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Development of Nanostructured and Surface Modified Semiconductors for Hybrid Organic-Inorganic Solar Cells

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Funding
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Collaborator
NREL - (funded by DDRD) Dave Ginley

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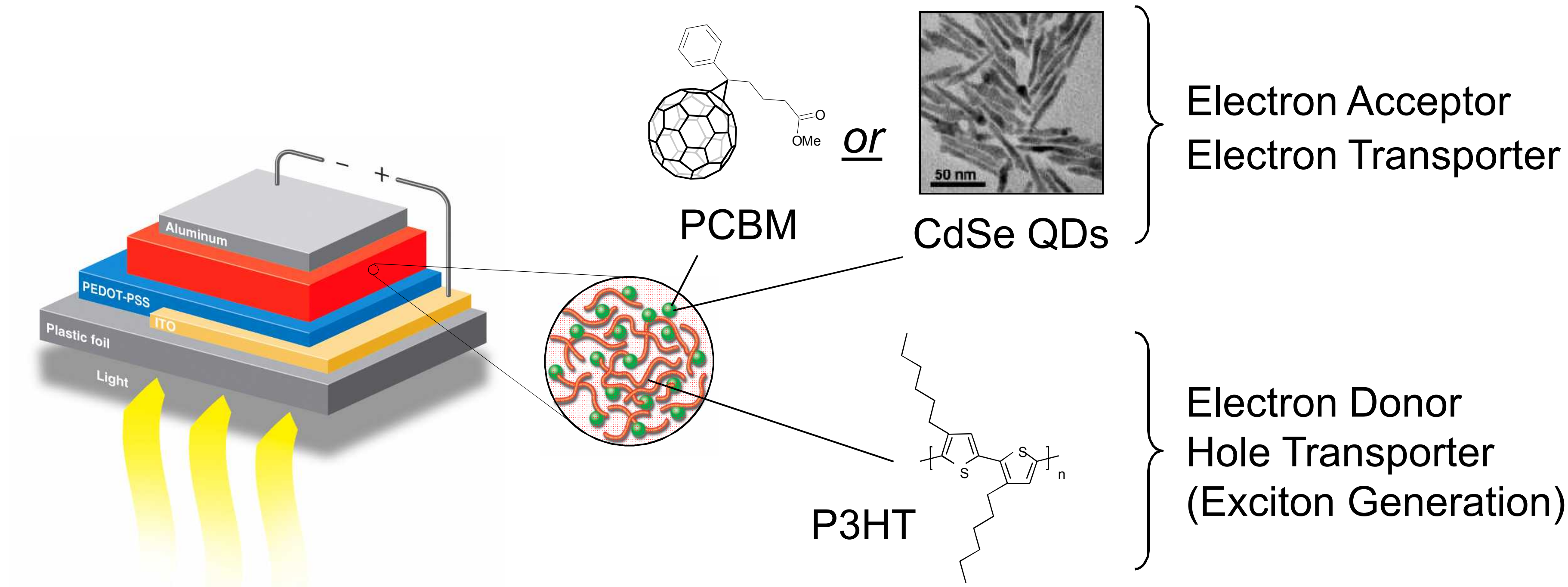
Interests & Goals for Organic and Hybrid PV

- Low cost photovoltaic devices
  - low temperature & non-vacuum processing
  - Printed at high speed on flexible substrates
  - Using roll-to-roll processing
  - Low installation and system cost
- Near term: 5 - 10% efficiency, lifetime 10,000 hrs (currently 2%)
  - "Niche" applications in consumer electronics
  - DOD: portable power, field deployed electronics, "future force warriors"
- Long term: 15% efficiency, lifetime > 3 - 5 yrs
  - Roof top power generation

Hybrid, Heterojunction-Based Solar Cells

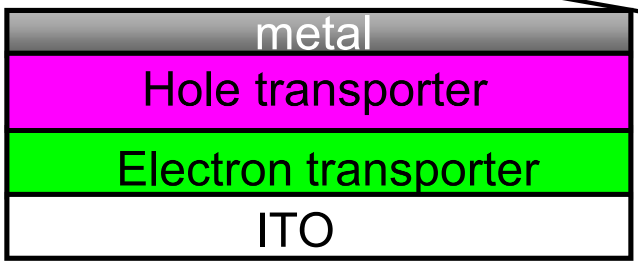


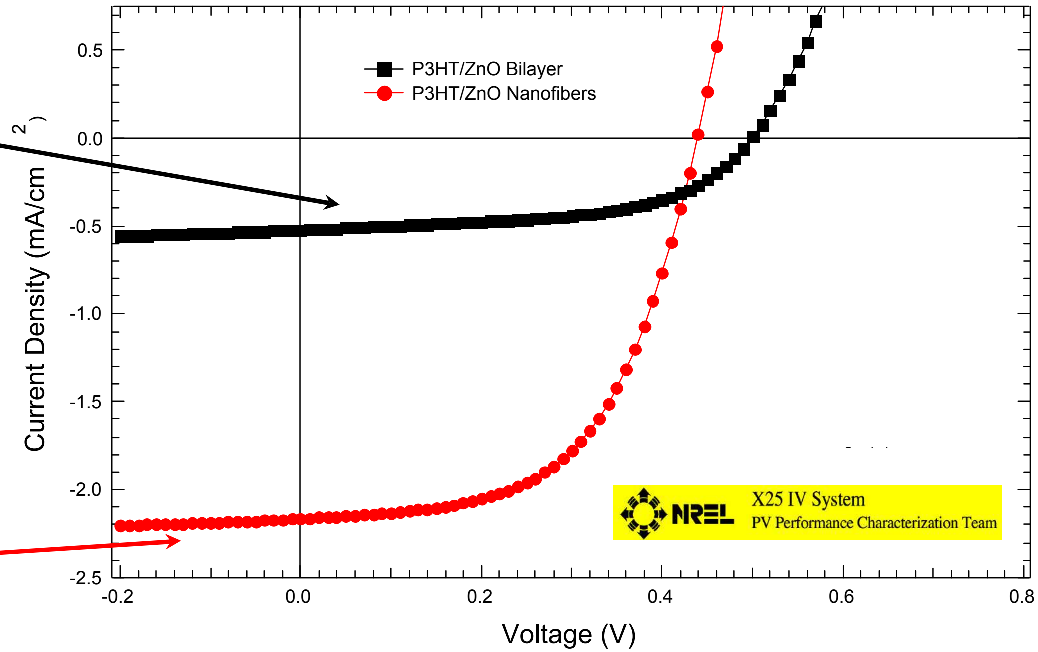
Project Objectives

- *Gain* expertise in the "nano-engineering" of controlled oxide growth, oxide/polymer assembly, and interface control as applied to hybrid organic-inorganic solar cells.
- *Develop* alternative power generation technologies to support Sandia initiatives.
- *Position* Sandia for future funding and partnership opportunities in the photovoltaic arena.

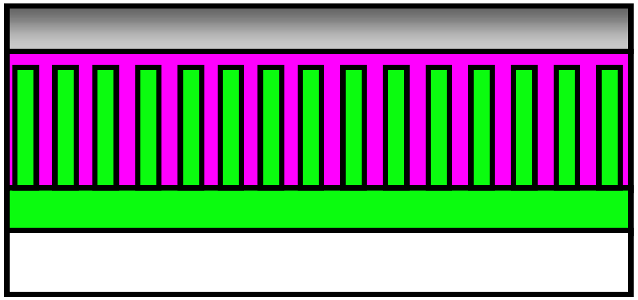
Why Nanostructures?

Bilayer



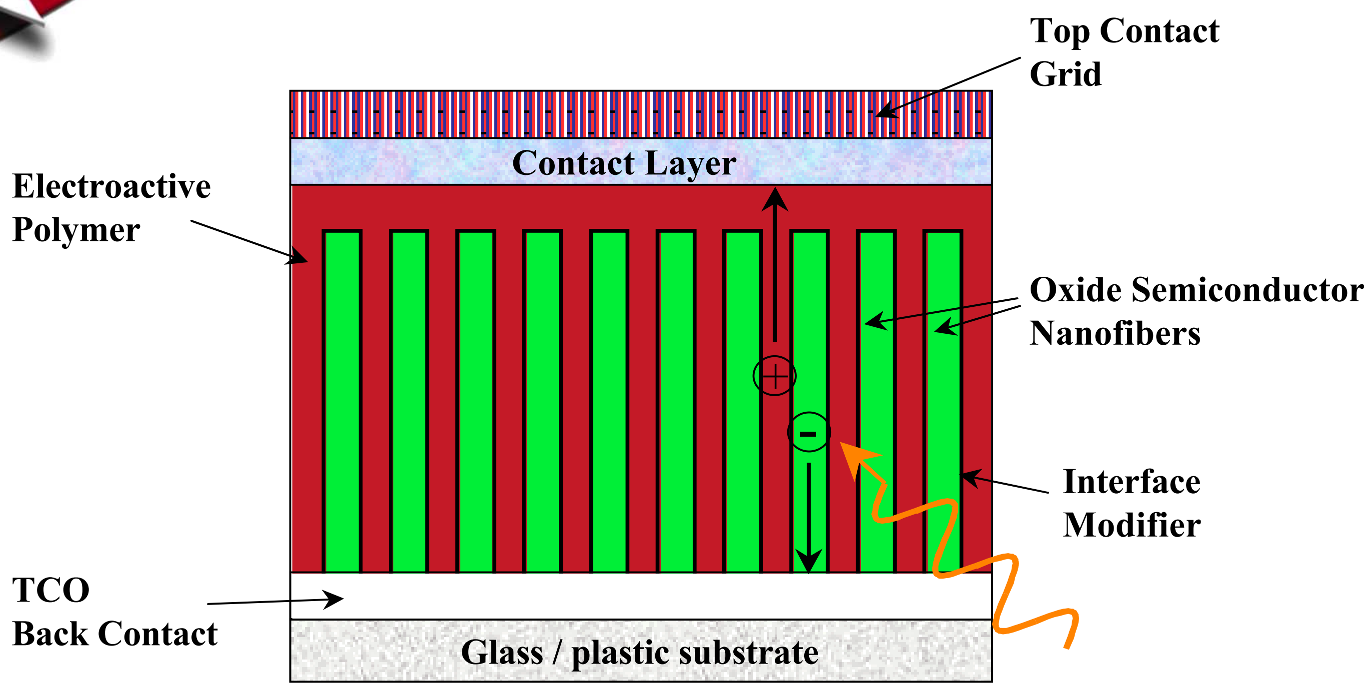


Nanostructures



- Higher interfacial area
- Spacing ~ exciton diffusion length
- Increase performance by 4x
- D. Olson, NREL, submitted to Adv. Func. Mater.

Why Organic-Oxide Semiconductor Hybrid Solar Cells?



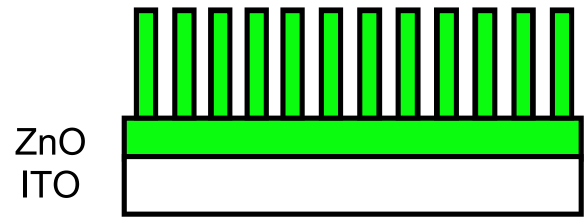
Proposed "Idealized Structure"

Advantages of using metal oxide semiconductor as the electron acceptor:

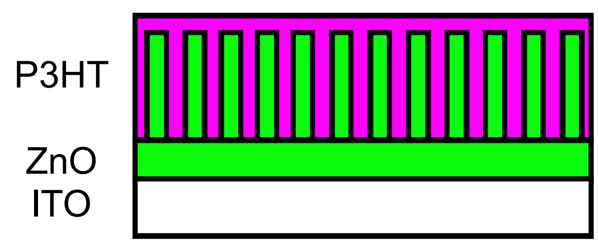
- Electron mobilities in crystalline oxide semiconductors is many orders higher than mobilities in organics
- Ordered structures might induce order in polymers to maintain high hole mobilities
- Control band alignments through judicious choice of materials
- Less susceptible to environments

Fabrication of Hybrid PV Devices

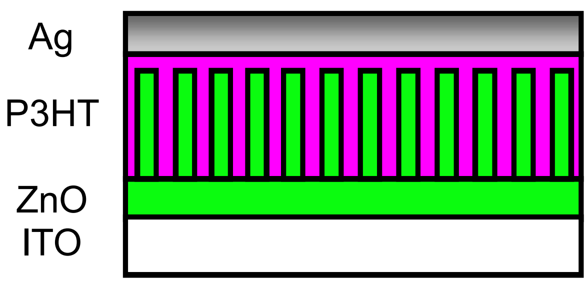
Deposit seed layer on TCO



Fiber growth from dilute aqueous solution



Infiltrate polymer among oxide nanostructures



Deposit top contact

6

Project Focus

What is limiting the efficiency in current cells?
Form a new basic understanding of the properties required for optimal electron transporter nanostructures.

I. What is the optimum size, spacing & morphology of the oxide nanostrucutres?

- Determine impact of acceptor structure on cell performance. (e.g., branched structures versus simple nanorod arrays)

II. Can we engineer the polymer/oxide interface?

- Demonstrate polymer wetting and infiltration at the nanoscale.
- Optimize electron transfer at interface.

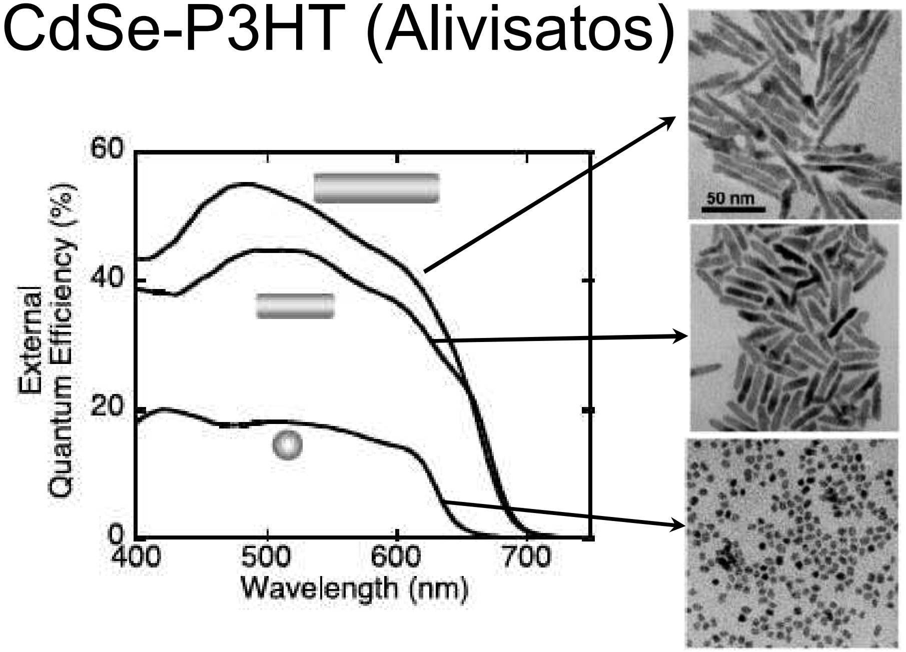
III. What is the best acceptor material system?

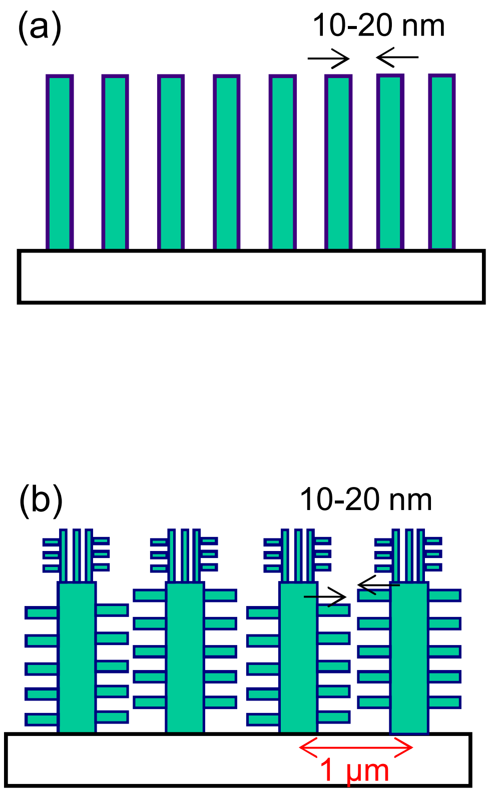
- Determine if other oxide semiconductor material systems provide advantages over ZnO and TiO_2.

NREL: Polymer development and cell characterization

I. What is the Best Morphology?

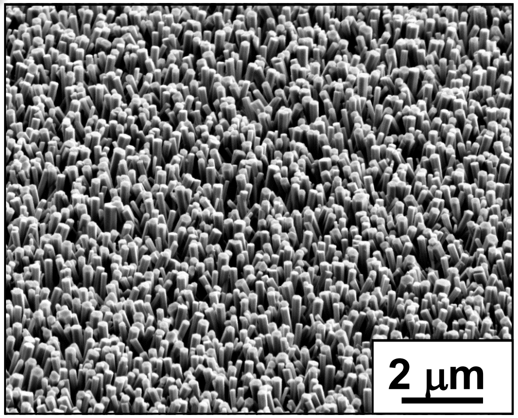
CdSe-P3HT (Alivisatos)



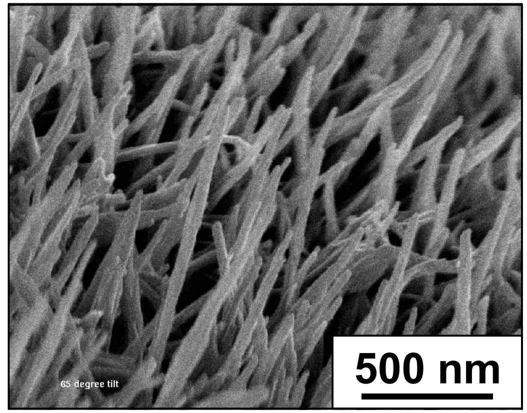


Control Growth of Nanostructures

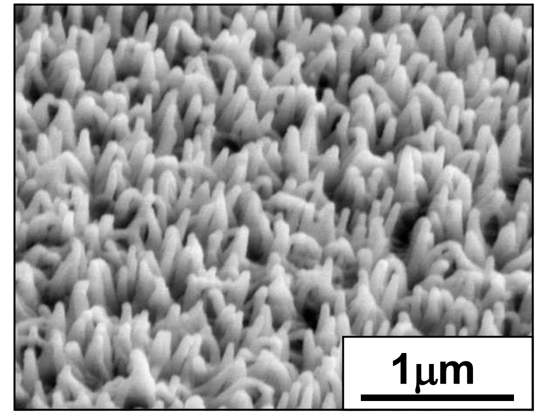
Nanorod Arrays



ZnO

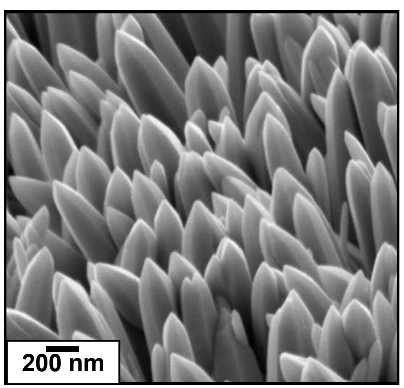


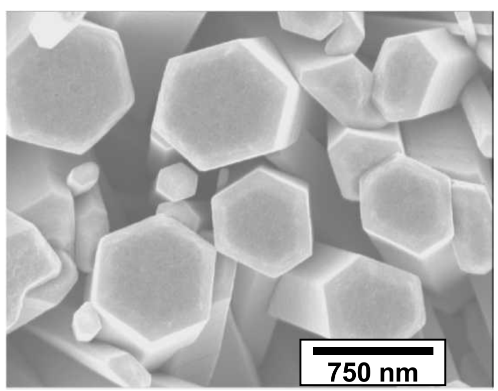
TiO_2

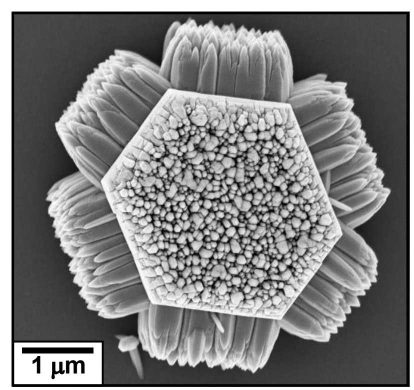


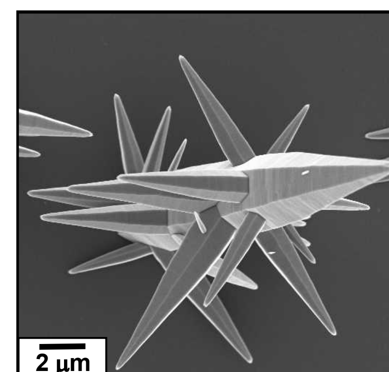
Conductive Polymers

Morphology Control of ZnO Nanostructures

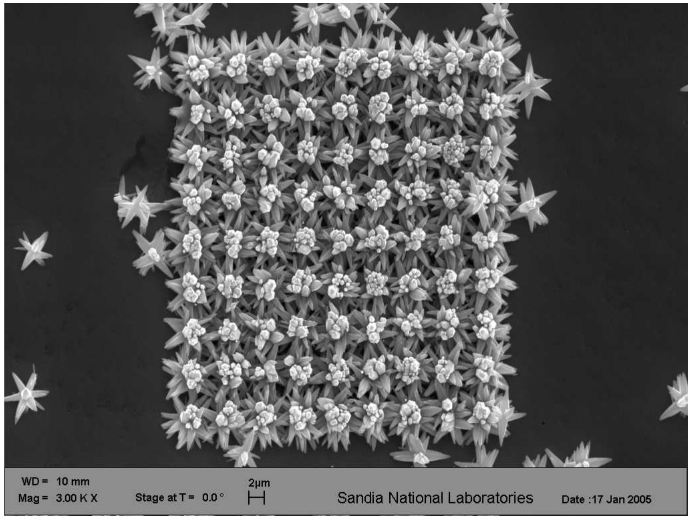


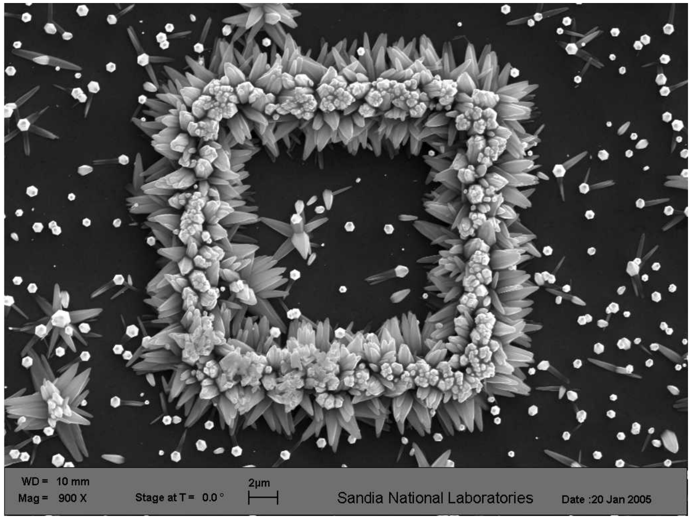


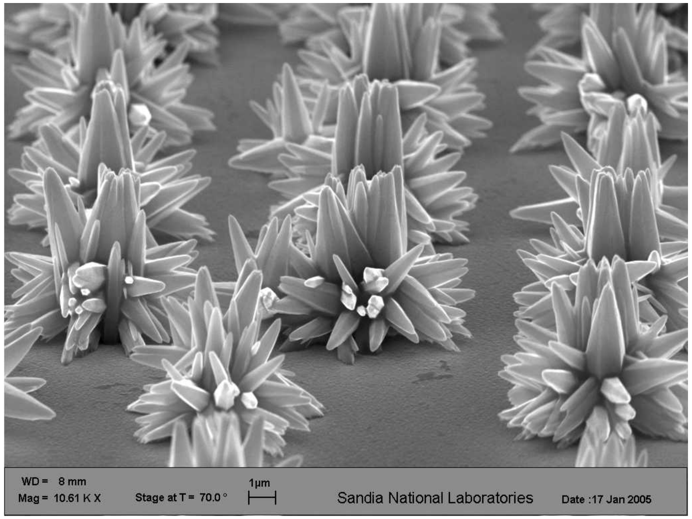


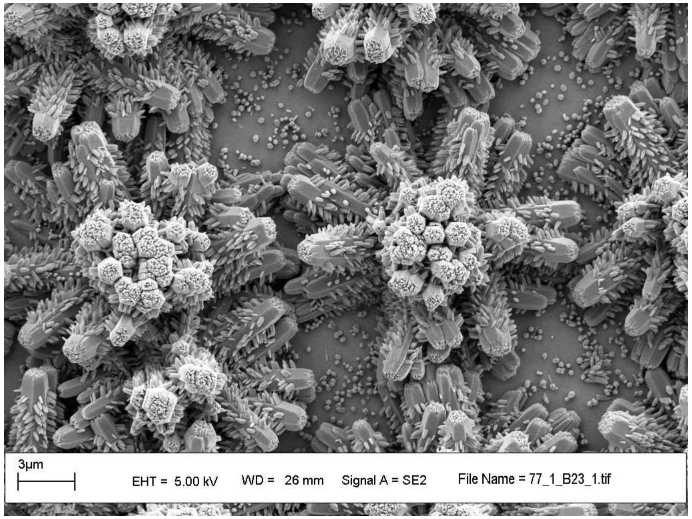


Control Placement of ZnO Nanostructures on Substrates









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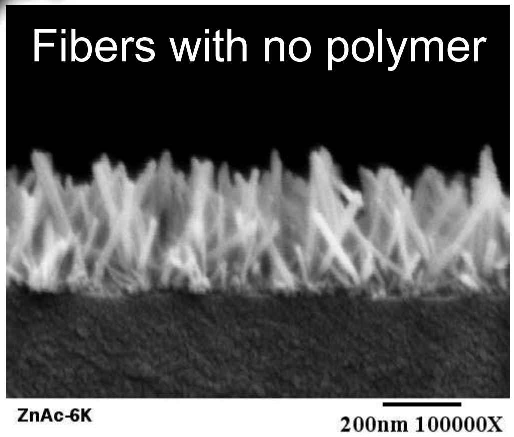
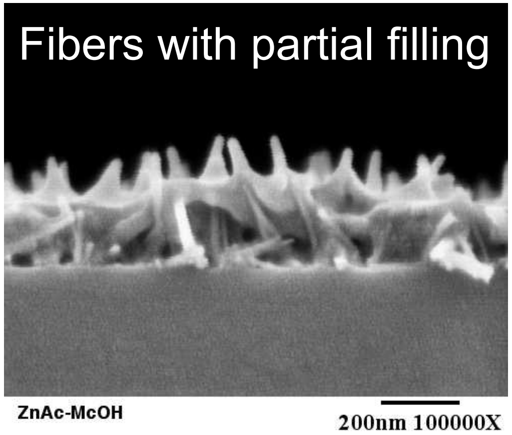
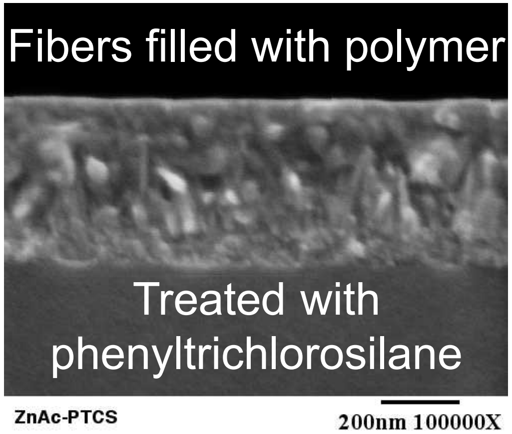
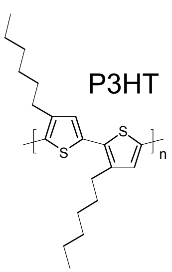
II. Infiltrating P3HT into ZnO Nanofibers

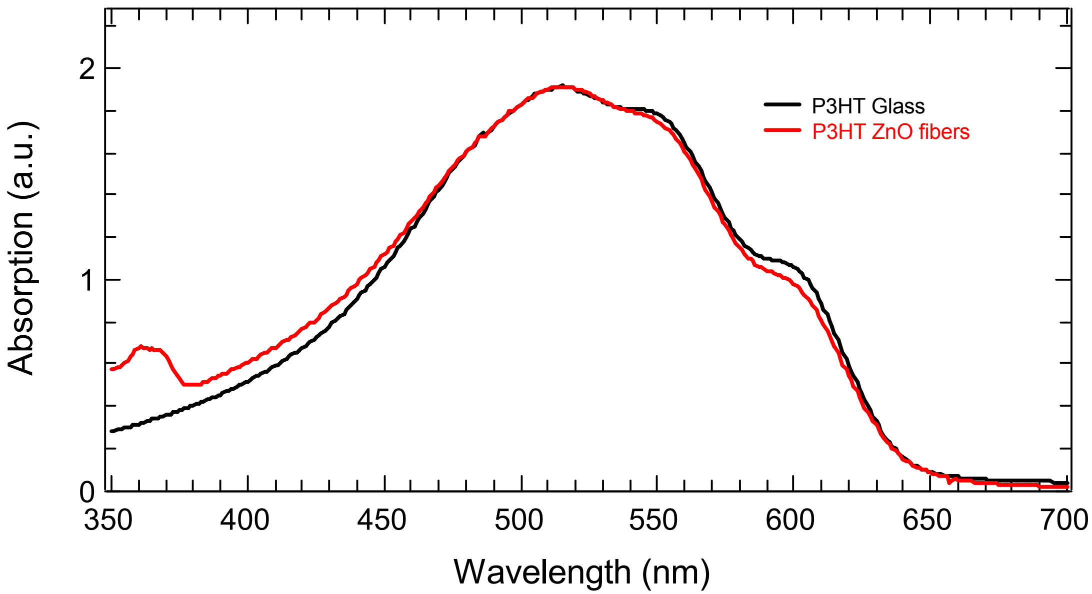






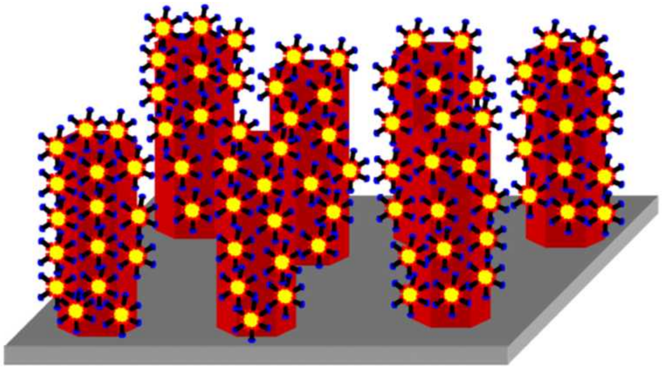
P3HT intercalated into ZnO nanofibers remains ordered



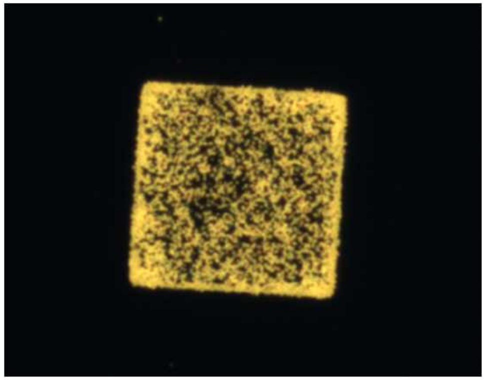


III. Surface Functionalization

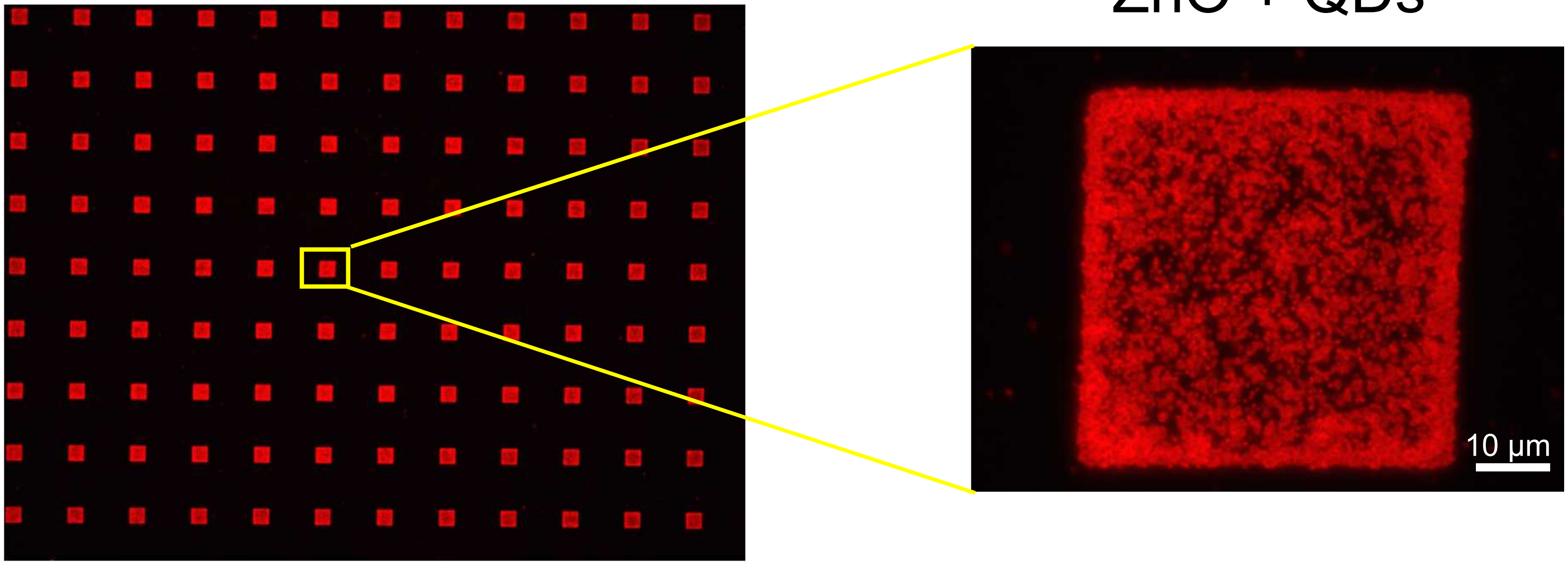
Quantum Dots on ZnO Nanorods



ZnO



ZnO + QDs



Summary

Hybrid Cell with Hierarchal Acceptor Structure