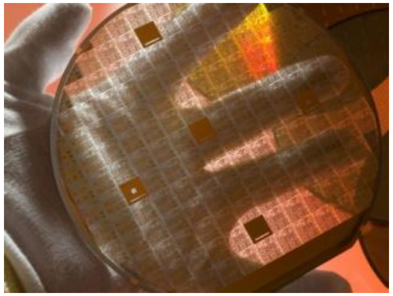


ASI Project 1-A026:
A high efficiency, integrated solar module on a transparent substrate

Grant to Sapphicon Semiconductor, part of the Silanna Group

Acknowledgement

The Australian Solar Institute

Silanna engineers, technicians and operators

Andrew Read

Chris Escott

Matthew Godfrey

Introduction to Silanna

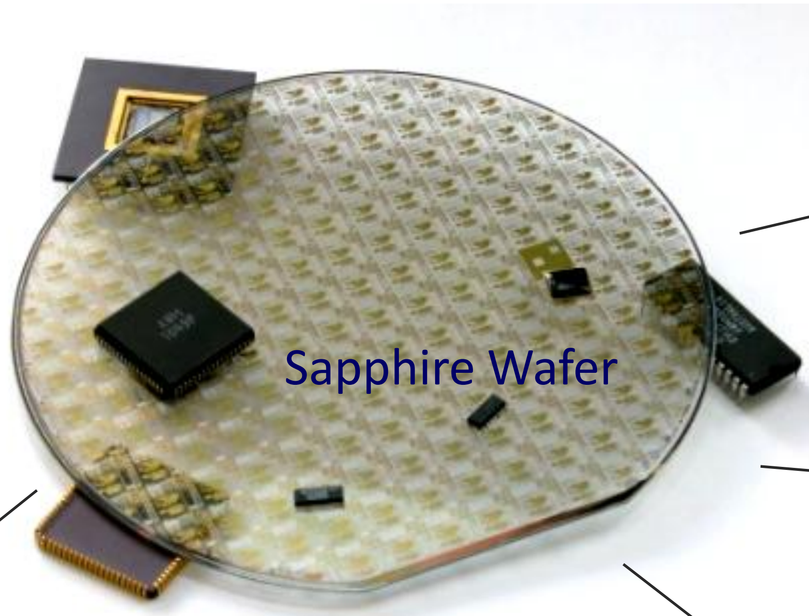
- **Silicon technologies**
  - Silicon CMOS
  - Thin film silicon on sapphire
  - 0.25µm FEOL, 0.50µm BEOL
- **Cleanrooms**
  - Class 10 Cleanroom, 460m^2
  - Class 1 Cleanroom, 460m^2
- **Installed Capacity**
  - 1,500 6” wafers/month (full loop)
  - Low to medium volume production
  - R&D support

- **Nitride technology (in development)**
  - III-Nitrides (2, 4, 6 and 8” capable)
- **Cleanrooms**
  - Class 10 Cleanroom, 435m^2
- **Installed capacity**
  - Over 400 6” epi-wafers per month
    (Over 5,000 2” epiwafers per month)

>20 years at Sydney’s Olympic Park

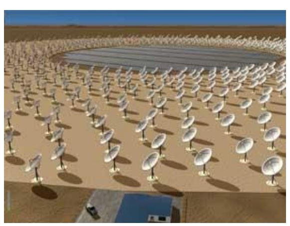
Silanna Silicon-on-Sapphire

Mobile
Base Stations



Satellites

Digital TV Tuners



Radio Astronomy

Addressable
CATV Taps

Mobile Phones

Low Noise Blockers

Project objectives

Develop thin-film, single-crystal silicon solar cells

Milestone 1:
17% efficiency under field realistic conditions
by end of October 2010

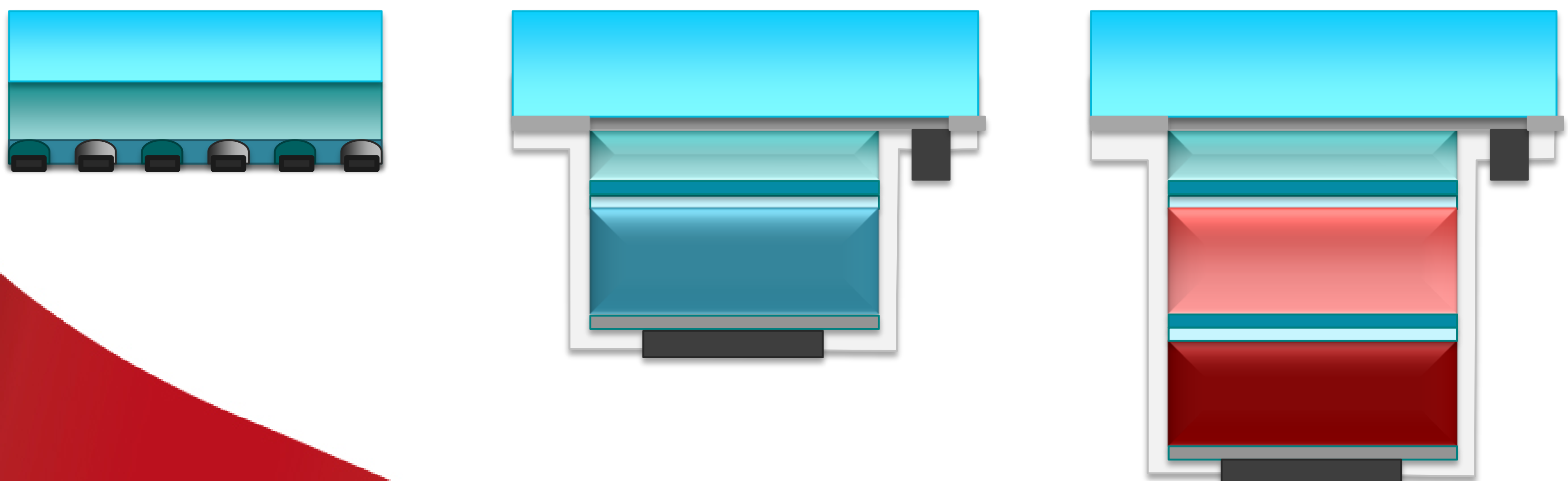
Milestone 2:
22% efficiency under field realistic conditions
by end of September 2011

A one-year feasibility study of a new solar cell …

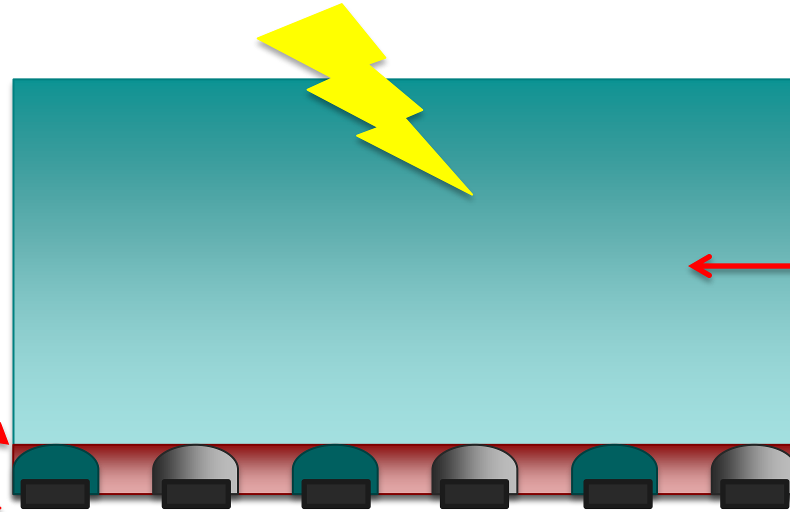
Silanna's Program Objectives (4 years)

Commercialize robust, high efficiency, low cost cells and modules for concentrating photovoltaic systems

Phase 1: Single junction, single crystal silicon on sapphire	Phase 2: Multi-junction silicon on sapphire	Phase 3: Hetero-junction on silicon on sapphire
Target: 24% (2011)	Target: 30% (2012)	Target: >40% (2014)



Cell #1 - A silicon-on-sapphire solar cell



Silicon
Excellent crystal quality
No shadowing
Low series resistance
High collection efficiency

Sapphire
Robust
Transparent
Good thermal conductor

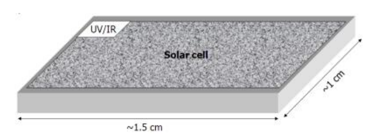
Space

Radiation hard
Trusted technology

Concentrating PV

Reduced efficiency loss
Adaptive control
Simpler solution than III-V

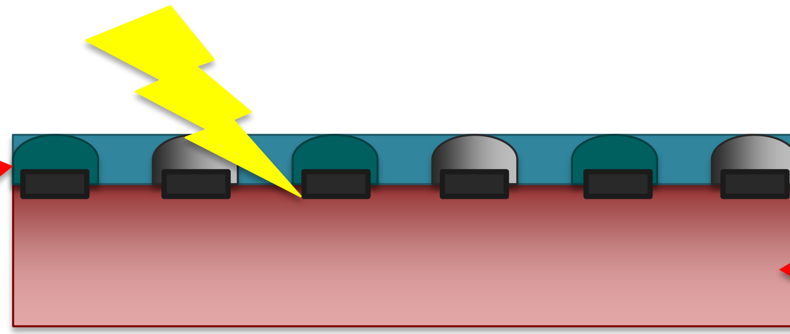
Self-powered circuits



Self-powered sensors, actuators, etc.

Cell #2 - Post-growth layer transfer solar cell

Silicon
Excellent crystal quality
No shadowing
Low series resistance
High collection efficiency



Handle wafer
Mechanical support
Heat sink
Integrated electronics

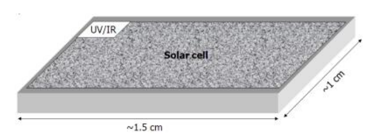
Space

Radiation hard
Trusted technology

Concentrating PV

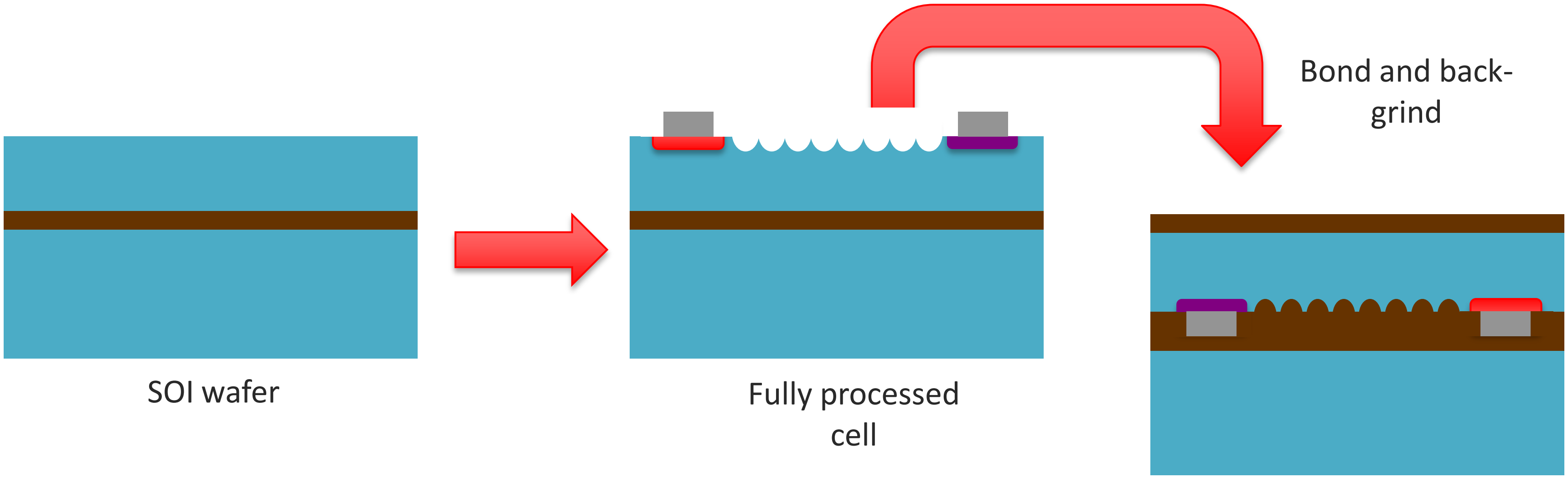
Reduced efficiency loss
Adaptive control
Simpler solution than III-V

Self-powered circuits



Self-powered sensors, actuators, etc.

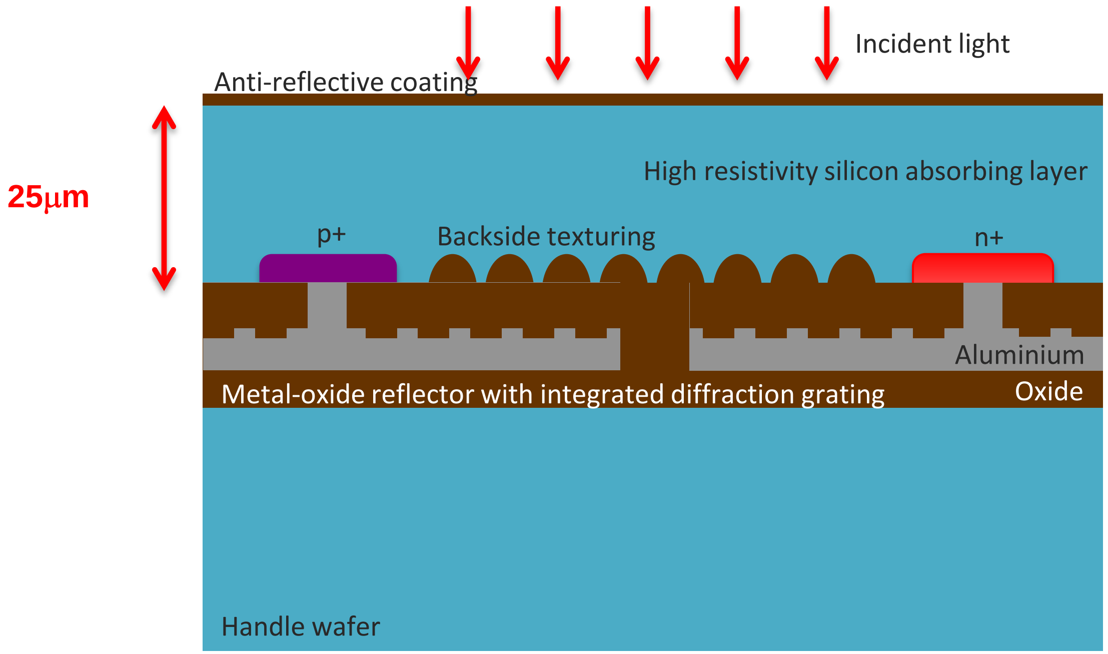
Fabricating the post-growth layer transfer cell



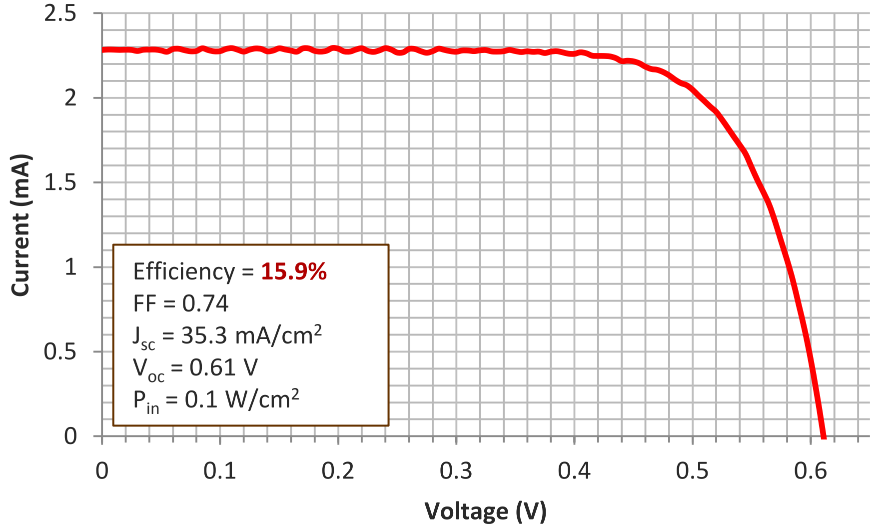
Experimental setup

- Experiments undertaken: 91 6” wafers processed at Silanna’s Fab
  1. **Surface passivation**: PECVD silicon nitride, thermal silicon nitride, alumina, thermal (dry) silicon dioxide, wet silicon dioxide, field passivation (doped via diffusion and implantation)
  2. **Light trapping**: Wafer-bonding, metal-oxide reflectors, DBRs, surface texturing through isotropic and anisotropic etching, diffraction grating
  3. **Cell design**: pitch, size, finger orientation, thickness
  4. **Contacts**: implant dose and energy, MIS contacts
  5. **Materials**: FZ vs CZ, resistivity, vendor
  6. **Processes**: order and optimisation
  7. **Cell isolation**: etch, shadow, spot size
  8. **Measurement**: quantum efficiency, solar simulator (CW and flash), concentration
- Measurement and characterizations performed at
  - Silanna
  - SUNLab at University of Ottawa, Canada
  - Fraunhofer ISE in Freiburg, Germany
- TCAD simulation (Synopsys Sentaurus) used extensively for virtual experimentation

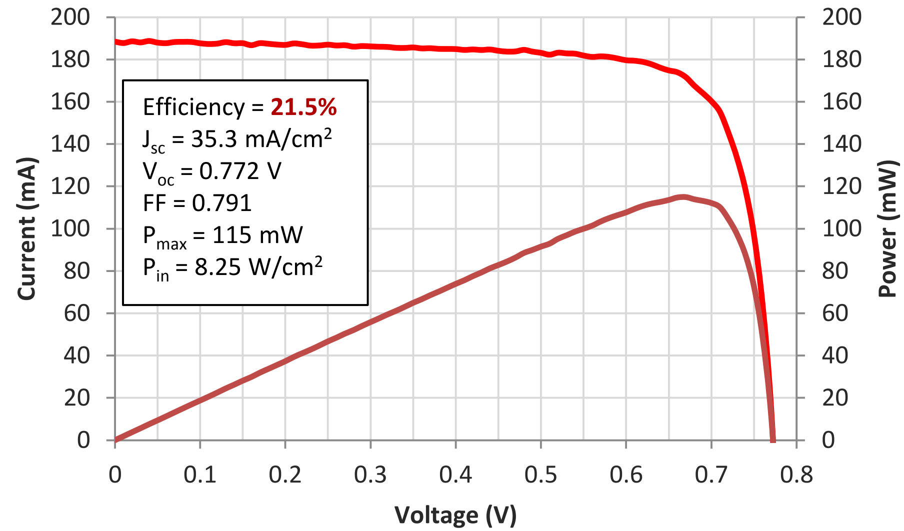
Optimal cell architecture



Single sun efficiency 15.9%



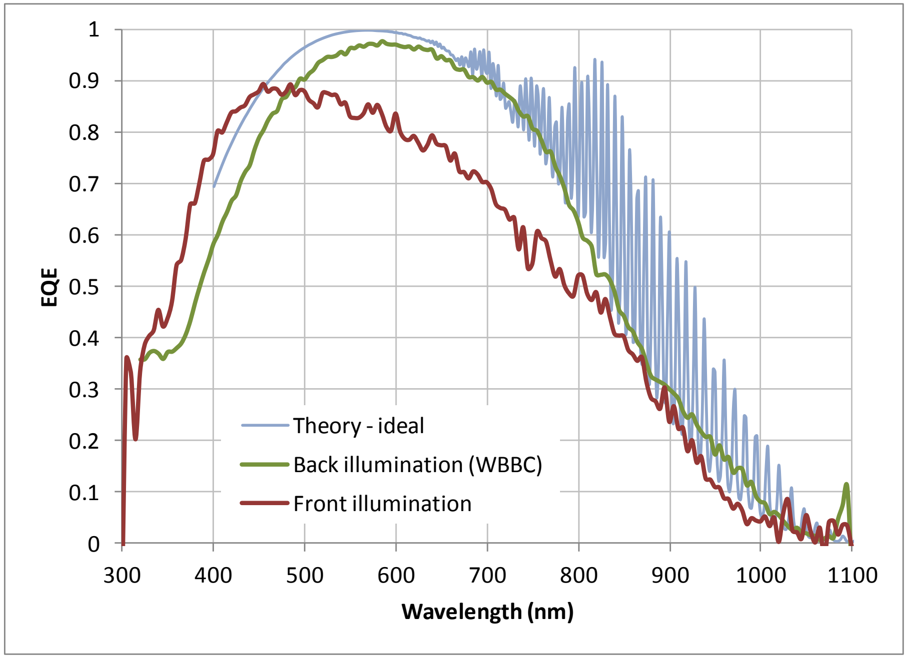
Maximum efficiency 21.5% at 82.5x

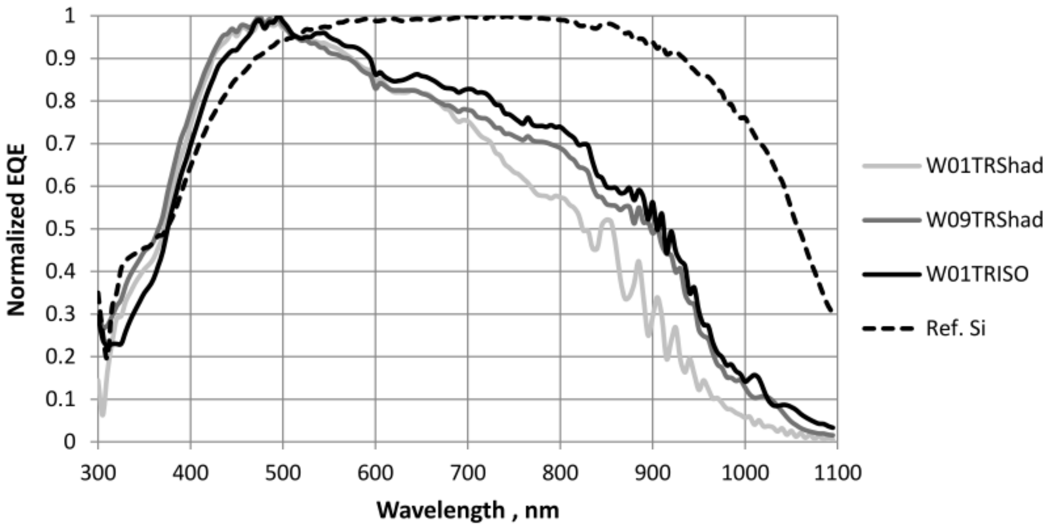


- Layer transfer cell with
  - 25um silicon layer
  - Backside texturing
  - Back reflector with integrated diffraction grating
- Measurements verified by SUNLab (Ontario)

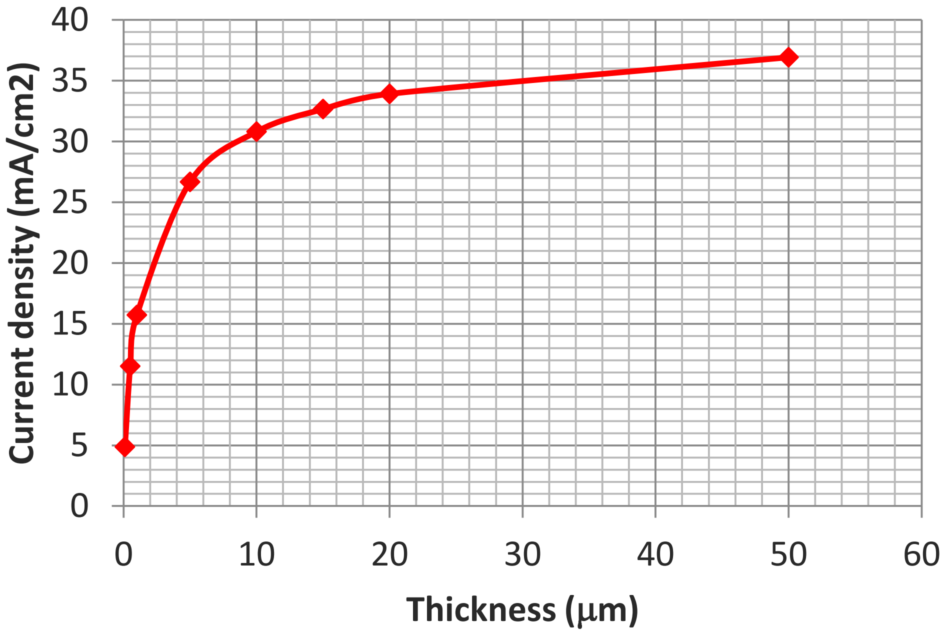
Results

- External quantum efficiency
  - Excellent blue-green photon capture and collection
  - Near 100% EQE for 550-650nm wavelengths (peak of solar photon flux)
  - Significantly increased QE at red and IR wavelengths from incident surface texturing





Current density vs silicon thickness



- Optimum thickness 20-50 µm
- Maximising V_{oc} (thin) while capturing as many photons as possible (thick)

Next steps

- Cost reduction of post-growth layer transfer
- Efficiency improvements
  - Improved light trapping
  - Improved (MIS) contacts
  - Surface plasmon resonances
  - Multi-junction cells
  - Optimized cell design

Thank you