4th Year Projects – The AC/DC Research Group

About the AC/DC Research Group

- **8-12** PhD students
- **9-11** Post-doc Researchers
- **3-5** Honour students
- **International group**: Australia, China, France, India, Iran, Israel, Jordan, Nigeria, Pakistan, Philippines, Taiwan, and Vietnam
- Six graduated students in leading PV companies; three have stayed as Research Fellows
- (Exchange students)
- Check our video: https://www.youtube.com/watch?v=1sWR2y-fTo8

Main Research Topics

- Development of characterisation tools and methods (for silicon and non-silicon devices)
- Development of machine learning applications for photovoltaics
- Investigation of defects in silicon wafers
- Development of PECVD-based passivating contacts
- Applications (agriPV, BV, BIPV, IoT, LCA)

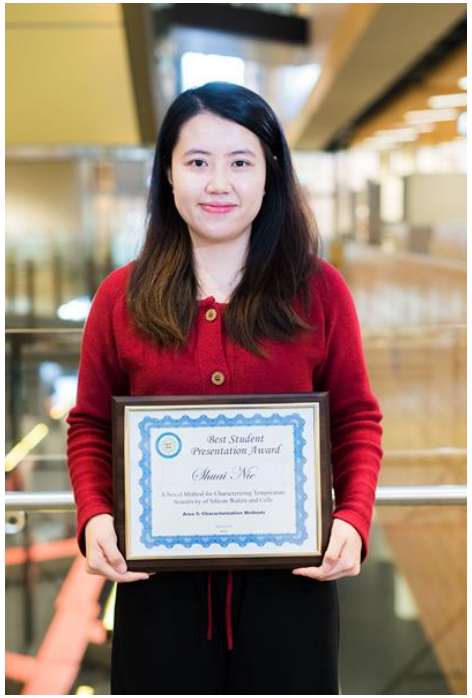
Main Collaborators:

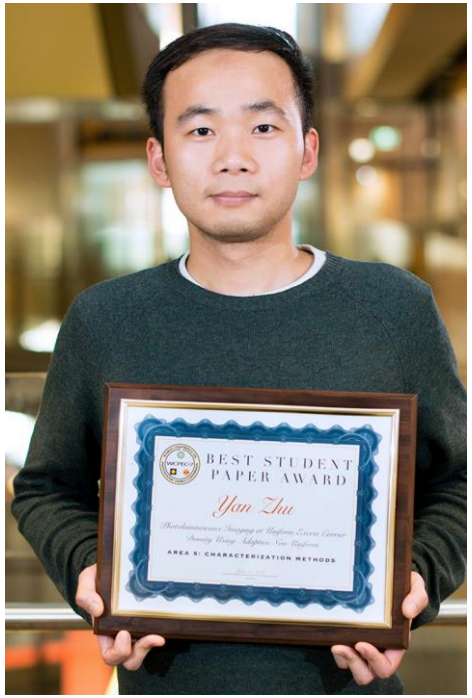
Aalborg University, Aalto University, Arizona State University (ASU), Australian National University (ANU), Beijing University of Technology, Dalarna University, Ecole Polytechnique Federale De Lausanne (EPFL), Fraunhofer ISE, Karlsruher Institut fur Technologie (KIT), King Abdullah University of Science and Technology (KAUST), Macquarie University, Madrid Universidad Politechnica, Massachusetts Institute of Technology (MIT), National Renewable Energy Laboratory (NREL), National University of Singapore (NUS), Norwegian University of Life Sciences (NMBU), University of Agder, University of Manchester, University of Melbourne, University of Milano-Bicocca, University of Oxford, University of Sydney, University of Technology Sydney (UTS), University of Warwick, University of Wollongong

BT Imaging, Canadian Solar, Jinko Solar, PV Lighthouse, PV Industries, Semilab, Sinton Instruments, Griddler Solar, Meyer Burger, Oxford PV, Sunrise/SAS

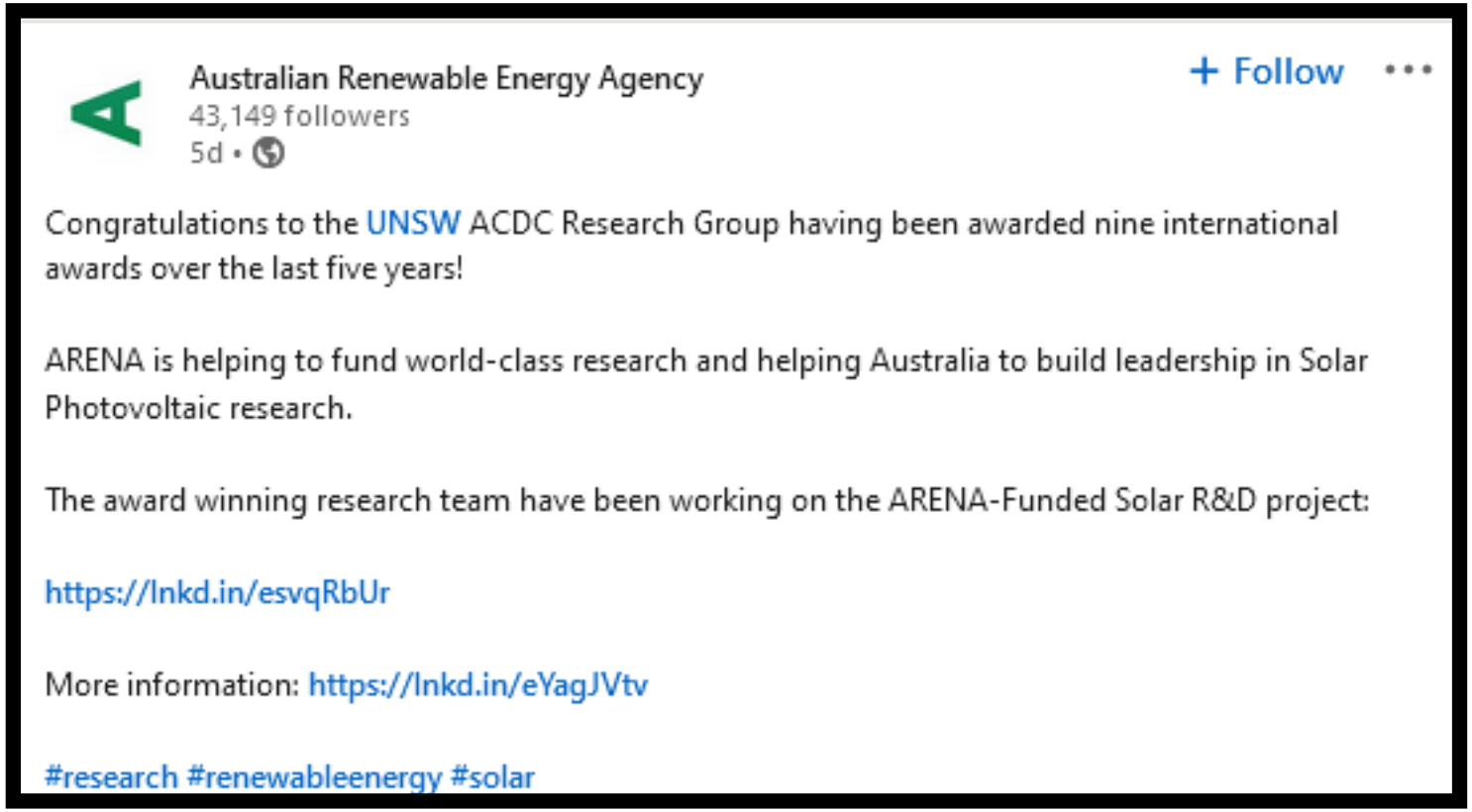
Awards

- **2018 Best Poster Award (Area 5)**
- **2018 Best Student Award (Area 5)**
- **2019 Best Student Award (Area 5)**
- **2020 Best Student Award (Area 5)**
- **2020 Best Student Award (Area 4)**
- **2021 Best Student Award (Area 5)**
- **2021 Best Paper Award (APSRC)**
- **2022 Best Poster Award (Areas 8)**
- **2022 Best Student Award (Eu-PVSEC)**





Awards



Australian Renewable Energy Agency
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Congratulations to the UNSW ACDC Research Group having been awarded nine international awards over the last five years!

ARENA is helping to fund world-class research and helping Australia to build leadership in Solar Photovoltaic research.

The award winning research team have been working on the ARENA-Funded Solar R&D project:

https://lnkd.in/esvqRbUr

More information: https://lnkd.in/eYagJVtv

#research #renewableenergy #solar

4th Year Students

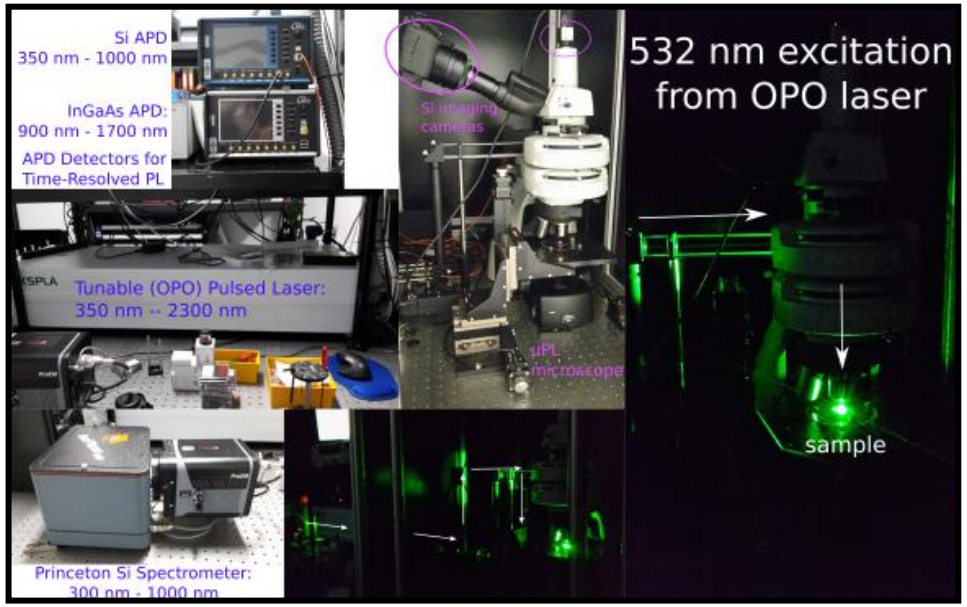
Best 4th Year Thesis Awards:

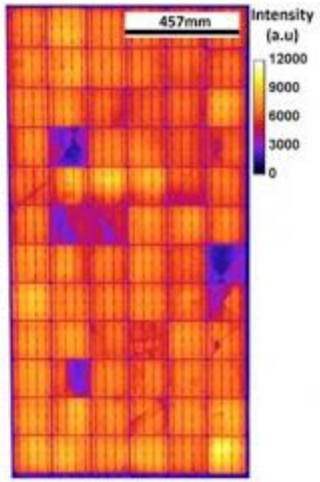
- 2018 Simon Zhang (SPREE)
- 2019 Victor Siu (EE)
- 2019 Alex Gu (SPREE)
- 2020 Zubair Abdullah-Vetter (SPREE)

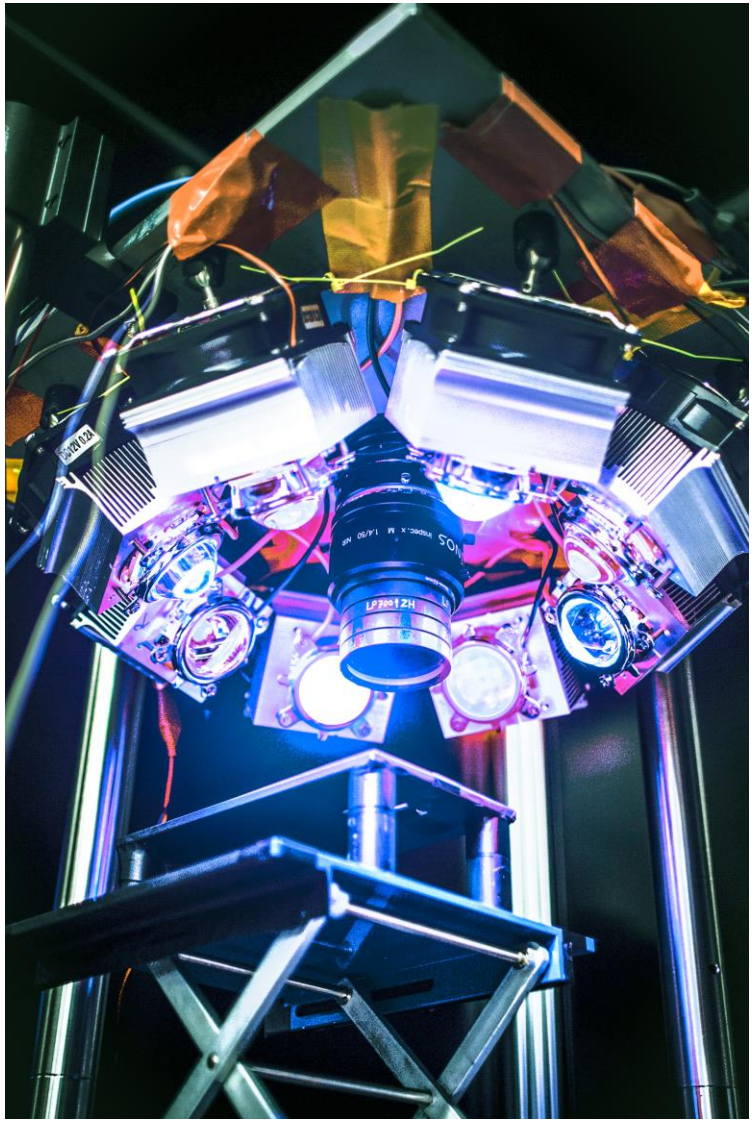
In the last five years, students who did their theses with us have published more than five journal papers and more than ten conference papers. They also travelled to the USA and Japan. One of them was nominated for the Best Student Award in the IEEE PVSC!

We make sure you get the best possible supervision. We also make sure you ENJOY the project

Characterisation







Characterisation

- Light emission resulting from external excitation, without corresponding increase in temperature
- **Photoluminescence** (PL):
  Luminescence due to the absorption of photons
- **Electroluminescence** (EL):
  Luminescence due to applied forward bias (i.e. operate the solar cell in reverse)
- In semiconductor luminescence emission is associated with radiative recombination
- PL imaging for photovoltaic (PV) applications was developed at UNSW!

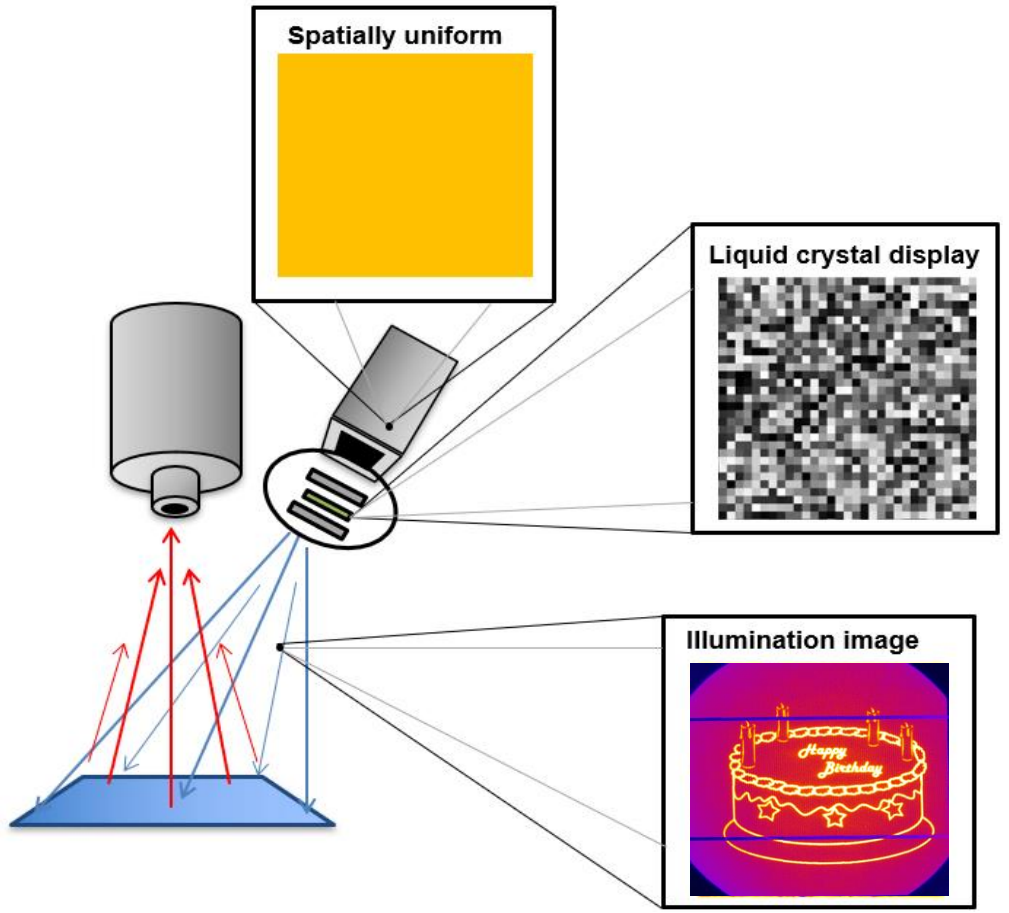
PL imaging with non-uniform illumination

- All the PL systems in the world use uniform illumination
- Can we do something better with non-uniform illumination? Yes, we can!

<u>Project aims</u>:

- To develop a novel system based on non-uniform illumination
- To develop a temperature-dependent PL imaging system with non-uniform generation
- To develop methods to map defects parameters in silicon wafers

This project has won the **Best Student Award** in an international conference!



PL imaging at elevated temperatures

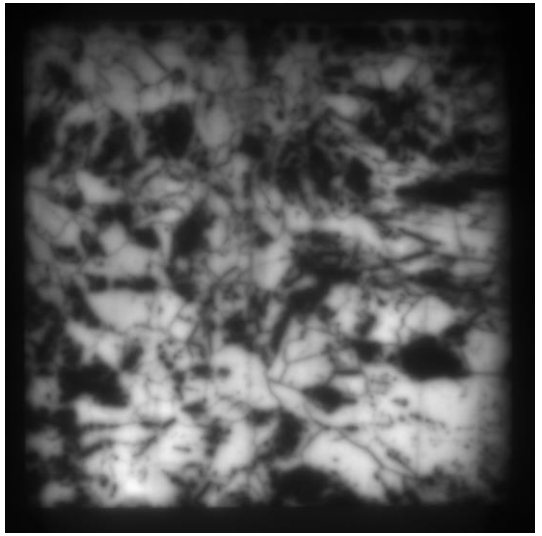
- The **same** wafer at **different** measurement temperatures
- What can we learn from the difference?

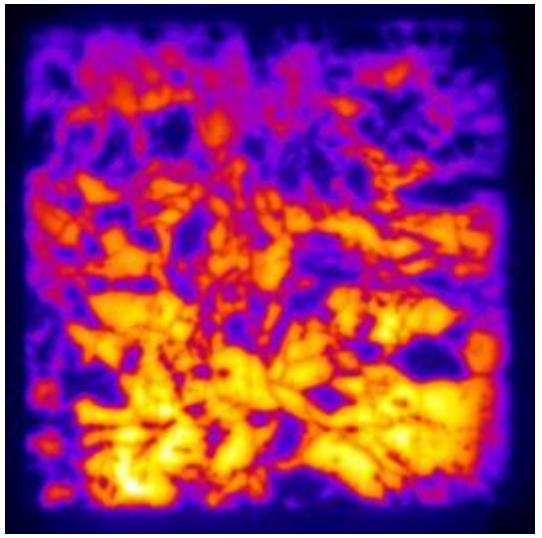
<u>Project aims</u>:

- To develop a PL imaging technique at elevated temperatures
- To develop various applications for this measurement method

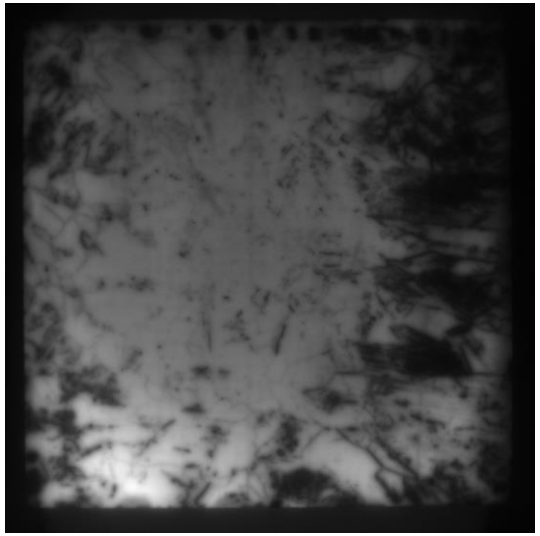
This project has won the **Best Student Award** in an international conference!

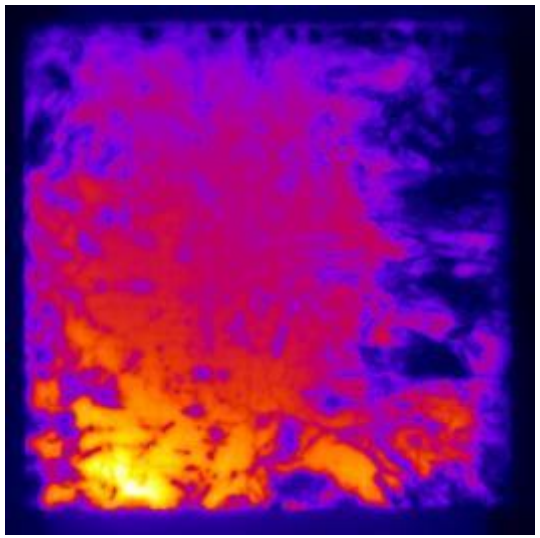
Room temperature:





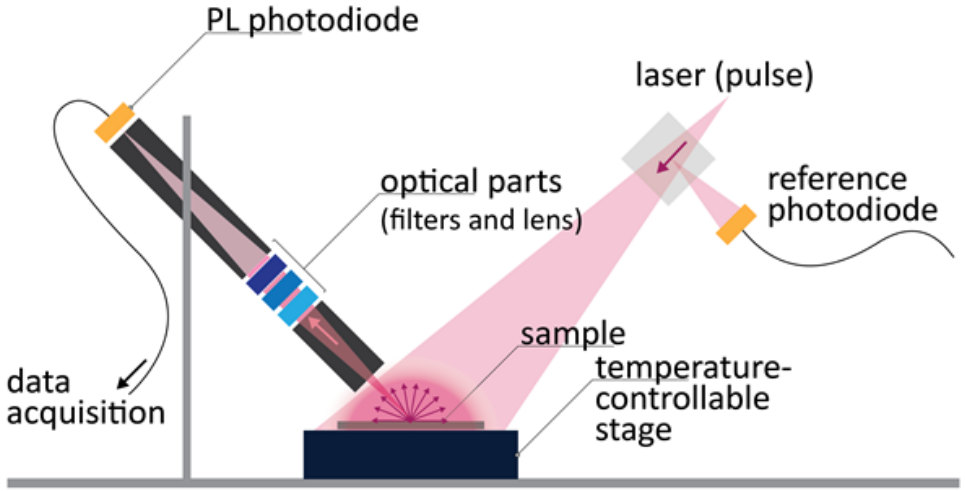
Elevated temperature:





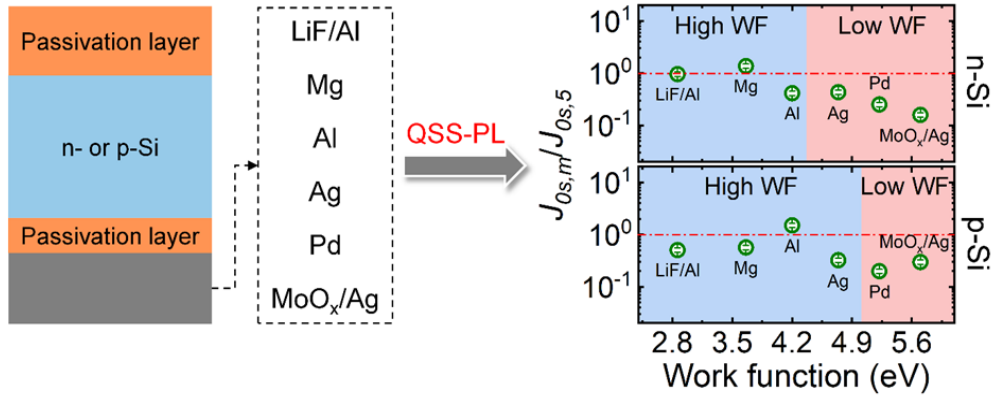
Quasi-steady-state PL (QSSPL) technique

- Challenge: Recombination at fully metallised contact is not easily measured with conventional lifetime measurement methods
- How does the contact's work function influence the recombination at the interface after metallisation?



Project aims:

- To develop the QSSPL technique to extract effective lifetime from metallised structures
- To evaluate the influence of metal work function on the recombination within a passivating contact

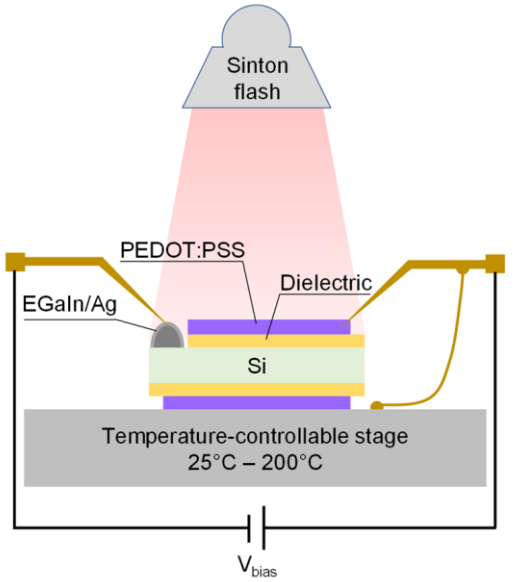


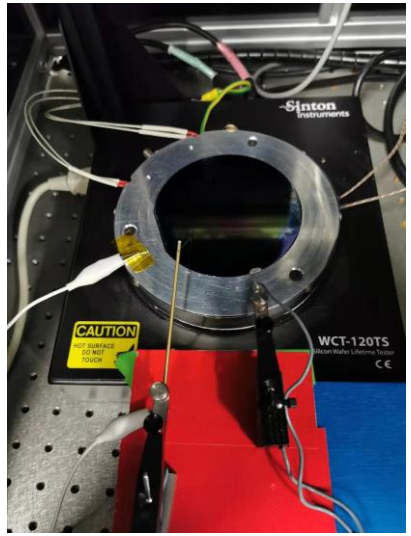
Surface passivation at elevated temperatures

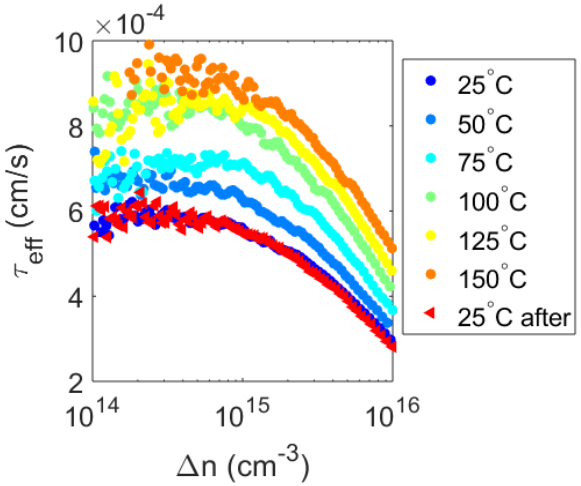
- Solar cells often operate at high temperatures
- However, they are usually only measured at 25 °C
- How does the surface passivation behave in real-life outdoor conditions?

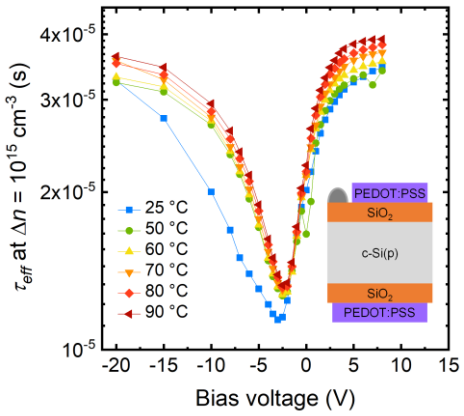
<u>Project aims</u>:

- To develop techniques to evaluate the quality of the surface passivation at elevated temperatures
- To assess the quality of various surface passivation materials in real-life conditions







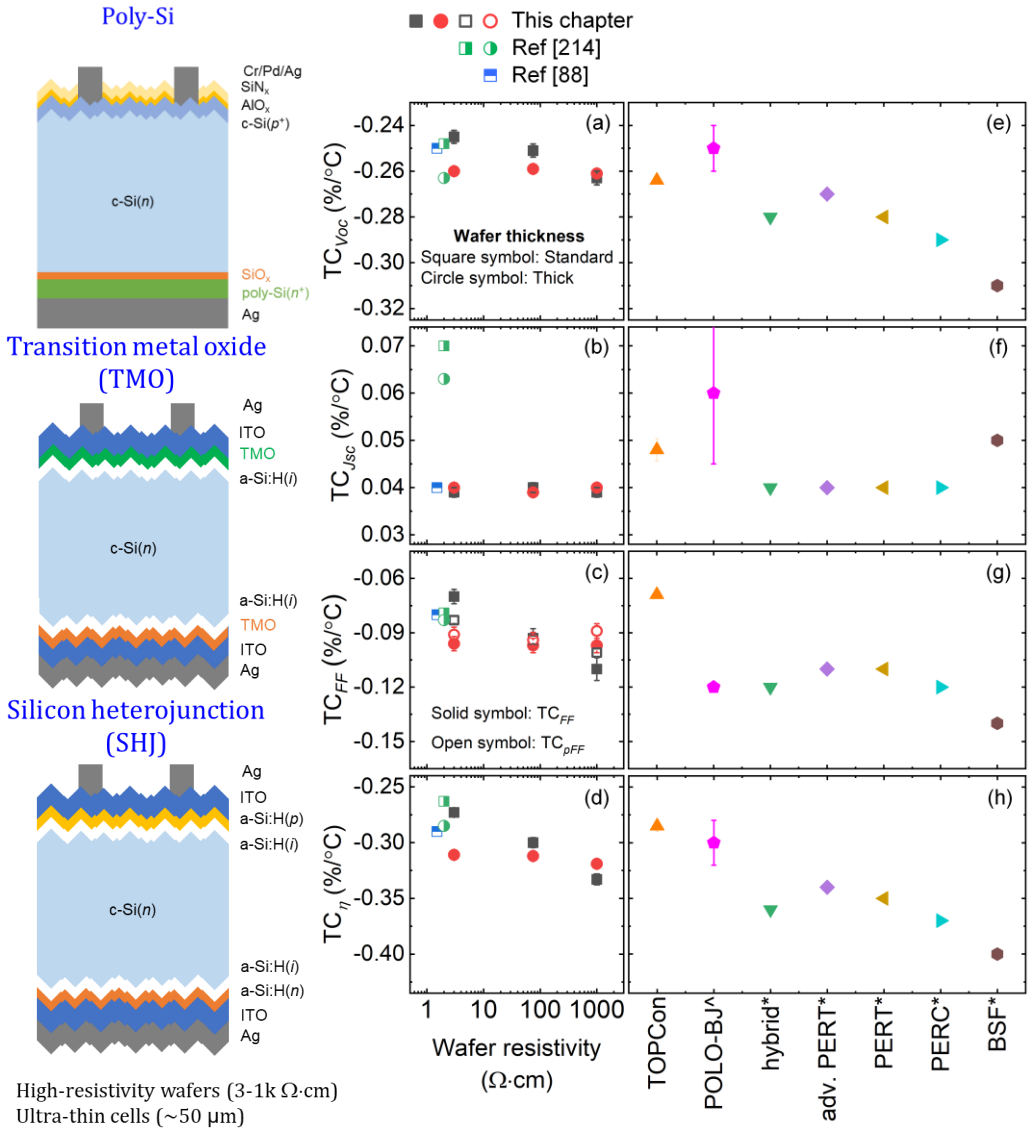


Temperature- and illumination-dependent cell performance

- How do modern solar cells with passivating contacts behave in real-life outdoor conditions?
- What are the correlations between the performance of these cells and their passivating contacts under such conditions?

Project aims:

- To investigate the temperature- and illumination-dependent performance of modern solar cells with passivating contacts
- To quantify temperature coefficients (TCs) of these cells



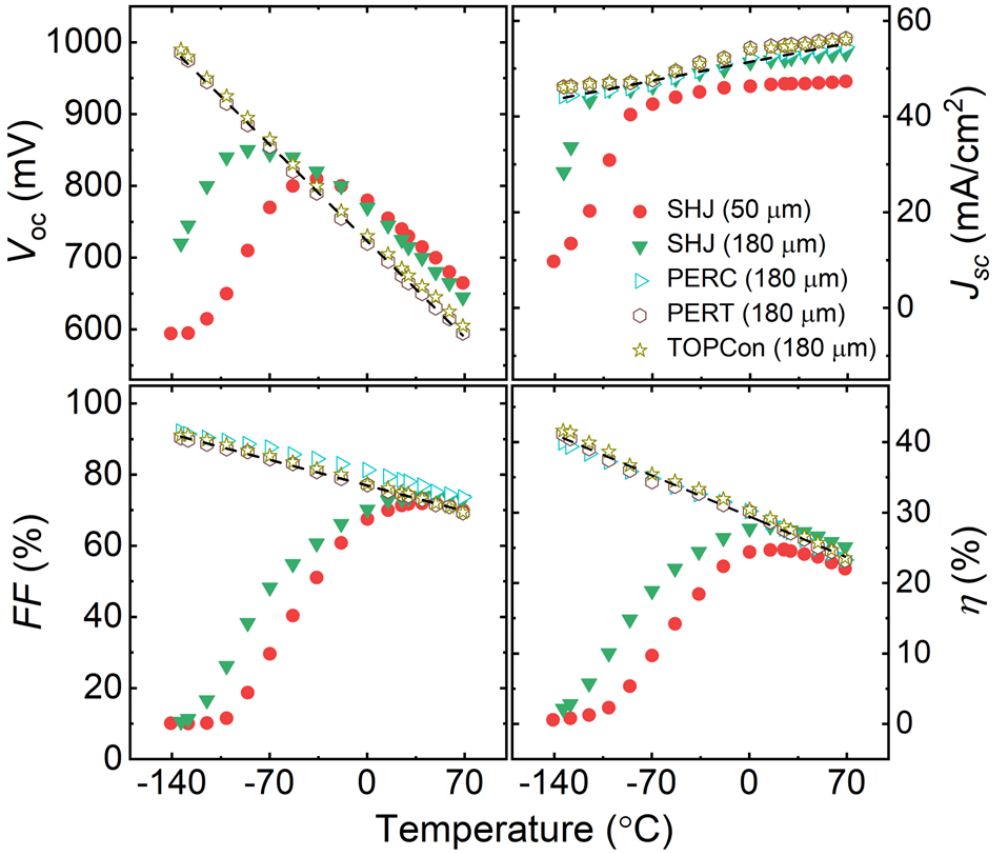
- High-resistivity wafers (3-1k Ω·cm)
- Ultra-thin cells (~50 μm)

Ultra-thin (50 µm) cells for space applications

- Ultra-thin solar cells can reduce the detrimental impact of radiation damage
- How do these cells behave in space-related conditions, i.e., in a wide range of temperatures under the air mass 0 (AM0) spectrum?

Project aims:

- To investigate the temperature- and dependent performance of ultra-thin silicon heterojunction cells in a wide range of temperatures under the AM0 spectrum
- Compare its behaviour to other cell structures
- Establish models to explain the temperature-dependent behaviour



Develop PL-based methods for perovskite and tandems

Project aims:

- To develop a method to map the series resistance of perovskite solar cells
- To develop other PL-based characterisation methods for perovskite solar cells

We have published the first ever PL and EL images of perovskite solar cells

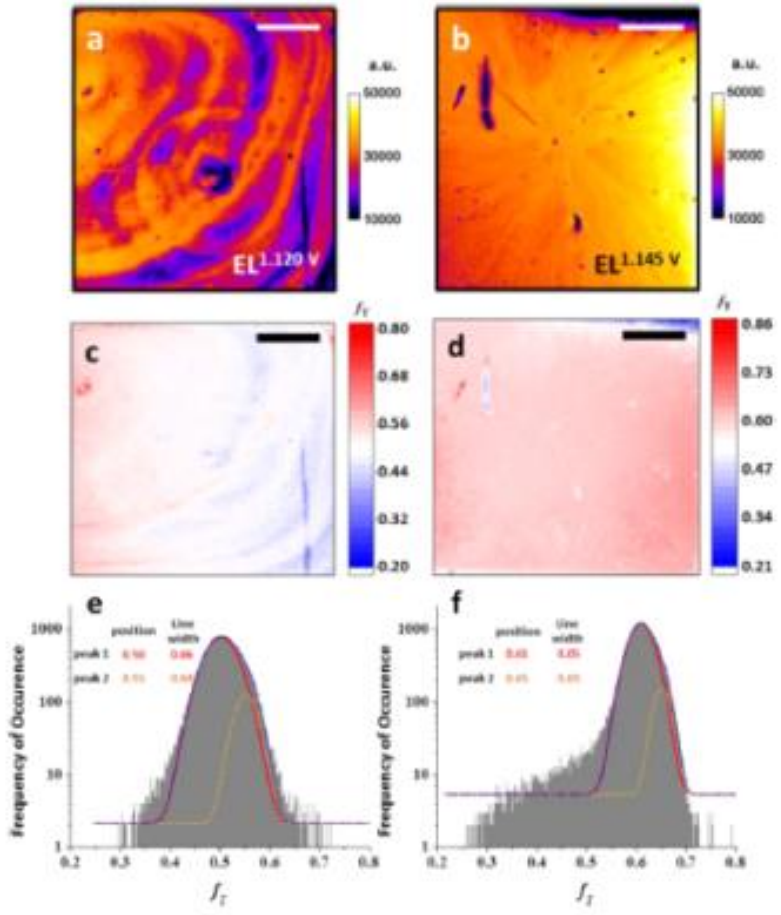
Progress in PHOTOVOLTAICS

PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS
Prog. Photovolt: Res. Appl. 2015; **23**:1697–1705
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/pip.2716

ACCELERATED PUBLICATION

Photoluminescence and electroluminescence imaging of perovskite solar cells

Ziv Hameiri[1]*, Arman Mahboubi Soufiani[1], Mattias K. Juhl[1], Liangcong Jiang[2], Fuzhi Huang[2], Yi-Bing Cheng[2], Henner Kampwerth[1], Juergen W. Weber[3], Martin A. Green[1] and Thorsten Trupke[1]

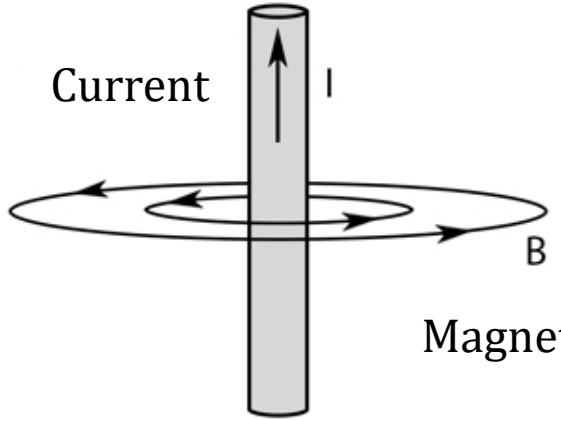


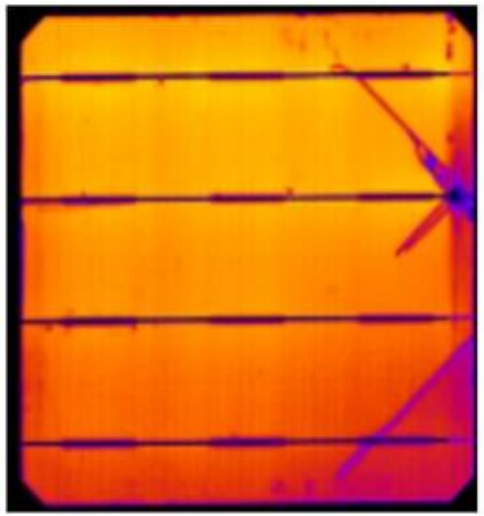
Outdoor performance of perovskite/tandem modules

- Perovskite and perovskite/silicon tandem solar cells have seen tremendous improvement in efficiency in the last decades. There is great interest in commercialising these technologies
- However, their outdoor performance has not been fully studied
- The spectrum, temperature, and humidity in an outdoor environment are different from the standard test condition
- This project aims to study the performance of these emerging solar cells under Australian outdoor conditions

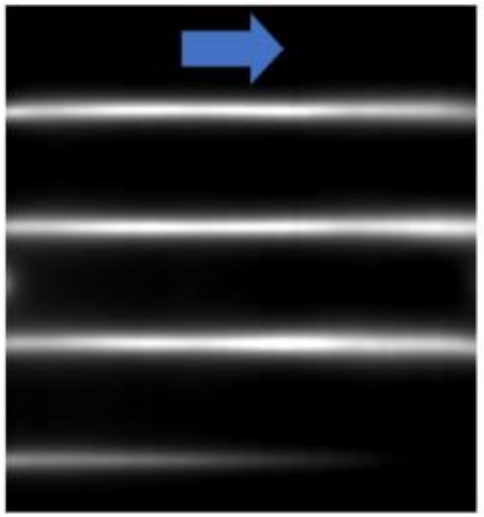
Magnetic field imaging of solar cells

- Luminescence imaging is perfect for studying the voltage distributions in solar cells
- The current flow is also important. How can we investigate that?
- We can use magnetic field imaging! Think about Ampere's law!
- This project aims to:
  - Investigate the novel method of magnetic field imaging
  - Combine magnetic field imaging and luminescence imaging to get a full picture of solar cells





Luminescence imaging



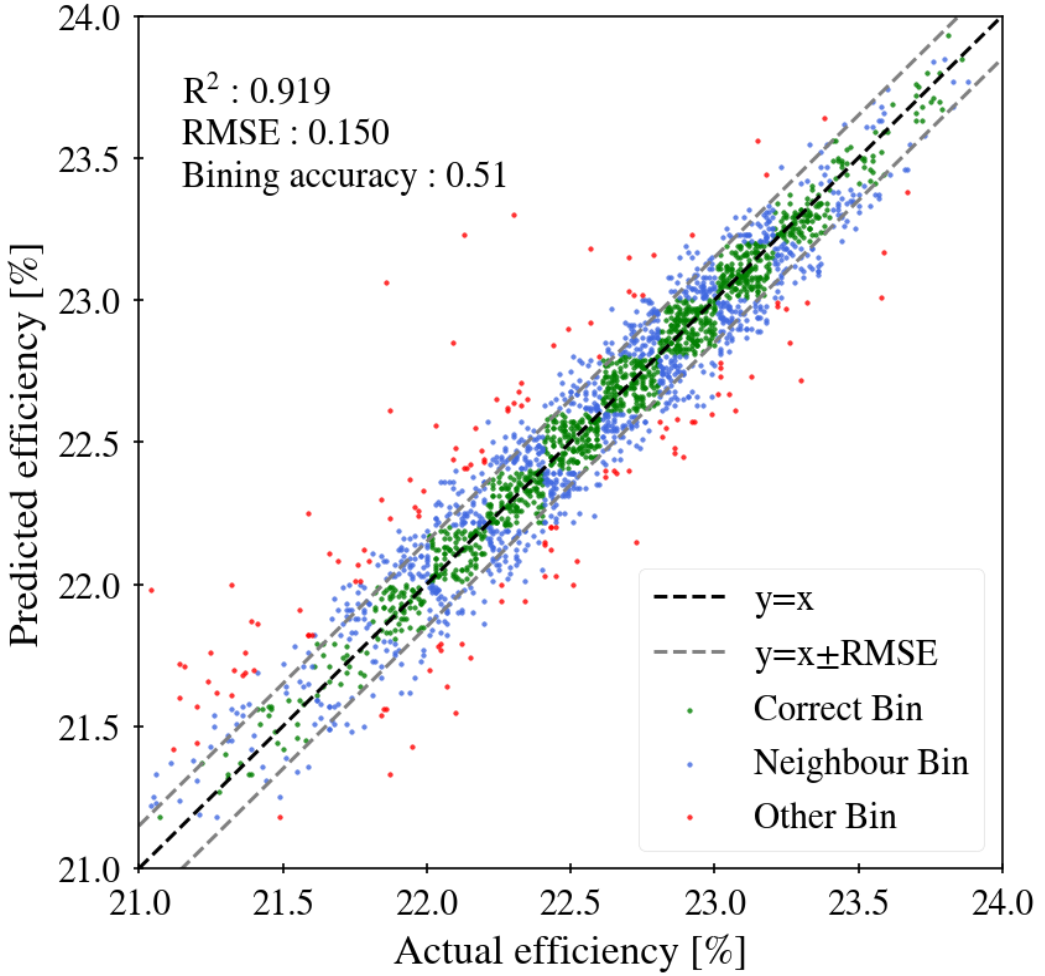
Magnetic field imaging

Machine Learning

Prediction of electrical parameters based on PL images

Aim:
Replacing current-voltage (I-V) measurements in solar cell production lines using machine learning analysis to predict the electrical parameters from EL and PL images and classify defects by type

Approach:
Train convolutional neural networks (CNN) using manufacturing dataset



Prediction of research directions

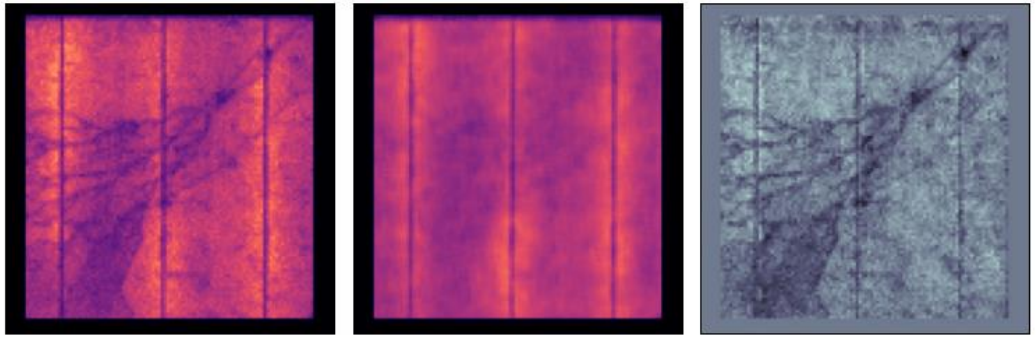
More than 3,000 PV-related scientific papers are published every month. **Can we use this data to predict the next 'big thing' in PV?**

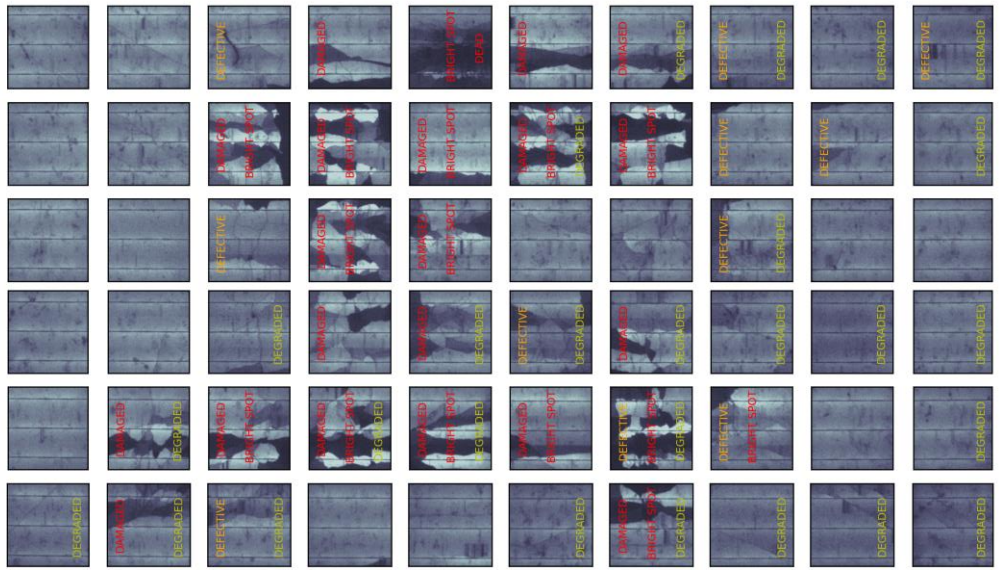
<u>Project aim</u>:
Develop methods to predict technologies that are likely to gain success based on deep learning

This is a joined project with the school of Computer Science Engineering

Identify Defects using Luminescence Images and Machine Learning

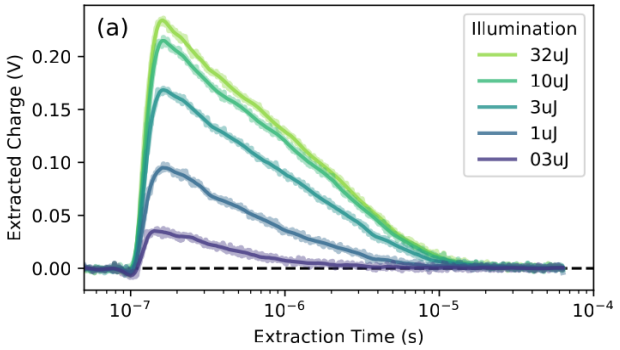
- **This project** will use machine learning to identify and classify defects in luminescence images of cells and modules
- This **will enable** a robust, scalable, and automated methodology to monitor and accurately identify defective modules, such that they can be replaced, and either re-used, repaired, or recycled
- **Deliverables**: prepared training datasets (cell luminescence images); performance validation (statistical assessment) and visual examples of model output (generated solar cell luminescence images) for each configuration of learning model; analysis of the influence of varying training dataset, model architecture, and learning methodology

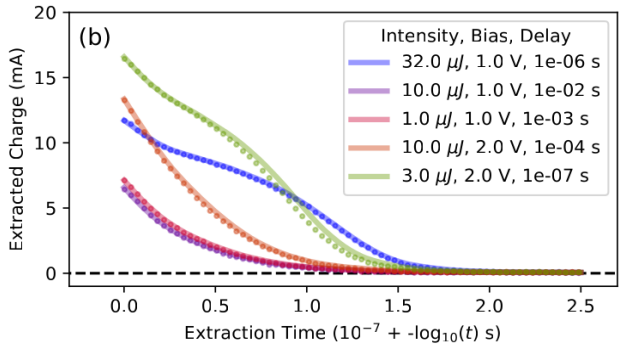


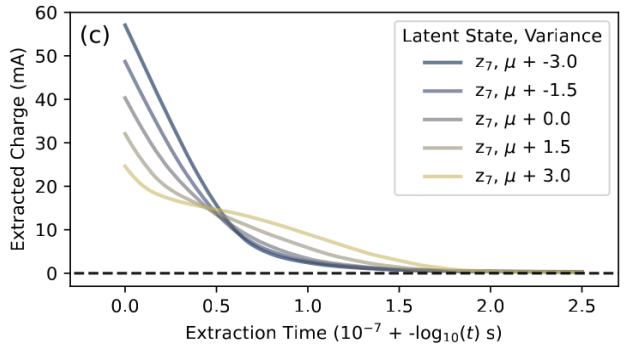


Model the Dynamics of Charge Carriers in Solar Cells using Machine Learning

- **This project** will use machine learning to model the transient charge extraction measurement, thereby enabling an improved understanding of the dynamics of charge carriers (transport, recombination) in operational solar cells, and provide a predictive model to classify behaviour and investigate underlying causal relationships. This **will enable** the characterisation and analysis of, as well as development of new design rules for, novel photovoltaic material systems and device architectures
- Through this research project **you will gain** an understanding of the physics of charge carrier solar cells, from light absorption to current extraction, and how these processes are influenced by material type and device architecture, as well as develop valuable skills regarding time-series data analysis and the development and training of machine learning models



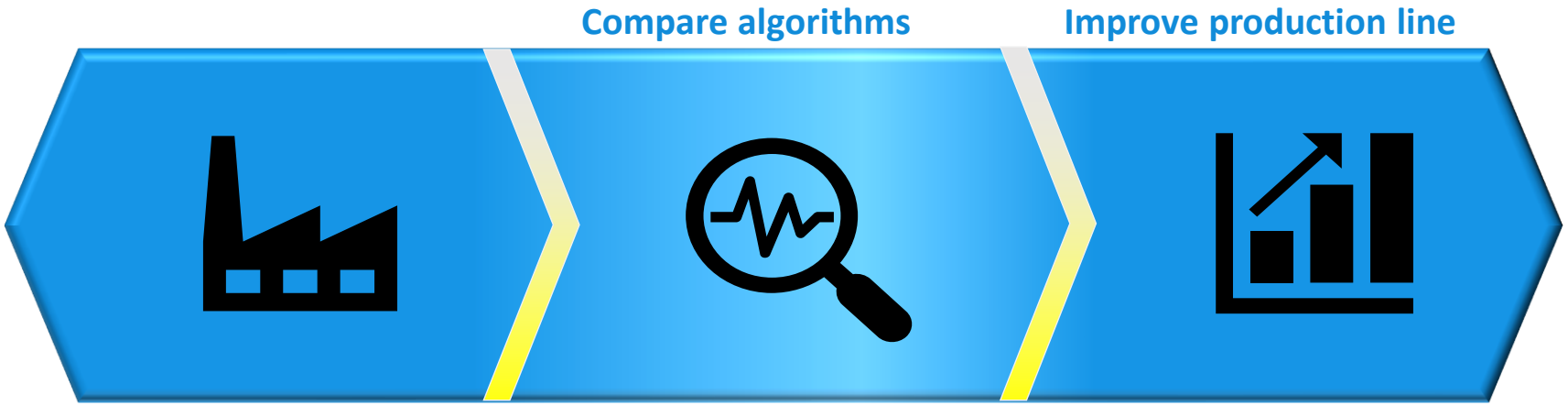


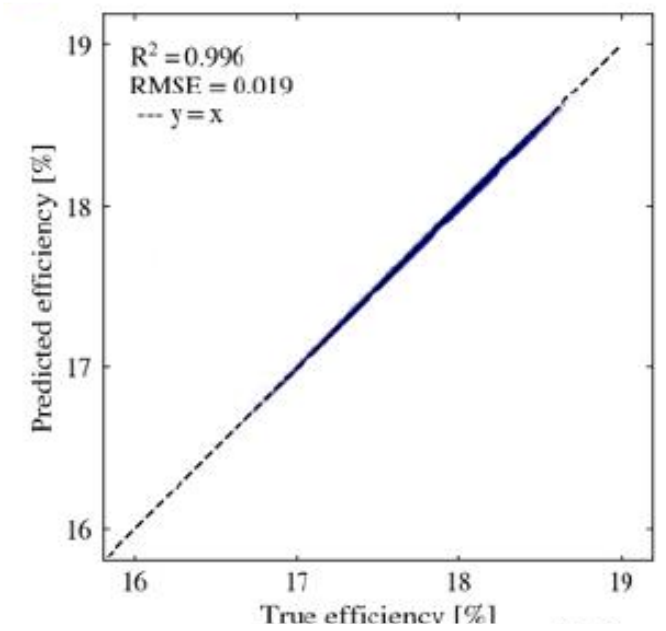


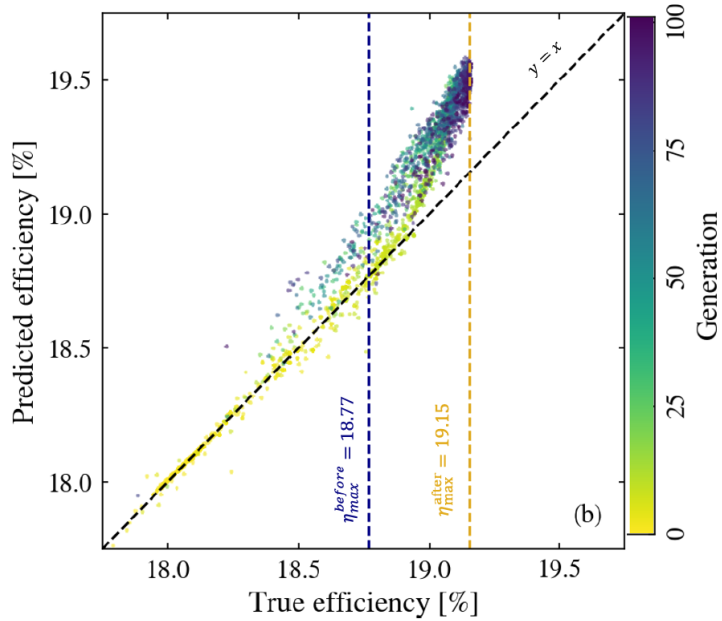
Optimisation of solar cell manufacturing

Can machine learning teach us how to make better solar cells?

<u>Project aim</u>:
Develop machine learning algorithms to predict solar cell production line efficiency
Optimize solar cell production lines (increase efficiency!) based on machine learning algorithms







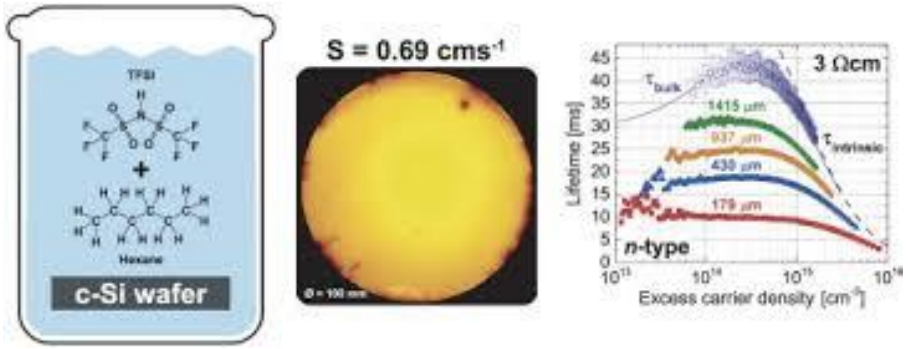
Fabrication

Room-temperature high-quality surface passivation

High surface passivation is a key requirement for investigation of bulk defects in silicon wafers and solar cells

In recent years, a few passivation methods have been developed. However, there are safety concerns with most of them

Can we develop a simple and safe passivation method that does not require high temperatures?



https://doi.org/10.1016/j.solmat.2018.03.028

Project aim:

Develop solution-based high quality surface passivation methods for silicon wafers and solar cells

Beta-voltaic (BV) batteries

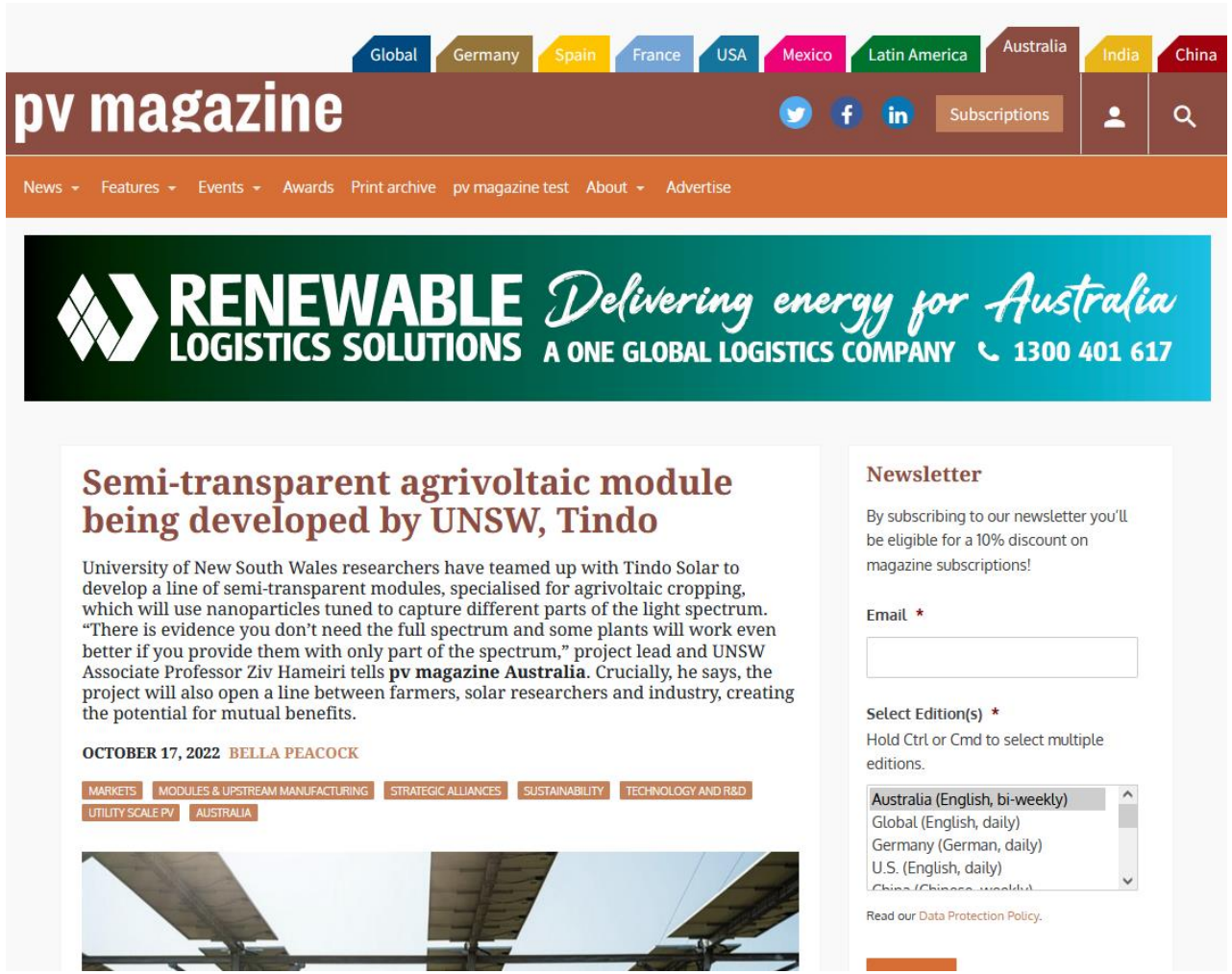
Wikipedia: Betavoltaic (BV) devices, are generators of electric current, which use energy from a radioactive source emitting beta particles (electrons)

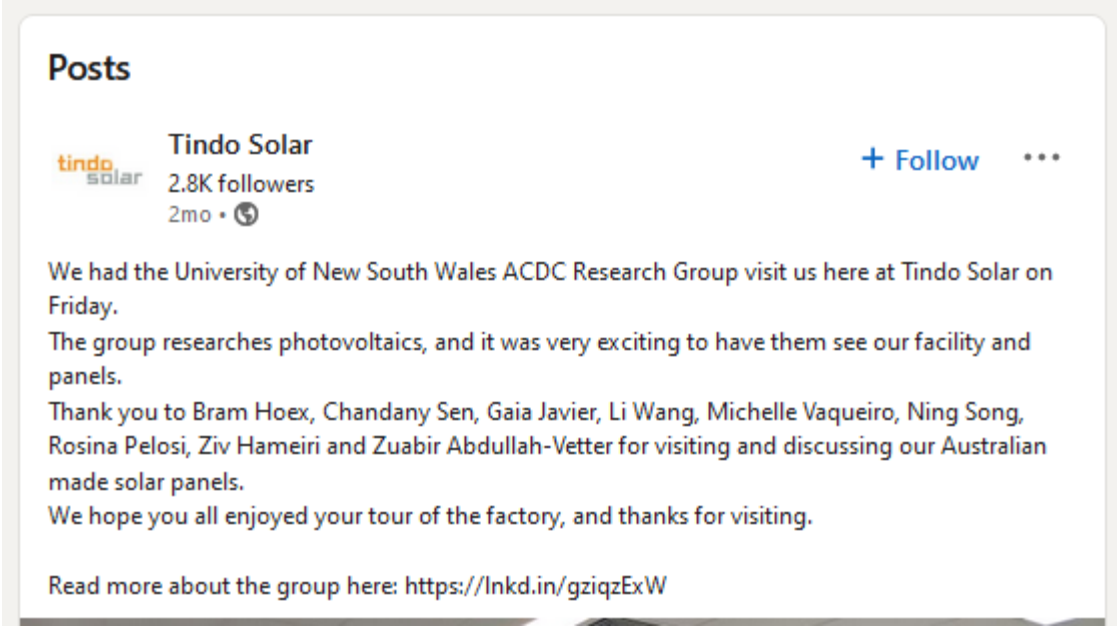
<u>Project aim</u>:
At the present stage of research, work is based around developing computational models of radiation transport and of the device characteristics, and validating these based on experimental trials

You will join an existing interdisciplinary team between SPREE, the UNSW nuclear engineering group, and ACSER in the School of Electrical Engineering

More

AgriPV (agriculture and photovoltaic)





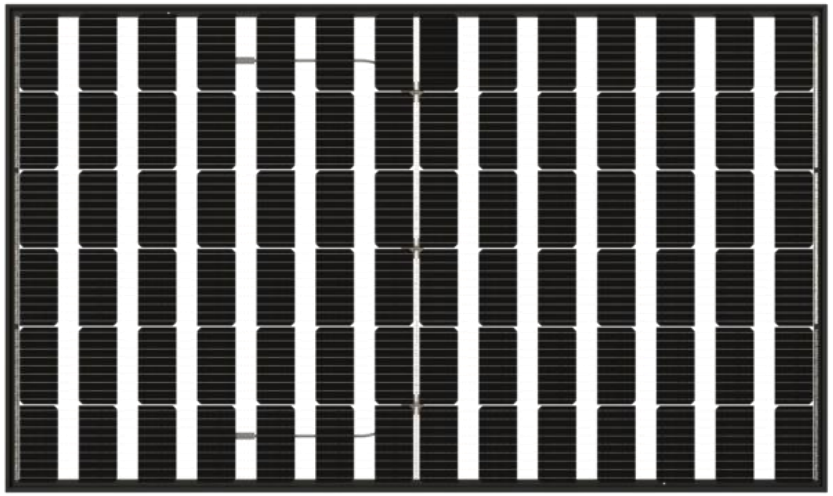
AgriPV (agriculture and photovoltaic)

AgriPV can be an efficient method to use our lands.
Can we use this method in Australia?

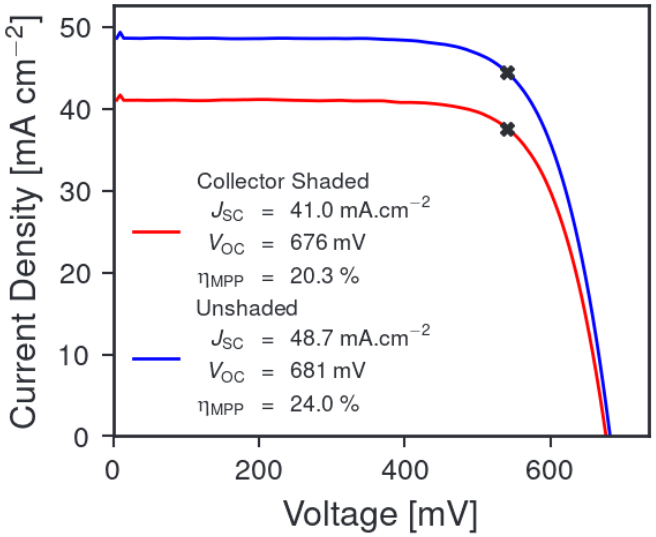
Main benefits:

- Double use of the land
- Second income for the farmer
- Reduction of:
  - Water use
  - Frost damage
  - Wind damage
  - Hail damage
- Better control of:
  - Soil temperature and humidity
  - Weed
- Higher electrical power output (cooler modules)

AgriPV (agriculture and photovoltaic)

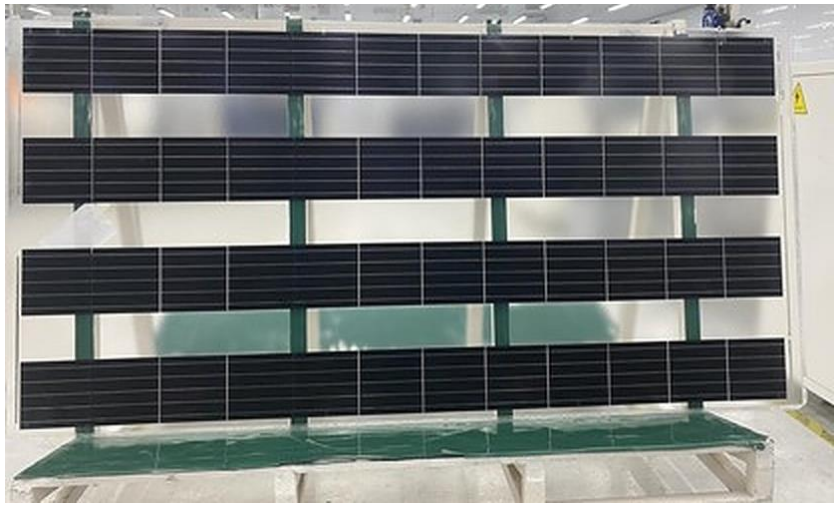


Bisol (Slovenia): 260 and 300 W. Front efficiencies ranges from 13.5% to 14.0%



<u>Project aims</u>:

- To model the benefits of agriPV in Australia
- To design and build agriPV modules
- If you have land, let us try agriPV in your garden!



Irex (Vietnam) Glass-glass solar panel with a power output of 265 W and a power conversion efficiency of 18.1%

LCA (life-cycle assessment)

We make our PV modules so strong that they will last for at least 25 years. However, we do such a great job, that it is very hard to recycle them. Does it make sense?

Project aims:

- Investigate if a shorter module lifetime, but easier disassemble, is beneficial from the environmental and economical points of view
- Develop an LCA framework to support these discussions

If you have your own idea for a project, do not hesitate to contact us

Thank you!

AC DC
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