Indian Institute of Technology Bombay

Silicon Solar Cell Research Activities at NCPRE

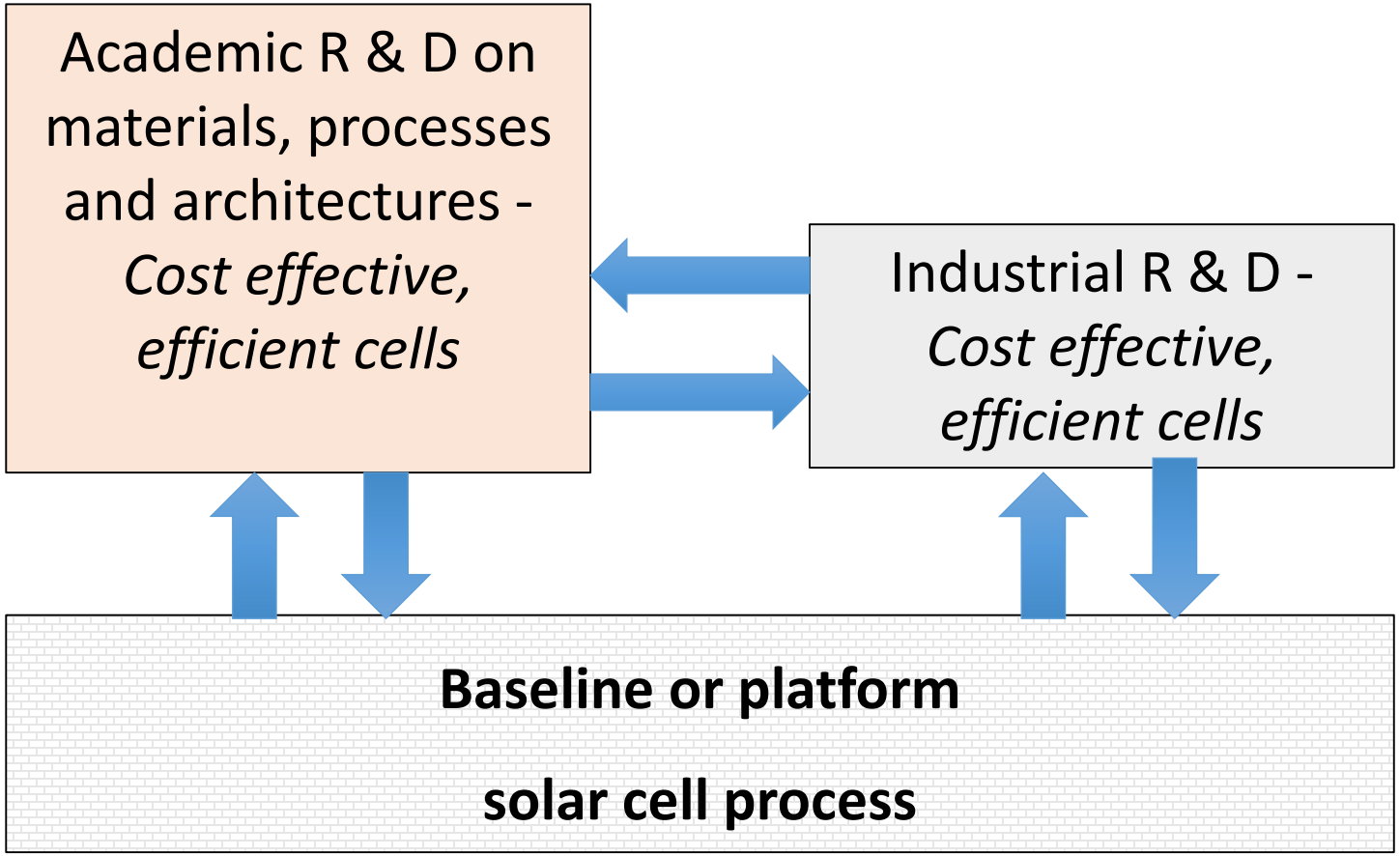
NCPRE

NATIONAL CENTRE FOR PHOTOVOLTAIC RESEARCH AND EDUCATION (NCPRE)

राष्ट्रीय प्रकाश वोल्टीय अनुसंधान एवं शिक्षा केन्द्र

-Supported by Ministry of New and Renewable Energy, Government of India

c-Si research objectives @ NCPRE



NCPRE Fabrication Lab

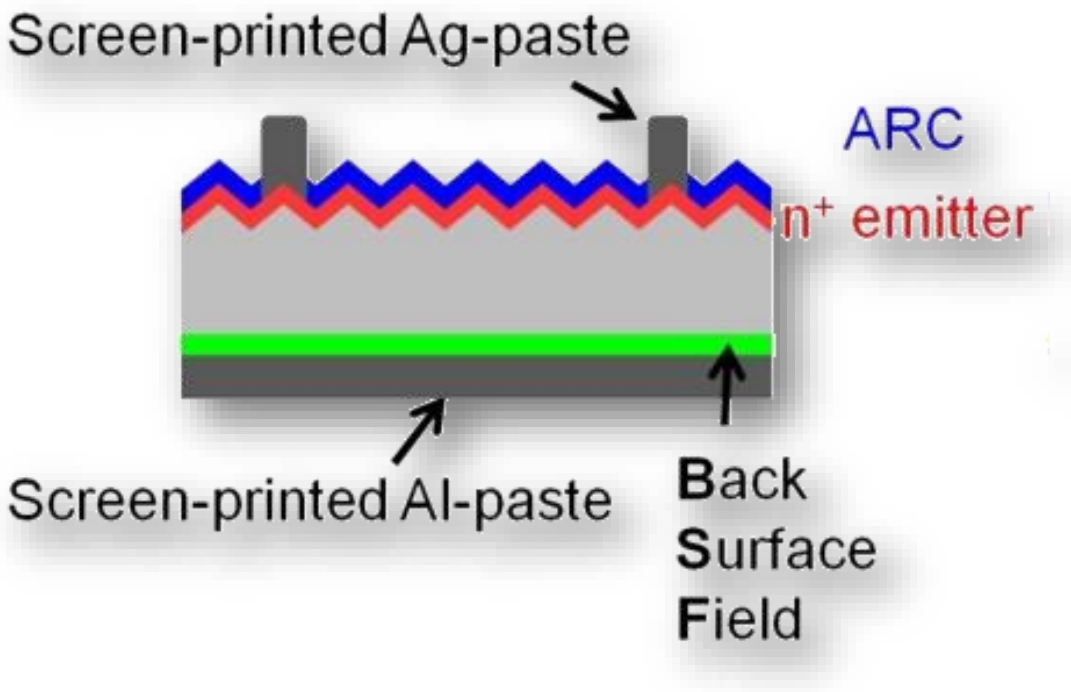
Fabrication Lab Corridor

Clean Room

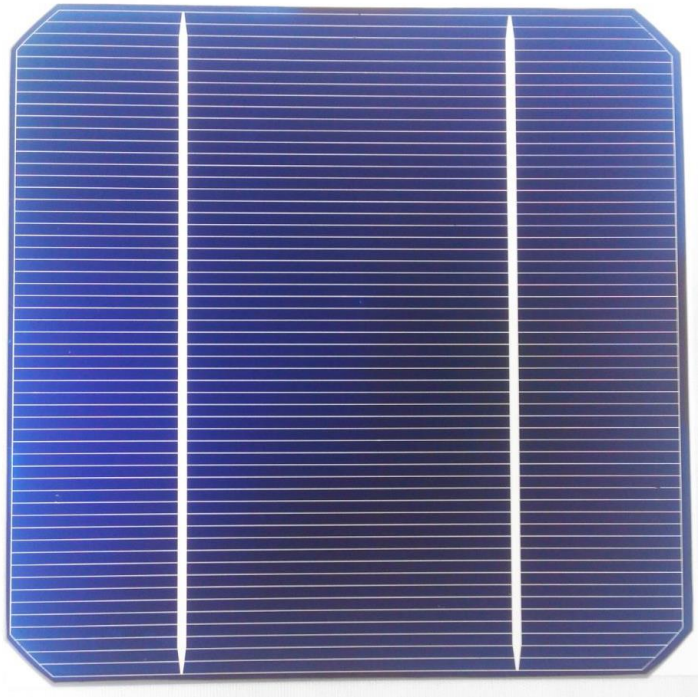
NCPRE Opto-electrical Characterization Lab

Solar Cells made at NCPRE

Structure of Al-BSF solar Cell

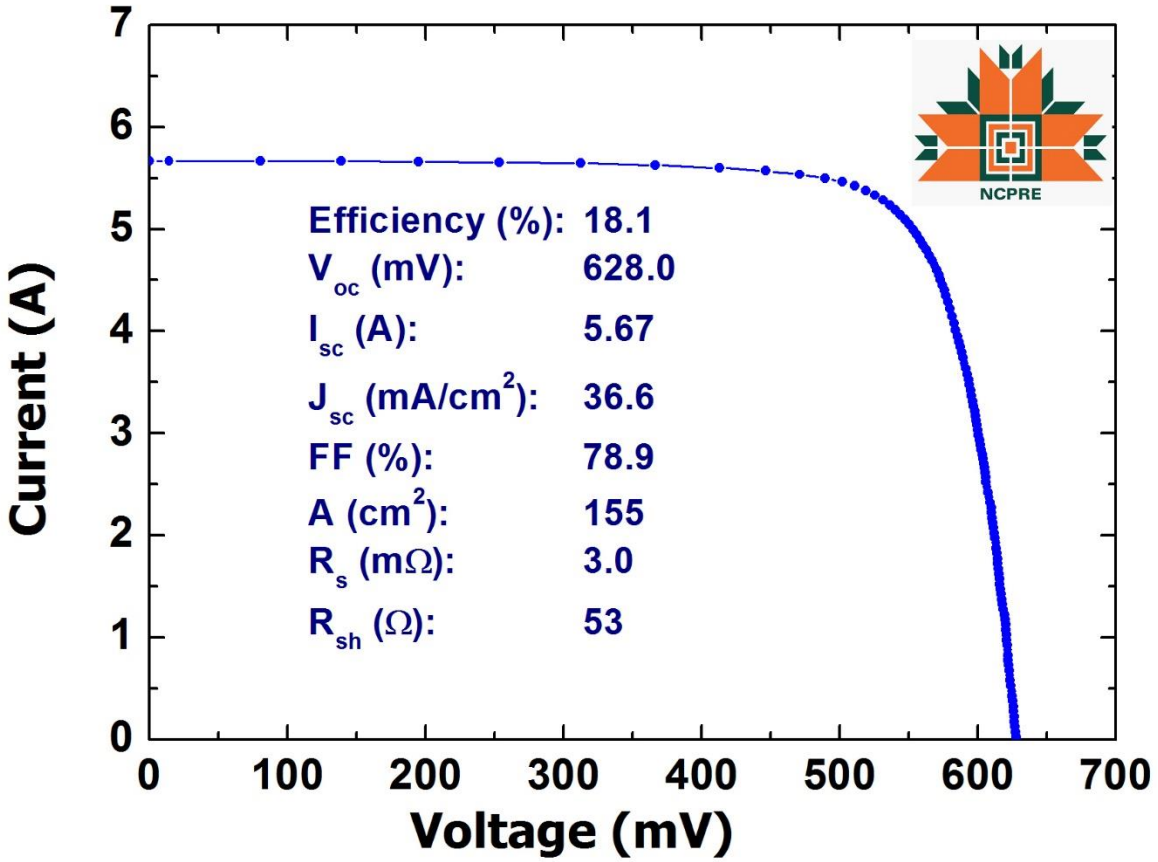


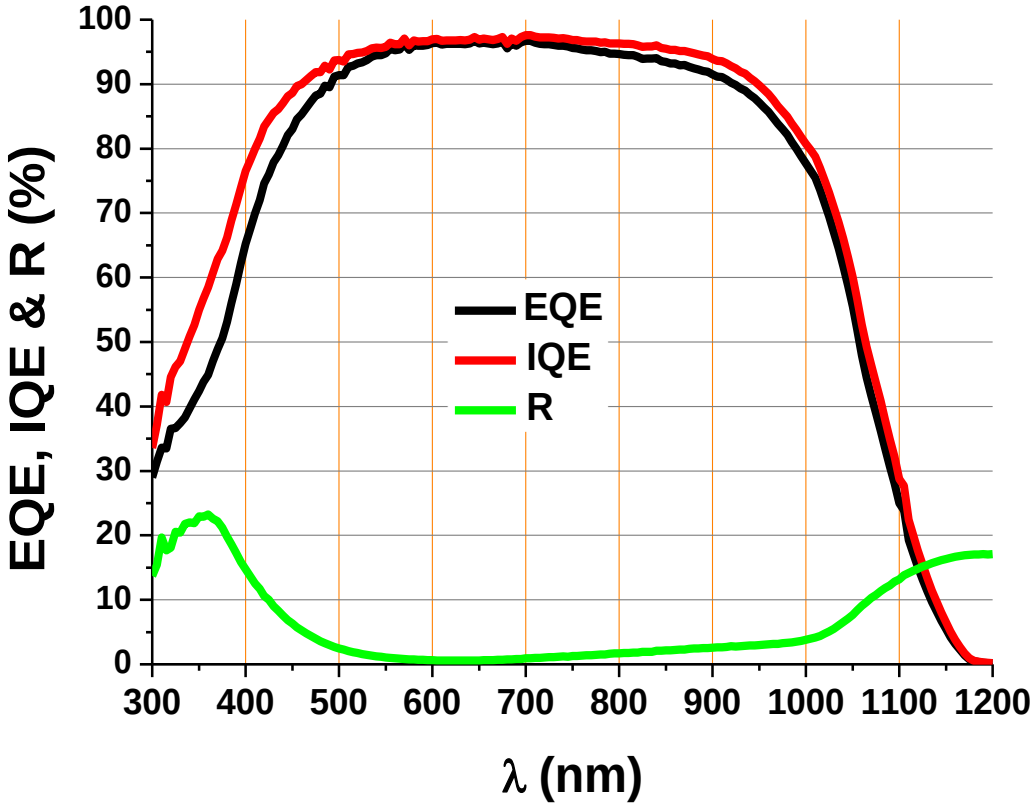
Top side



Rear side

Solar Cells made at NCPRE





NCPRE Al-BSF Process

	Process Flow	Fabrication Tools	Characterization Tools
1	Saw Damage Removal	Wet Bench	Zeta 3D Microscope
2	Alkali Texturization	Texturization Wet Bench	Zeta 3D Microscope, SEM, UV-Vis-NIR Spectrometer
3	Diffusion	Diffusion Furnace	SAN Four Probe, ECV Dopant Profiler*
4	PSG Removal & Thermal oxidation	Wet bench, Oxidation furnace	
5	Anti Reflective Coating	Plasma Enhanced Chemical Vapor Deposition (PECVD)	UV- Vis- NIR Spectrometer, Ellipsometer*
6	Plasma Edge Isolation	Reactive Plasma Etcher	
7	Contact Printing	Screen Printer & Drying Oven	Zeta 3D Microscope
8	Co-firing	Rapid Thermal Processing (RTP)	Zeta 3D Microscope

Sinton Lifetime Tester (up to contact printing), Photoluminescence

* Under the process of procurement

Post Cell Fabrication Characterization, Modeling and Special Characterizations

Electrical and optical characterizations:

- Dark & Illuminated Current Voltage
- Quantum Efficiency
- Electroluminescence (EL)
- Light Beam Induced Current (LBIC) *
- Lock-in Thermography*

Modeling:

- Sentaurus TCAD
- Griddler
- PC1D

Loss analysis:

- Loss analysis to quantify different types of losses for targeted process optimization

Special Characterizations:

- TEM, XPS, UPS, XRD, ICP-MS, ICP-AES, EDAX, FTIR, Raman Spectroscopy

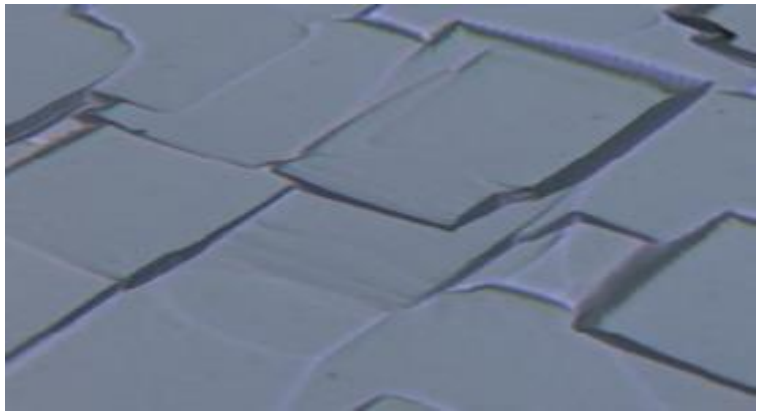
*Under procurement

Saw Damage Removal (SDR)

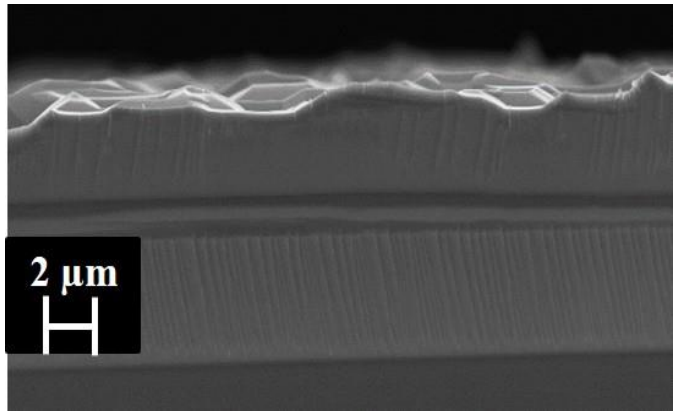
SDR Wet Bench $

$ New one under procurement

Zeta 3 D (Zeta-20) Microscope



Scanning Electron Microscope (SEM) (EVO 18 Carl Zeiss with EDX)

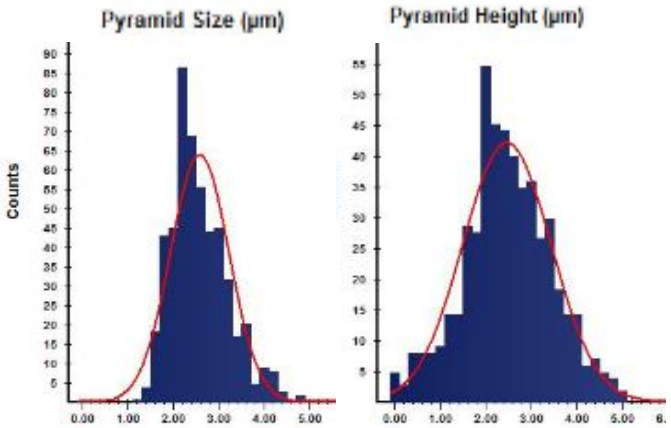


Alkali Texturization

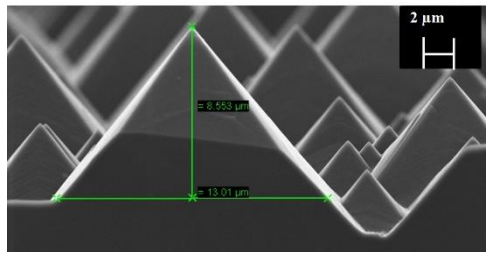
Wet Benches $

$ New one under procurement

Zeta 3 D Microscope

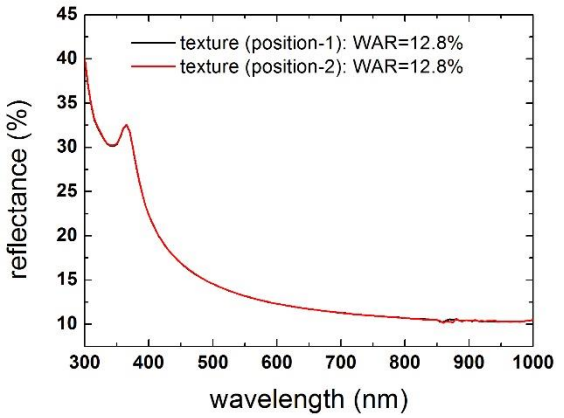


SEM



Elem-ents	At. concentration (%)	
	Existing process	Modified process
Na	0.21	0.04
K	0.05	0.00
Cl	0.17	0.08

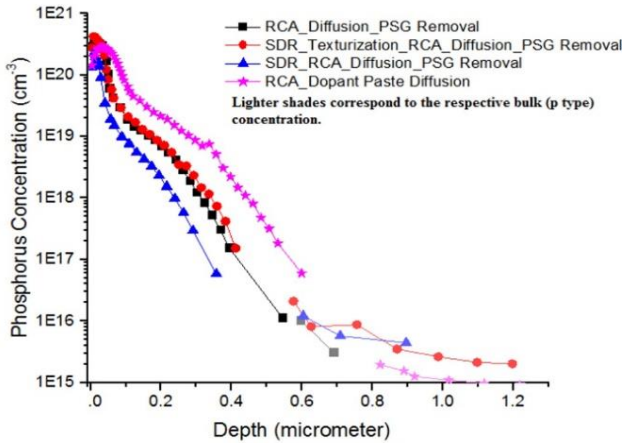
UV-Vis NIR Spectrometer (Lambda 950 Perkin Elmer)



Diffusion

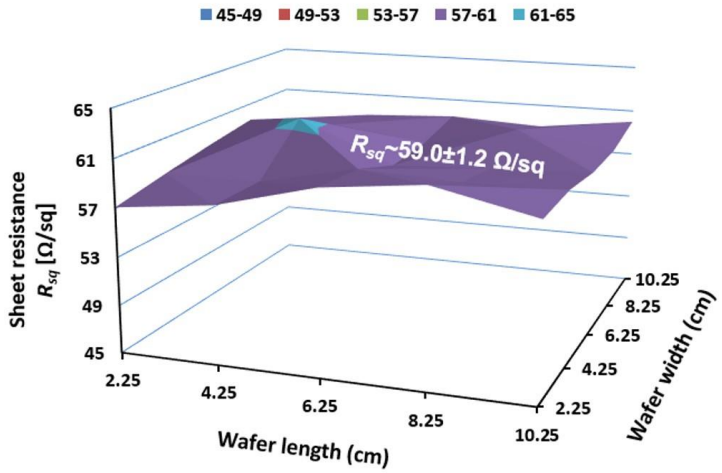
Diffusion Furnace (ProTemp)

*ECV Profiler **



ECV measurement done on NCPRE sample by potential supplier.

Four Probe System (Keithley system with Jandel probe)



*** Under the process of procurement.**

PSG Removal & Oxidation

Wet Bench

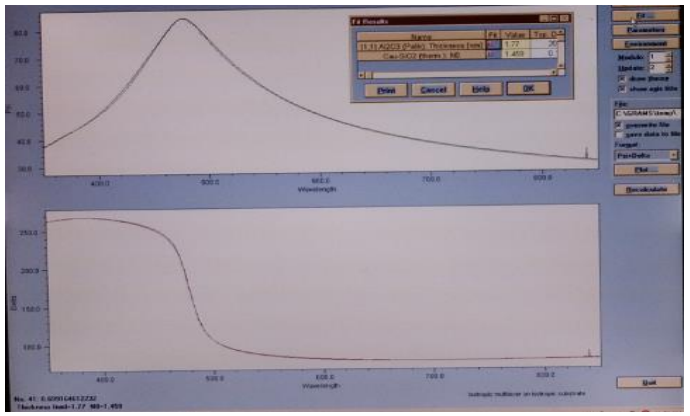
Oxidation Furnace (ProTemp)

Anti Reflective Coating

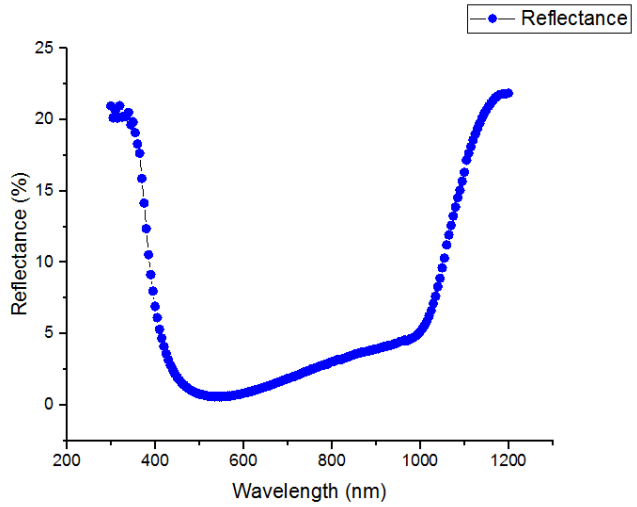
PECVD System$ (PlasmaLab 100, Oxford Instr.)

$ New one under procurement

*Ellipsometer **



UV VIS NIR Spectrometer

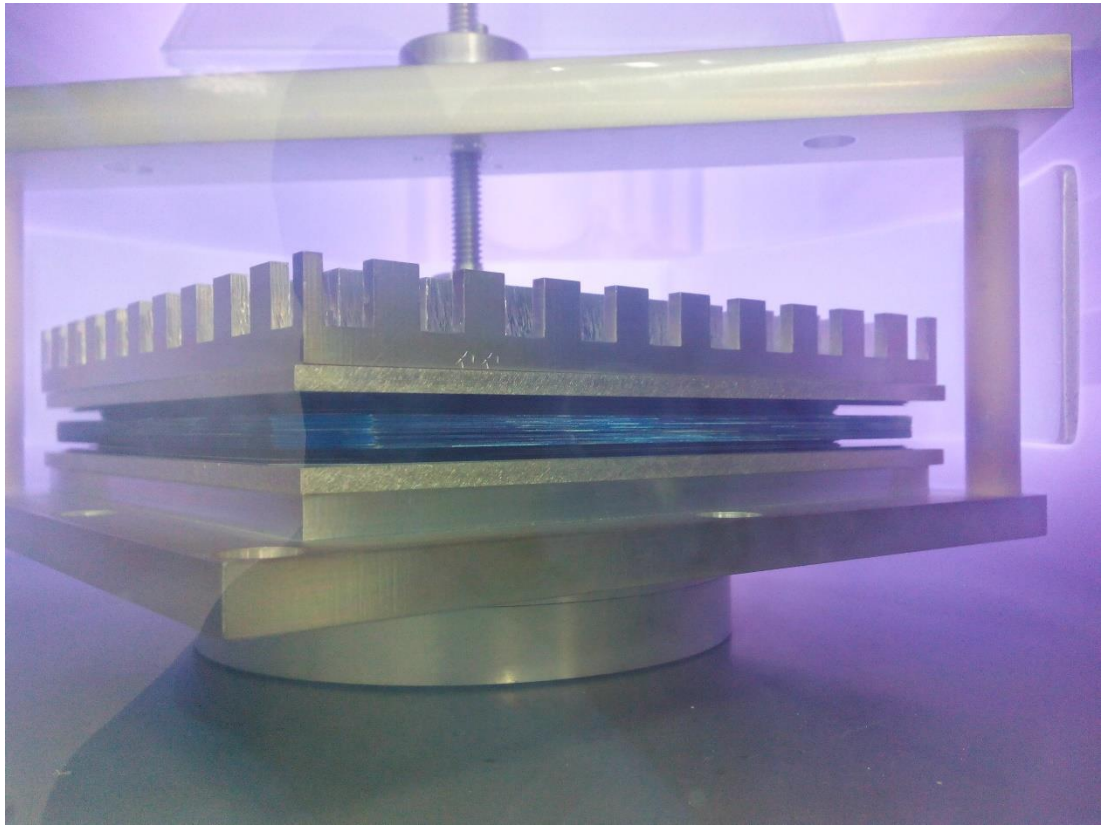


* Under the process of procurement for textured samples.

Plasma Edge Isolation

Reactive Plasma Etcher ¶
(NT-2, BEST EQ)

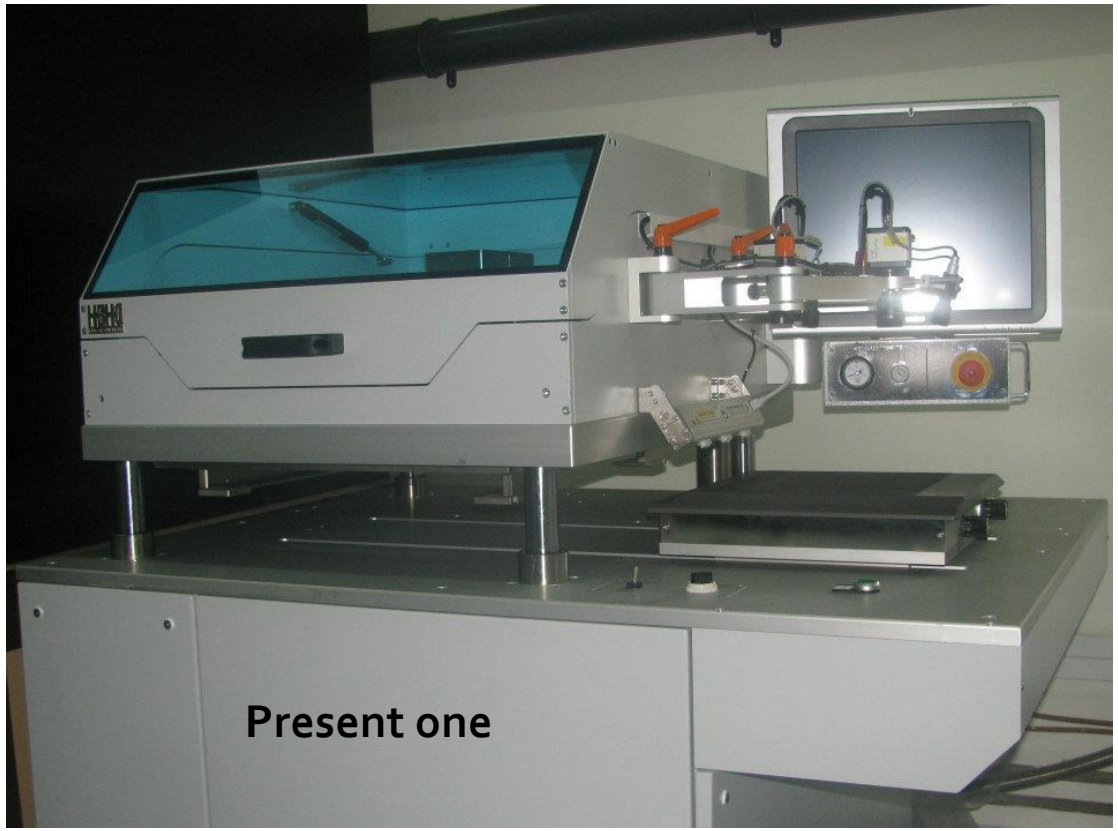
Coin stack arrangement of cells inside the system



¶ alternate chemical process under planning

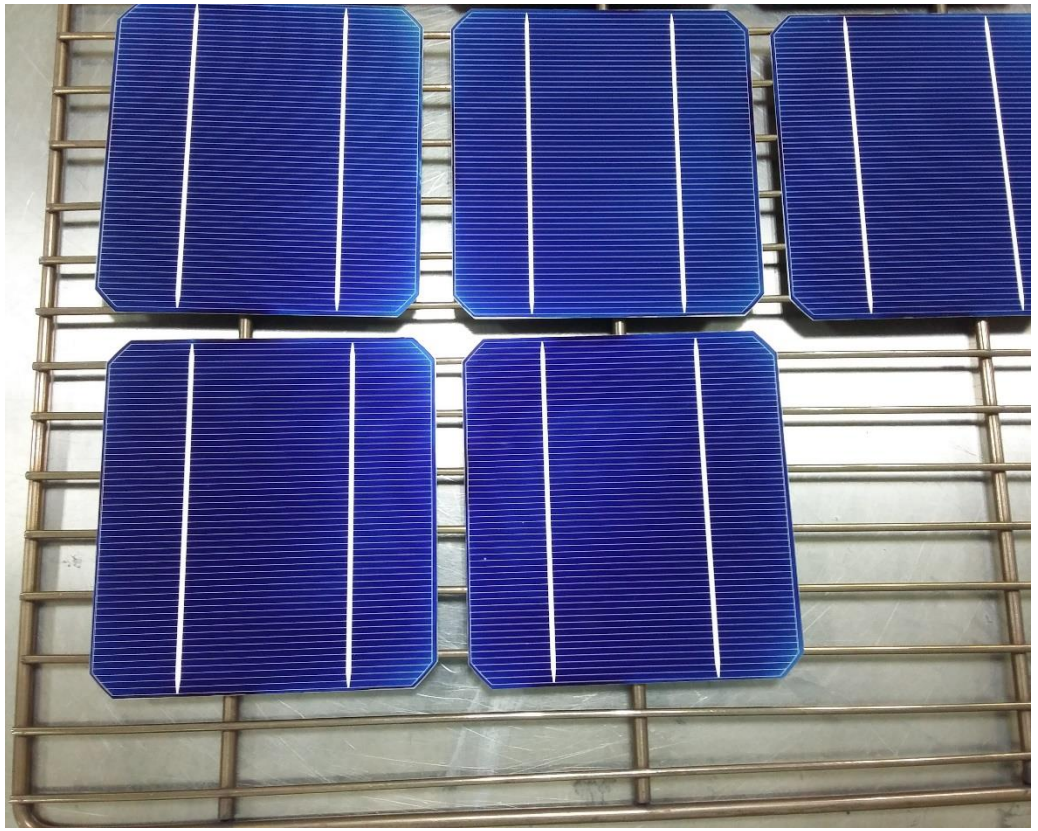
Contact Printing

Screen Printer$ (P-200S, Haikutech, Netherlands)



$ New one under procurement

Top Contact Printed Wafers

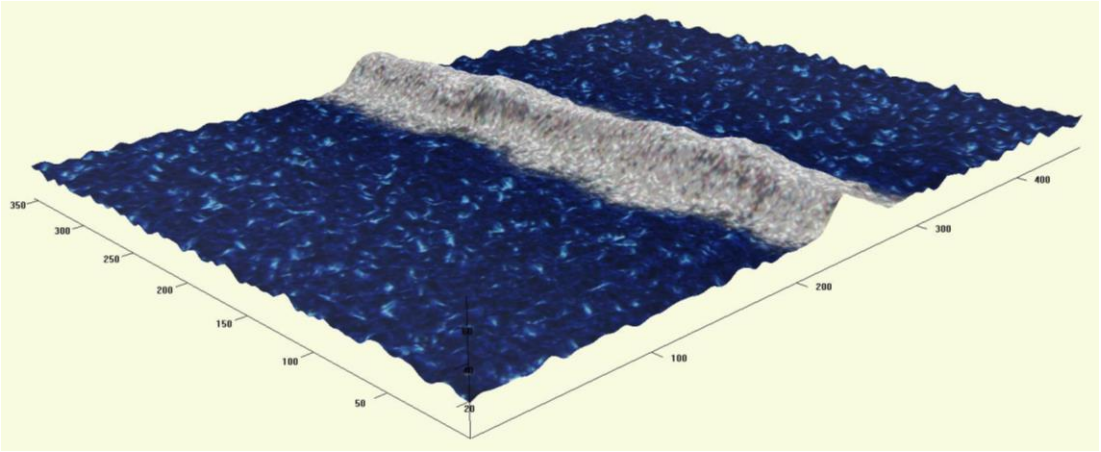


Co- firing

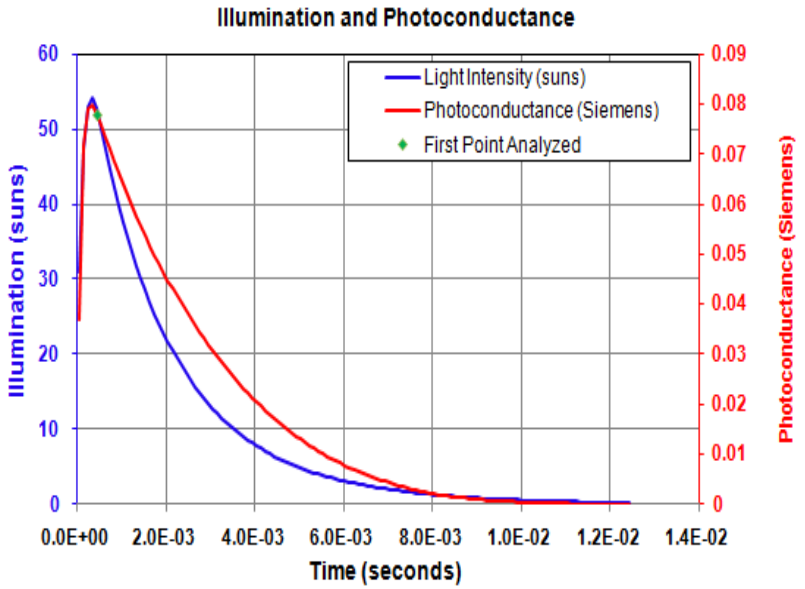
Rapid Thermal Processing Tool $ (AW 610, Allwyn21 Crop)

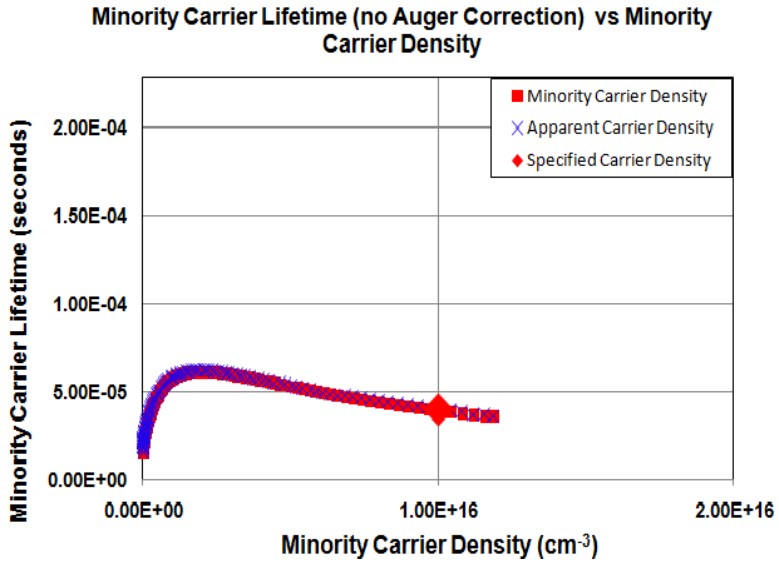
$ New belt furnace under procurement

Zeta 3 D Microscope

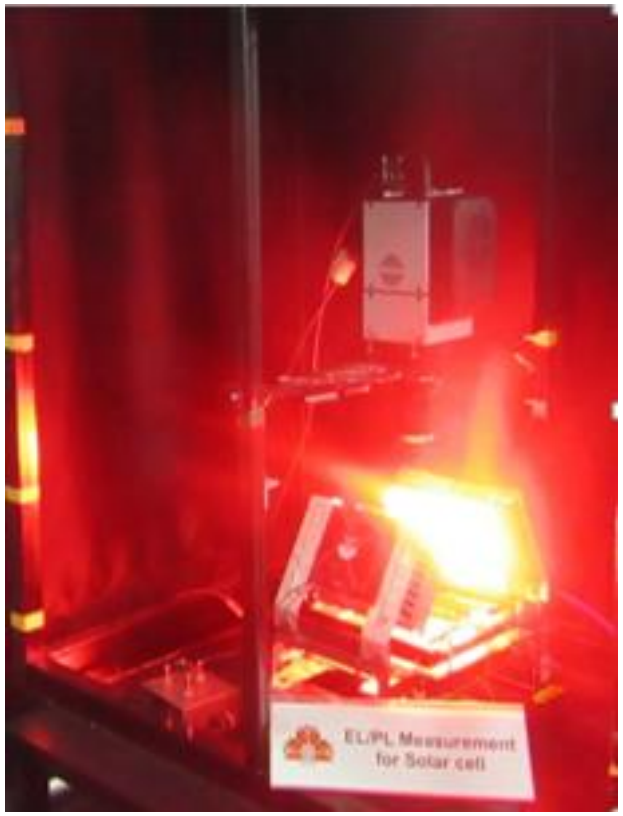


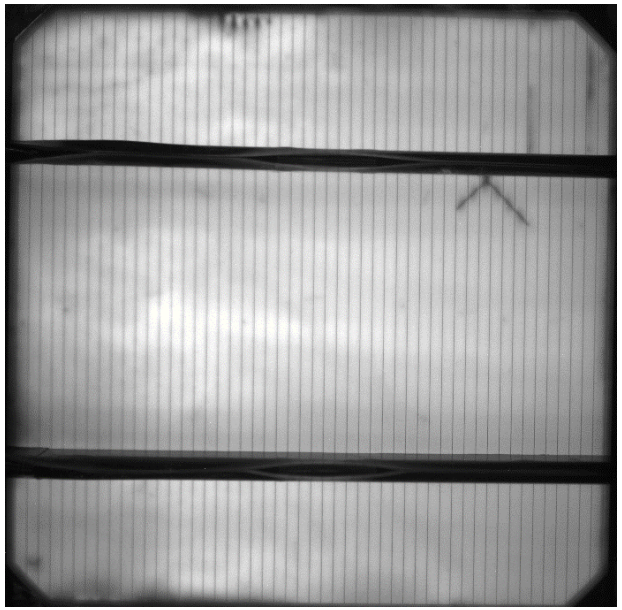
Other In-line characterizations during fabrication – Lifetime Tester (Sinton WCT-120)

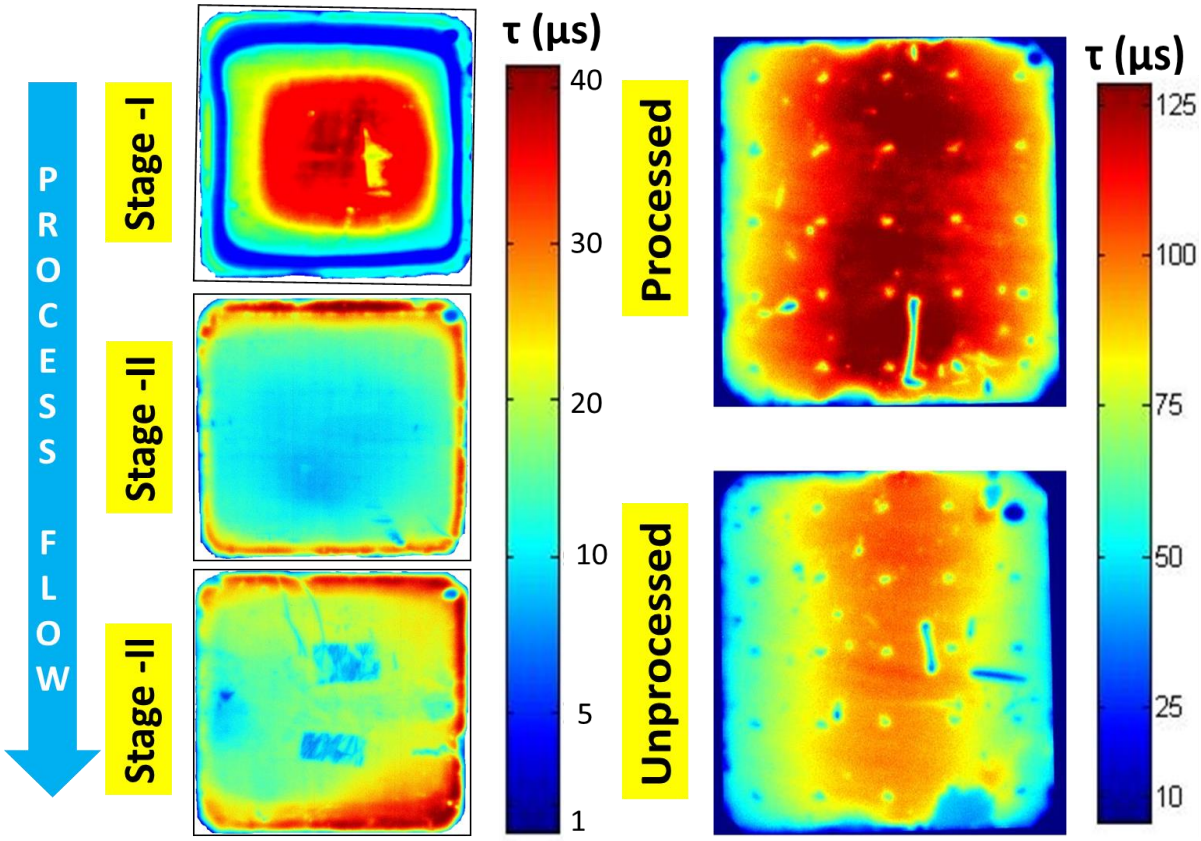




Other In-line characterizations during fabrication- Photoluminescence (Developed at NCPRE)

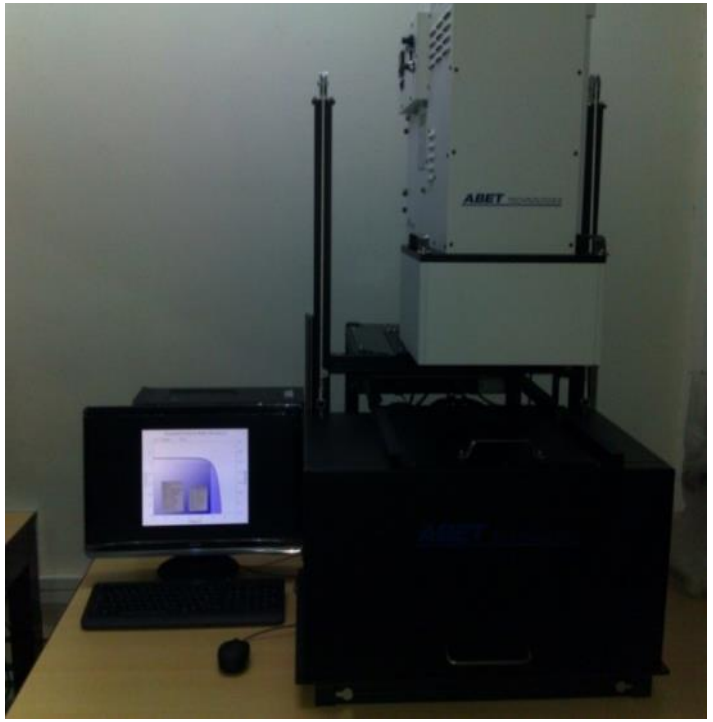






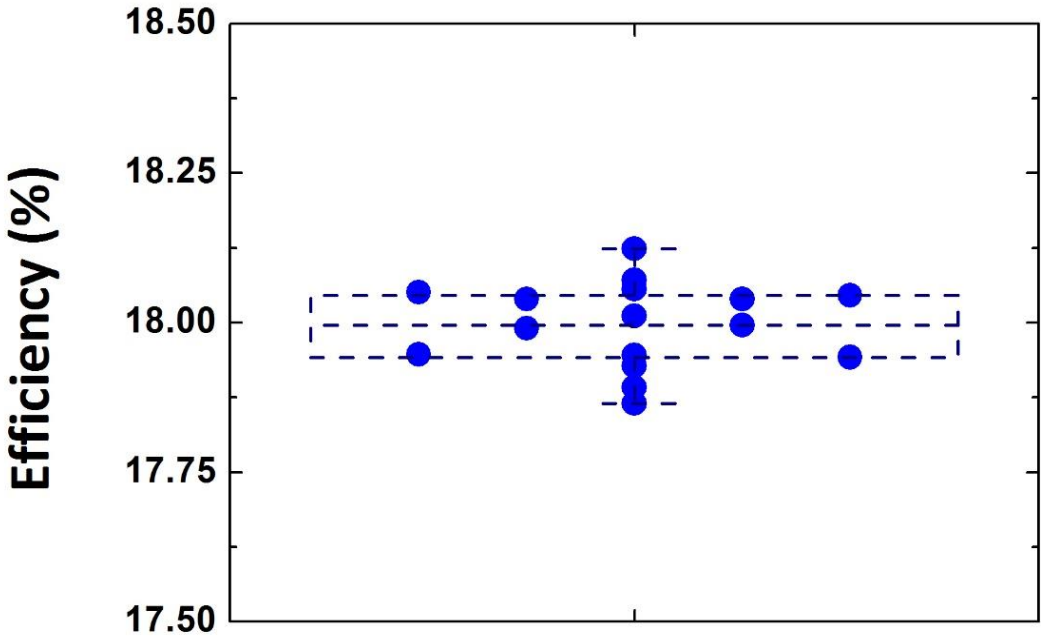
Post Cell Characterization – Current – Voltage Measurements

Class AAA Solar Simulator (SUN 3000, ABET Tech.)

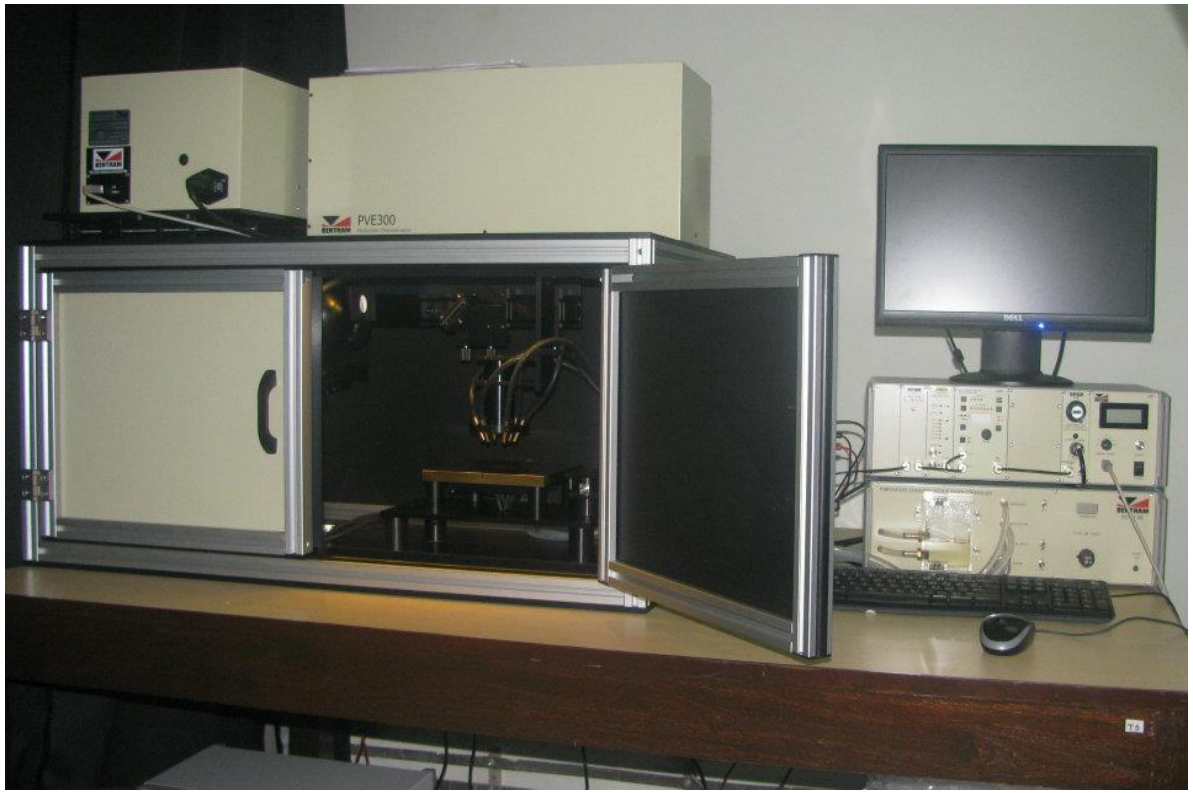


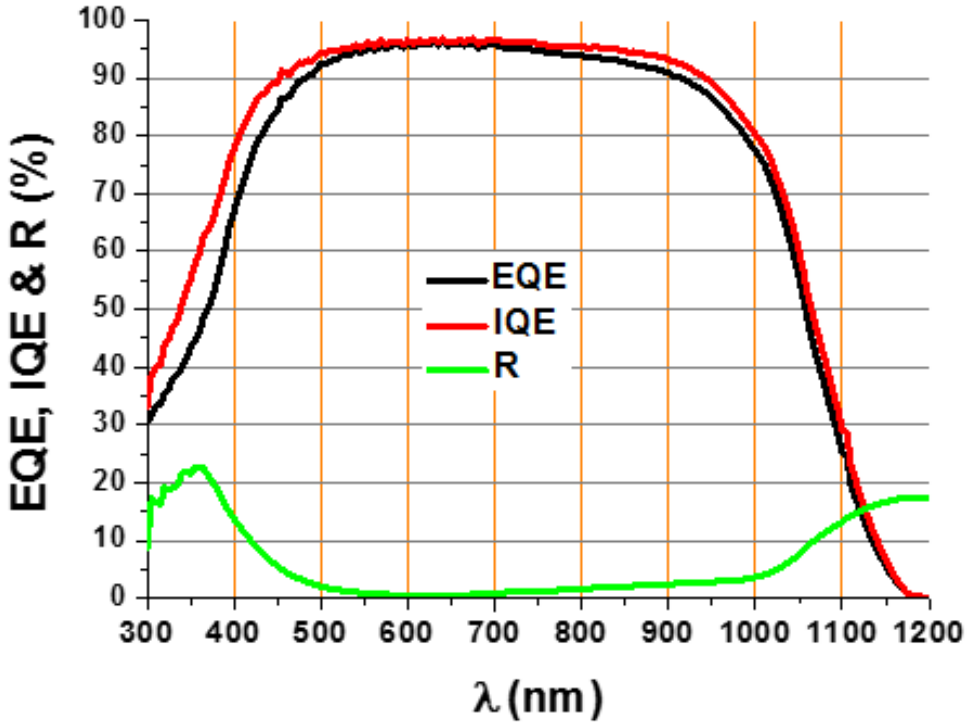
Sun's Voc Measurement (Sinton WCT-120)

Batch results_2017



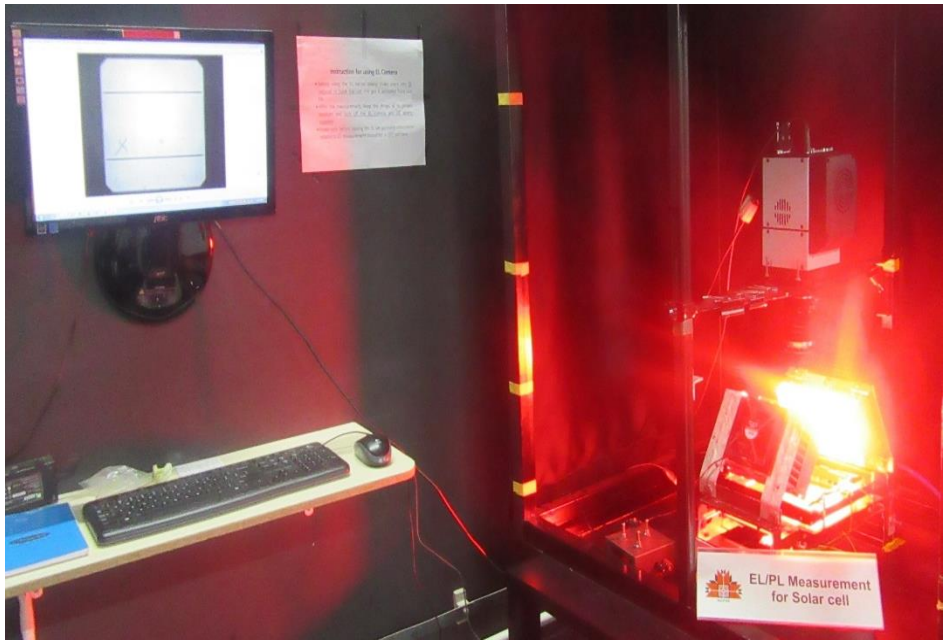
Post Cell Characterization – Quantum Efficiency Measurement (Bentham PVE 300)

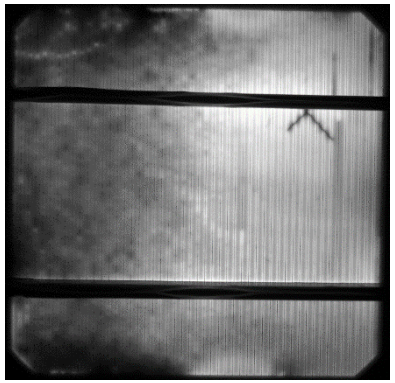


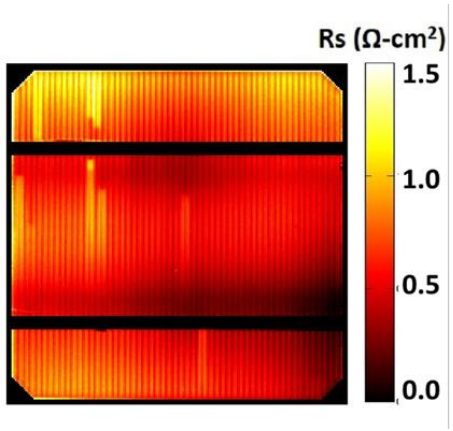


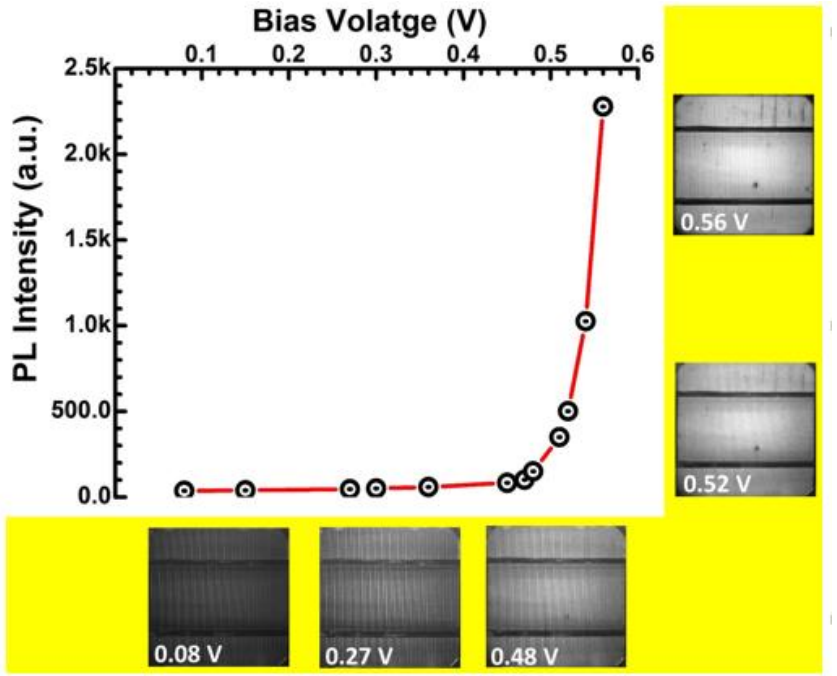
Post Cell Characterization – Electro and Photo Luminescence (Developed at NCPRE)

Luminescence Measurement Setup



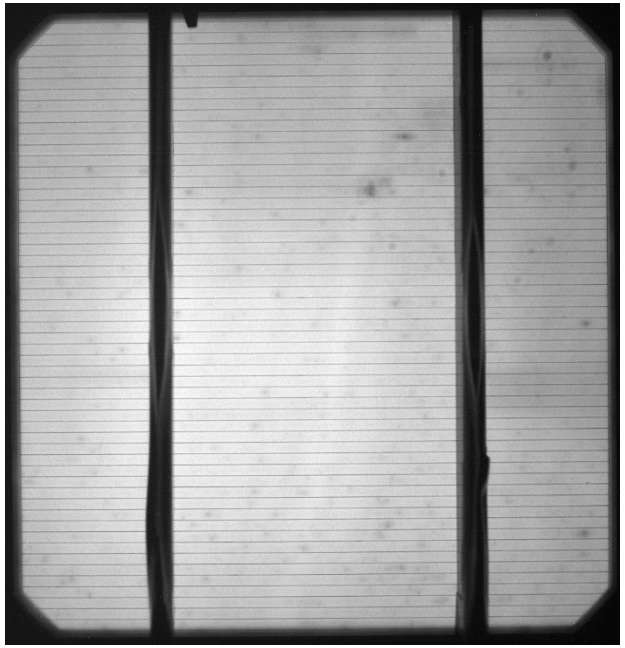




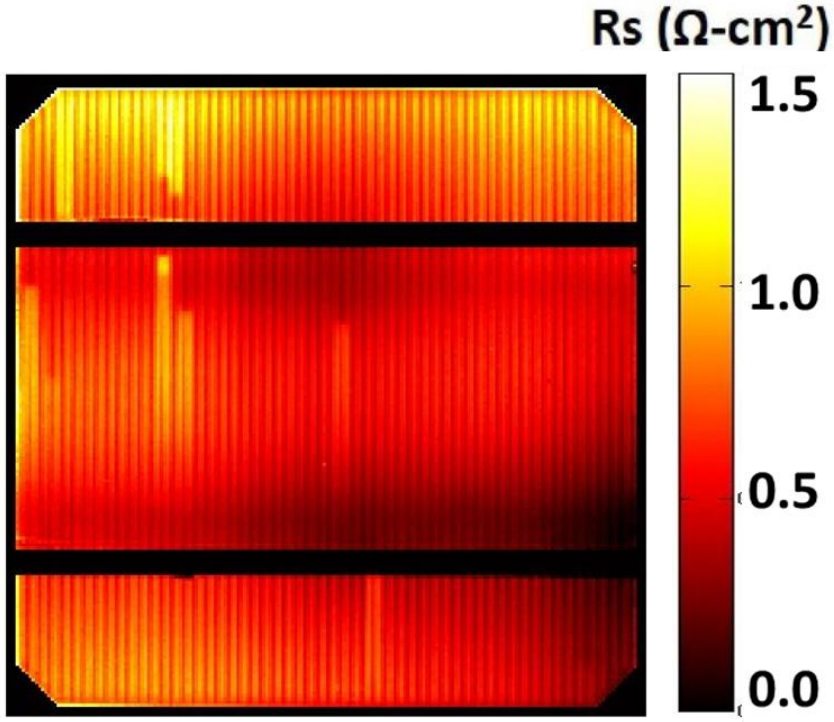


Post Cell Characterization – Luminescence contd..

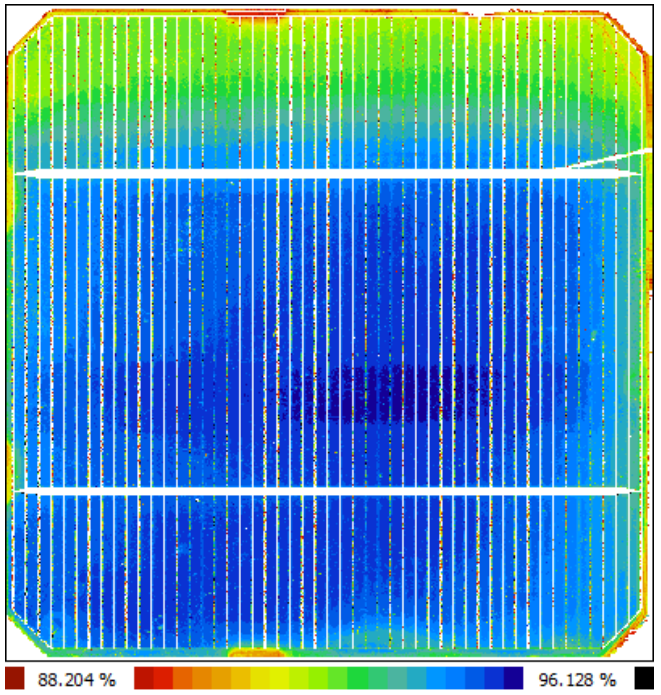
EL for shunt detection

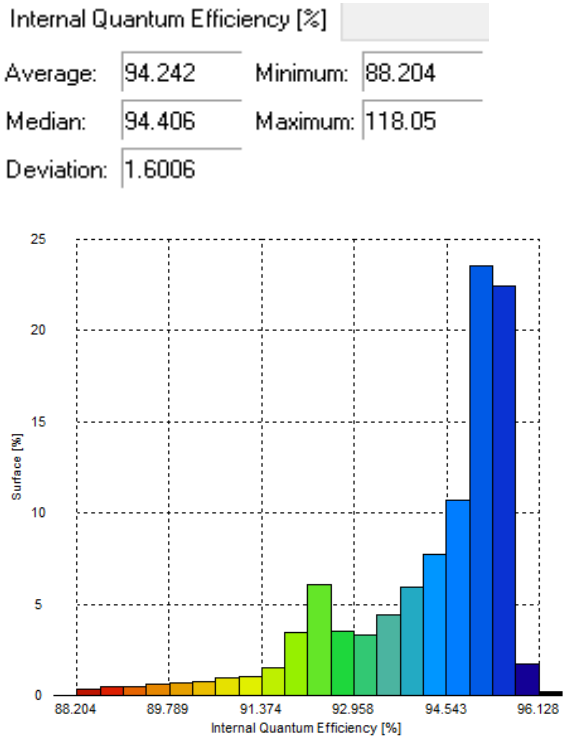


EL for series resistance detection



Post Cell Characterization – Light Bean Induced Current Measurements *

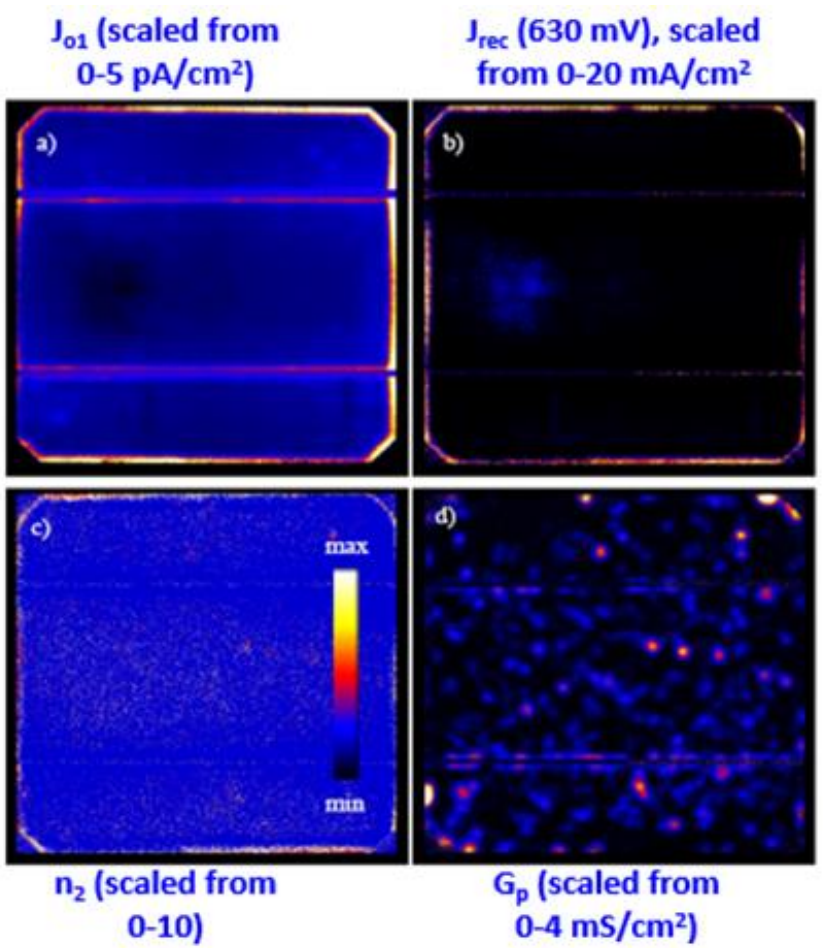


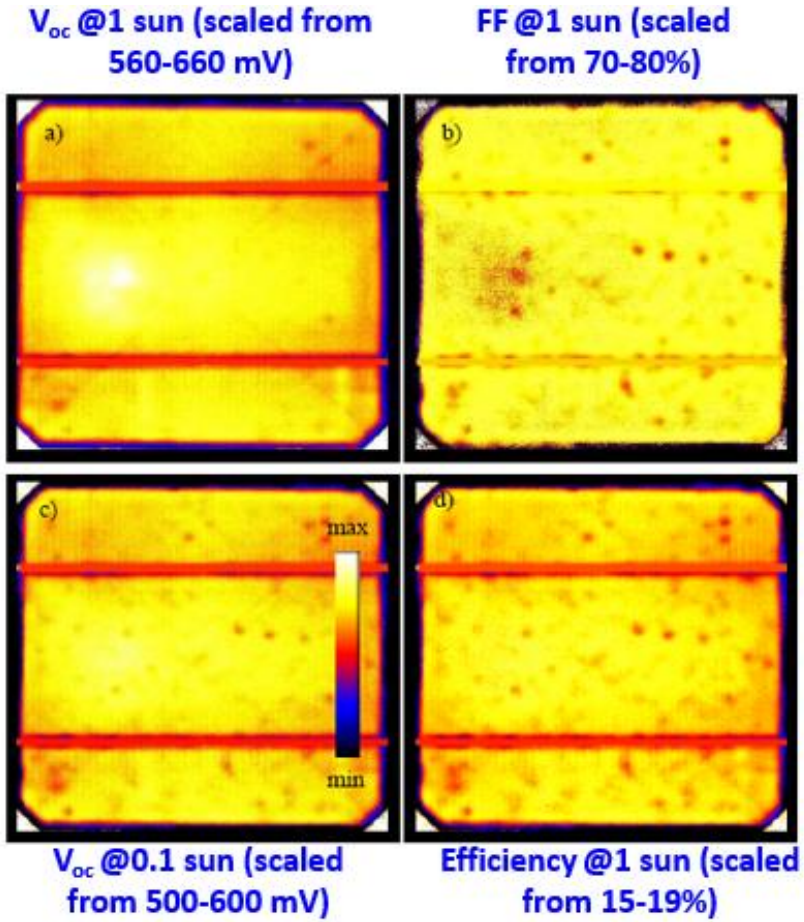


Measurement done on NCPRE sample by potential supplier.

* Under the process of procurement.

Post Cell Characterization – Lock In Thermography *



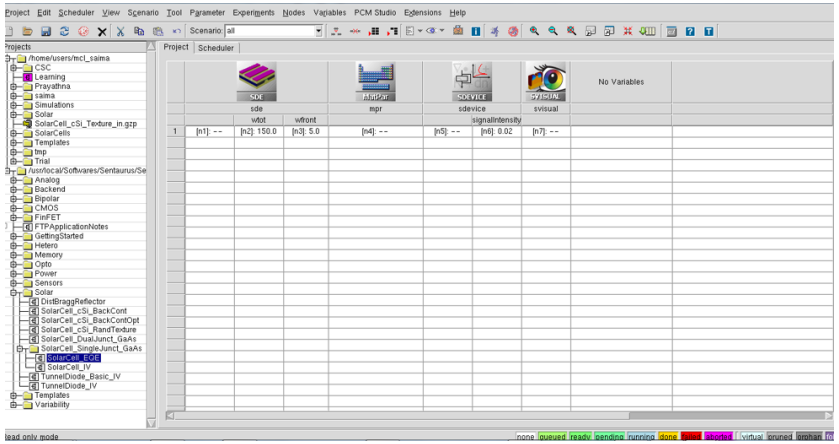


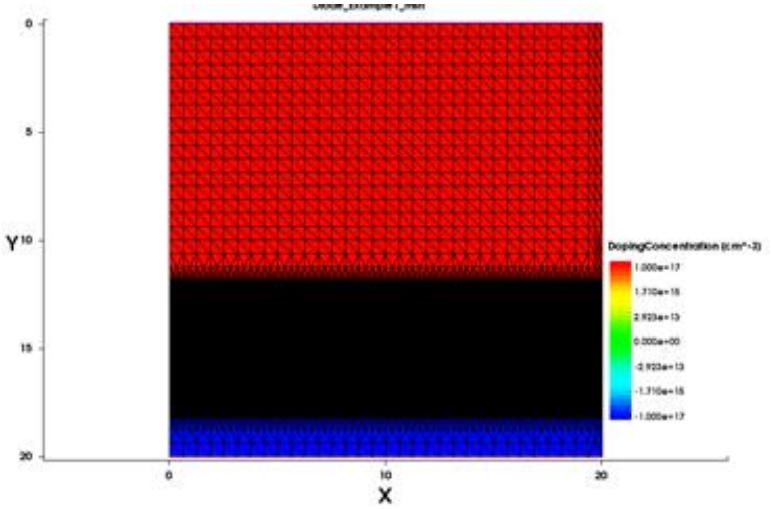
Measurement done on NCPRE sample by Dr. Breitenstein, MaxPlank Institute Halle, Germany

* Under the process of procurement.

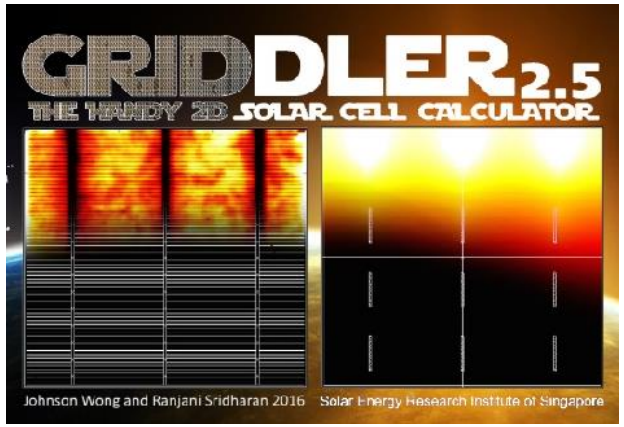
Modeling

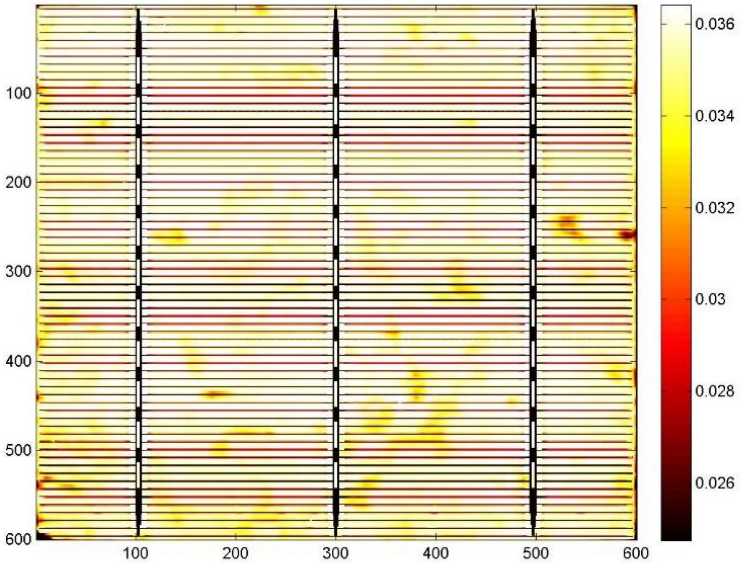
Sentaurus TCAD



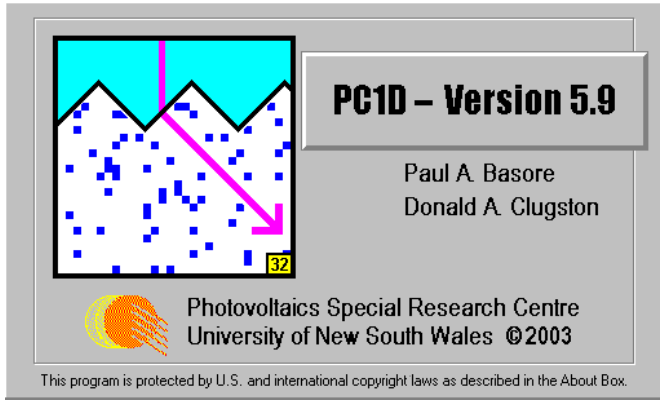


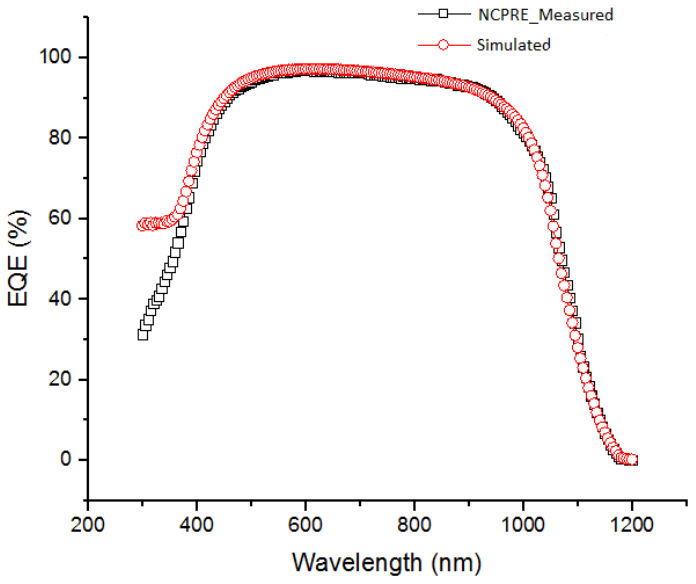
Griddler





PC 1D





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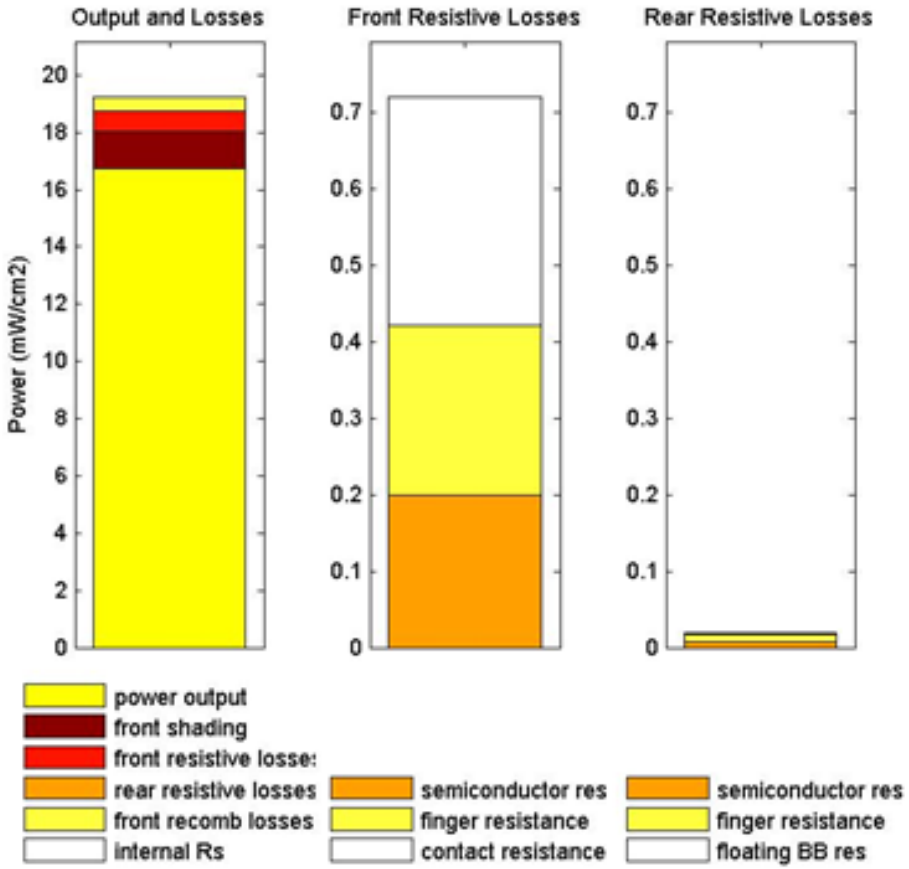
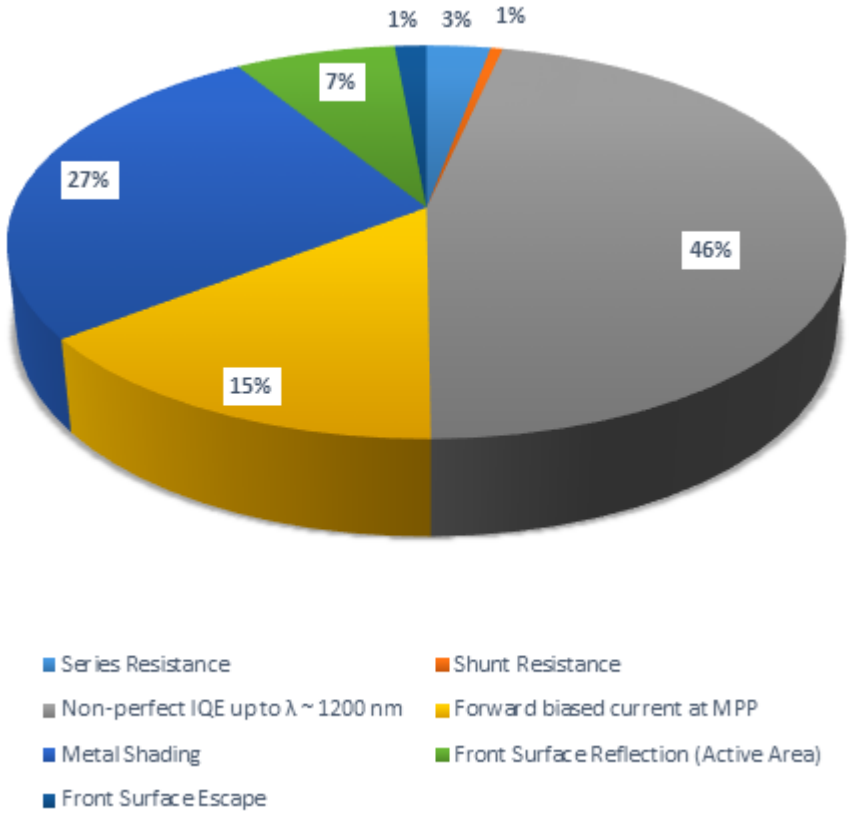
-Supported by Ministry of New and Renewable Energy, Government of India

Loss Analysis

Griddler



Analytical Power Loss Analysis



What can NCPRE offer the silicon PV cell manufacturers and supply chain?

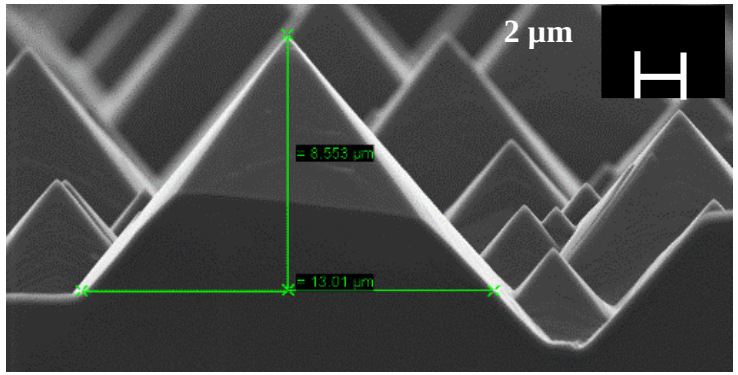
- **Process development**
  - Engagement with one cell manufacturer on advanced texturization
  - Engagement with an Indian chemical company for development of metallization
  - In discussions with two international players on junction technologies
- **Extensive wafer level characterization and analysis**
  - Engagements with 3 cell manufacturers in the country on loss analysis
- **Joint development of advanced cell technologies**
  - Phase 2 commitments
    - Al-BSF cells with copper front metallization
    - PERC cells with 20% efficiency
    - IBC cells with 22% efficiency
    - Carrier selective contact cells with 18% efficiency
- **Joint internship programs**
  - M. Tech students spent part of their time at cell manufacturer to pick up development and manufacturing related topics for co-development

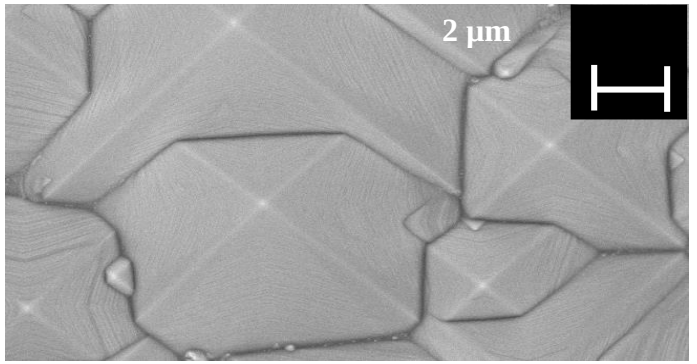
Technology Ready for Industrial Evaluation

IPA-free texturization process for monocrystalline Si wafers

Indian patent application number 201621039056

- A new industrial alkaline texturization process of mono-Si wafer by using an IPA-free commercial additive is developed
  - ✓ Clean SDR and pyramidal surfaces
  - ✓ Low WAR values
  - ✓ Good and uniform pyramid formation
  - ✓ The process permits repeated use of the SDR and neutralization solutions for multiple batches
  - ✓ Highly suitable as an industrial process with high throughput and low-cost involved





The Team

- **Faculty members: Prof. B. M. Arora, Prof. K. L. Narsimhan, Prof. Balasubramiam Kavaipatti, Prof. Saurabh Lodha, Prof. Manoj Neergat, Prof. Anil Kottantharayil**
- **Senior Research Staff: Dr. Prabir Basu, Dr. Ashok Sharma, Dr. Archana Sinha, Dr. Diksha Makwani**
- **Ph. D. Students: Amruta Joshi, Kalaivani, Tarun Yadav, Saima Cherukat, Dhiman Nag, Sreejith KP, Astha Tyagi, Suren Patwardhan, Divya Priyadarshini, Raja Sekhar Baddula**
- **M. Tech students: Pradeep Padmanabhan**
- **Research support staff: Sandeep Kumbhar, Abhishek Bhattacharya, Suchishmita Banerjee, Prashant Shinde, Guru Burkul**