



The value and importance of the Solar Industrial Research Facility (SIRF)

Project Name: [Overcoming the fundamental performance limitations of commercial solar cells](#)

Knowledge Category:	Technical
Knowledge Type:	Operation and maintenance
Technology Type:	Solar PV
State/Territory:	New South Wales

Key learning

The value and importance of a Solar Industrial Research Facility (SIRF)

Results achieved in laboratories around the world in general lack credibility in the eyes of industry because they make use of specialised and sophisticated low volume processing equipment and semiconductor grade, small area wafers that are far superior and far more expensive than the low cost wafers used commercially. To be useful to industry, achievements and technologies need to be developed and demonstrated with commercial high throughput manufacturing equipment and on full-sized commercial grade wafers.

Implications for future projects

All projects aiming to develop commercially significant technology would benefit greatly through the use of a SIRF to demonstrate the suitability of the respective technology for industry and large-scale manufacturing.

Knowledge gap

The SIRF has at present only been partially established. Although all the tools required to complete the SIRF are now located at UNSW ready for installation, funding at present is not available for the commissioning of these tools.

Background

Objectives or project requirements

Following the development of new and innovative technology through this project, a particular aim was to demonstrate the commercial viability and significance of the technology through the use of SIRF where available or through the use of the equipment and facilities of industry partners.

Process undertaken

The establishment of SIRF at UNSW was facilitated by donations of virtually all the tools by leading industry companies and tool manufacturers such as Roth & Rau, Kuttler, Suntech, Meyer Burger and 3S. The concept for SIRF was made possible by the construction of a \$15 million purpose built facility satisfying all the requirements for a SIRF. The running costs for SIRF have been provided primarily through ARC and ARENA grants. Seeking the remaining funding needed for installing the remaining tools is a priority at present.

Even though the SIRF is not yet complete, its valuable functions already include:

- demonstration of the commercial value and relevance of new technology;
- carrying out collaborative research with industry;
- conducting technology transfers;
- providing education and training;
- providing the opportunity for equipment development;
- establishing pilot production for new technology;
- technology evaluation such as processing parameter tolerances, yields, throughput, costs etc

Supporting information

New Solar Industrial Research Facility (SIRF)

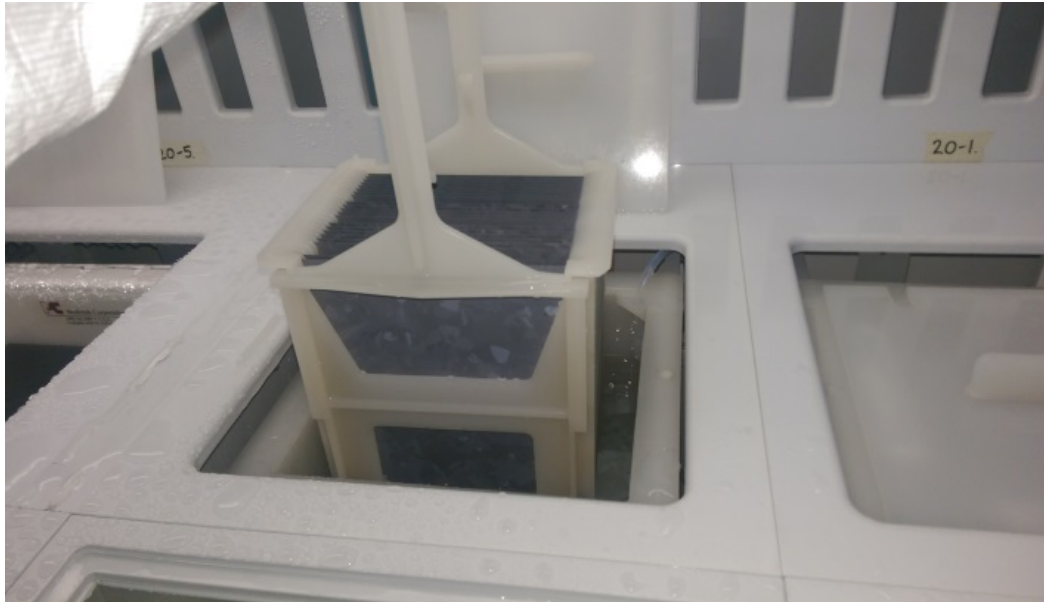
The installation of the first operational tool in the new Solar Industrial Research Facility (SIRF) was reported in 2013. During 2014, numerous new tools were either installed and commissioned or delivered in preparation for installation. Most tools have been donated by companies such as Roth & Rau, Suntech, Meyer Berger, Sunshare, Kuttler, 3S and Schmid. In some cases, the tools have been donated primarily in support of collaborative research projects between UNSW and the respective companies, although in most other cases it has been clear that the intention of donating tools was so that they could be adapted to suit UNSW internationally leading technologies and for use by UNSW researchers, students and industry partners.

The SIRF forms a particularly important purpose for the Centre's more commercially significant research and technologies to demonstrate their suitability for the industrial environment and large-scale manufacturing. This involves taking the laboratory technologies and developing and adapting them for use with the commercial tools in SIRF. This makes the SIRF particularly well suited for interfacing with industry such as for technology transfers. Collaborative research, pilot production of new technology or simply demonstration of the compatibility of state-of-the-art UNSW technology with fabrication with high throughput commercial tools.

UNSW has been particularly fortunate to attract Dr Bram Hoex into joining the team of academic staff in SPREE. Dr Hoex is particularly well known internationally for his industrially relevant research in silicon wafer-based photovoltaics that he has conducted in recent years at SERIS in Singapore where he was Deputy Director responsible for wafer-based technology development. Earlier

technologies of Dr Hoex are now gaining traction commercially through licensing by industry. The SIRF will be particularly well suited for Dr Hoex's industrially relevant research due to its similarities to the laboratories at SERIS that comprised large-scale commercial tools similar to those being installed in SIRF.

The following photos show some of the key tools provided to UNSW by various companies for use in the SIRF.



(a)



(b)

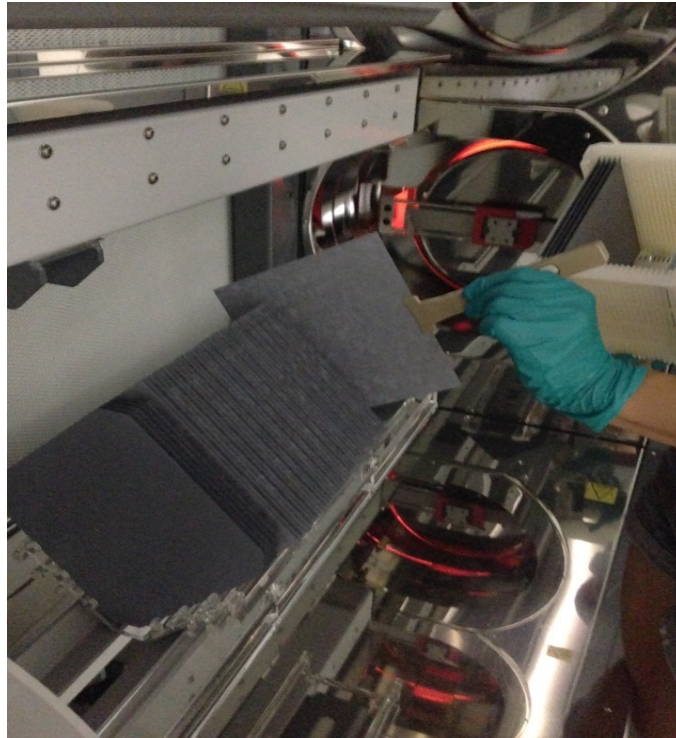
Figure 1: Chemical baths for cleaning and texturing wafers prior to device processing at elevated temperatures.

Front-surface phosphorus emitter diffusion is one of the most important processes in terms of determining the final device performance and is shown below in Figure 2 taking place in SIRF at UNSW. In particular, the direct link between the emitter doping profile and the ability to hydrogen passivate defects and recombination sites throughout the device via hydrogen charge-state control has not been previously recognised or understood prior to this work. This important relationship and the ability to optimise the corresponding processes for maximising device efficiencies have been captured within a patent portfolio developed as part of the “Advanced Hydrogen Passivation” work originating from UNSW projects.

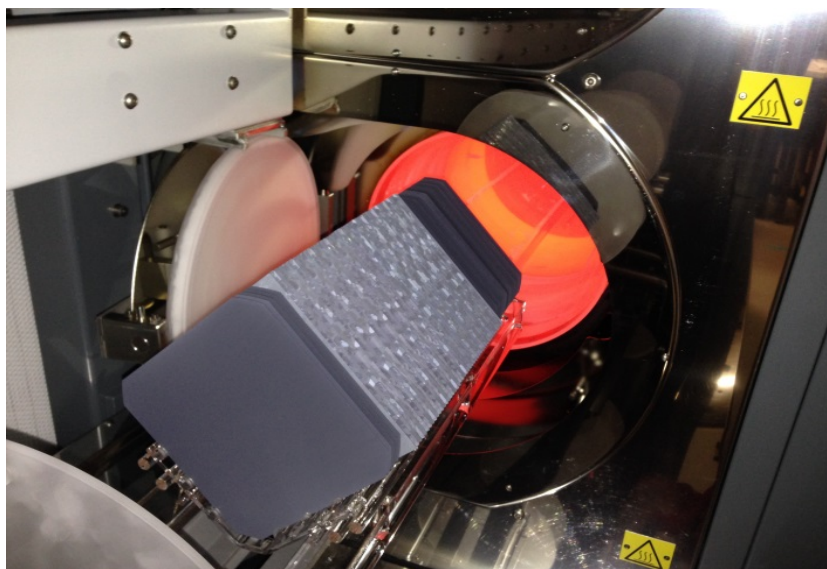
Note in the photos below, the relatively large number of wafers as well as their size, able to be processed in a single operation when using the commercial tools in SIRF.



(a)



(b)



(c)

Figure 2: Furnace tubes for high temperature processing in SIRF. Figure (c) shows 200 wafers being loaded into a tube to be diffused with phosphorus at 850degC

Dielectric deposition is carried out in SIRF at UNSW by PECVD to give the wafers the blue colour as shown in the photos below in Figure 3. To maximise the ability of the resulting dielectrics to act as good hydrogen sources for the subsequent hydrogen passivation processes, the dielectric layers are deposited at the relatively low temperature of 350degC to increase hydrogen content. Deposition parameters are also optimised so as to control the temperature at which the hydrogen is released. This is a particularly important aspect for the implementation of the hydrogen passivation technology to a range of different cell technologies that employ different thermal processes such as

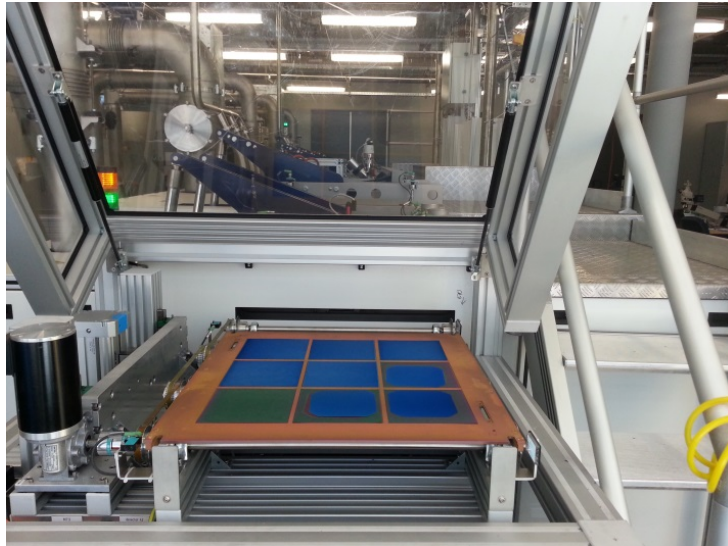
firing temperatures for the metallisation. The tool shown is the \$3 million state-of-the-art MAiA tool donated to SIRF by Roth & Rau specifically for this hydrogen passivation work.



(a)



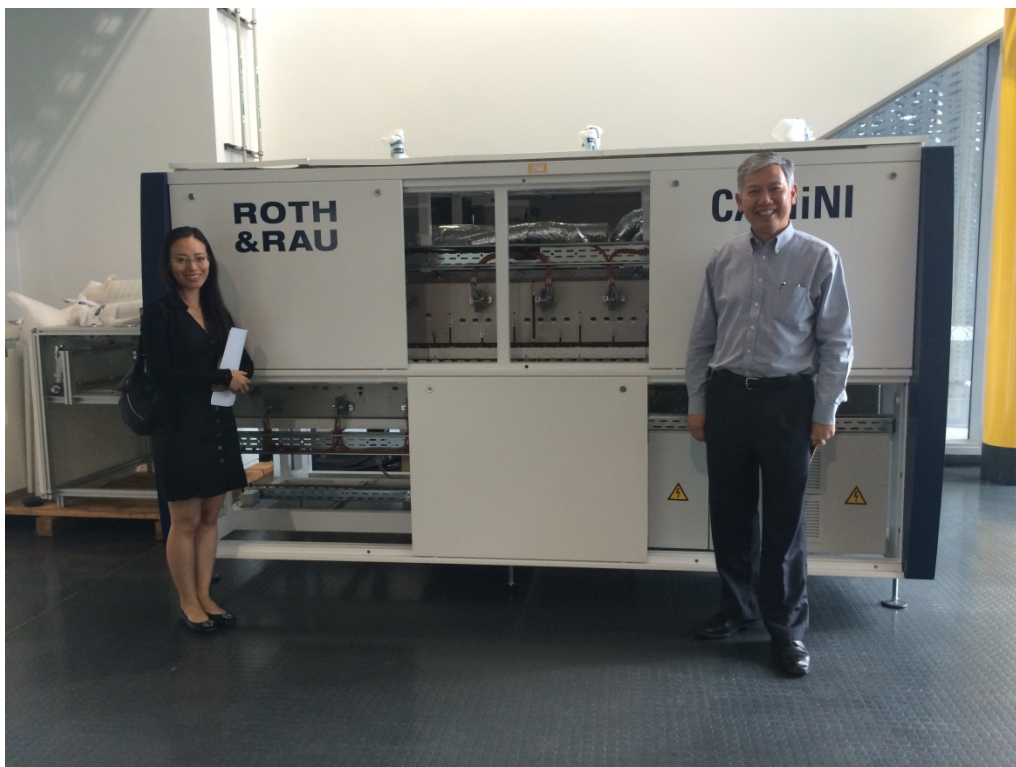
(b)



(c)

Figure 3: PECVD tool for the plasma enhanced deposition of a range of dielectric layers onto the silicon wafer surfaces such as for surface passivation, antireflection coating, hydrogen sources and chemical protection.

Advanced Hydrogen Passivation involves the use of hydrogen charge state manipulation to enhance both the mobility and reactivity of the hydrogen atoms. The tool below in Figure 4 donated by Meyer Berger, allows this hydrogen charge state manipulation through the use of varying illumination levels to control the carrier concentrations in the vicinity of the hydrogen atoms. Large improvements in material quality have been demonstrated and have contributed significantly to increased mono and multi cell efficiencies. This is particularly important for the multi material to reduce recombination in the vicinity of grain boundaries and other crystallographic defects that normally limit efficiencies to well below those normally achieved with the mono wafers.



(a)



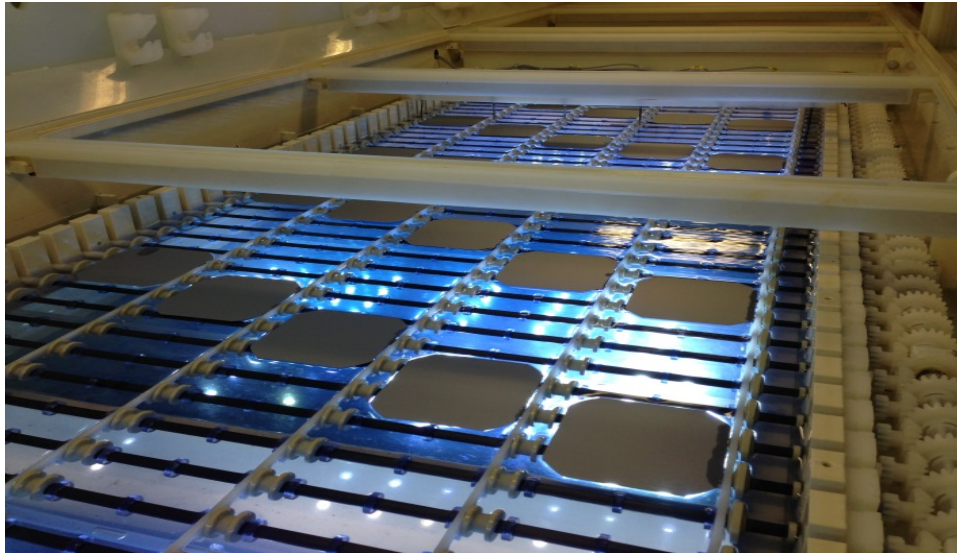
(b)

Figure 4: One of only two Camini roller furnaces existing internationally shown in (a). This furnace has unique capabilities that suit it particularly well to UNSW's innovative hydrogen passivation technology while simultaneously being well suited to conventional metallization firing such as required by screen-printed solar cells. Fig (b) shows a conventional Centrotherm belt furnace, also located in SIRF.

The Metallisation/Plating technology is perhaps the most advanced or at least important of all the newly developed technologies at UNSW. The International Technology Roadmap for Photovoltaics (ITRPV) produced by an international team of experts, predicts that plated cell metalisation will eventually displace the use of screen-printed contacts. This transition however is expected to take as long as 5-10 years (2014 ITRPV), due in part to this lack of suitable commercial plating tools for large-scale manufacturing. To accelerate UNSW's technology implementation into large-scale manufacturing at Suntech, the fabrication, installation and evaluation of the plating baths of Figure 5 have taken place in SIRF. These plating baths are based on the UNSW developed plating technology and are suitable for large-scale manufacturing. These baths were designed by Dr Ji, a world expert in plating technology and now an academic at UNSW, and have been constructed in China by the company Kuttler.



(a)



(b)



(c)



(d)

Figure 5: Plating baths suitable for large-scale manufacturing, designed by world expert Dr Ji for forming solar cell contacts based on the UNSW developed plating technology. Figure (d) are low throughput prototype plating baths.



Figure 6: Chemical baths for general chemical processing and cleaning with spin-dryers shown on the right.

UNSW is often credited with pioneering the use of lasers for photovoltaic device fabrication. Lasers are routinely used for a range of processes such as patterning dielectrics, selective emitter formation through laser doping, surface grooving for buried contacts, edge junction isolation, surface texturing, hydrogen charge-state control, localised heating, etc. The laser types and corresponding specifications required vary somewhat for the various laser functions. SIRF consequently has several lasers available with more to follow. Two donated lasers are shown in Figure 7, one being UV with ps pulse lengths (left) while the other is Q-switched at 1064nm wavelength (right).

Following completion of device fabrication, cells are tested such as in the automated testing station of Figure 8 manufactured by Bacini and donated for use in SIRF.

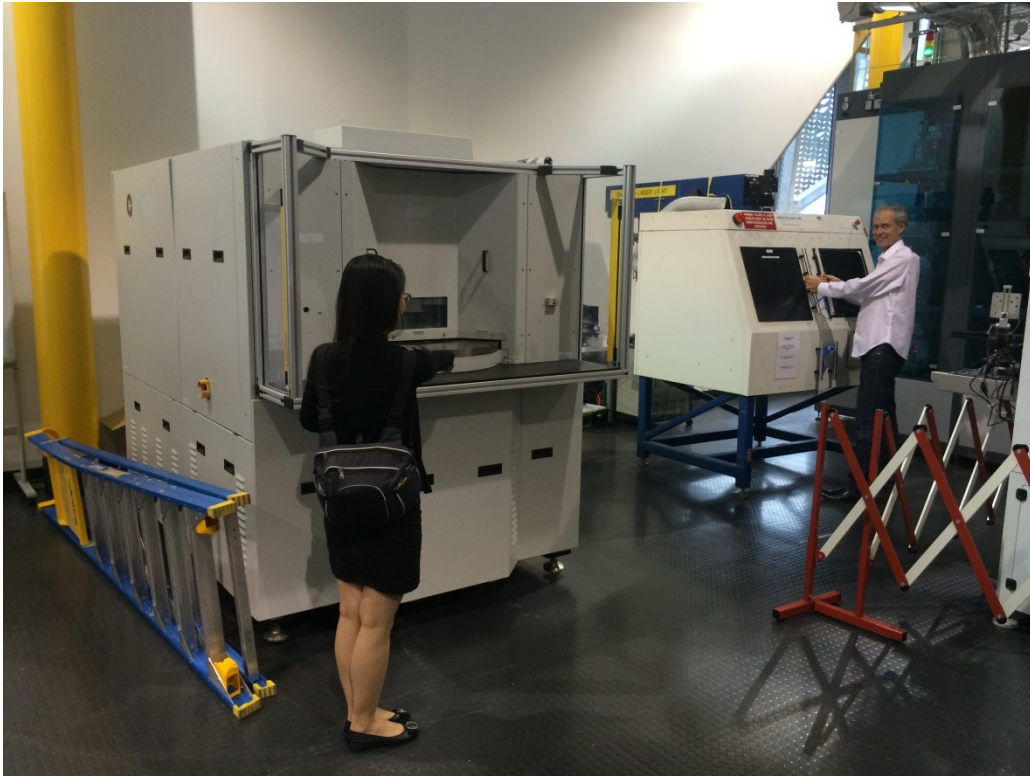


Figure 7: Two donated lasers are shown, one being UV with ps pulse lengths (left) while the other is Q-switched at 1064nm wavelength (right).



Figure 8: Following completion of device fabrication, cells are tested in the automated testing station manufactured by Bacini

Encapsulation is necessary to protect solar cells in the field from the environment, particularly moisture. Figure 9(a) is an environmental test chamber planned for installation in SIRF in mid 2015 to simulate and accelerate environmental testing of solar modules.. A solar module is the term given to a collection of cells that have been electrically interconnected and then encapsulated. Figure 9(b) shows a state-of-the-art 3S laminator donated to SIRF for module fabrication taking place at UNSW.



(a)



(b)

Figure 9 : (a) is an environmental test chamber while (b) is a laminator by 3S for encapsulating cells into a module.