Nanostructured Solar Energy Devices

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This program is a collaboration between

Condensed Matter Physics Laboratory

NIP – UP Diliman

- Dr. Arnel Salvador
- Dr. Roland Sarmago
- Dr. Armando Somintac

Ateneo de Manila University

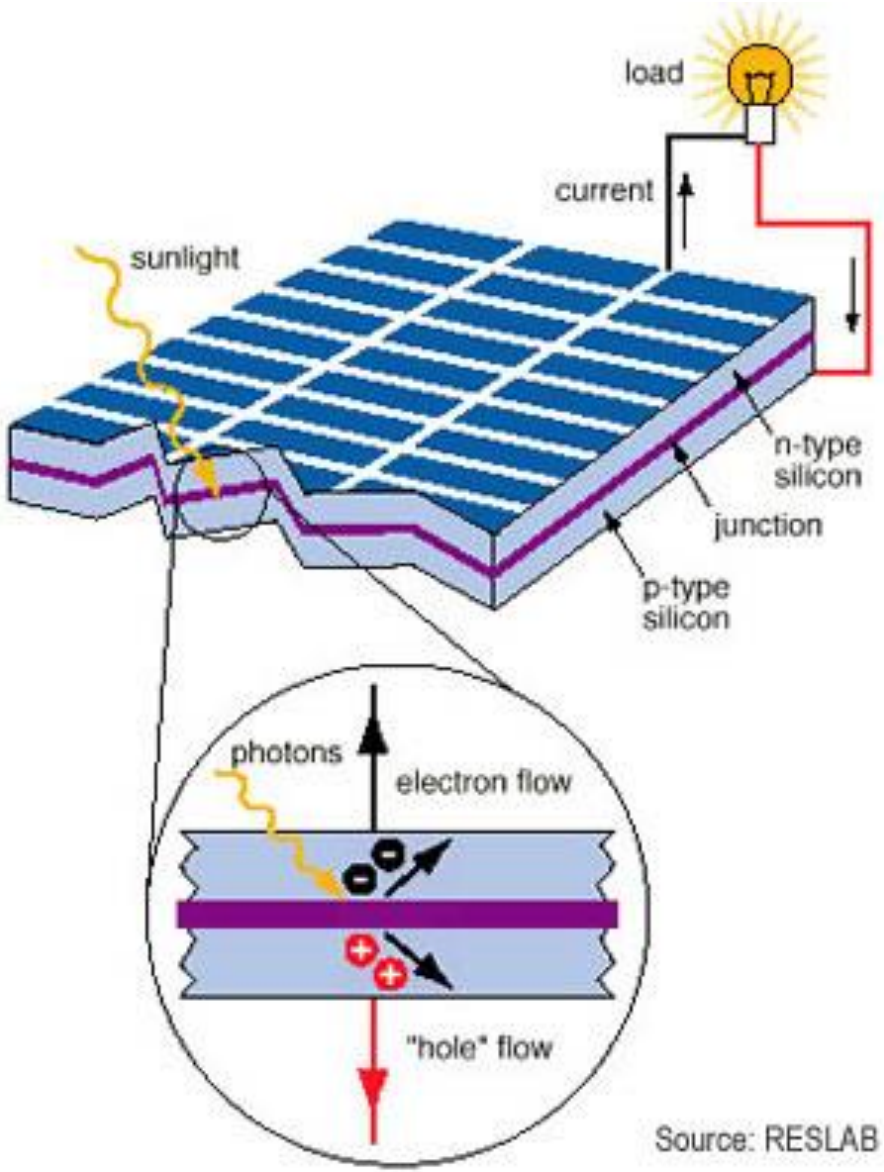
- Dr. Erwin Enriquez

The program addresses various aspects and issues which affect the performance of solid-state and dye-sensitized solar cells.

The Solar Cell

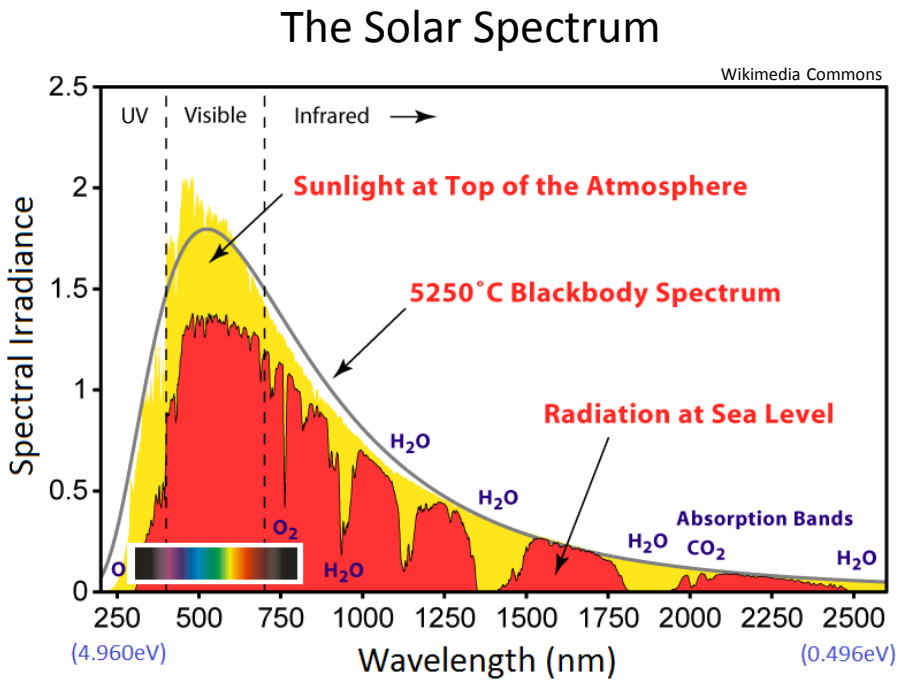
LIGHT → ENERGY

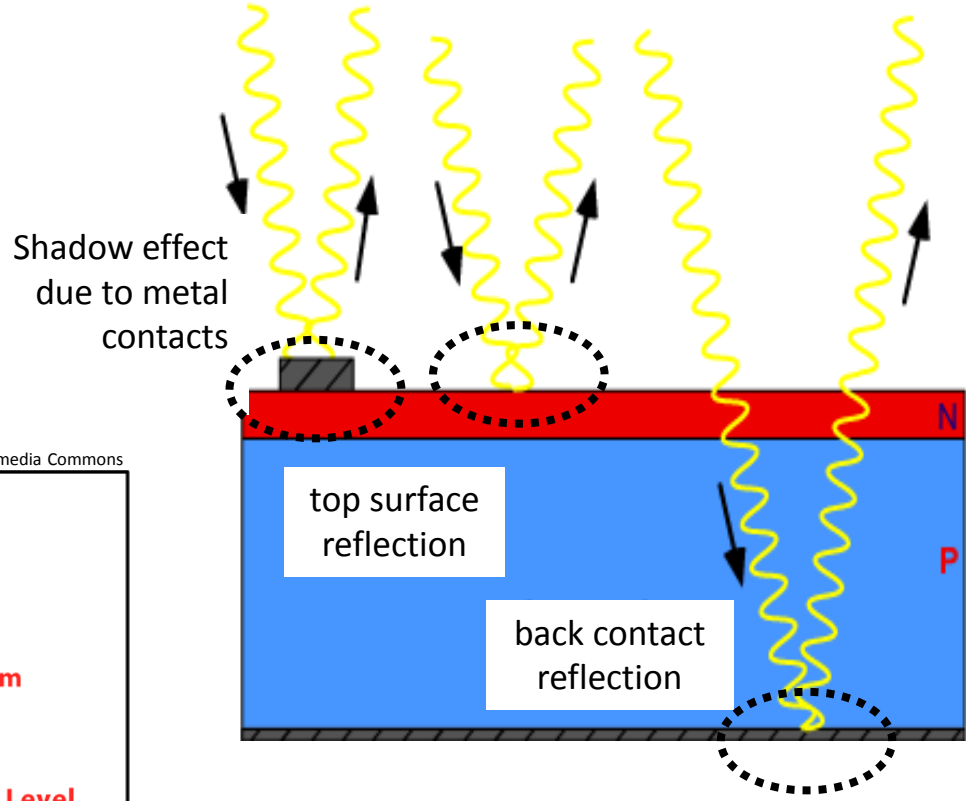
- Light induces the production of electron-hole pairs (charge carriers)
- Charge carriers flow to metal contacts and produce current



Issues on solar cell performance

- Reflection losses
- Shadow loss
- Collection efficiency





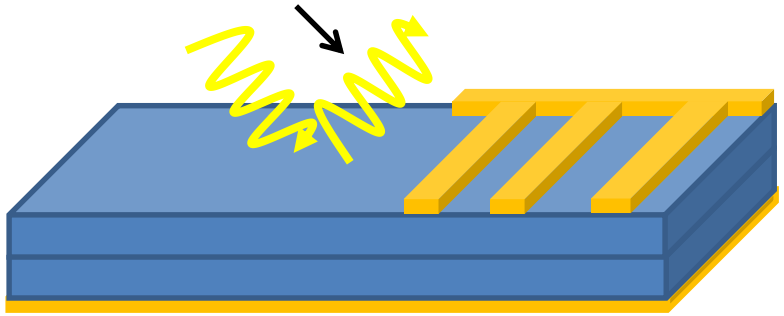
Reflection Losses

Inefficient light trapping due to reflection at the front surface

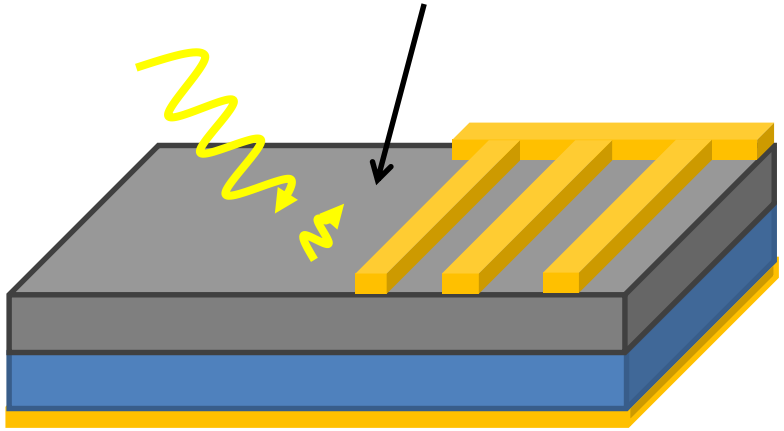
Solution:

- Surface modification (nanostructures)
- Anti-reflection coating (ARC)

Reflection loss account for roughly 30% of the optical loss in silicon solar cells

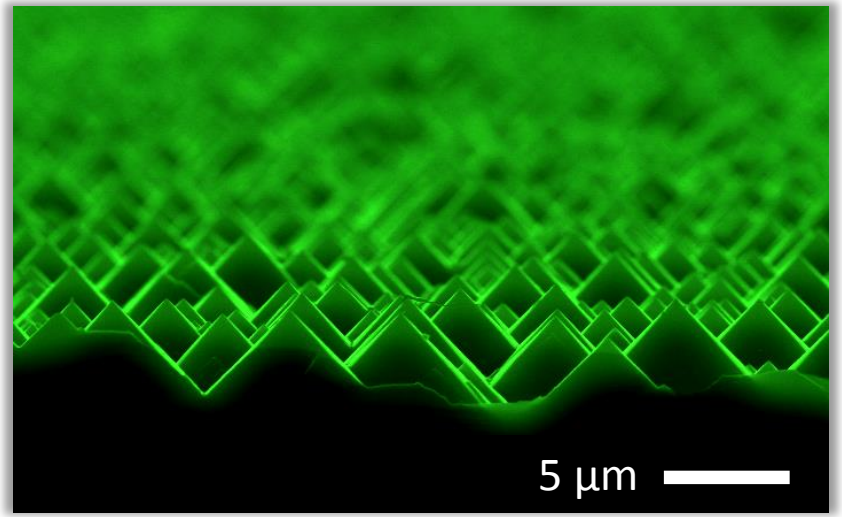


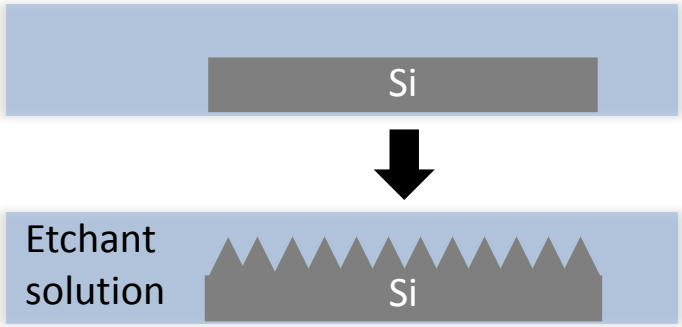
Anti-reflection coating and surface modification reduce the reflectance of silicon by 70-90%

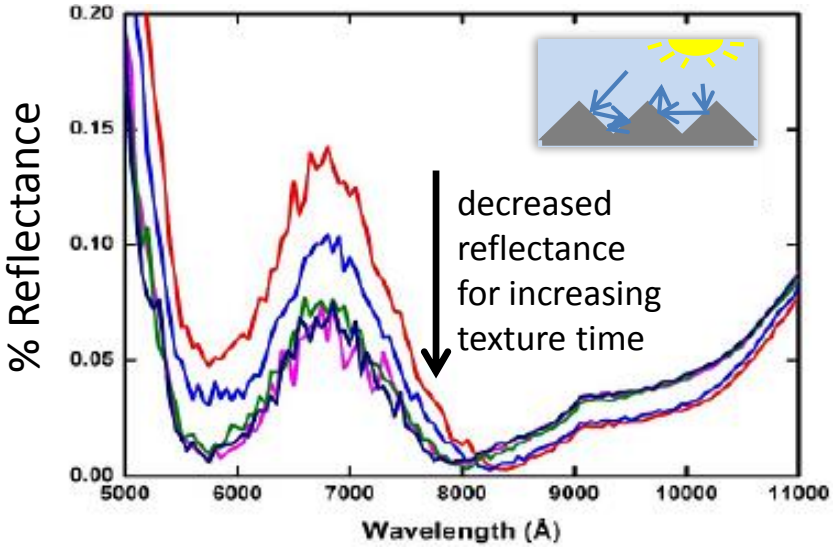


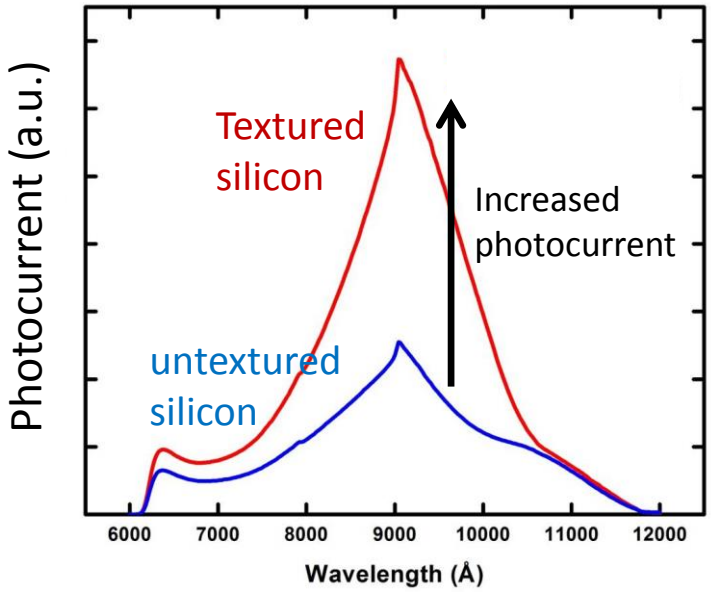
Nanostructures: Textured silicon

Silicon nanopyramids by chemical texturing



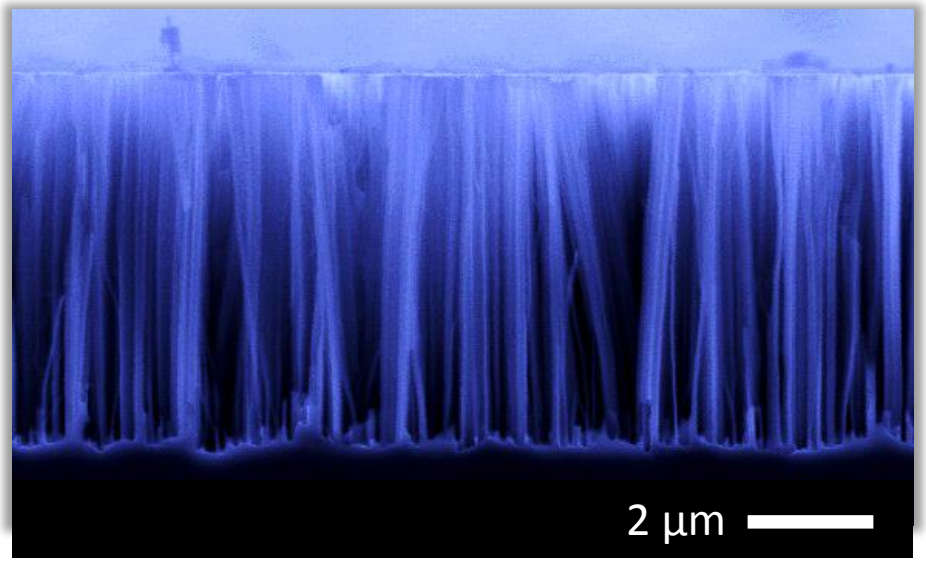


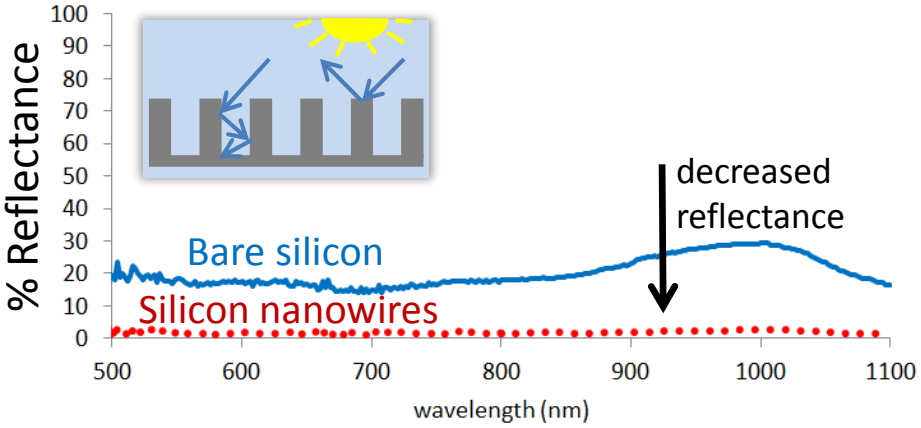


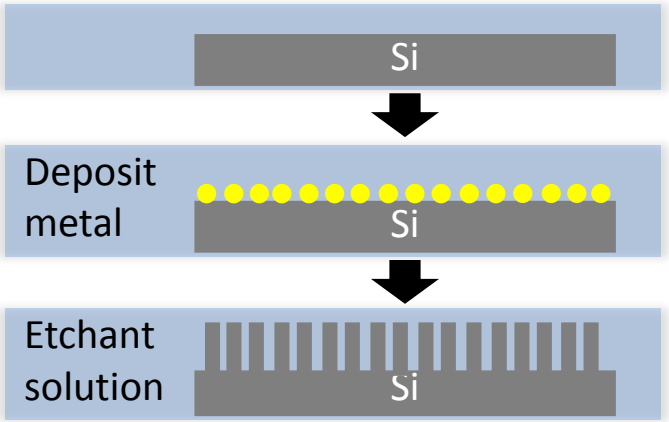


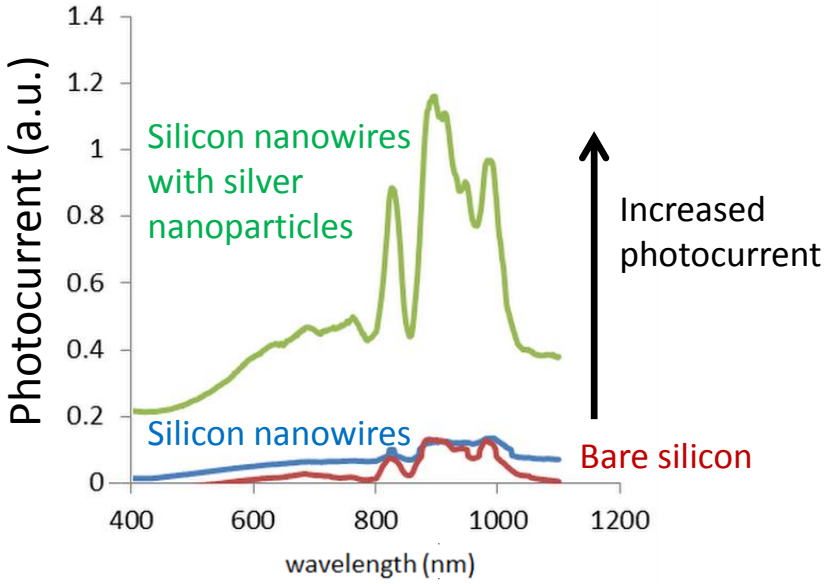
Nanostructures: Silicon nanowires

Silicon nanowires (SiNW)
by metal-assisted electroless etching



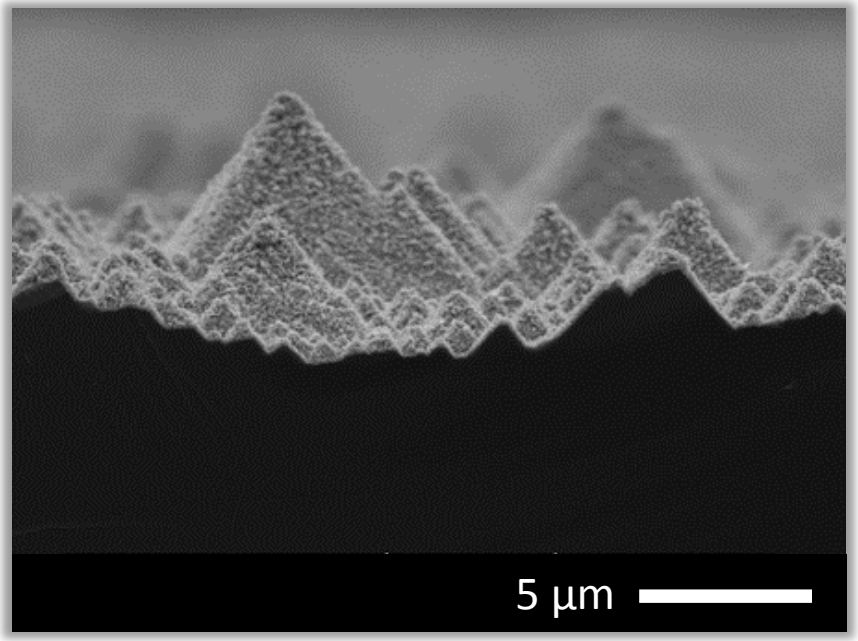


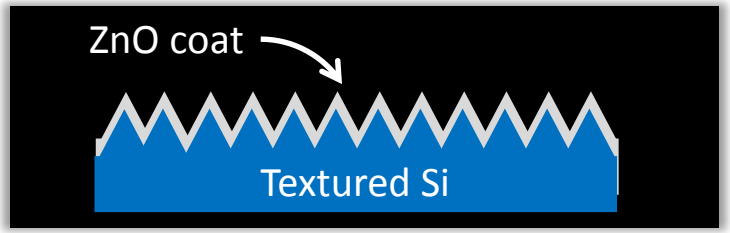


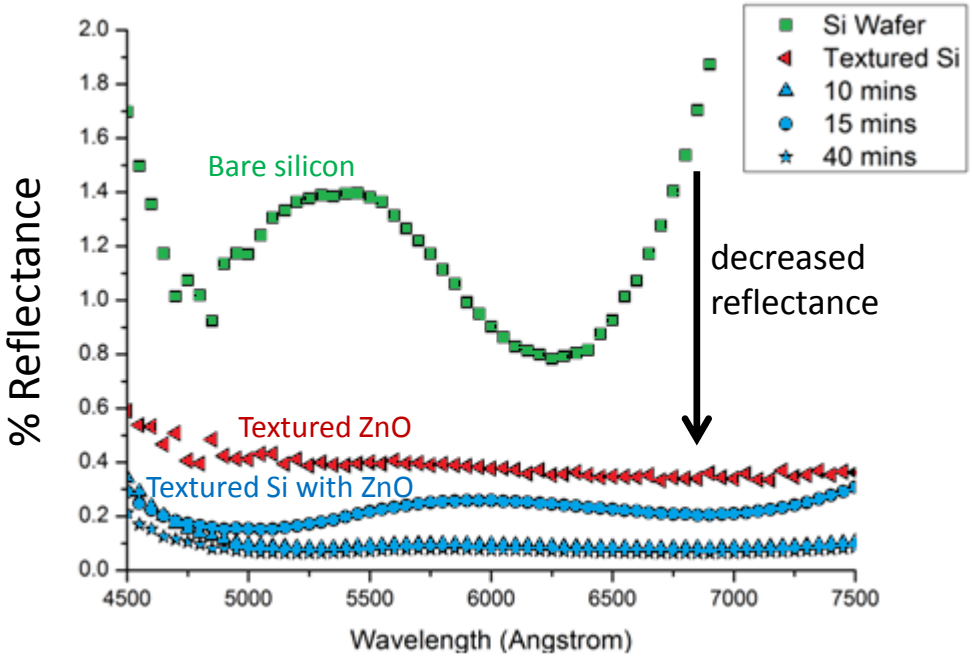


ZnO Anti-Reflection Coating

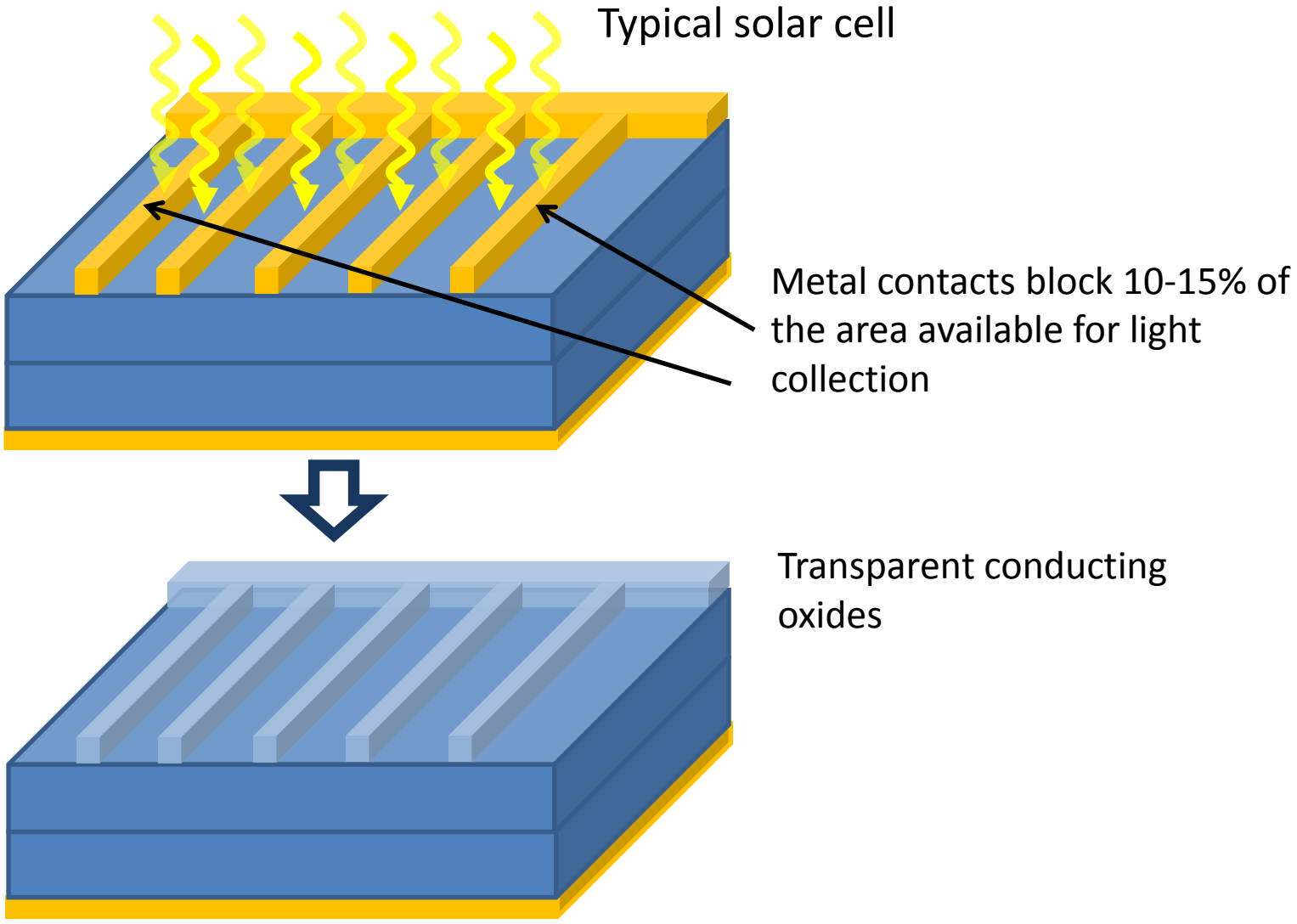
Zinc oxide (ZnO) deposited on textured silicon





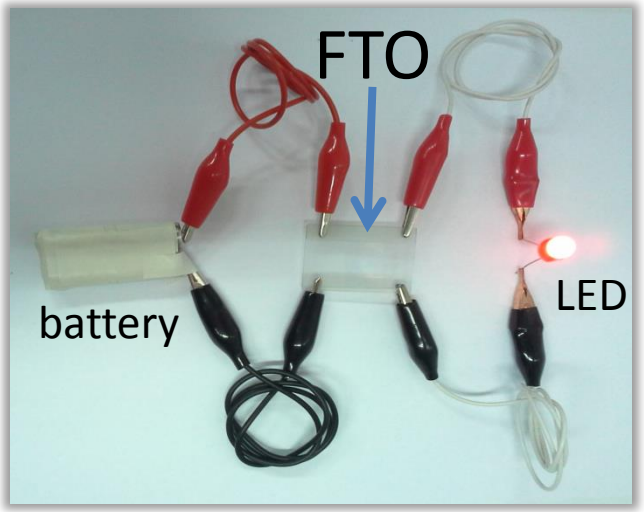


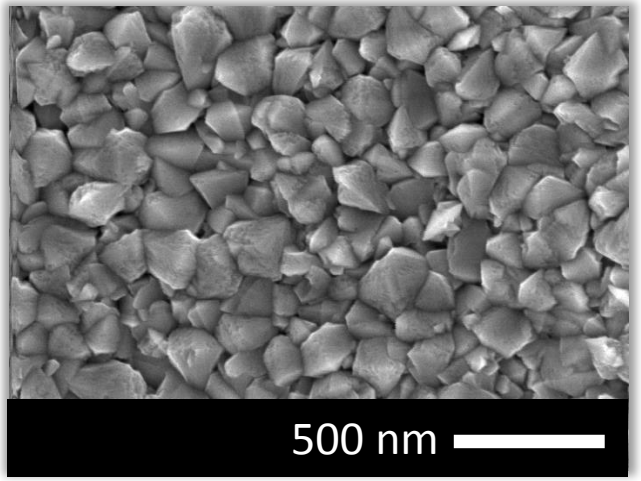
Shadow Loss


Typical solar cell
Metal contacts block 10-15% of the area available for light collection
Transparent conducting oxides

Fluorine-doped tin oxide (FTO)

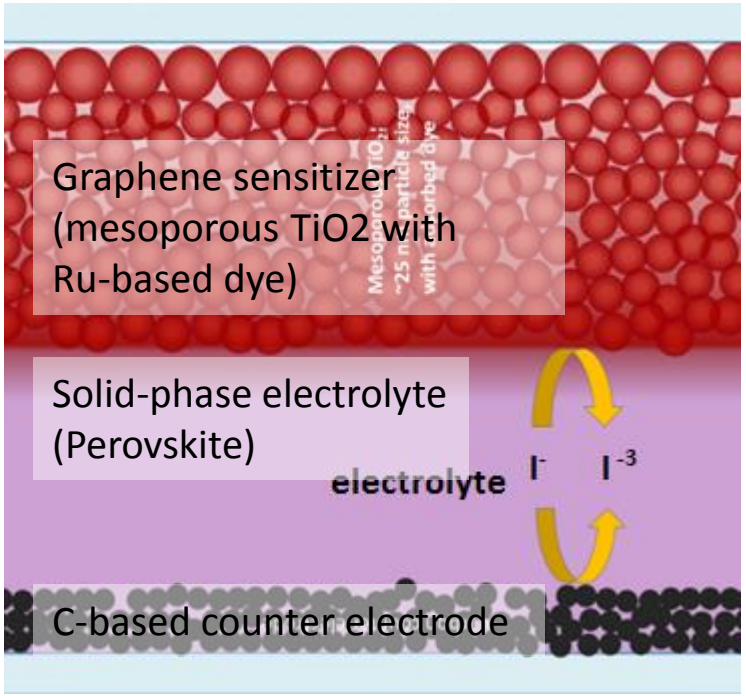
Highly transmitting
~80% transmission in the visible region





FTO-graphene nanocomposite for DSSC

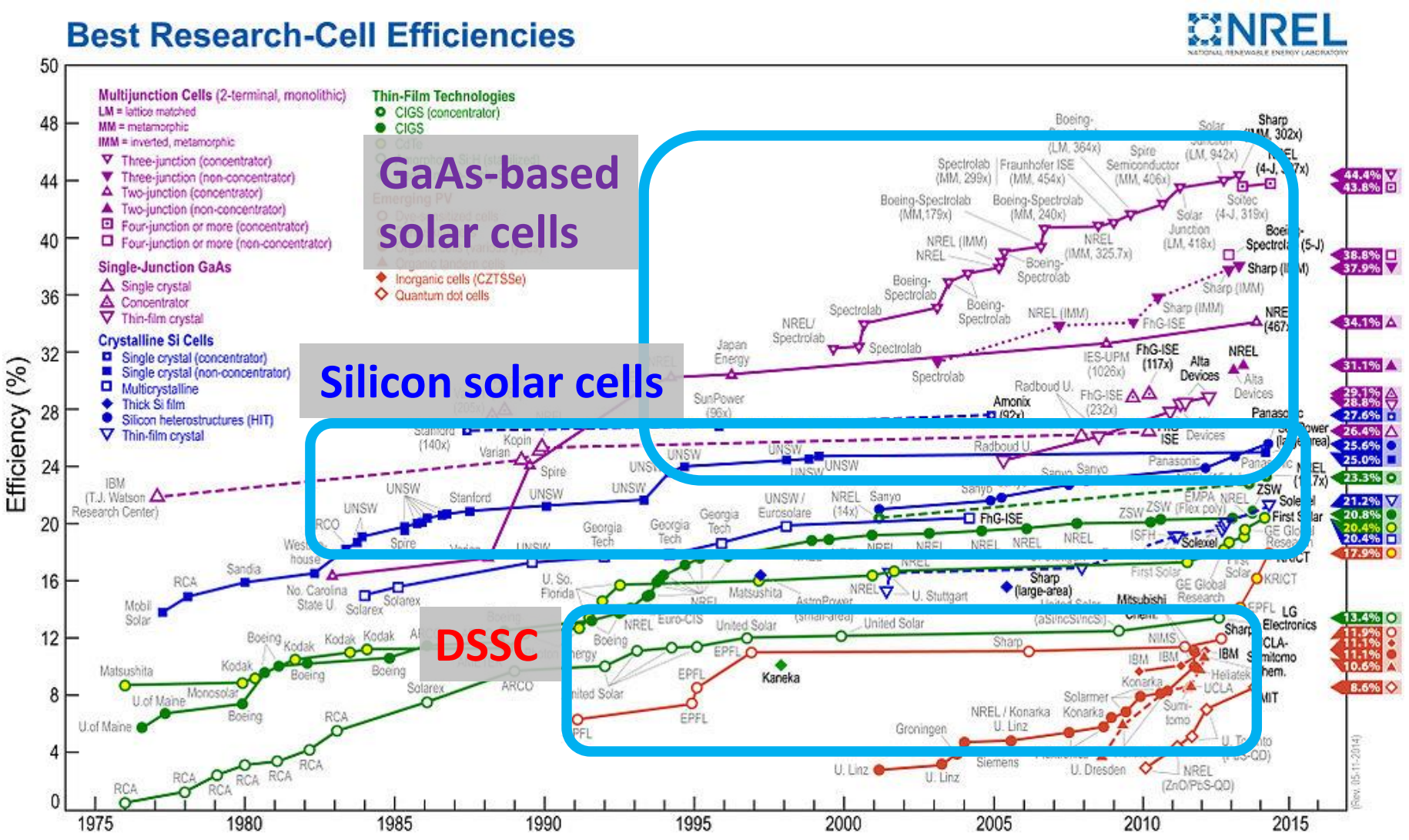
Dye-sensitized solar cell (DSSC) structure



10-12%
efficiency

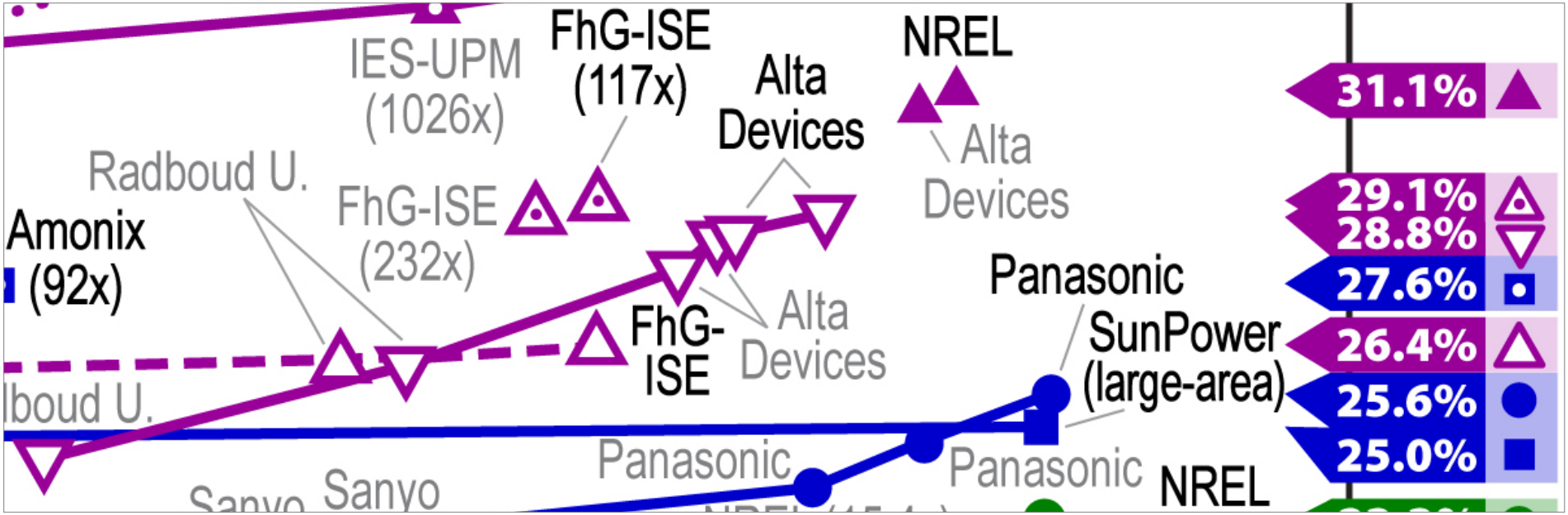
Modified graphene as TCO
(FTO-graphene nanocomposite)

GaAs-based solar cells



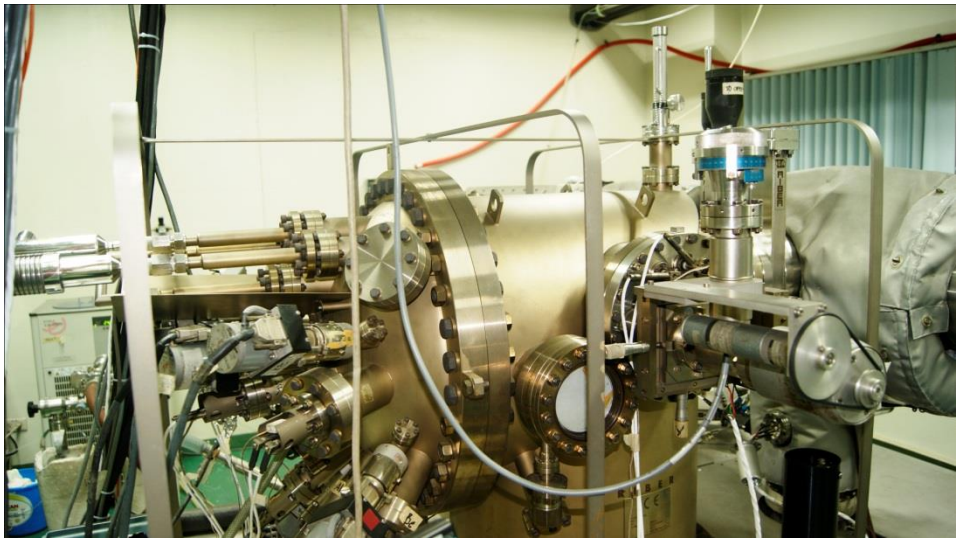
GaAs-based solar cells

Single-junction thin film GaAs solar cell

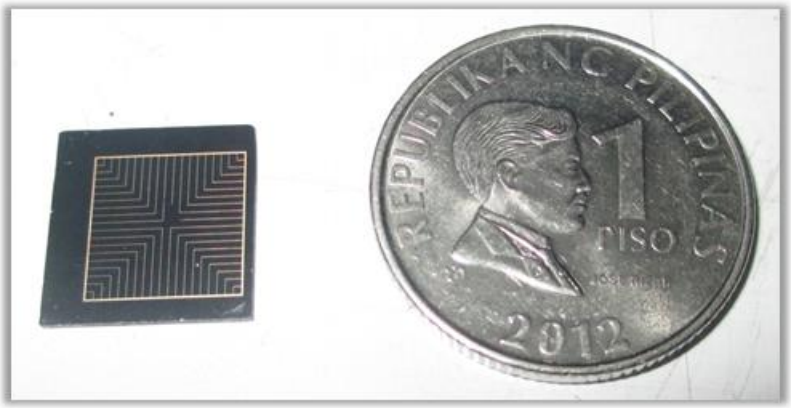


GaAs-based solar cells

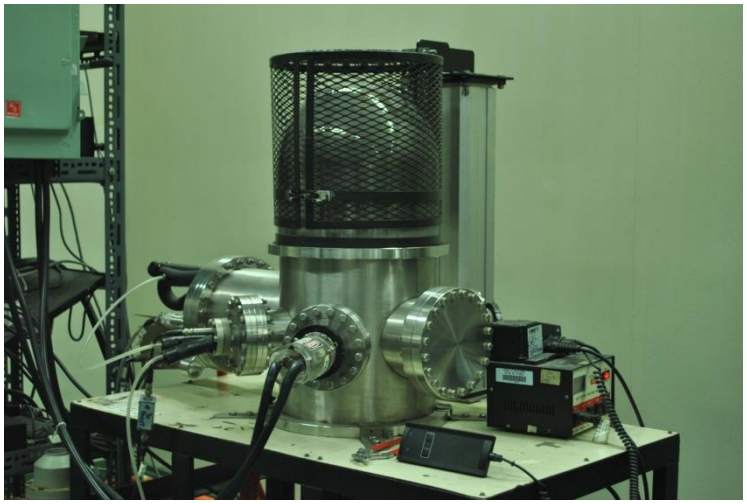
Riber32 Molecular Beam Epitaxy



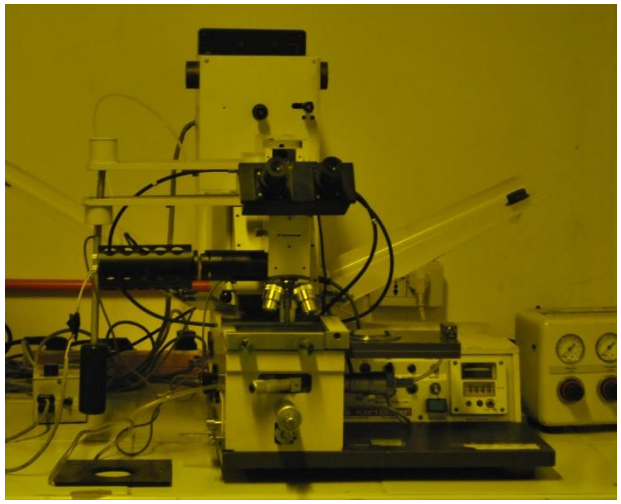
Fabricated GaAs-based solar cell



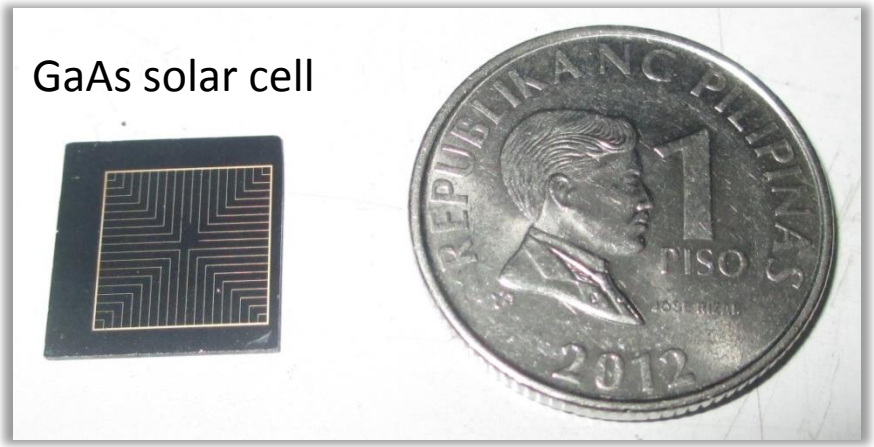
Metal Deposition



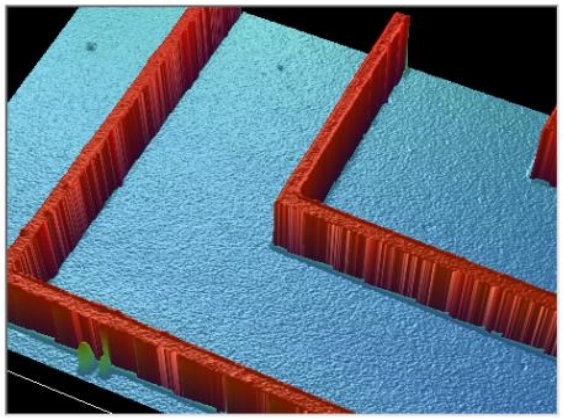
Mask Aligner

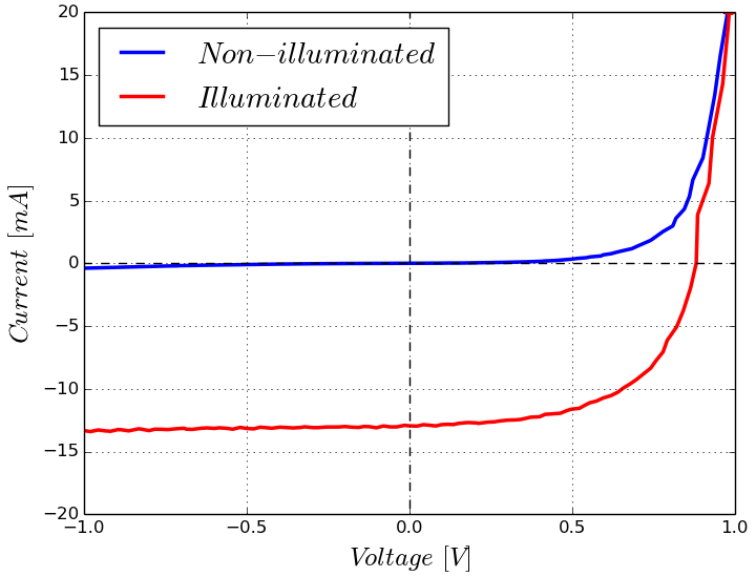


GaAs-based solar cells



Metal contacts on GaAs solar cell





23.5%

efficiency

Current world record:
28.8% (Alta Devices)

GaAs-based solar cell -Demonstration

LED array powered by the fabricated GaAs solar cell under a sun simulator

National Solar Cell Characterization Facility at NIP

Other studies

Our work on nanostructures will also be utilized in other disciplines and applications in the future:

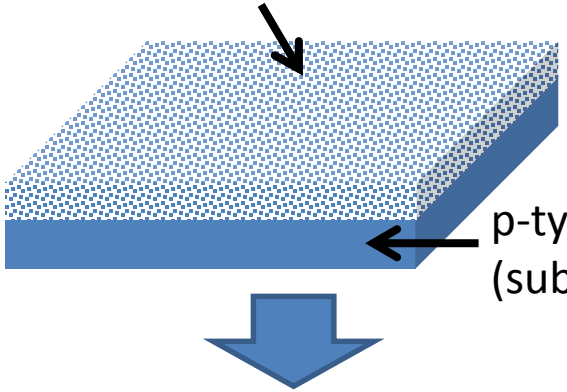
- Biosensing
- Alternative energy (Thermoelectric and Piezoelectric devices)
- Lab-on-a-Chip (LOC)
- Emerging optical and spectroscopy techniques

  Terahertz spectroscopy

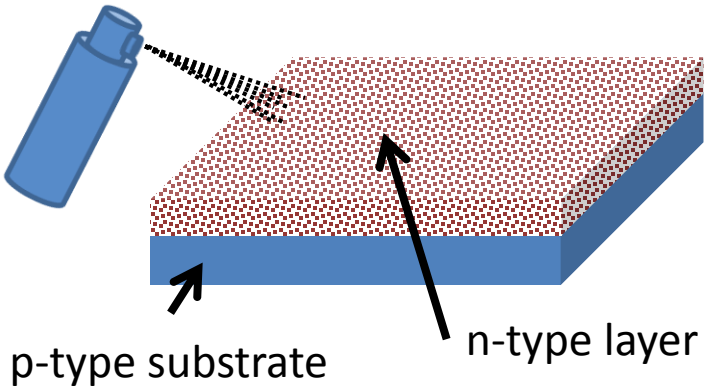
  Multi-spectral imaging

Doping techniques for silicon

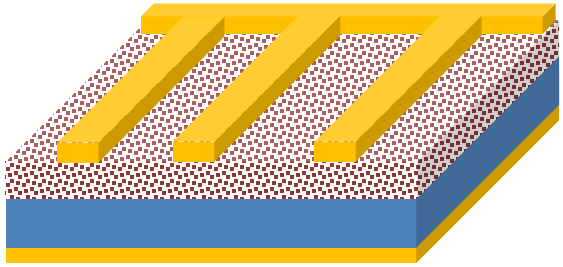
Textured silicon
(porous Si, Si nanowires, pyramid)

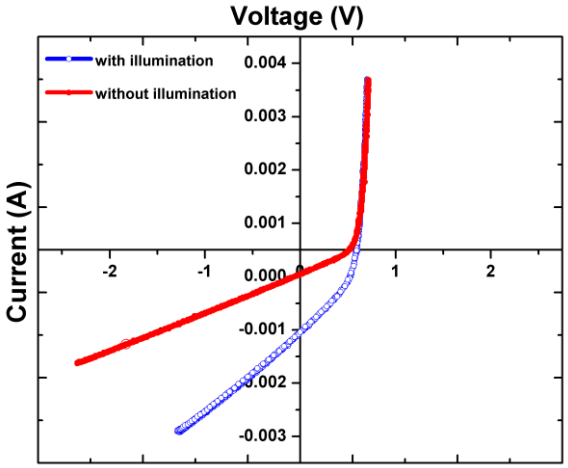


Spray pyrolysis
(phosphorus or doped ZnO)



Silicon solar cell

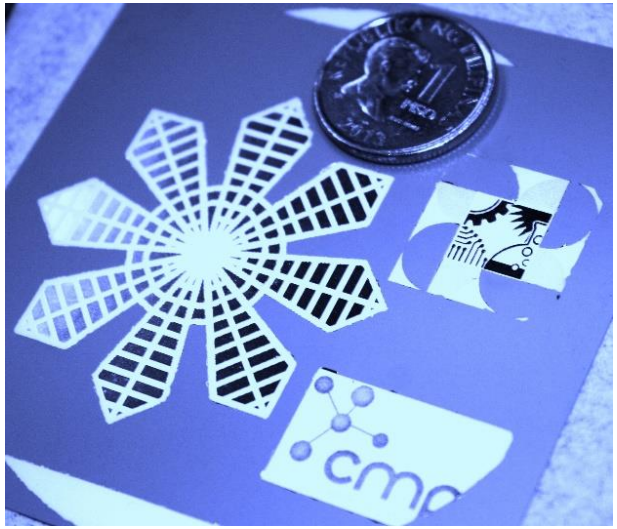


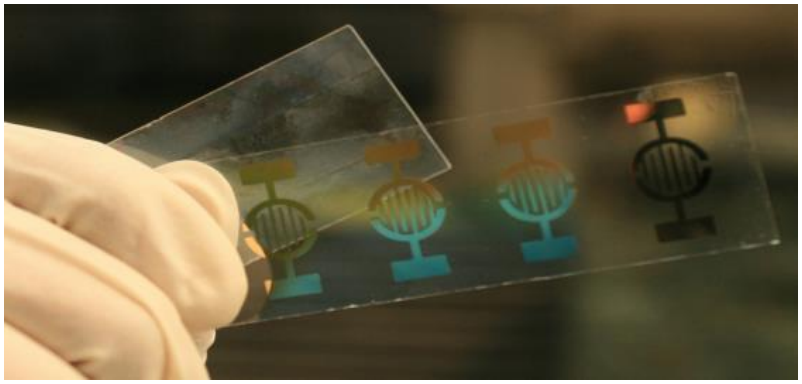


IV-curve for pn-junction produced using spray pyrolysis

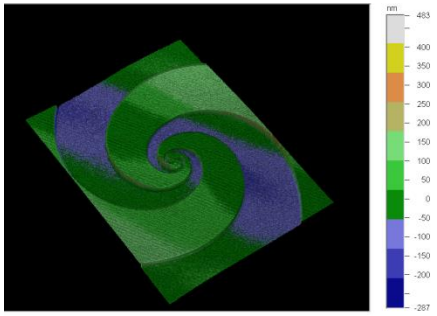
Metallization Techniques

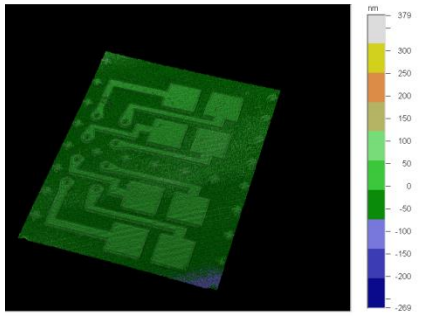
In-house fabricated masks for metallization of macroscopic devices

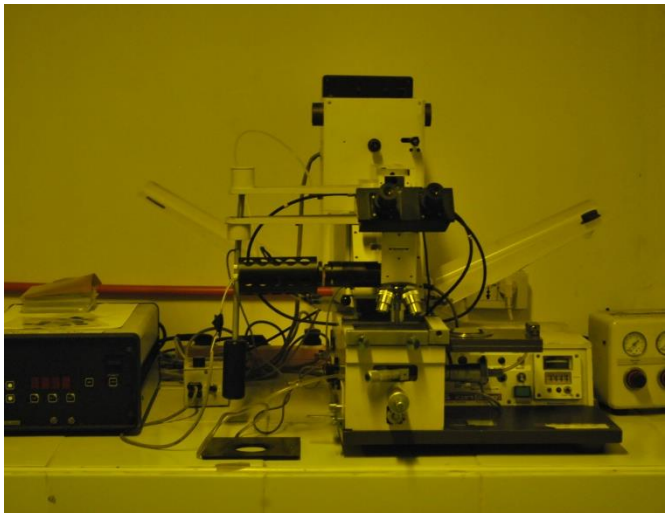




Nanolithography for other optoelectronic devices (WYKO images)



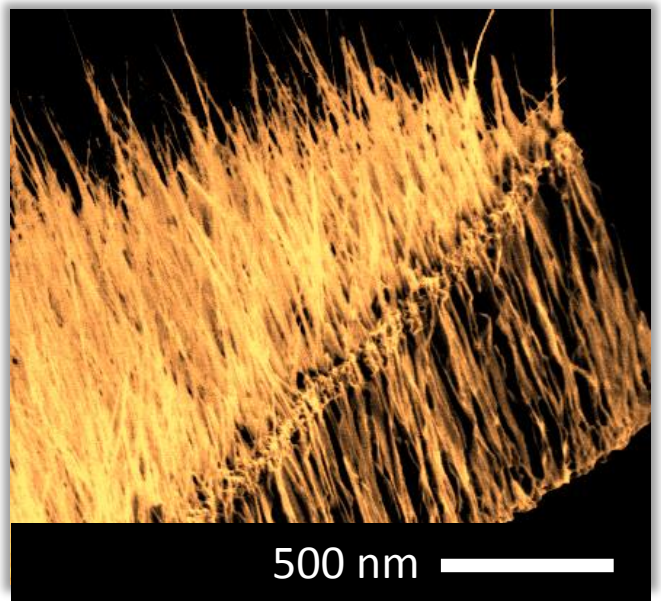


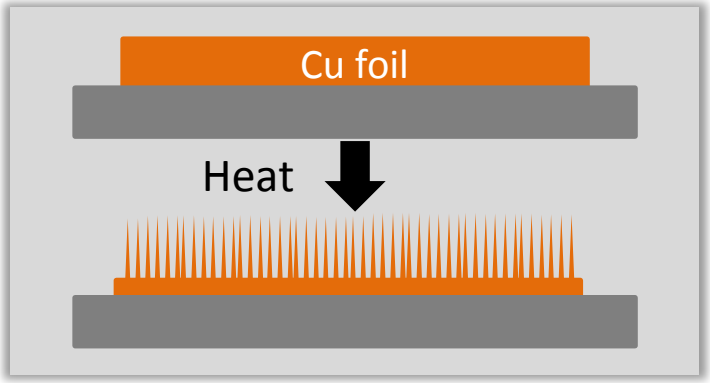


Karl-Suss mask aligner

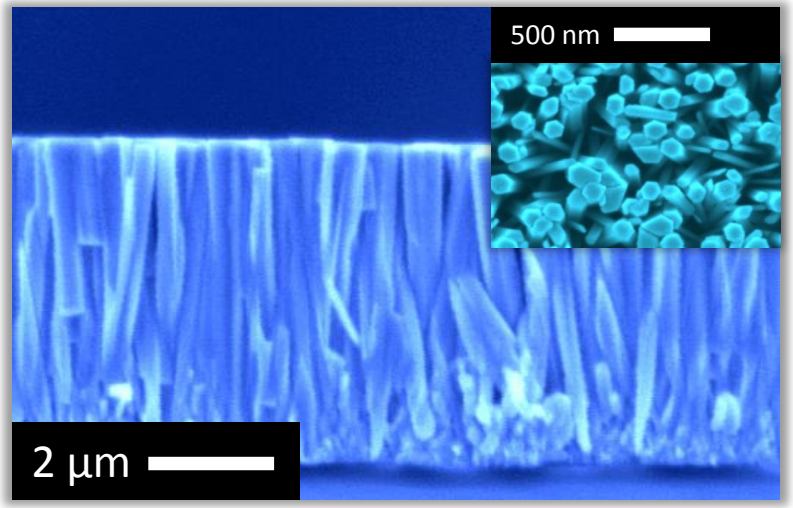
Metal-oxide nanostructures for ion-sensing applications

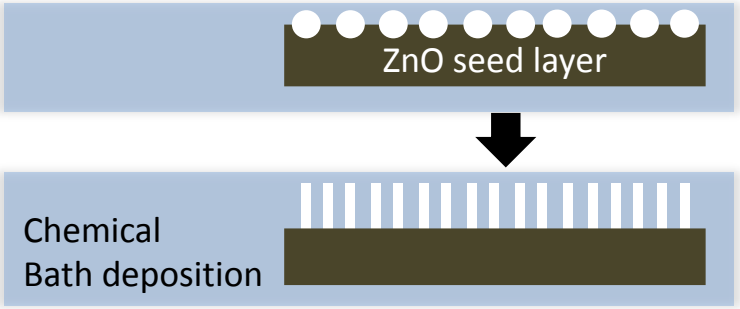
Copper oxide (CuO) nanowires
by thermal oxidation





Zinc Oxide (ZnO) nanowires
by chemical bath deposition





Nanostructures provide larger surface areas for adsorption, thus increasing the sensitivity of metal-oxides making them suitable for **ion-sensing applications**.

Human Resource Development

We have trained people capable in the growth, fabrication and characterization of solar cells

GRADUATE STUDENTS in the industry: **> 15 MS graduates**
RECENT Phd Graduates: **3 graduates**
CURRENT GRADUATE STUDENTS, MS and PhD: **> 30 students**

cmpl semiconductor group

Various Facilities for Growth, Characterization and Fabrication