Faculty of Engineering
School of Photovoltaic and Renewable Energy Engineering

4^{th} Year Projects – Ziv Hameiri

Email: ziv.hameiri@unsw.edu.au

Join a friendly research group of eight PhD students and four researchers

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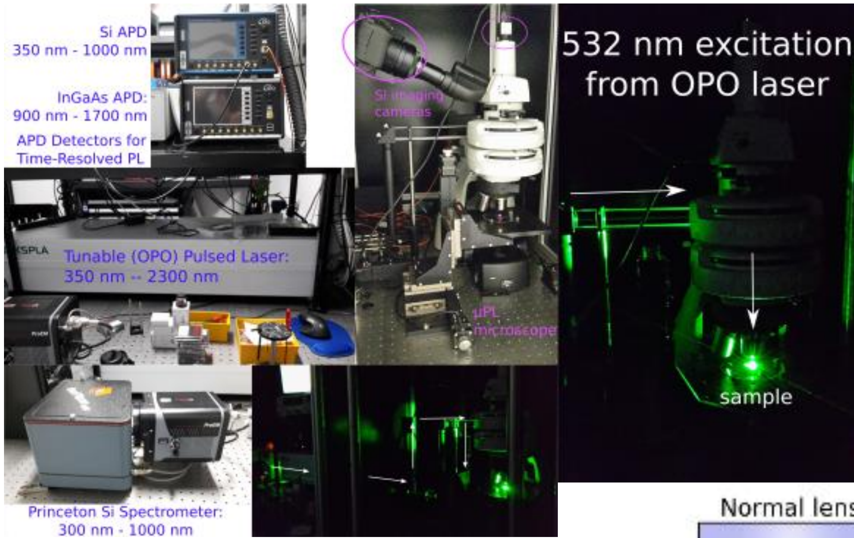
Our main research topics

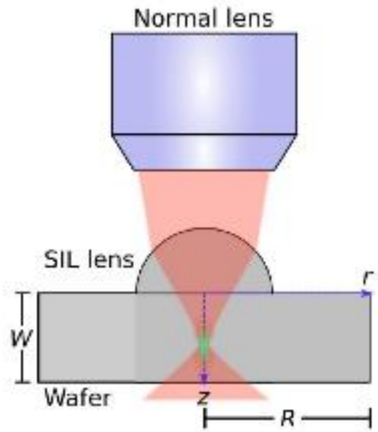
- Development of characterisation tools and methods (for silicon and non-silicon)
- Investigation of defects in silicon wafers
- Development of PECVD-based passivating contacts
- Development of machine learning applications for photovoltaics (PV)
- Development of high efficiency beta-voltaic (BV) batteries for space
- Applications of solar cells for Internet of Things and agriculture PV (AgriPV)

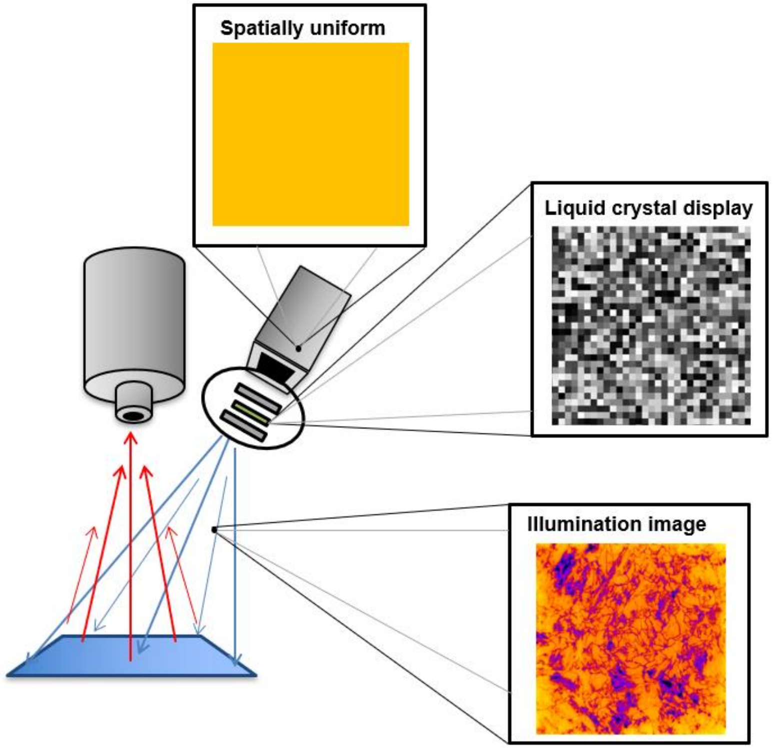
If you have your own idea for a project, do not hesitate to contact us – ziv.hameiri@unsw.edu.au

In the last five years, students who did their theses with us have published **seven conference papers** and **two journal papers**. Three of them have won the **Best Thesis Award** and two have won the **Best Taste of Research Award**. 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

Characterisation

PL imaging for photovoltaic (PV) applications was developed at UNSW:

APPLIED PHYSICS LETTERS **89**, 044107 (2006)

Photoluminescence imaging of silicon wafers

T. Trupke[a)] and R. A. Bardos
Centre of Excellence for Advanced Silicon Photovoltaics and Photonics, University of New South Wales, Sydney 2052, Australia

M. C. Schubert and W. Warta
Fraunhofer Institute for Solar Energy Systems, Heidenhofstrasse 2, D-79110 Freiburg, Germany

(Received 24 October 2005; accepted 4 June 2006; published online 26 July 2006)

The group at UNSW is one of the leading groups in this research area:

APPLIED PHYSICS LETTERS **93**, 202102 (2008)

Advanced luminescence based effective series resistance imaging of silicon solar cells

H. Kampwerth,[1,a)] T. Trupke,[2] J. W. Weber,[1] and Y. Augarten[1]
[1]*Centre of Excellence for Advanced Silicon Photovoltaics and Photonics, University of New South Wales, Sydney 2052, Australia*
[2]*BT Imaging Pty. Ltd., NSW, Sydney 2000, Australia*

JOURNAL OF APPLIED PHYSICS **109**, 083111 (2011)

Bulk minority carrier lifetimes and doping of silicon bricks from photoluminescence intensity ratios

Bernhard Mitchell,[1,a)] Thorsten Trupke,[1,2] Jürgen W. Weber,[2] and Jørgen Nyhus[3]
[1]*School of Photovoltaic and Renewable Energy Engineering, University of New South Wales, Sydney, NSW 2052, Australia*
[2]*BT Imaging, Surry Hills, NSW 2010, Australia*
[3]*REC Wafer, Norway AS, 3908 Porsgrunn, Norway*

Calculation of quantitative shunt values using photoluminescence imaging

Yael Augarten[1*], Thorsten Trupke[1], Martha Lenio[1], Jan Bauer[2], Juergen W. Weber[3], Matthias Juhl[1], Martin Kasemann[4] and Otwin Breitenstein[2]
[1] University of New South Wales, ARC Photovoltaics Centre of Excellence, Sydney, New South Wales, Australia
[2] Max Planck Institute of Microstructure Physics, Exp. Dep II, Halle, Germany
[3] BT Imaging, Sydney, New South Wales, Australia
[4] University of Freiburg, Freiburg, Germany

Spatially resolved photoluminescence imaging of essential silicon solar cell parameters and comparison with CELLO measurements

Chao Shen[a,*], Henner Kampwerth[a], Martin Green[a], Thorsten Trupke[a], Jürgen Carstensen[b], Andreas Schütt[b]
[a] *University of New South Wales, Sydney, NSW 2036, Australia*
[b] *Christian-Albrechts-Universität zu Kiel, Kaiserstrasse 2, Kiel 24143, Germany*

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Characterisation

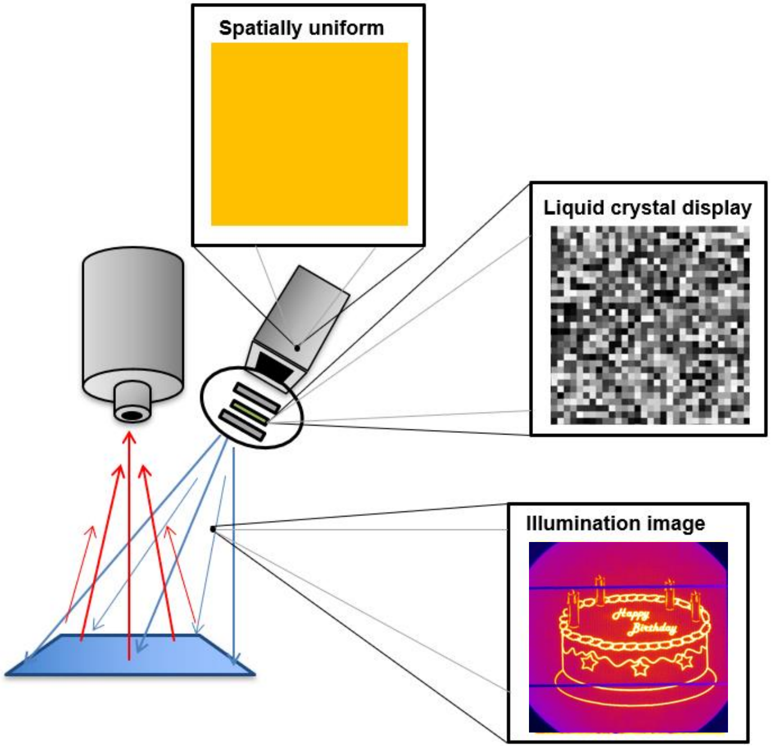
Join us to take PL to the future!

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!

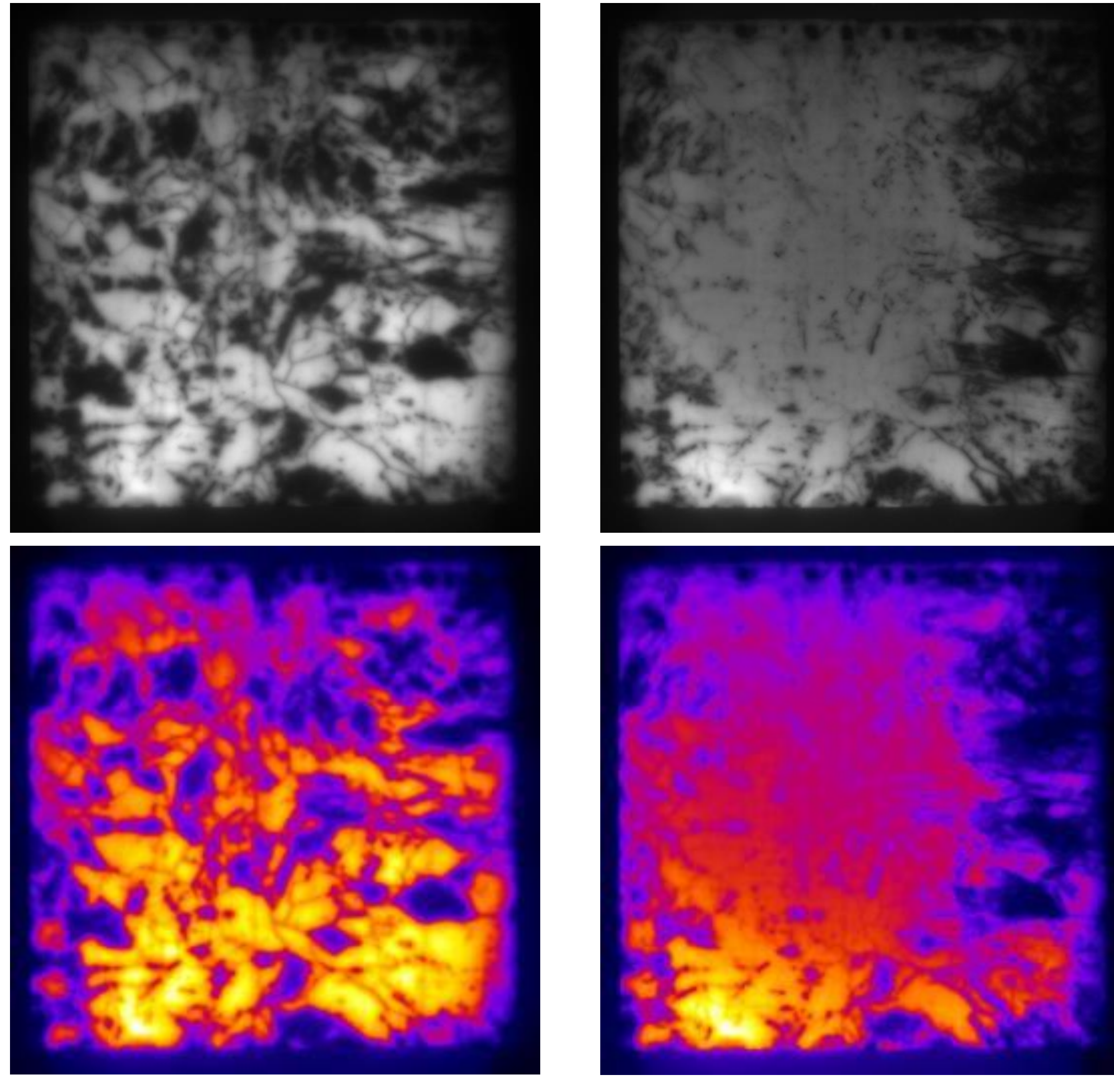
PL imaging at elevated temperatures

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

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

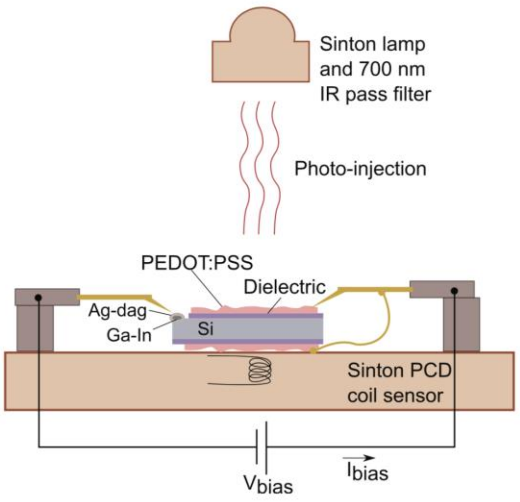
This project has won the **Best Student Award** in an international conference!

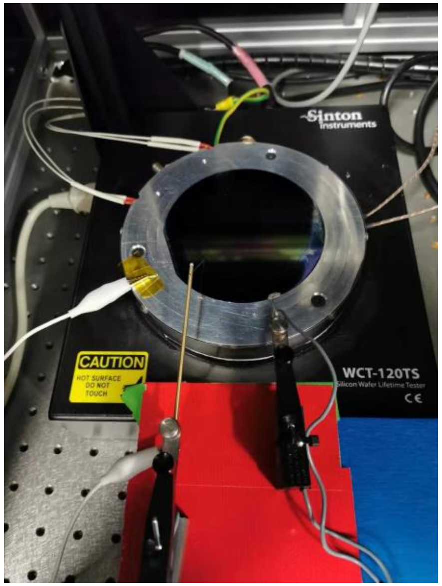
Room temperature: Elevated temperature:



Surface passivation at elevated temperatures

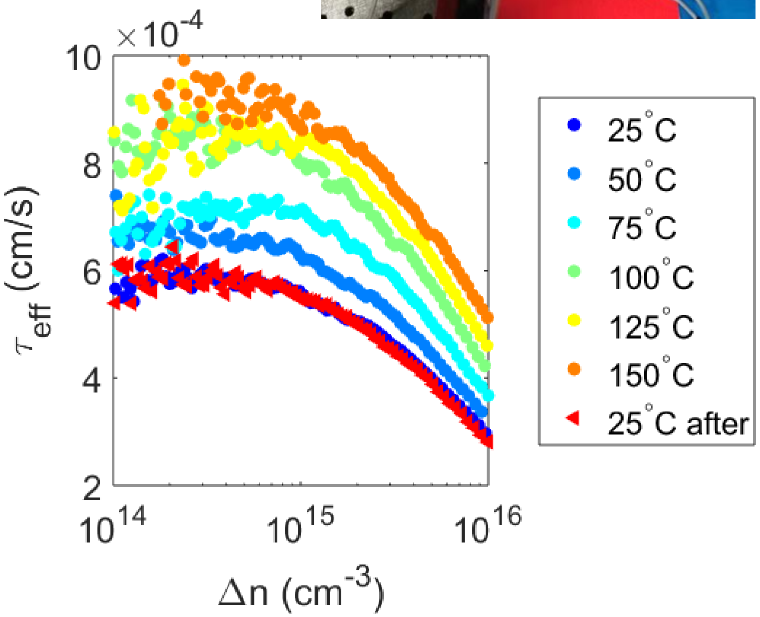
- Solar cells often operate at high temperatures
- However, they are usually only measured at 25 degC
- How the surface passivation behaves in real-life outdoor conditions?





<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



Surface passivation at elevated temperatures

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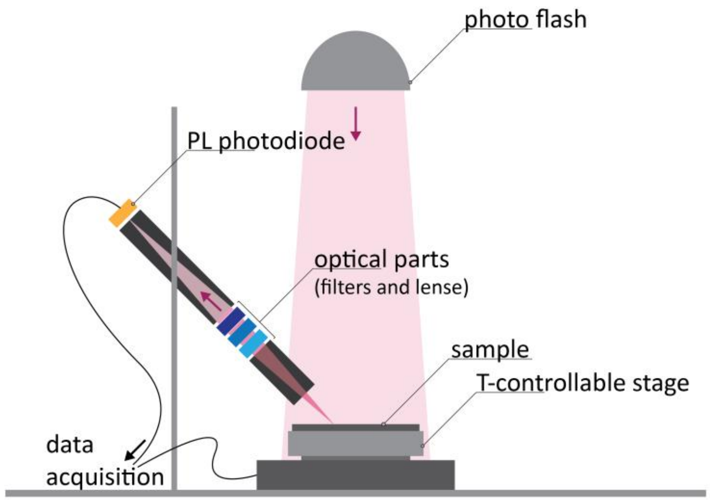
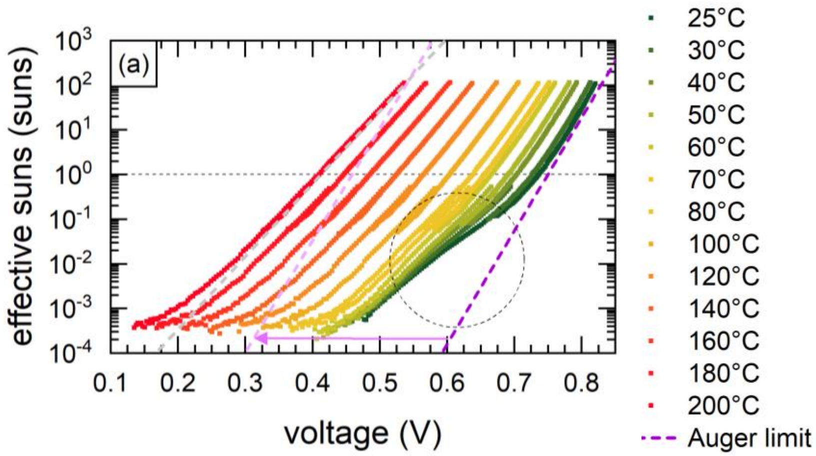


Project aims:

- To develop a new tool to characterise solar cells and their behaviour at elevated temperatures
- To develop analysis methods to support the new tool



Machine Learning

Prediction of electrical parameters based on PL images

Aim:

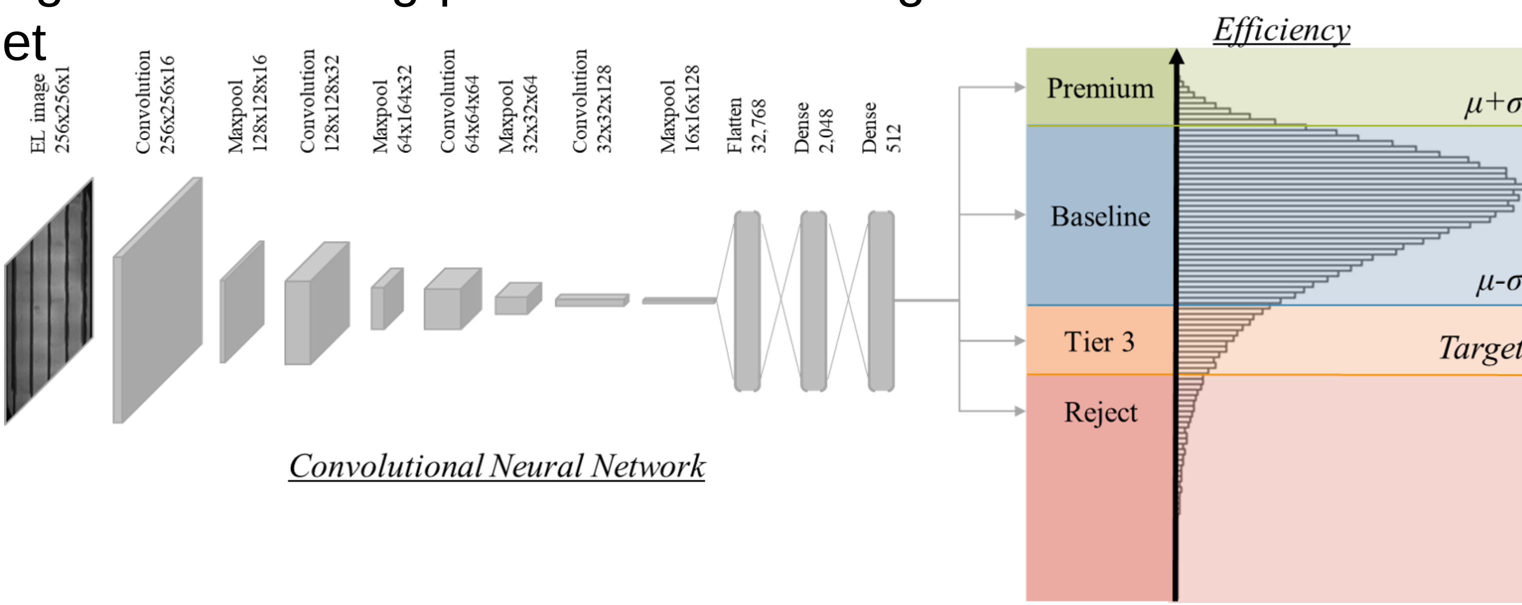
Replacing current-voltage (I-V) measurements in solar cell production lines using **machine learning** analysis to predict the electrical parameters from EL and PL images and classify defects by type

Approach: Train convolutional neural networks (CNN) using manufacturing partners' EL/IV image pair dataset

CNN prediction results

Predicted bin	Actual bin: Premium	Baseline	Tier 3	Reject
Premium	41	28	0	0
Baseline	105	5125	78	0
Tier 3	0	134	237	4
Reject	0	3	12	58

Accuracy **93.8%**



Prediction of research directions based on machine learning

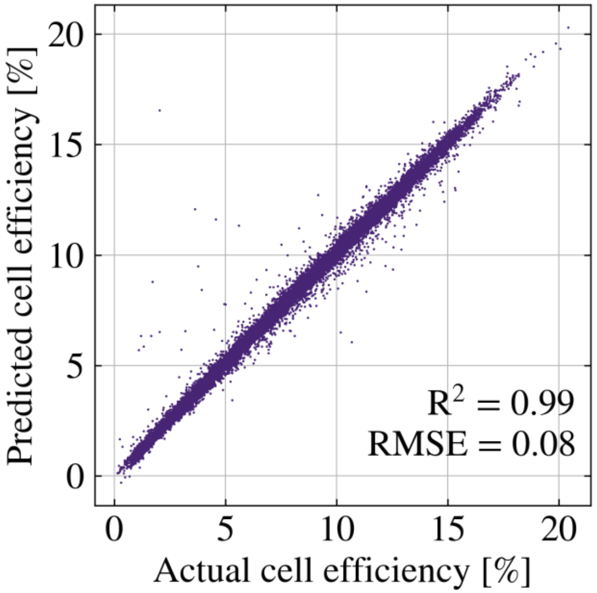
- More than 3,000 PV-related scientific papers are published every month
- Can we use this data to predict the next ‘big thing’ in PV?

Project aim:
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

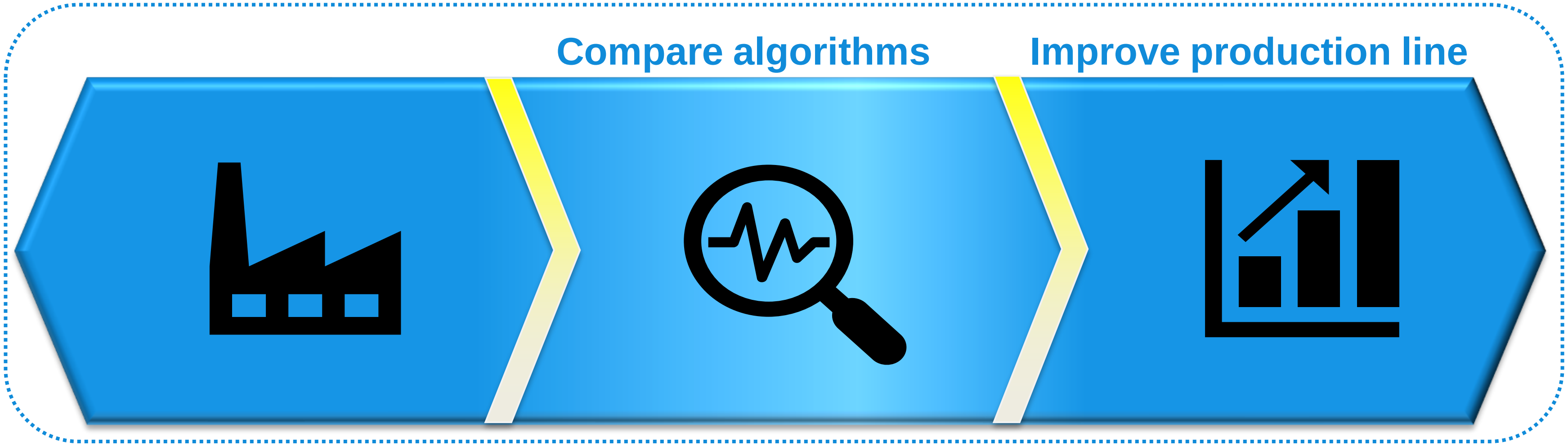
Optimisation of solar cell manufacturing using machine learning

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



<u>Project aims</u>:

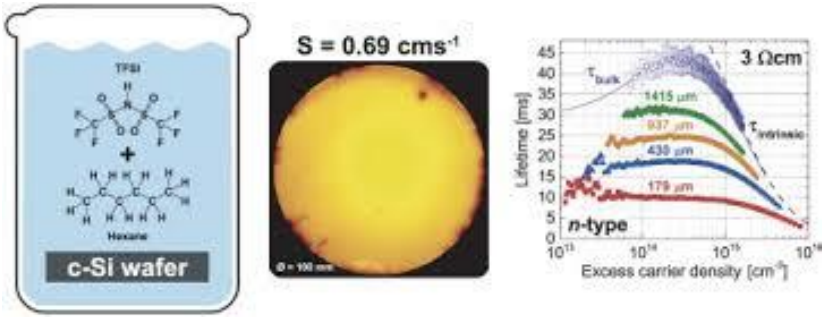
- Develop machine learning algorithms to predict solar cell production line efficiency
- Optimize solar cell production lines (increase efficiency!) based on machine learning algorithms



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

Photovoltaic powered internet of things

- Wikipedia: *The internet of things is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction*.
- Can we develop solar cells to power all these applications?

Kuva 1. Internet of Things. Lähde: Huffington Post

<ins>Project aim</ins>:

- Define the requirements from solar cells for this type of application
- Compare different solar cells technologies for this application
- Develop solar cells to power internet of things

Beta-voltaic (BV) batteries

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

One of the challenges of sending a small satellite towards Mars or beyond is to find a suitable power source. Travelling further away from the sun, the available power from solar energy reduces according to the inverse square law.
In this project, we are researching BV nuclear battery technology and aiming to build and test such a device.

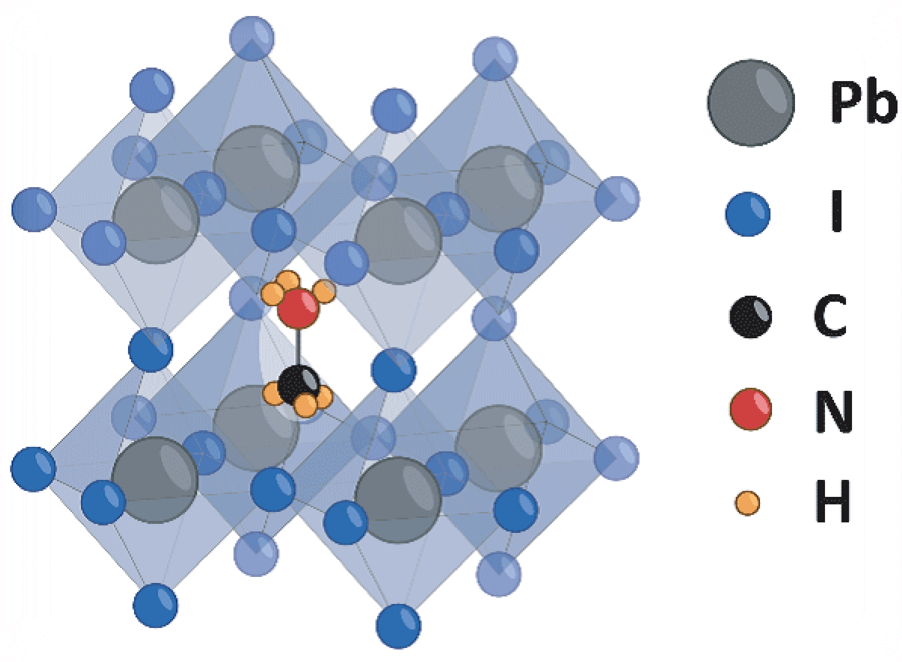
You might make many different contributions to this research. We are looking for students who can contribute their efforts in computer science, physics, electrical engineering, battery technology, nuclear engineering or space engineering.

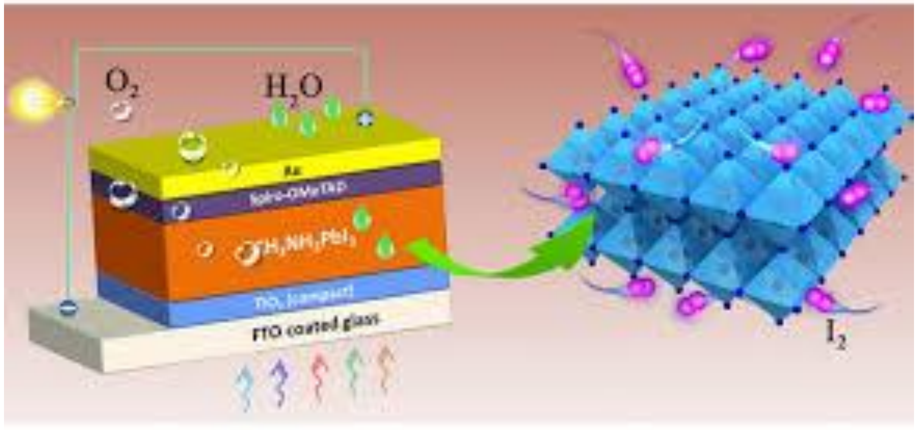
Beta-voltaic (BV) batteries

Aim: 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.

Perovskite





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

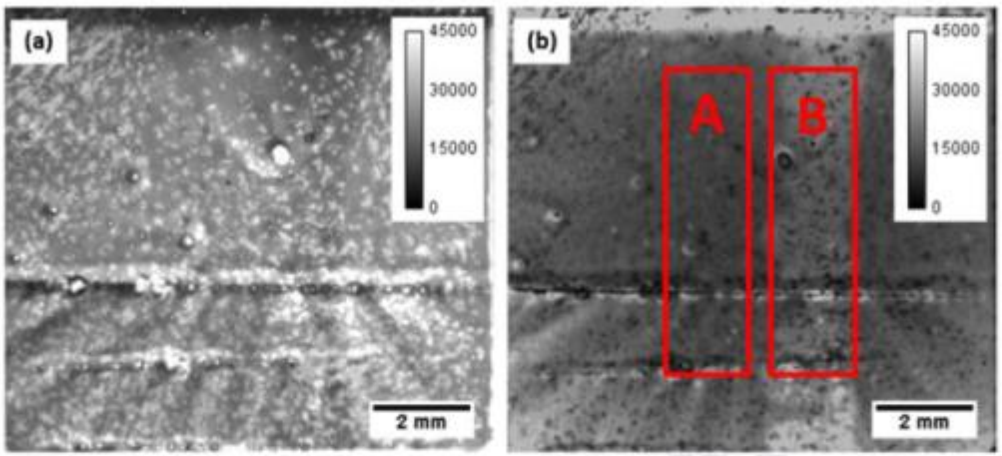
Progress in PHOTOVOLTAICS

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

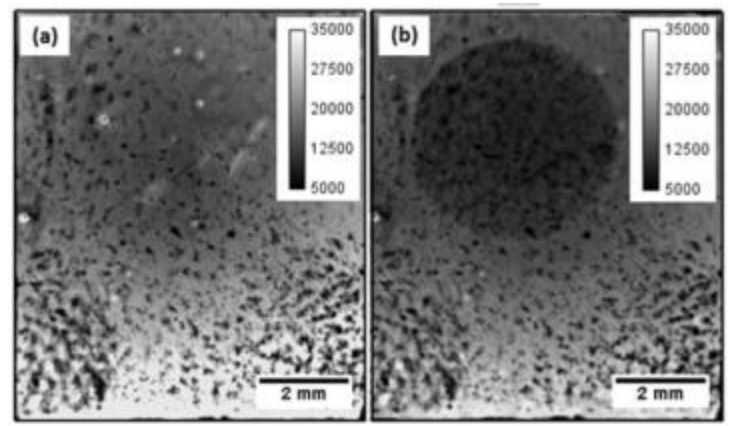
ACCELERATED PUBLICATION

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]



(a) PL image (under an illumination of 0.1 suns) and (b) EL image (under a forward bias voltage of 1.45 V) of a perovskite solar cell



Luminescence images of a perovskite solar cell before (a) and after (b) a sequence of three current–voltage measurements using a slow voltage sweep rate (13.4 mV/s)

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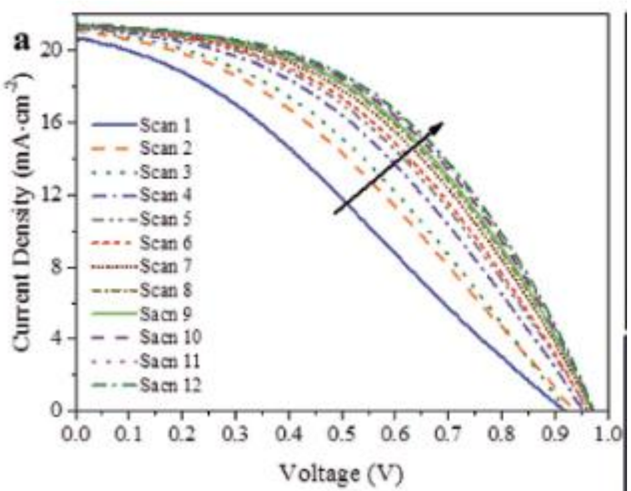
Perovskite solar cell luminescence imaging projects

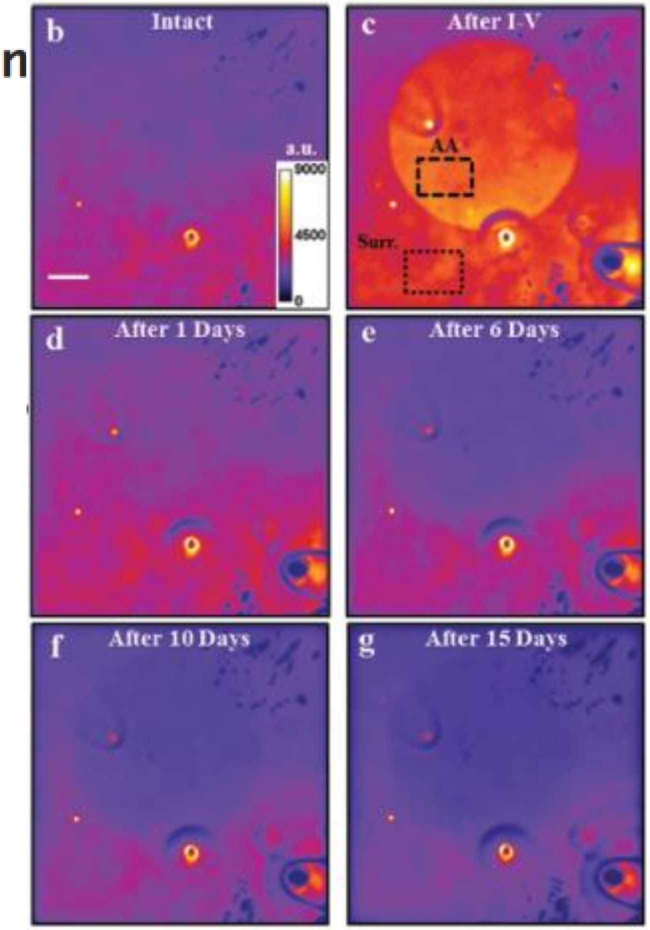
ADVANCED SCIENCE NEWS
www.advancedsciencenews.com

ADVANCED ENERGY MATERIALS
www.advenergymat.de

Lessons Learnt from Spatially Resolved Electro- and Photoluminescence Imaging: Interfacial Delamination in $CH_3NH_3PbI_3$ Planar Perovskite Solar Cells upon Illumination

Arman Mahboubi Soufiani, Ziv Hameiri, Steffen Meyer, Sean Lim, Murad Jehangir Yusuf Tayebjee, Jae Sung Yun, Anita Ho-Baillie, Gavin J. Conibeer, Leone Spiccia, and Martin A. Green**





Perovskite solar cell luminescence imaging projects

ESSAYS
Luminescence Imaging

ADVANCED ENERGY MATERIALS
www.advenergymat.de

Luminescence Imaging Characterization of Perovskite Solar Cells: A Note on the Analysis and Reporting the Results

Arman Mahboubi Soufiani, Jincheol Kim, Anita Ho-Baillie, Martin Green, and Ziv Hameiri*

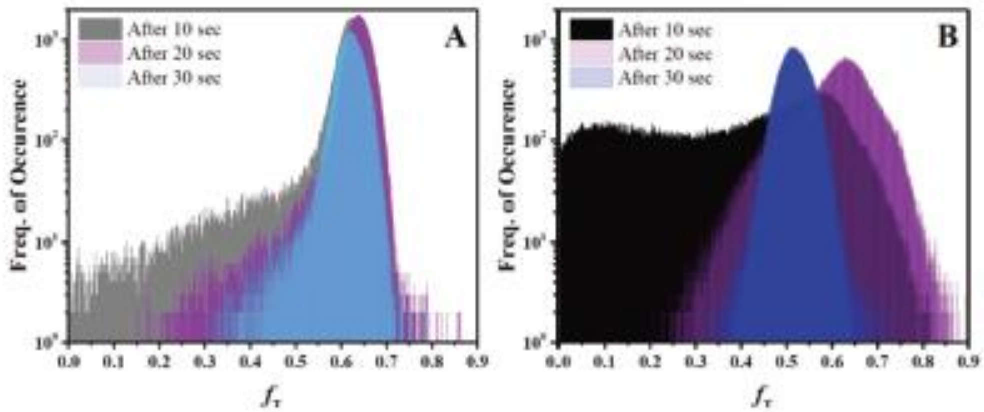
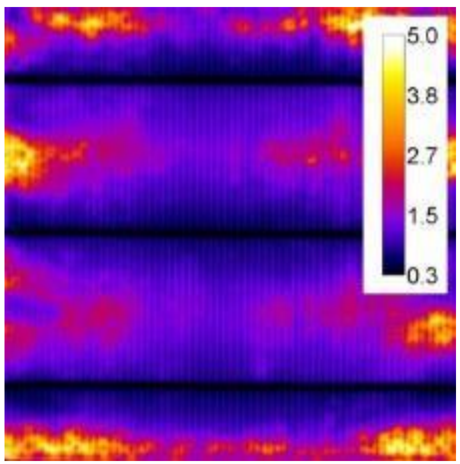


Figure 2. Time evolution of f_T distribution of PSCs. A) Current transport efficiency distribution for **Device A** measured through analysis of two EL images collected at 1.145 and 1.155 V at three different elapse times after bias initiation. B) Current transport efficiency distribution for **Device B** measured through analysis of two EL images collected at 1.120 and 1.130 V at three different elapse times after bias initiation. The lowest of these incremental voltage biases is set to be ≈20 mV higher than the devices open-circuit voltage (see inset tables in Figure 3).

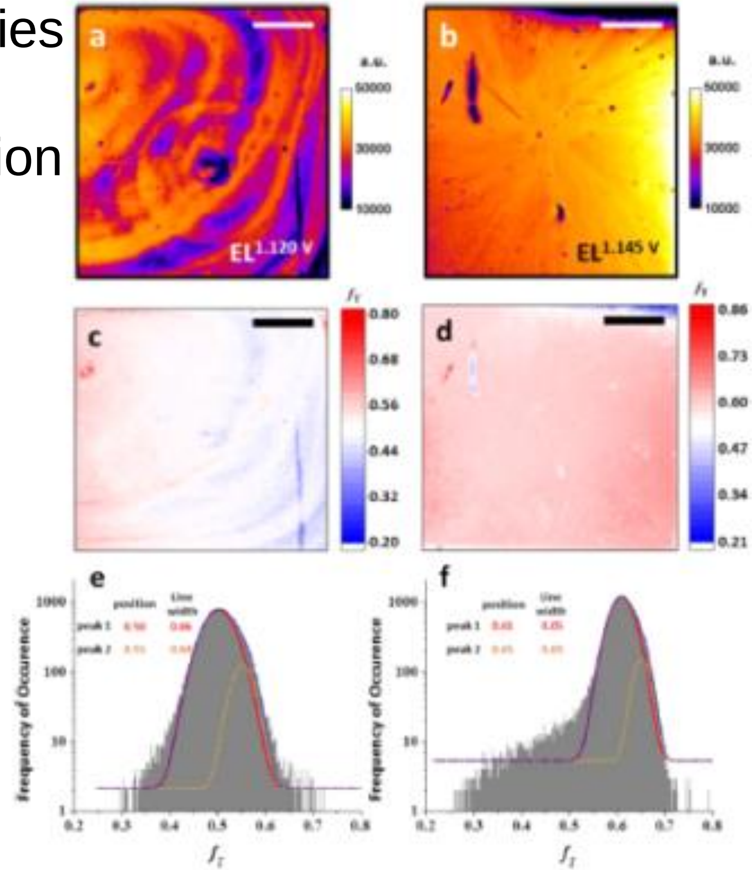
Develop PL-based methods for perovskite

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



Series resistance [in Ω.cm]




MORE!
MORE!
MORE!

AgriPV

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

<u>Project aims</u>:

- To model the benefits of agriPV in Australia
- If you have land, try agriPV in your garden!

LCA

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?

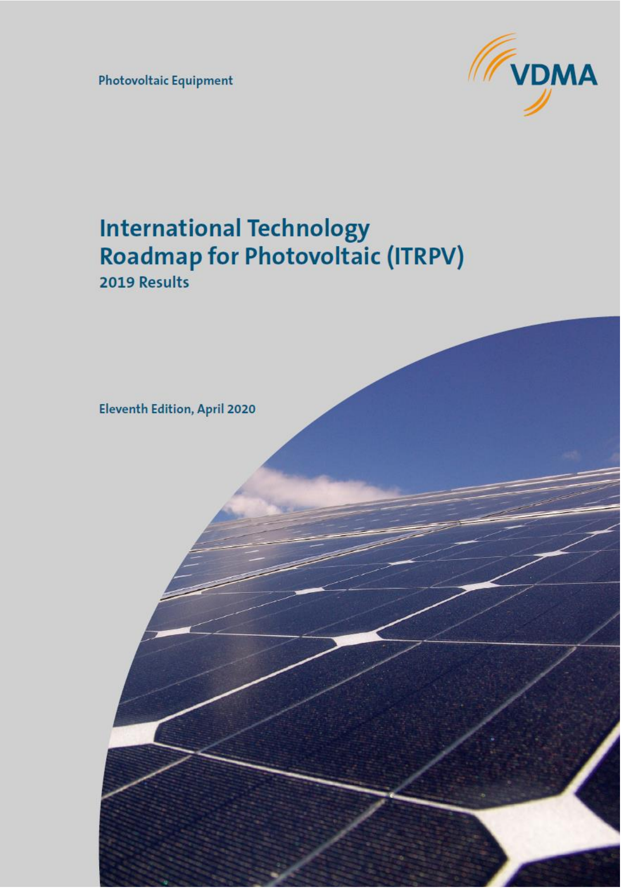
Project aims:

- 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

International Technology Roadmap for PV (ITRPV)

The ITRPV has a critical importance within the PV community. It is often being referenced in regards of future directions of the industry. However, it seems that many times it is wrong..

Project aims:
Come to speak with me!

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