Nanostructured Solar Energy Devices

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Nanostructured Solar Energy Devices

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This program is a collaboration between
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The program addresses various aspects and issues which affect the performance of solid-state and dye-sensitized solar cells.
The Solar Cell

LIGHT $\rightarrow$ ENERGY

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

Source: RESLAB
Issues on solar cell performance

- Reflection losses
- Shadow loss
- Collection efficiency

![The Solar Spectrum](Image)

- Sunlight at Top of the Atmosphere
- 5250°C Blackbody Spectrum
- Radiation at Sea Level

- UV
- Visible
- Infrared

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- Shadow effect due to metal contacts
- Top surface reflection
- Back contact reflection
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

- Etchant solution
- Textured silicon
- Photocurrent (a.u.)
  - Increased photocurrent
  - Textured silicon
  - Untextured silicon

% Reflectance for increasing texture time

Silicon nanopyramids by chemical texturing
Nanostructures: Silicon nanowires

Silicon nanowires (SiNW)
by metal-assisted electroless etching

Silicon nanowires with silver nanoparticles

Increased photocurrent

Bare silicon

Decreased reflectance
ZnO Anti-Reflection Coating

Zinc oxide (ZnO) deposited on textured silicon

Textured Si with ZnO

% Reflectance

Wavelength (Angstrom)

decreased reflectance

Textured ZnO

Bare silicon

ZnO coat

Textured Si
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
Dye-sensitized solar cell (DSSC) structure

- Graphene sensitizer (mesoporous TiO2 with Ru-based dye)
- Solid-phase electrolyte (Perovskite)
- C-based counter electrode

10-12% efficiency

Modified graphene as TCO (FTO-graphene nanocomposite)
GaAs-based solar cells

Silicon solar cells

DSSC

Best Research-Cell Efficiencies
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

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)

p-type silicon (substrate)

Spray pyrolysis (phosphorus or doped ZnO)

n-type layer

p-type substrate

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
Various Facilities for Growth, Characterization and Fabrication