School of Photovoltaic and Renewable Energy Engineering, UNSW

Emerging Solar Cell Research at University of New South Wales

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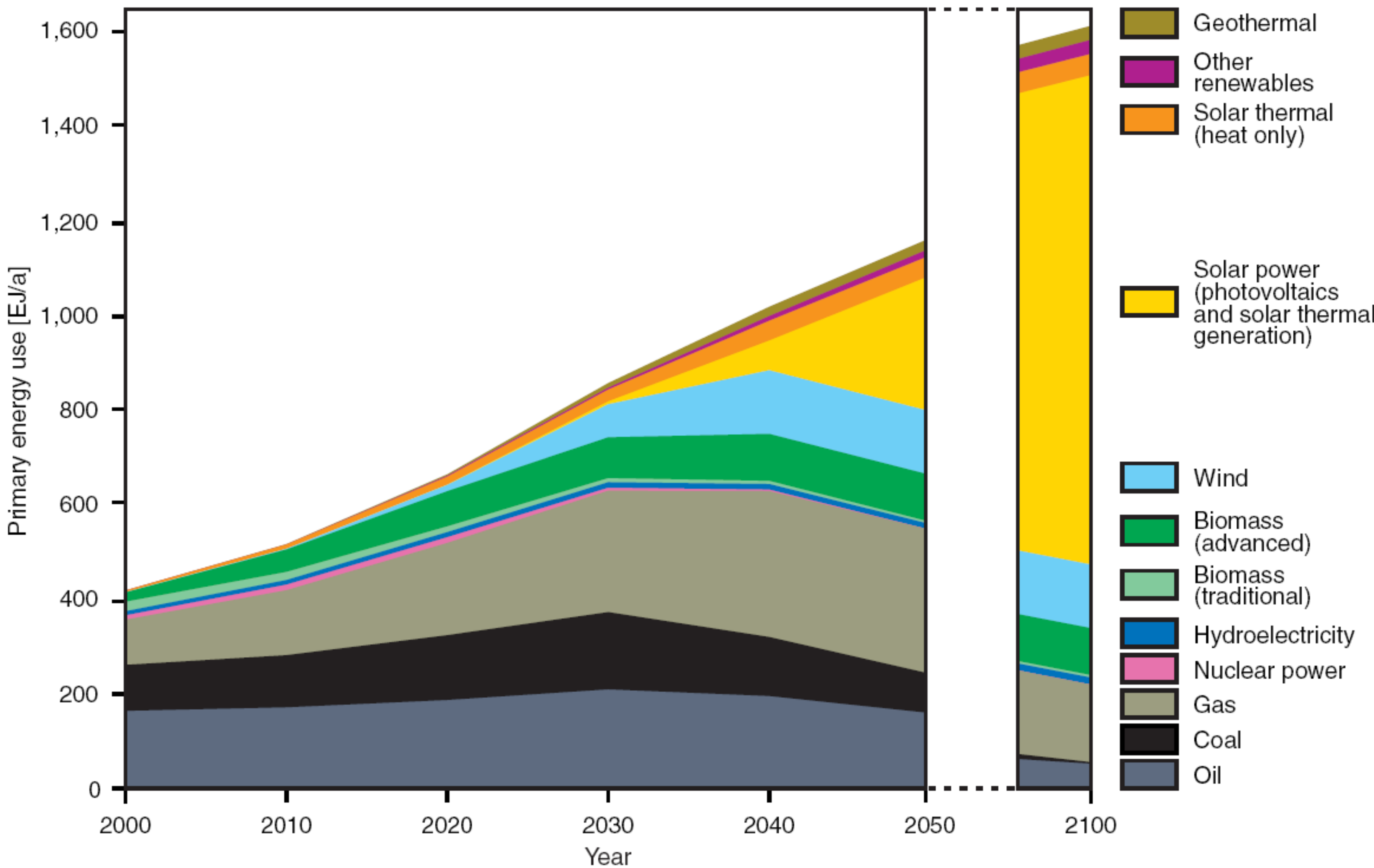
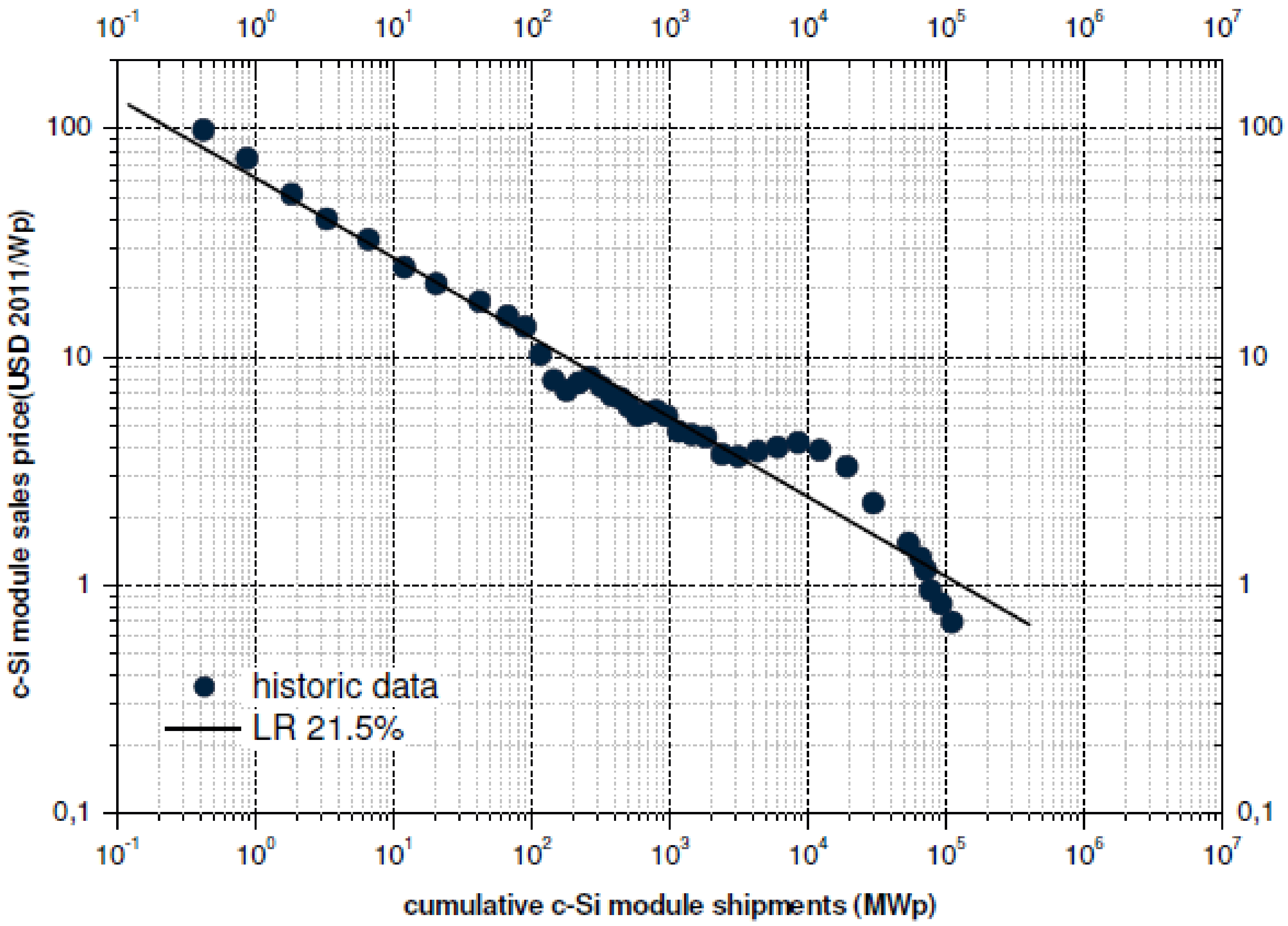
Context: The exemplary path until 2050/ 2100



Reference: "World in Transition: Turning Energy Systems Towards Sustainability (Summary for Policy Makers)," German Advisory Council on Global Change, Berlin 2003. www.wbgu.de

Learning Curve



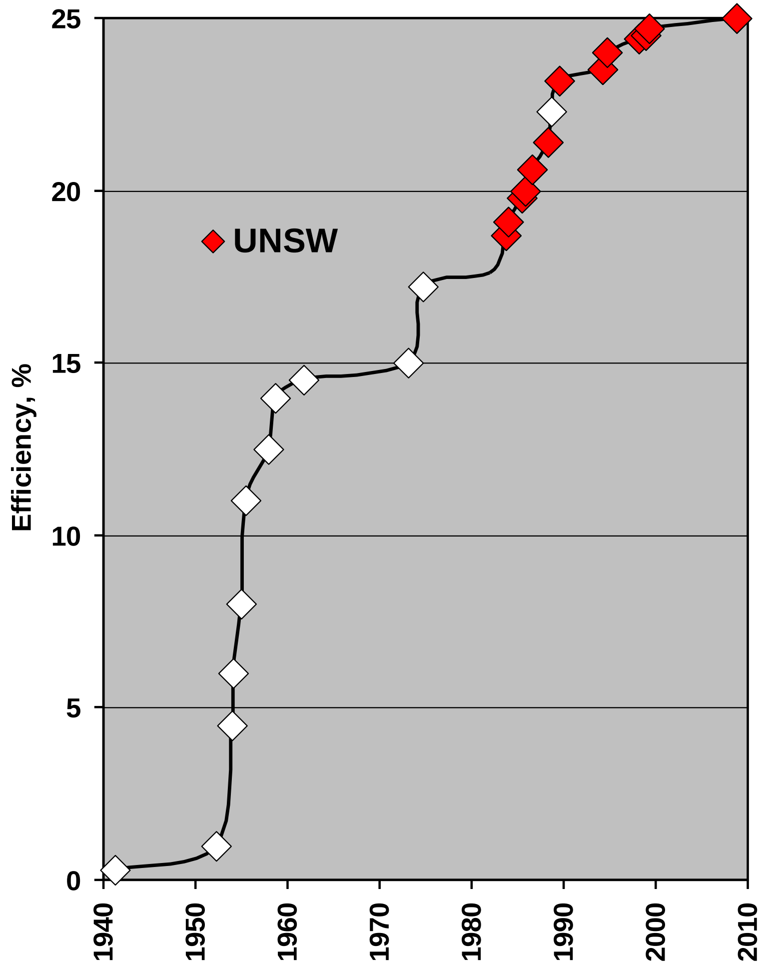
International Technology Roadmap for Photovoltaics (ITRPV) Results 2012, www.itrpv.net

PV production in 2012

- Down from 2011 due to GFC and oversupply
- Asia dominating cell (95%) and module production (86%)
- Mainland China produced 63% of world cell and 64% of module supply
- Production grew 5% in China but declined 12% in RoW

School History

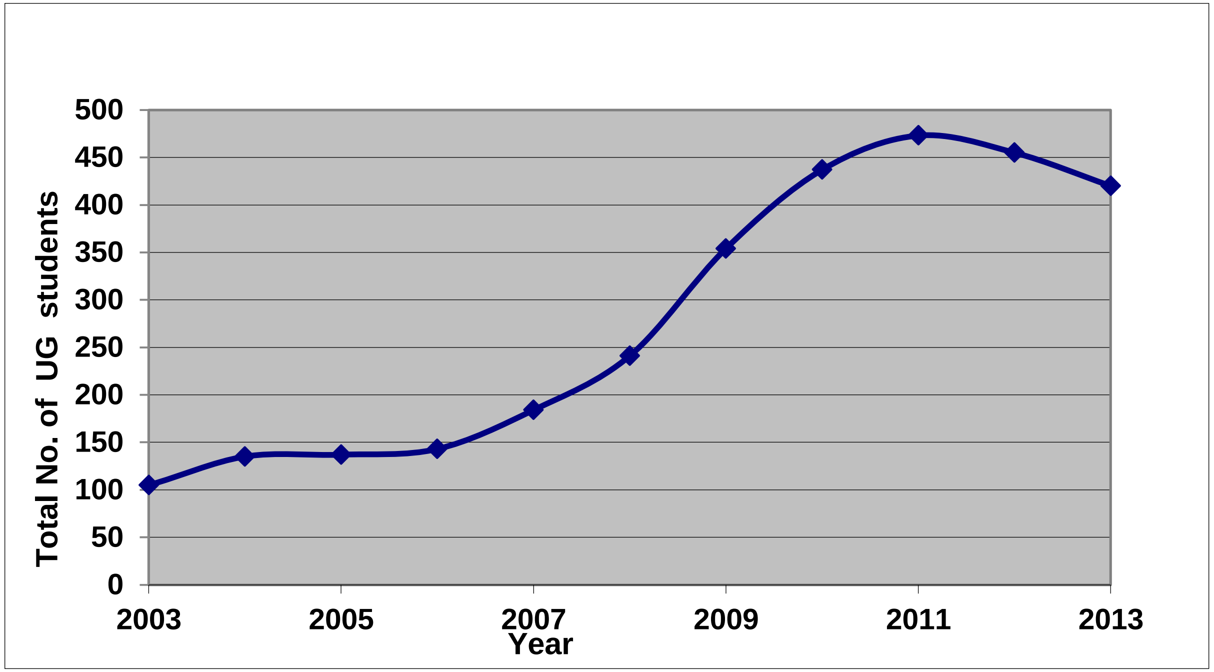
- PV research within UNSW Electrical Eng. 1974 - 1998
- Separate Centre 1999 - 2005
- Pioneering UG photovoltaics engineering program 2000
- PG coursework program 2001
- Second UG program 2003
- New School declared 2006

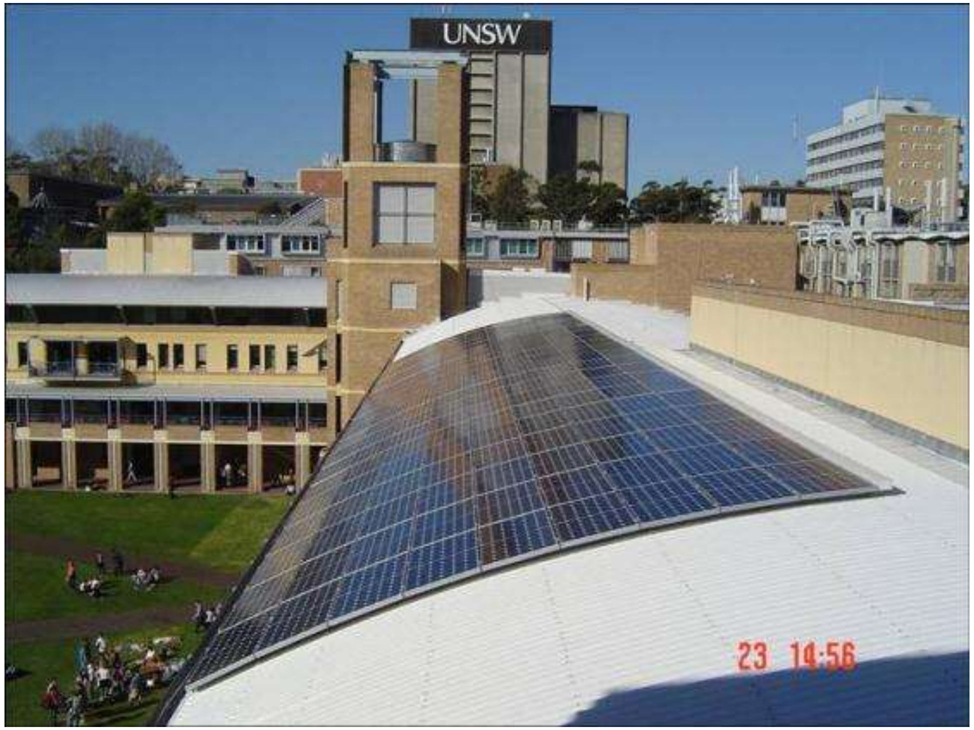


Undergraduate Education

Two 4-year Engineering programs (420 students):

- Photovoltaics and Solar Energy (started 2000)
- Renewable Energy (started 2003)

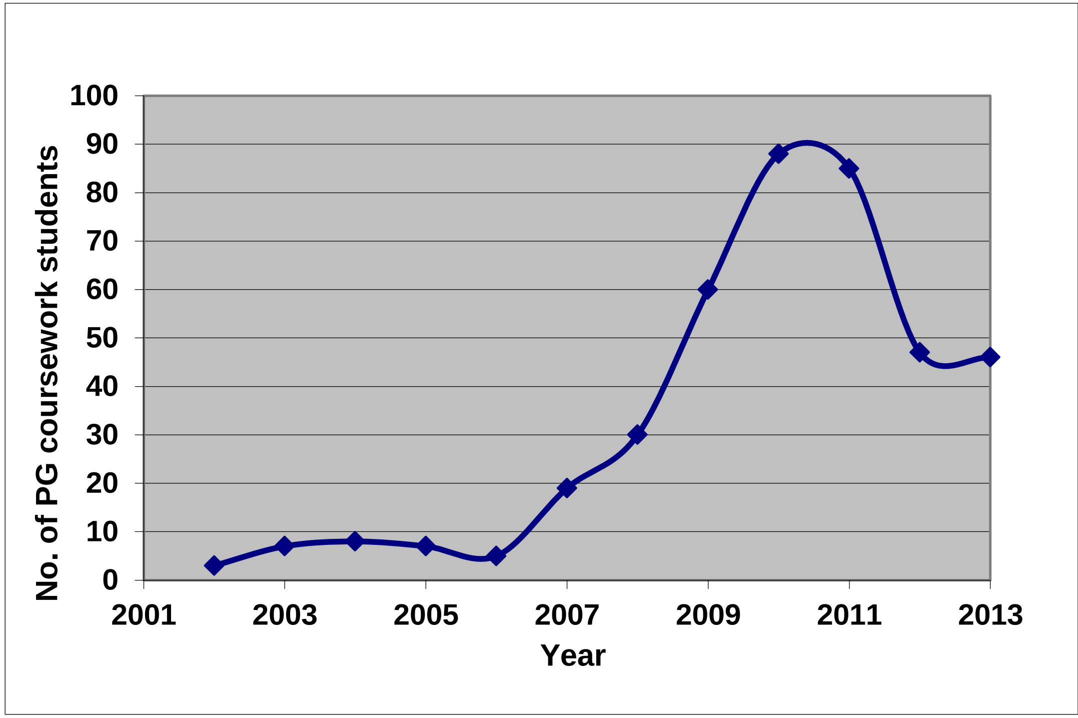




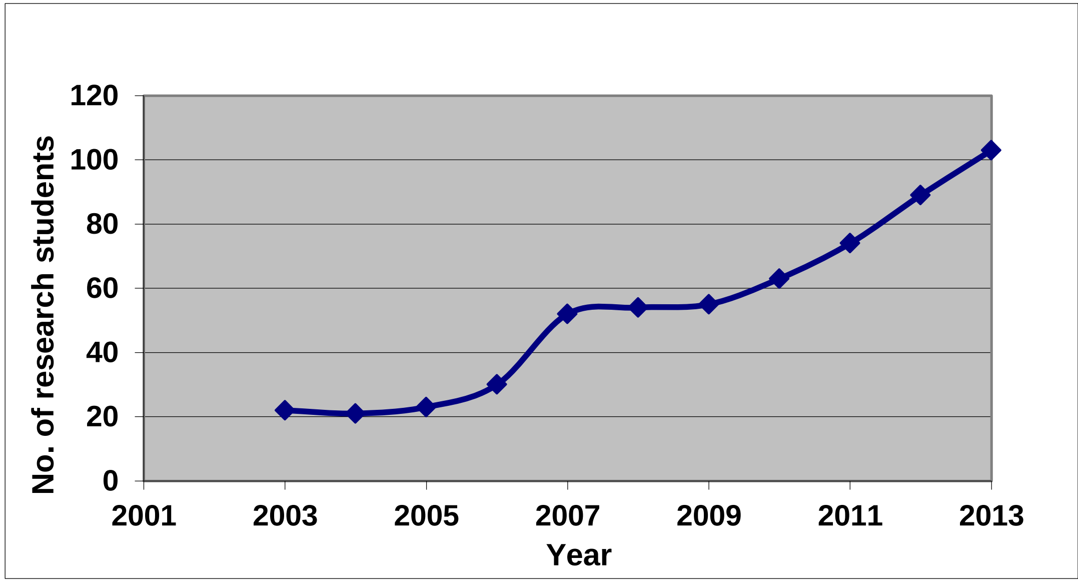
(Session 2, 2013 figures)

Postgraduate Education

- **PG Coursework** (46 students)
  - Rapid growth 2007-10
  - Strong AUD in 2011, 2012
  - 1.5 year addition to 4-year BEng. or 4-year BSc

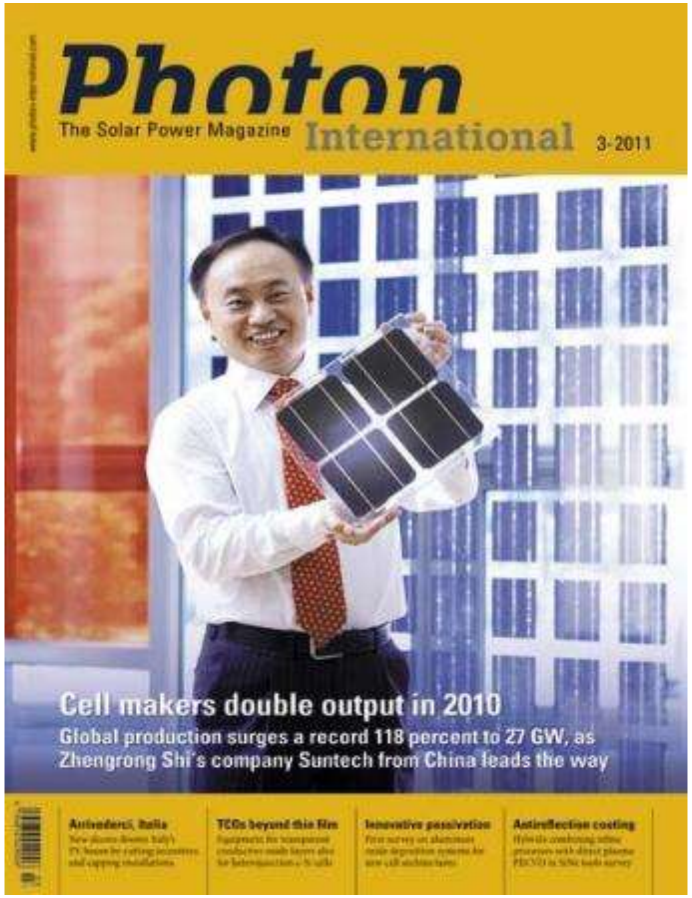


- **Research degrees**
  - PhD (93 students),
  - Masters Research (10 students)
  - Historically through Electrical Eng.



(S2, 2013 figures)

Major Collaborations



- BEng (2+2) partnerships
  - Nankai University
  - Sun Yat-Sen (Zhongshan) University
  - Tianjin University
  - Zhejiang University
  - Nanchang University
  - Beijing Jiao Tong University
  - South China University of Technology
- Several Asian PV manufacturers
  - R&D collaborations and Intellectual property licenses
  - Several former Centre members in key technical positions in major manufacturers
- ARC Linkage Projects with Suntech, Guodian, CSun and Tianwei
- QESST at Arizona State University
- US National Renewable Energy Laboratories
- Colorado School of Mines

Australia-US Institute for Advanced PV

Funded through the Australian Government's United States- Australia Solar Energy Collaboration, which is managed by the Australian Renewable Energy Agency

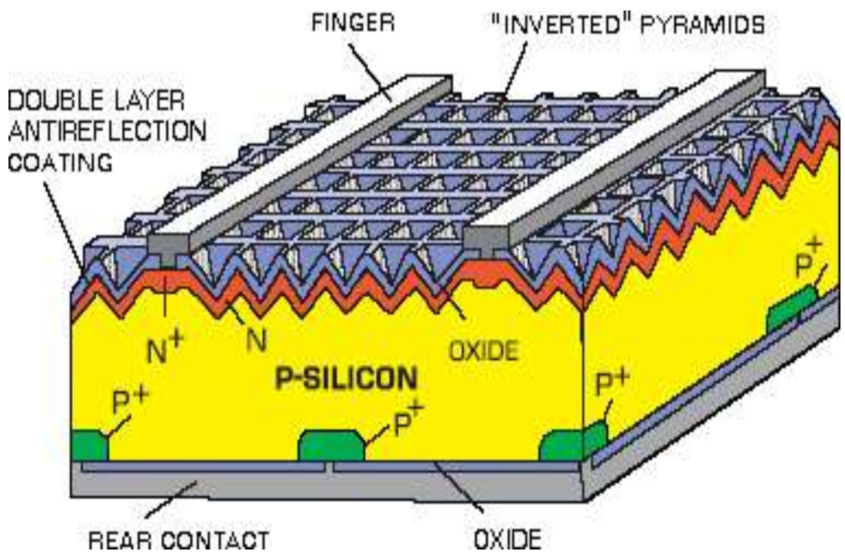
- UNSW
- Australian National University
- University of Melbourne
- Monash University
- University of Queensland
- CSIRO

- NSF-DOE QESST (Arizona State Univ.)
- U.S. National Renewable Energy Laboratory (NREL)
- Sandia National Laboratories (U.S.)
- Molecular Foundry (U.S.)
- Stanford University
- Georgia Institute of Technology
- University of California - Santa Barbara

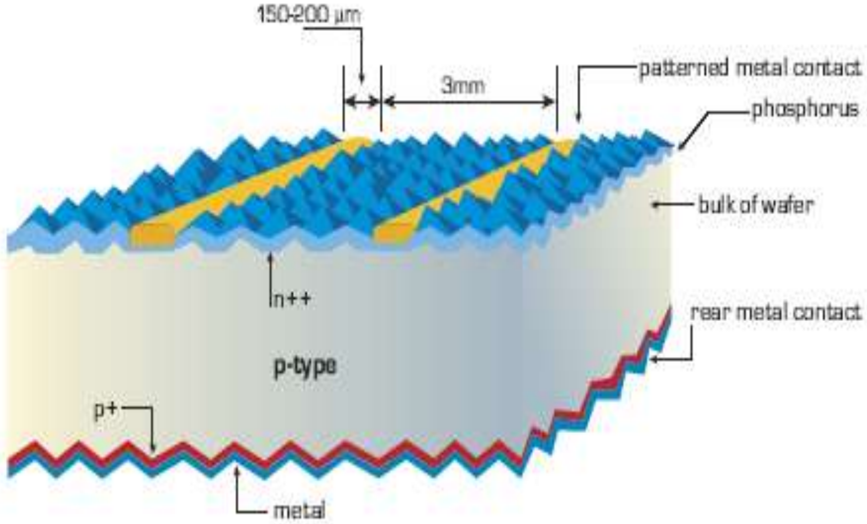
- Suntech R&D Australia
- BT Imaging
- Trina Solar Energy
- BlueScope Steel

- PP1: Silicon Cells
- PP2: Organic and Earth-Abundant Inorganic Thin-Film Cells
- PP3: Optics & Characterisation
- PP4: Manufacturing Issues
- PP5: Education, Training and Outreach

First Generation: Wafers/Ribbons



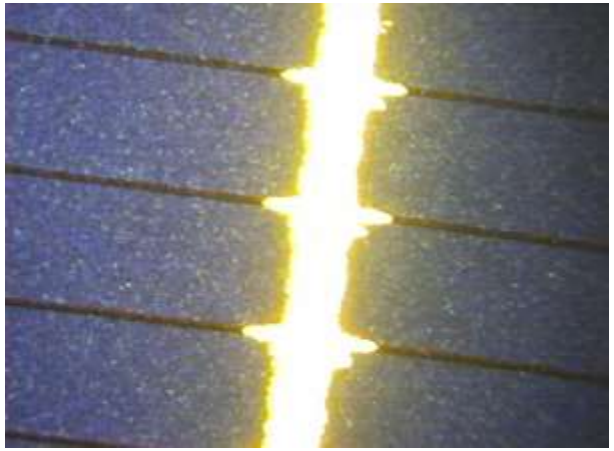
25% Efficient PERL Cell

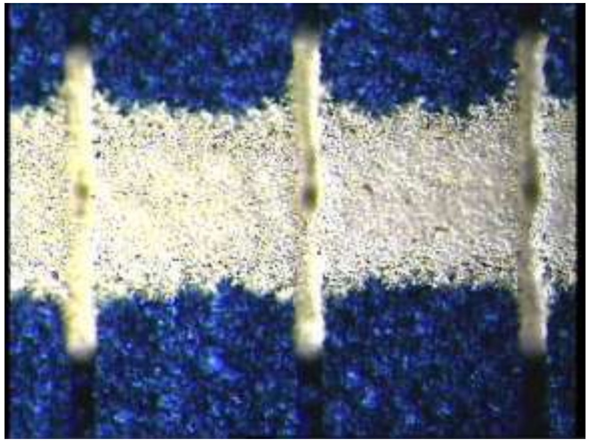


17% Industrial Screen Printed Cell

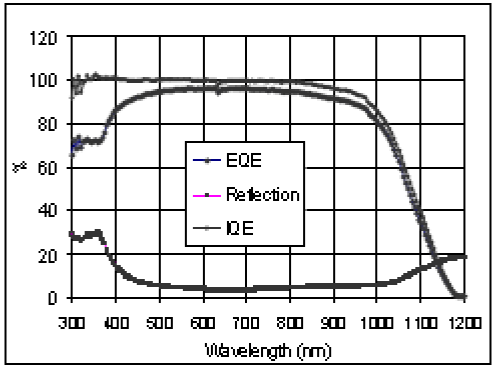
Selective Emitter – 3 Technologies

- Semiconductor Fingers:
  - Diffusion doped lines replace doped grooves
  - Screen-printed metal fingers run perpendicular to diffused lines

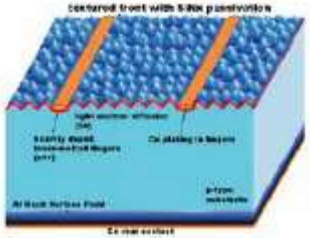


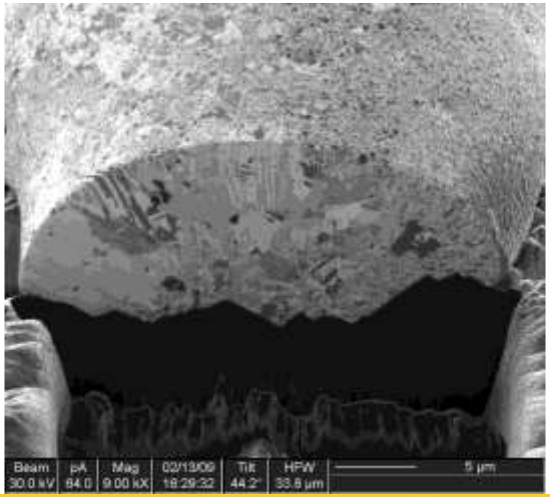


- Laser Doped Selective Emitter
  - Laser doping through/from dielectric layer
  - Dielectric doubles as ARC and plating mask
  - Laser doping gives heavily doped surface ideal for self aligned plating and selective emitter



- Transparent Fingers
  - Semiconductor Fingers with laser doped lines
  - Laser doped lines replace doped grooves

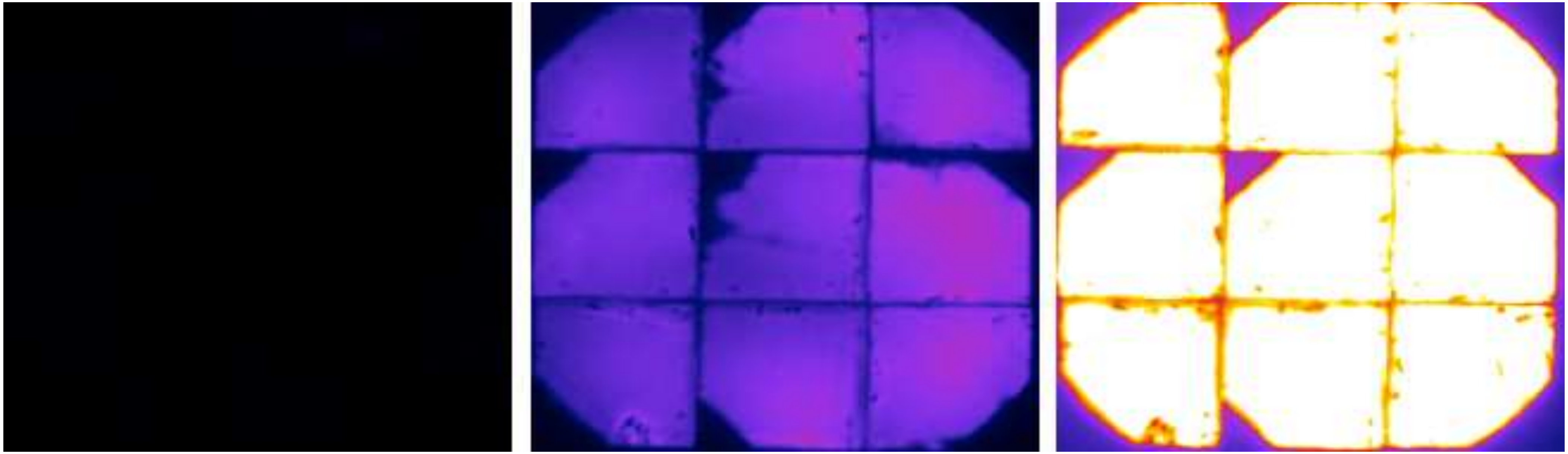




Advanced Hydrogenation on UMG Material

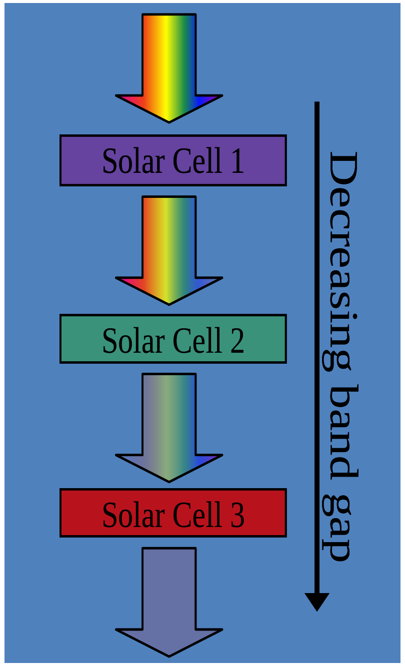
Lifetime: <1 microsec **several microsec** **>400 microsec**

No Hydrogenation Standard Hydrogenation UNSW tricks



GaAsP - Si/Ge Tandem Cell

- UNSW, AmberWave Inc., Veeco Inc., Yale University, University of Delaware, Arizona State University, and the National Renewable Energy Laboratory.ASI - supported partnership with Amberwave Inc.
- Si substrate
- Si/Ge alloy bottom cell to convert long wavelength light
- GAsP top cell to convert short wavelength light



III-V - Si Tandem Cell on Virtual Ge Substrate

- UNSW and the National Renewable Energy Laboratory.
- Low cost Si substrate
- Thin layer of crystalline Ge to be grown on a Si wafer by economic physical vapour deposition - “virtual Ge wafer”
- GaInP/GaInAs top cells to convert short wavelength light

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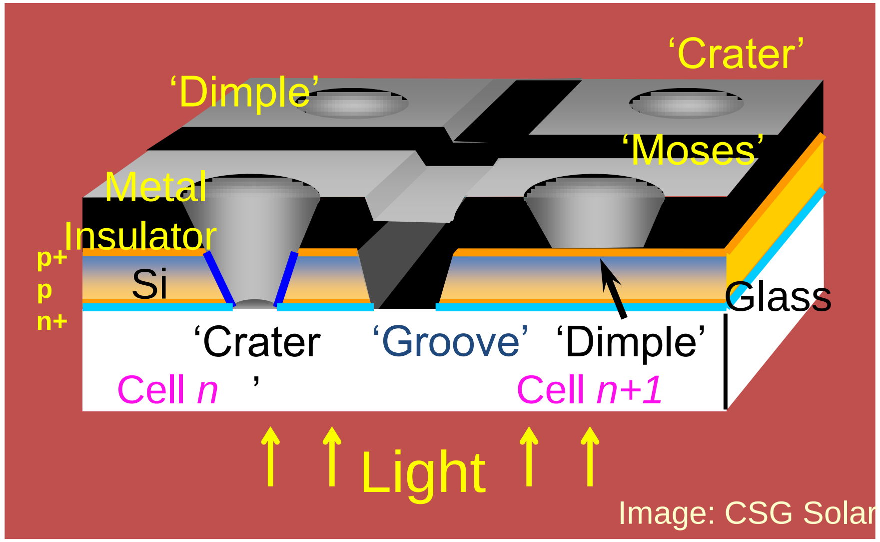
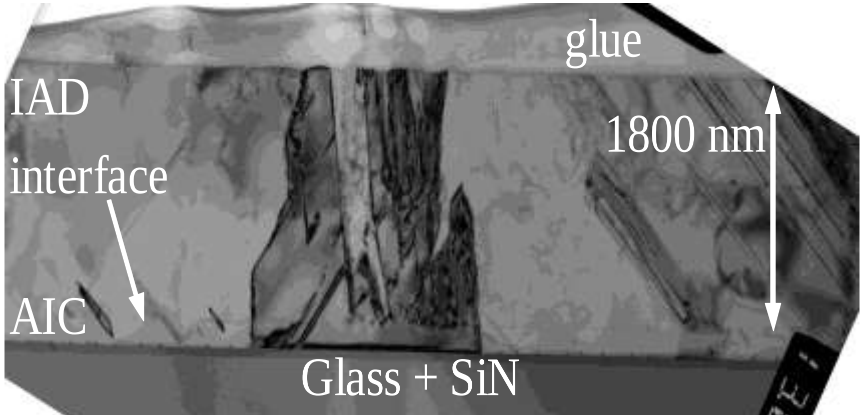
Second Generation (Thin Films) - Si

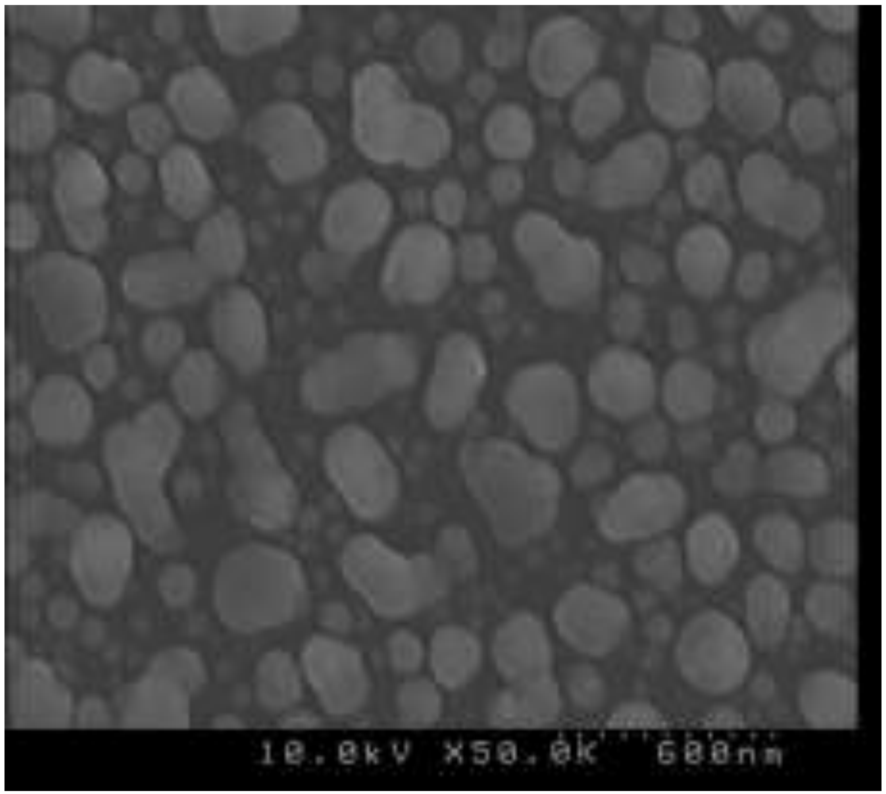
- Thin films on supporting substrate
  - Amorphous/microcrystalline Si
  - CIGS (In: CRITICAL (US DoE))
  - CdTe (Te: NEAR-CRITICAL (US DoE))
  - Crystalline Si on glass or conductive carrier
  - Cu_2ZnSnS_4 (CZTS)
  - Organic PV
- Lower efficiency than wafers but lower cost per m^2
- Large manufacturing unit
- Fully integrated modules
- Aesthetics

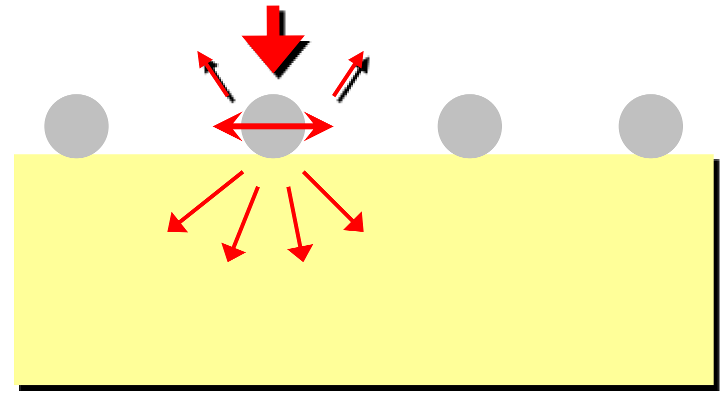


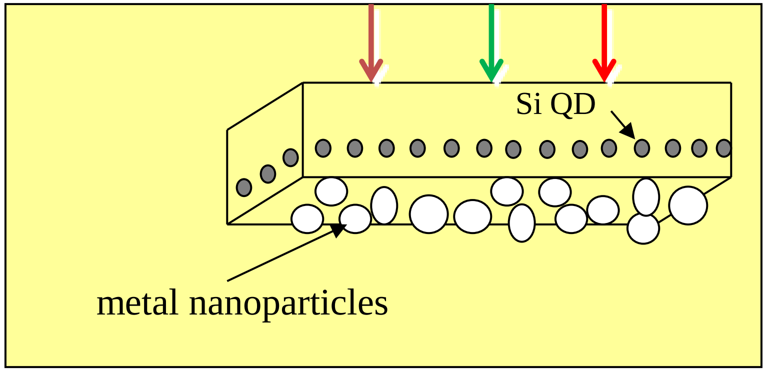


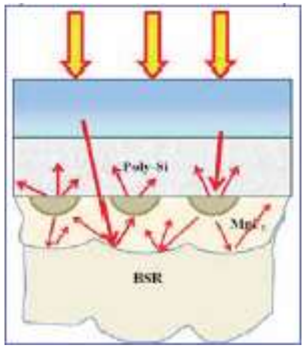
Plasmonic Evaporated Cells

Surface plasmon enhanced light-trapping (planar glass)

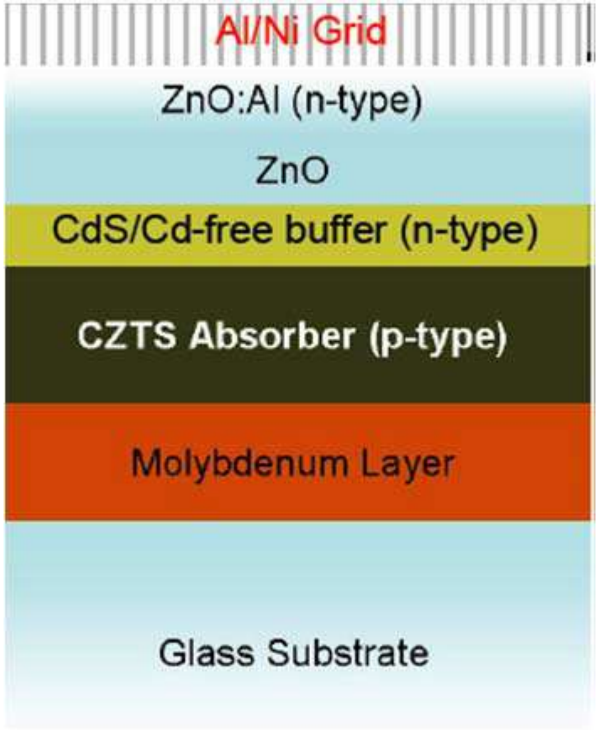




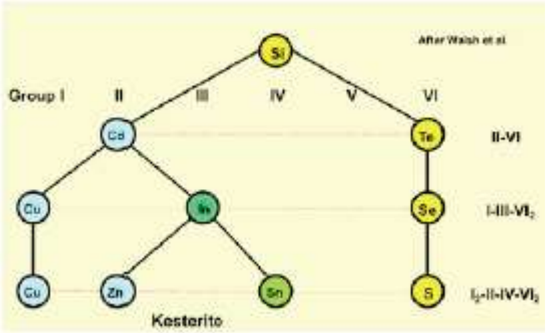


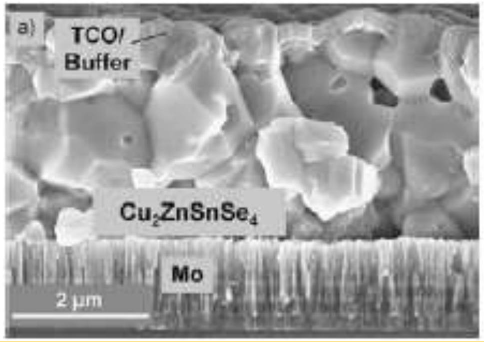


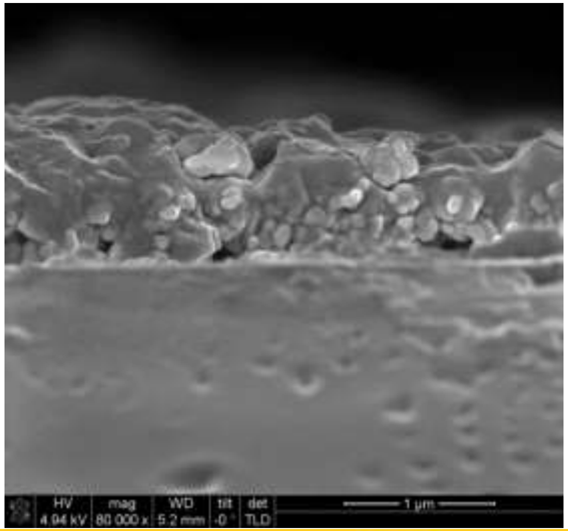
CZTS thin films



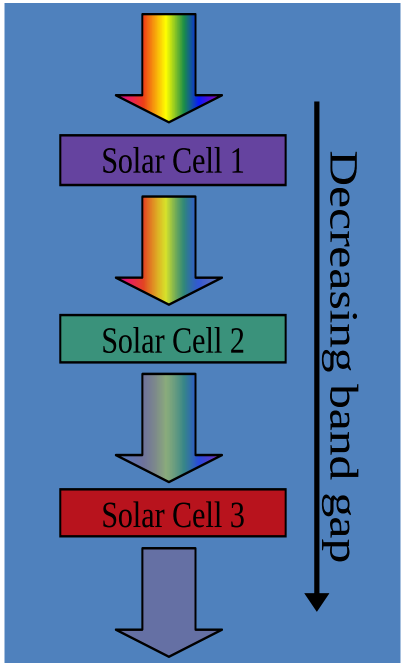
- Earth-abundant
- Low toxicity
- IBM demonstrated 9.7% in 2009
  - Hydrazine-based solution deposition
- Physical vapour deposition
  - Reactive sputtering



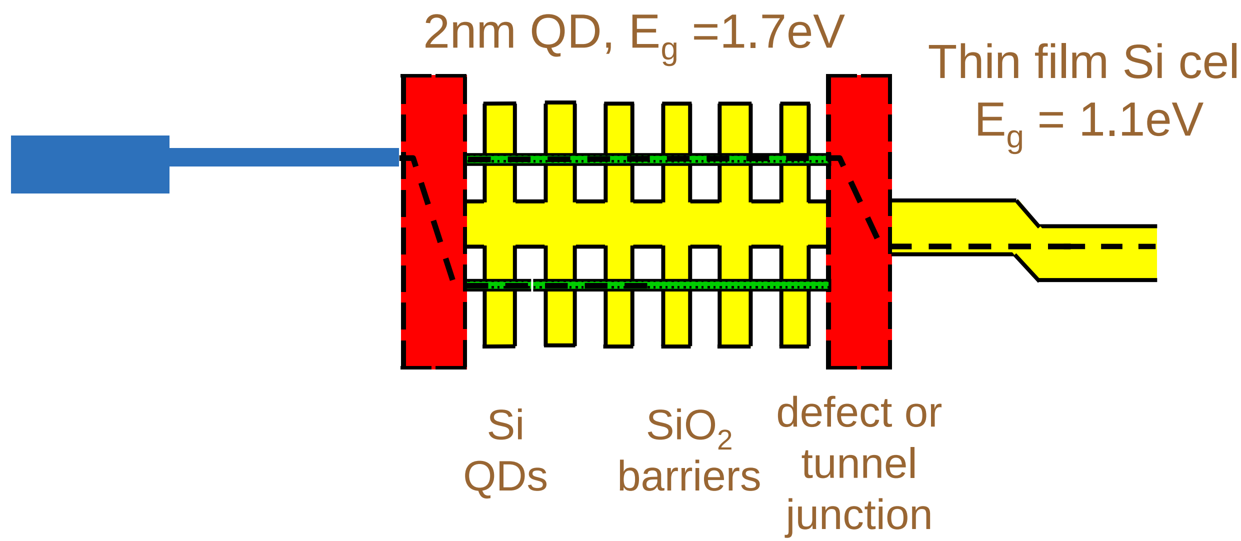


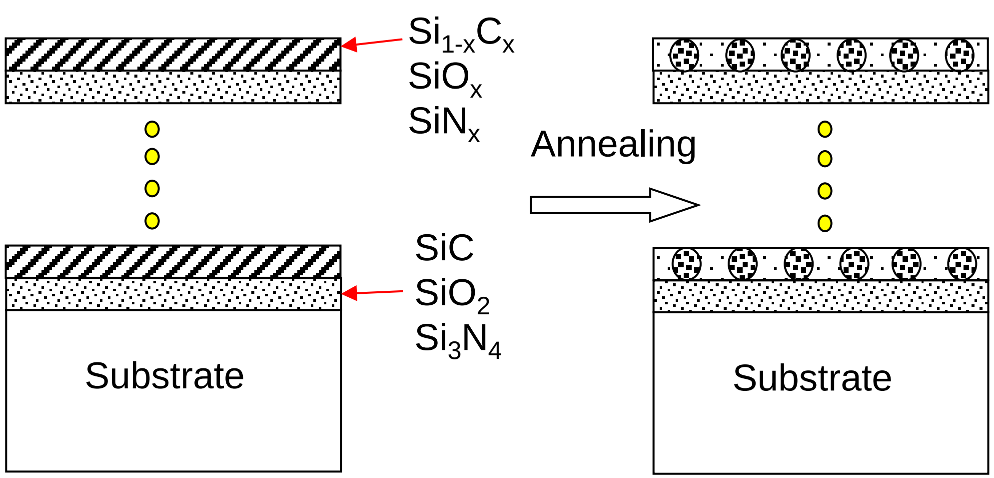


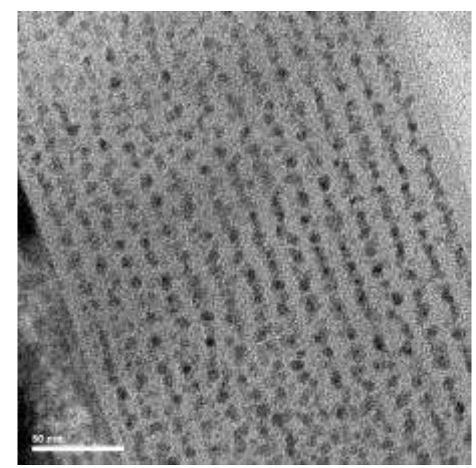
Silicon based Tandem Cell



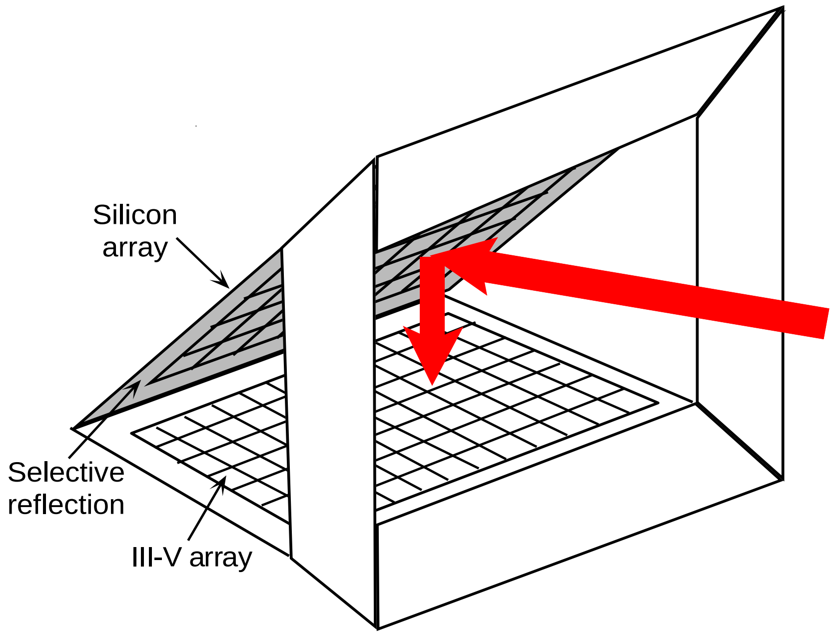
Engineer a wider band gap – Si QDs

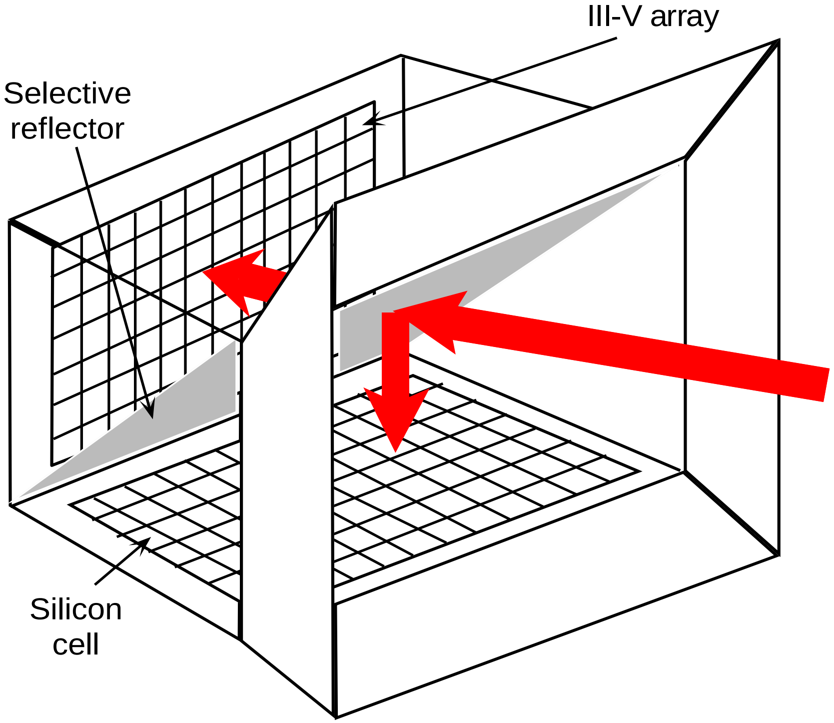




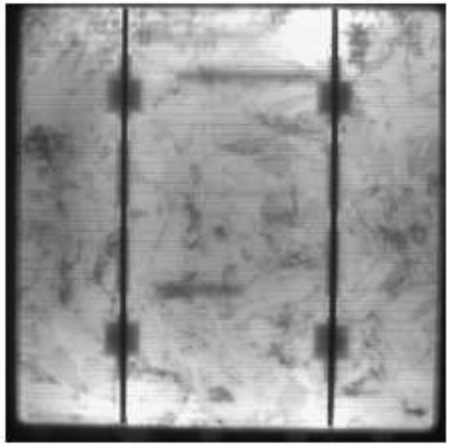


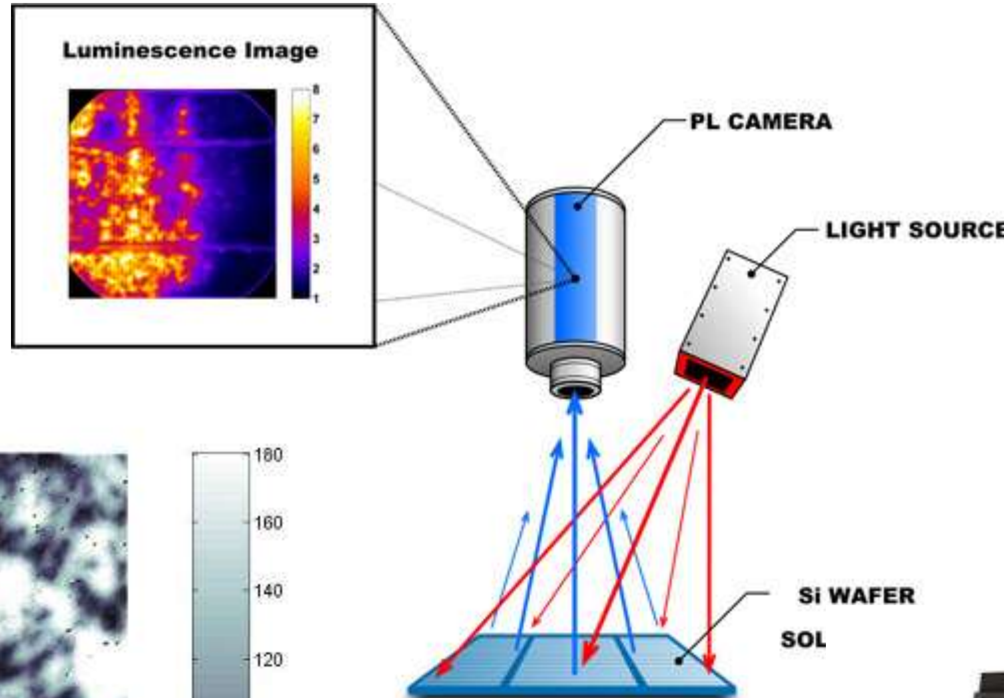
Spectrum Splitting for Concentrating PV

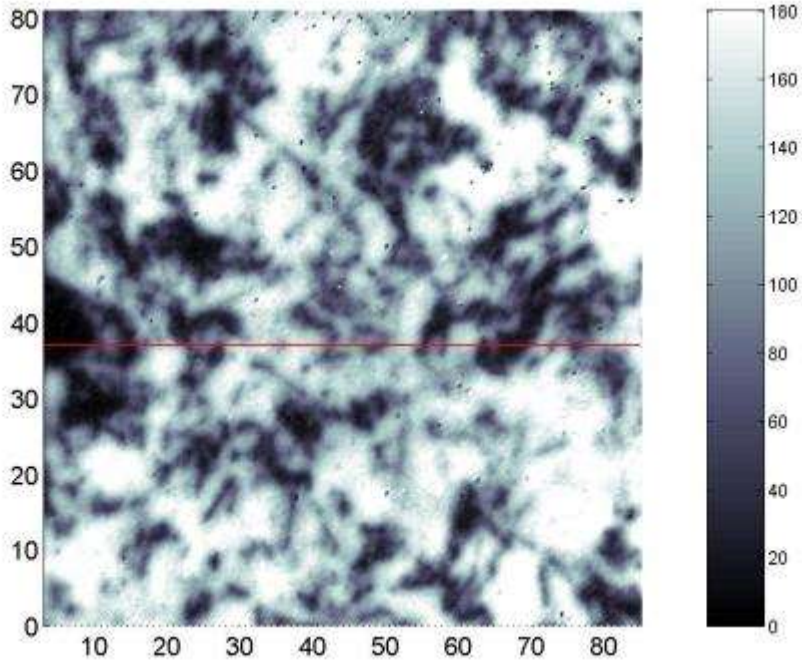




Photoluminescence Imaging







Images courtesy of BT Imaging

Thanks for your attention!

“This Program has been supported by the Australian Government through the Australian Renewable Energy Agency (ARENA). The views expressed herein are not necessarily the views of the Australian Government.”