the project was then focussed on testing these technologies on solar cells. The developed technologies were incorporated into six solar cell test processes to determine their effectiveness. Solar cells were made using these solar cell processes and evaluated against an agreed set of criteria. Three of these solar cell processes passed these criteria, demonstrating their potential at a proof of concept level.

The two most promising of these solar cell process sequences were then tested against more stringent criteria and in larger batches to determine if the incorporated technologies would be suitable for manufacturing. One of these cell processes passed this more stringent trial successfully, demonstrating solar cell efficiencies of greater than 24.1%, and has since been transferred into pilot production at TRINA.

A characterisation tool was also developed at UNSW for testing the adhesion of the front metal fingers to solar cells. This is a key metric of the reliability of the metal contacts as it demonstrates the potential of the metallisation to remain attached to the cell as the module experiences stresses resulting from the daily temperature cycles.

A finger adhesion measurement tool was developed in collaboration with the project team for TRINA Solar to allow them to perform similar measurements in their research facilities in China. This tool moves a stylus across the surface of the wafer and measures the force required to dislodge a contact from the solar cell. The quality of the adhesion is a key metric to determining if the cell is likely to survive the 25 year life of a solar module. This tool was featured on TRINA Solar's main web page for several months.

Transferability

As research universities, knowledge sharing is a core activity at both ANU and UNSW. We have published widely at conferences and in academic journals producing more than 30 publications. When working on commercial activities, the need for IP protection and confidentiality is critical. Ideas that can be effectively protected by patenting can be published once protection has been sought. Other findings are deemed necessary to remain as trade secrets due to the difficulty in demonstrating use by others or challenges in determining patentability and are therefore kept confidential to ensure the commercial competitiveness.

Both institutions had a number of early career researchers who were exposed to commercial manufacturing for the first time. This experience increases their understanding of the challenges associated with industry development and positions them well to engage with industry partners in future projects.

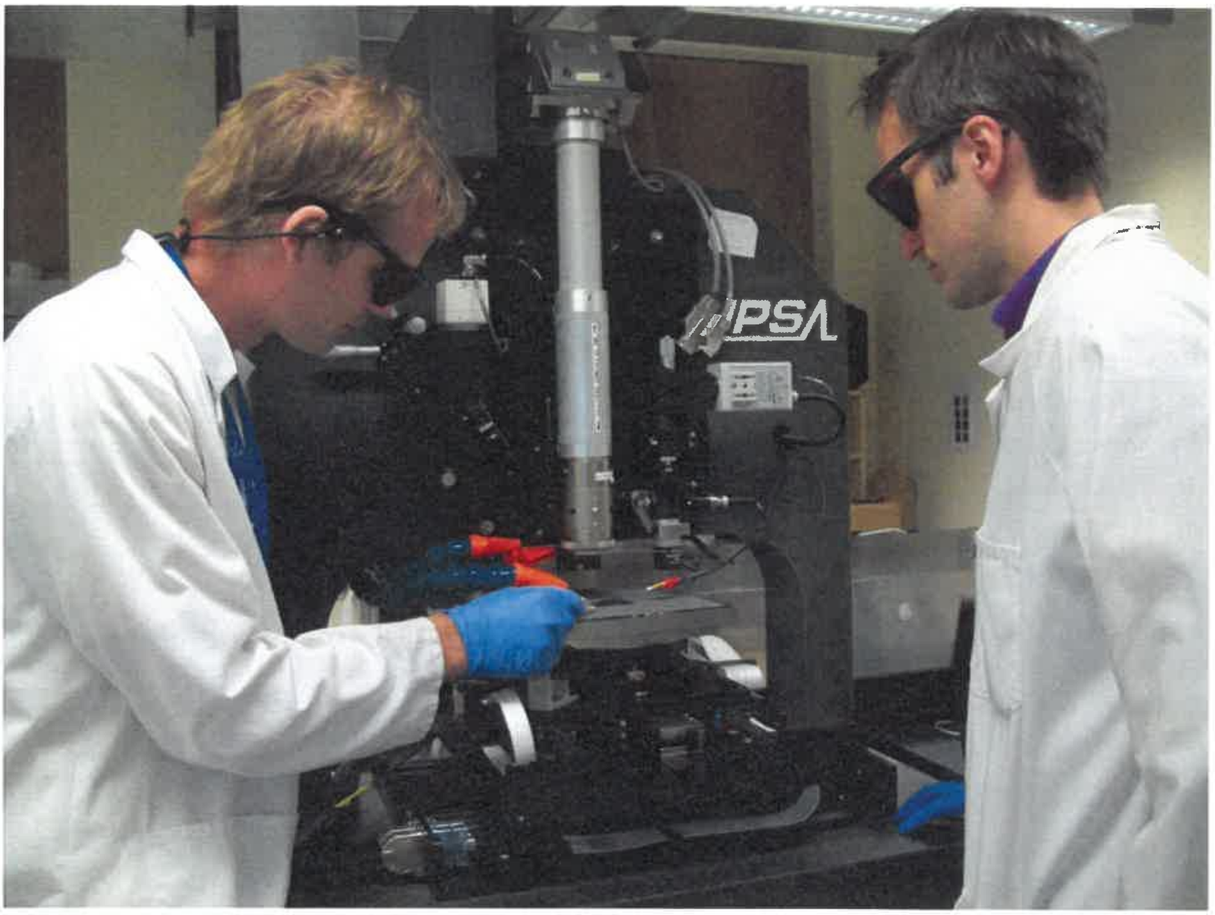
Conclusion and next steps

At the commencement of the project, TRINA was the leading manufacturer of solar modules in Australia. The developments from this project will help to further reduce the cost of manufacture of TRINA's modules and assist in improving their reliability.

Working with TRINA has increased the understanding of the Australian researchers to the challenges of commercial manufacture of solar cells. Team members have learnt that process development will often not occur on research only machines and trials need to be undertaken on equipment that is used on manufacturing lines with associated conflicts. R&D team members in industry are also often called upon to support activities outside their core projects or have shifting priorities that can make timely experimental progress difficult.

During this project, the ANU and UNSW developments were tested using a gating process to evaluate suitability of the technologies being developed. Importantly, this process helped to identify processes that were not ready for commercial transfer before large scale trials commenced. It is expected that ANU will continue to use this quality control process in other projects with commercial manufacturers in future.

Sputtering was one of the promising approaches used for depositing novel dielectric films for coating the solar cells.



Australian National University researchers undertaking trials of advanced laser patterning processes.

Lessons Learnt Report: International collaboration

***Project Name: Advanced Surface and Contact Technologies for Industrial Silicon Photovoltaics* (2014/RND003)**

Knowledge Category:	Logistical
Knowledge Type:	Other (please specify): Project management
Technology Type:	Solar PV
State/Territory:	ACT

Key learning

There is greater benefit and likelihood of researchers travelling to industry sites than industry travelling to researcher sites. The research project is often one of a suite of priorities for industry personnel and therefore managing travel is difficult resulting in delays and/or cancellations.

Implications for future projects

There will be several changes in planning future projects between Australian researchers and international manufacturers. This includes consideration including:

- Planning for site visits to be predominantly at industry partner sites rather than researcher;
- Ensuring project members are made aware of the likely travel requirements during the project before committing to the project; and
- Ensuring sufficient travel budget allocated in researcher budgets.

Knowledge gap

Working with international manufacturing partners on a major development project.

Background

Objectives or project requirements

Information exchange is key to technology transfer. This is usually more effectively completed face to face rather than via reports or teleconferencing. The project planned significant times for the two teams to work together to aid this process. This involves:

- Researchers benefit significantly from access to a broader range of industry engineers for training and development;
- Improved understanding of constraints and limitations of industrial solar cell manufacturing;
- Broader networking with industry for future development and employment opportunities

Process undertaken

The project evolved from one where expectations of similar time spent by the two teams at the complementary sites to one where ANU/UNSW predominantly travelled to TRINA in China.

Lessons Learnt Report: Equipment availability

***Project Name: Advanced Surface and Contact Technologies for Industrial Silicon Photovoltaics* (2014/RND003)**

Knowledge Category:	Logistical
Knowledge Type:	Risk Management
Technology Type:	Solar PV
State/Territory:	ACT

Key learning

Availability of equipment had significant impacts on the planned project progression. Two pieces of manufacturing capable equipment (e.g. a plating bench and laser workstation) were not purchased by the industrial partner (TRINA) due to changes in their budgets and priorities. This impacted on the project ability to deliver some of the potential technology developments on industrial size wafers with demonstrations restricted to small area laboratory cells and not transferred to manufacturing scale. Vendor trials/demonstrations of equipment are typically insufficient to provide the volume needed to demonstrate commercial viability.

Implications for future projects

Ideally, when developing a new solar cell process sequence, it is best if all of the equipment is available at both partner's sites at commencement of the project.

The availability of key equipment should be considered in the risk analysis of pre-project planning. Consideration should be given to whether small scale demonstrations are sufficient or whether including key equipment in the commercial partner's project budget is necessary rather than relying on other projects which may change priority.

Knowledge gap

Changes in manufacturing partners plans for equipment purchases during the project.

Background

Objectives or project requirements

The transition from laboratory to manufacturing stages of the project were affected. Large scale trials with significant volumes of wafers processed are required to test the suitability of a new cell technology for the manufacturing environment. This is necessary to test the yields of the process and to build sufficient volumes of working cells to undertake accelerated lifetime testing to evaluate module reliability.

Process undertaken

When it was recognised that TRINA was not purchasing the equipment originally proposed, the work program was adjusted. For example, in the proof of concept work, the focus moved to smaller laboratory scaled cells to demonstrate the performance improvements afforded by the technologies developed. Subsequent demonstration of larger volumes was managed through the use of equipment vendor trials. This arrangement is less satisfactory than equipment on site as the cycle times for cell processing are greatly increased and expanded by the transport and scheduling process. There is also an increased chance of damage occurring during transport process and less flexibility in modifying processes.