Nano for Next Generation Organic PV

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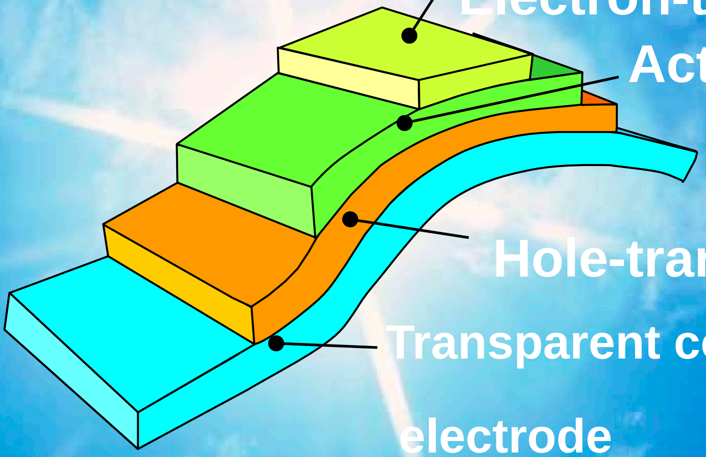


Solar Energy and Energy Storage: Answering the Energy Challenge Workshop

September 14th , 2010

ORNL

Center For Nanophase Materials Sciences

A highly collaborative and multidisciplinary nanoscale science <u>user research and research education center</u>

Nanotechnology
at Oak Ridge National Laboratory

DISCOVER
Center for Nanophase Materials Sciences

Center for Nanophase Materials Sciences

DEVELOP
NanoApplications Center

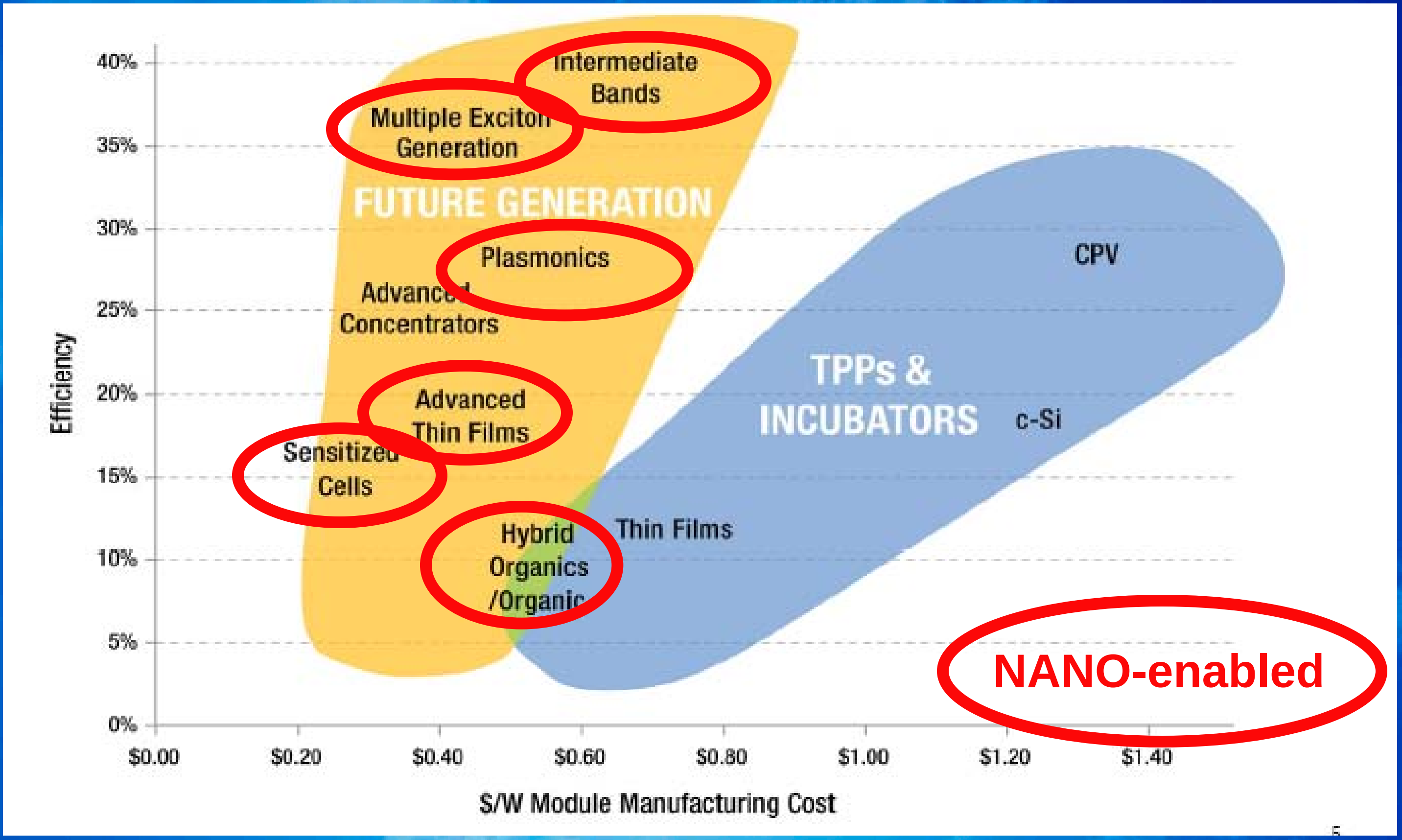
NanoApplications Center

DELIVER
Technology Transfer and Economic Development

Technology Transfer and Economic Development
Putting Science to Work

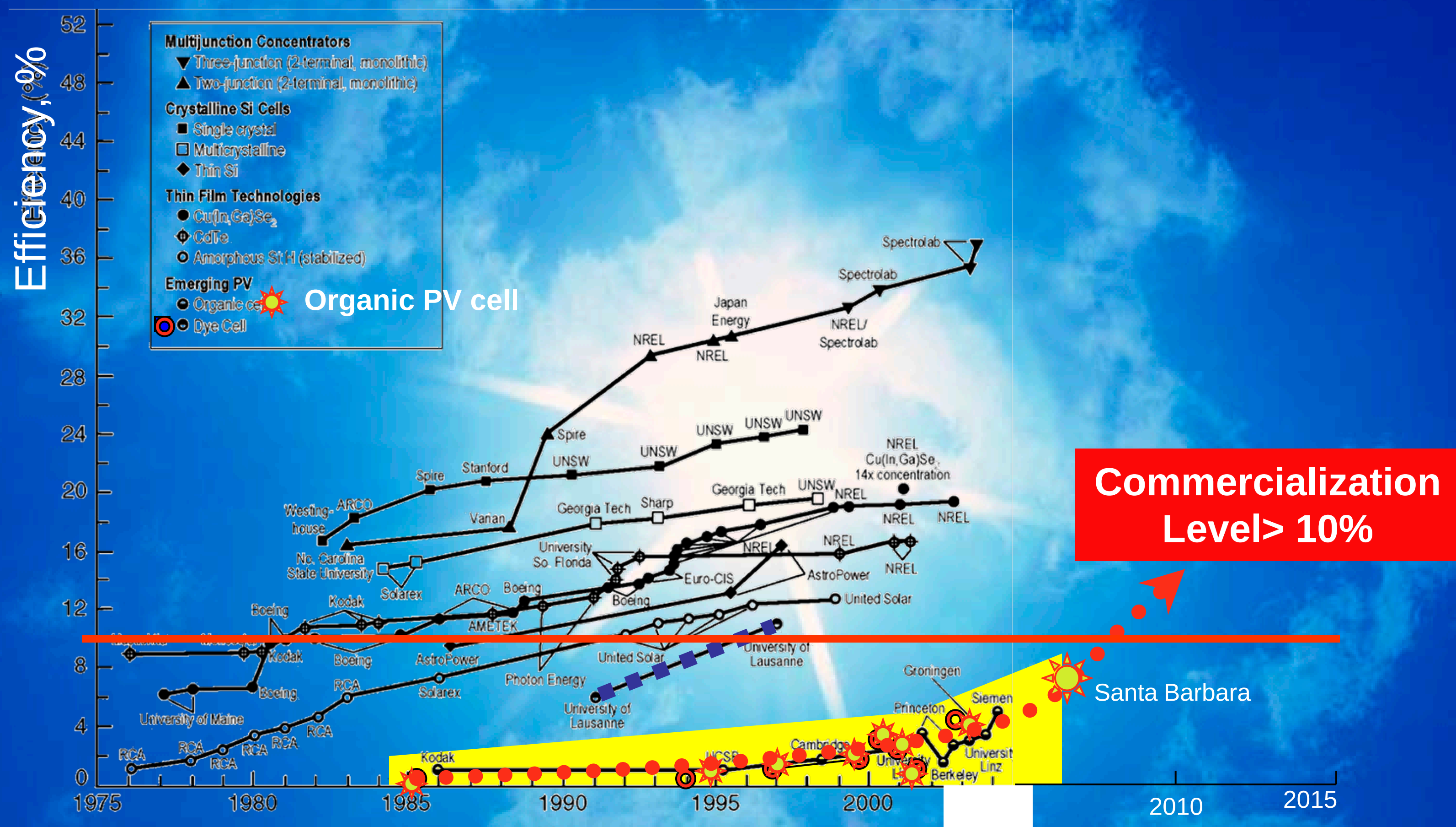
http://nano.ornl.gov/

DOE Solar Program Roadmap



- Organic and Hybrid PV will enable low cost-high efficiency PV
- Nano-interface is a key to next generation of PV

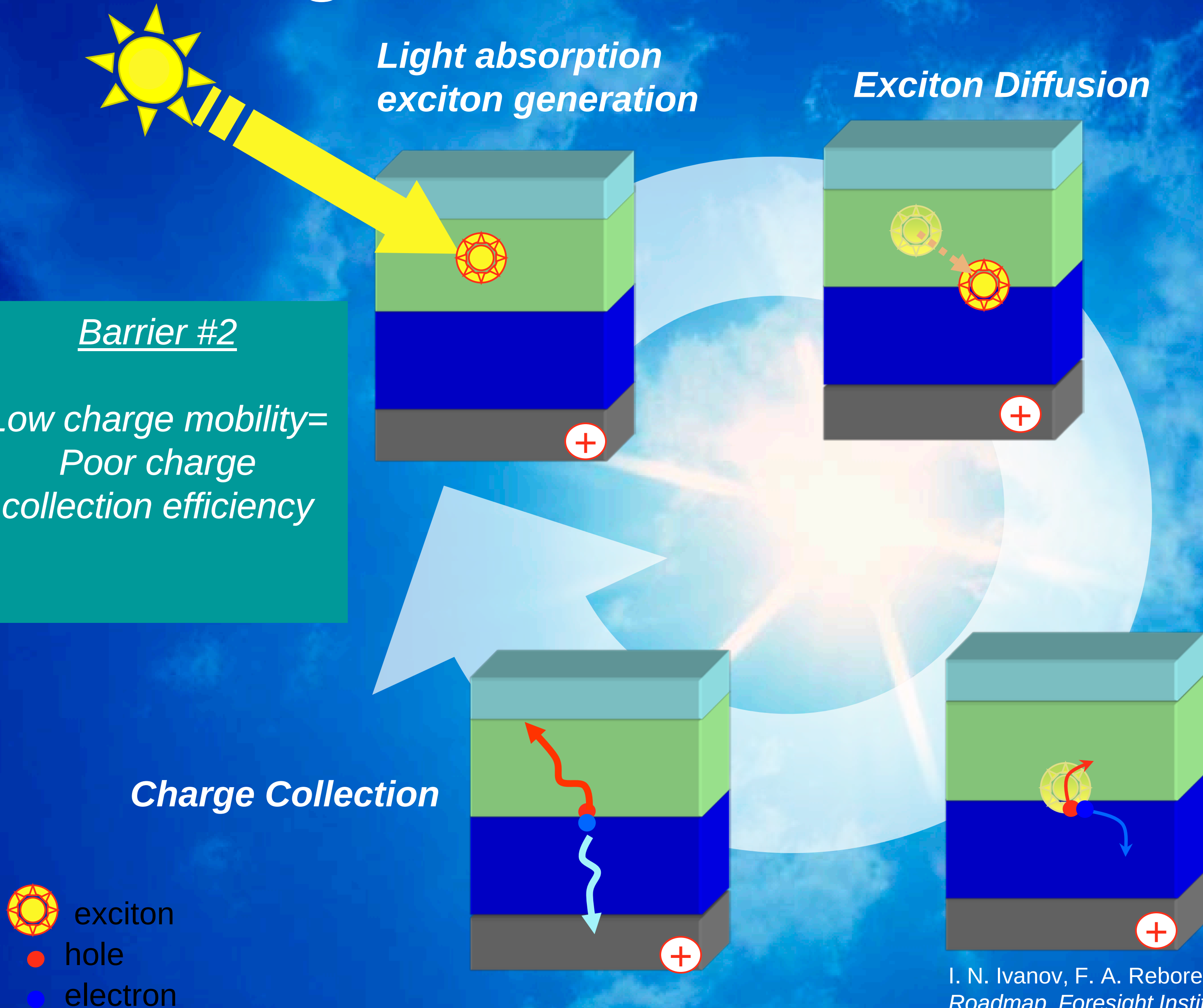
Historical data on efficiency of PV devices



Adapted from *Next-Generation Photovoltaic Technologies in the United States*
NREL/CP-520-35347 R. McConnell and R. Matson

Commercialization of OPV is expected at above 10 % efficiency
Current (2010) NREL confirmed record 8.13% (Solarmer)

Organic Photovoltaics Challenges



Barrier #2

Low charge mobility=
Poor charge
collection efficiency

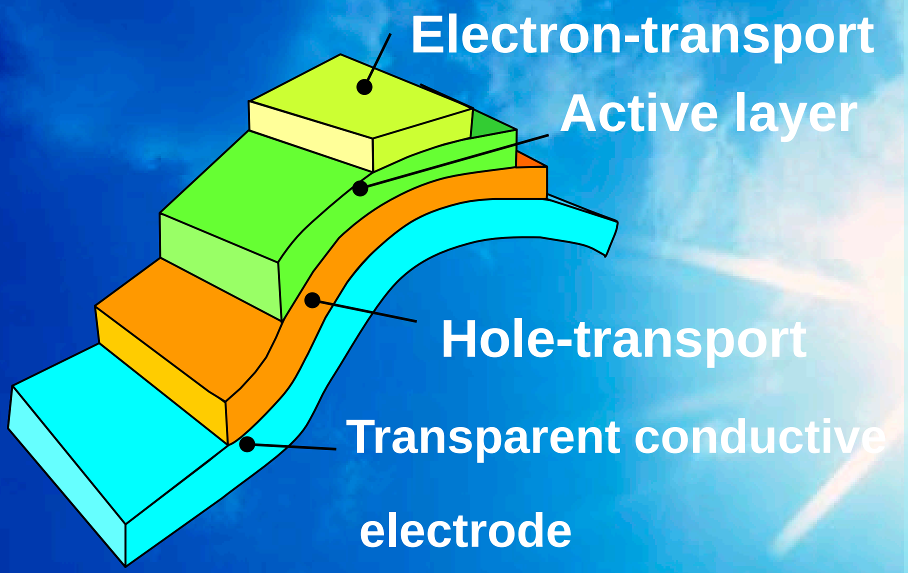
Barrier #1

Exciton's short lifetime
limits diffusion ~10 nm
"exciton diffusion
bottleneck"

I. N. Ivanov, F. A. Reboredo "*Nanosystems. A Technology Roadmap, Foresight Institute,* October 10 2007

Plus environmental stability

How Nano Can Benefit Organic Photovoltaics?

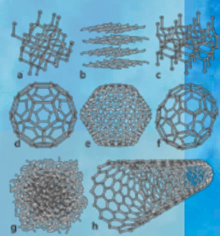


- <u>ITO replacement</u>
- New tool to address OPV barriers
  - Exciton diffusion bottleneck
  - Low charge mobility
- Encapsulation
- Improve spectral response (NIR)
- <u>3 D structures/nonlinear effects/ multi exciton</u>
- Improved environmental stability

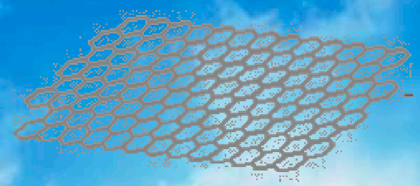
Multifunctionaliy of nanomaterials

Carbon nanostructures -attractive materials for next gen. PV

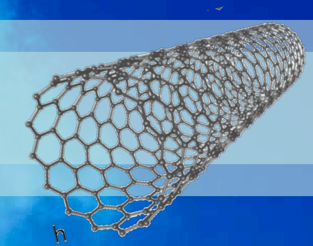
C



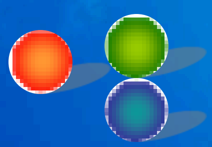
Carbon



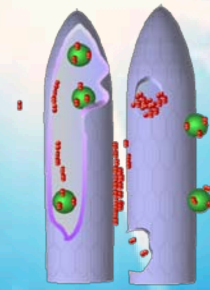
Graphene



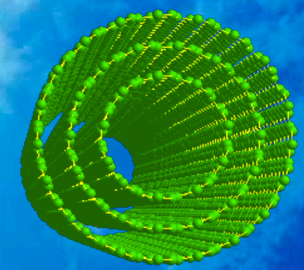
Single wall nanotube



Quantum dots



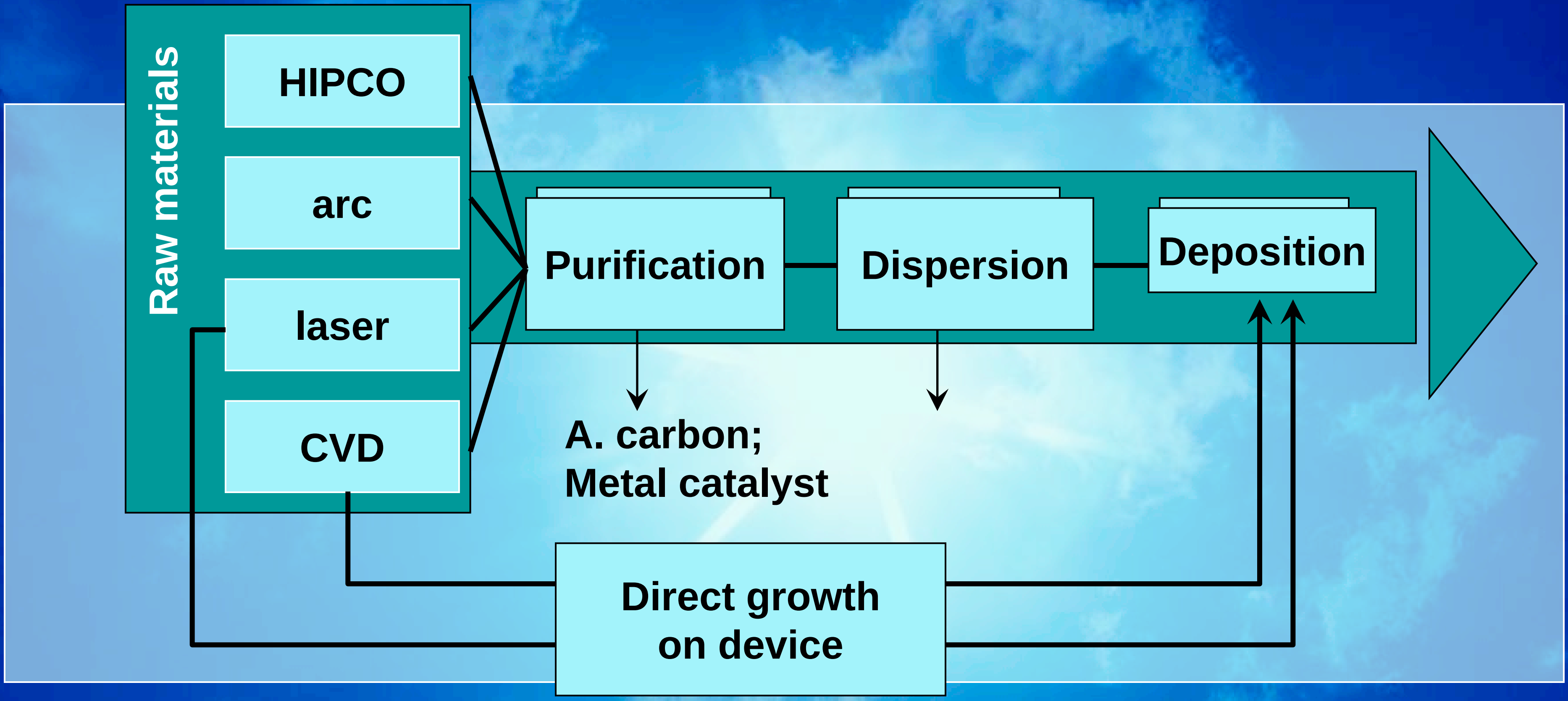
Carbon nanohorns



Multi walled nanotube

Sustainable, renewable, 4th most abundant element, high surface to volume ratio, tunable electro-optical properties

Processing of High Quality Nanotubes



Electro-optical applications are most demanding

Organic Photovoltaics at the CNMS-SNS

(1)

Synthesis of Polymers for bulk heterojunction (self-assembled long range order + encapsulation)

(2)

Synthesis of ultra-high purity Functional Nanomaterials for flexible electrodes with tunable work function, balanced charge transport in polymer/small molecule configuration

(3)

Controlled atmosphere multi glove box system for OPV assembly

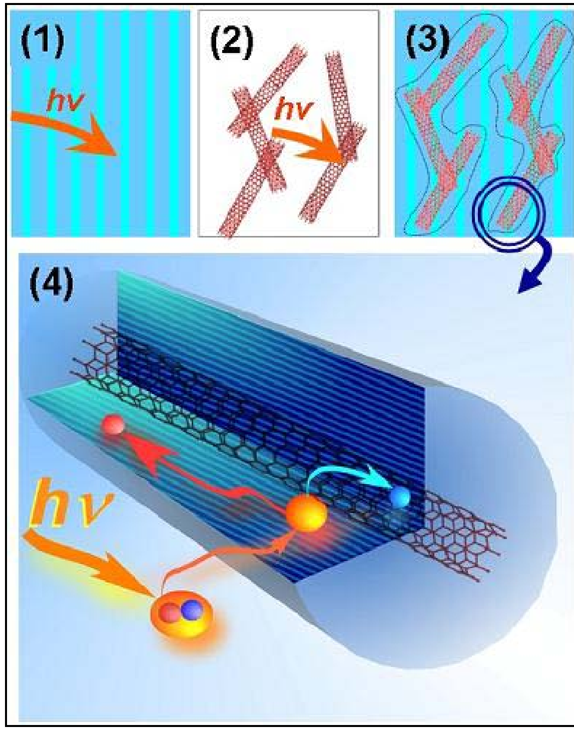
Scalable deposition of materials and composites for PV

(4)

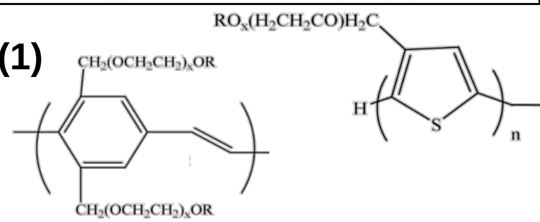
Characterization of OPV (exciton dynamics and dissociation-ultrafast spectroscopy, charge formation and transport)

(5)

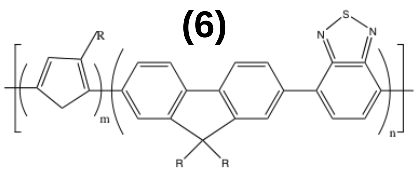
Modeling of exciton dynamics and charge transport

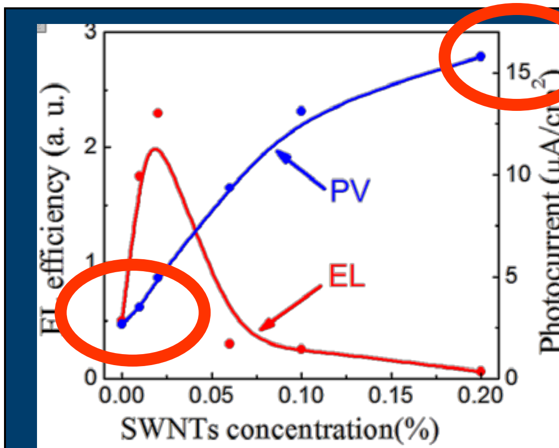


(1)



(6)





In collaboration with Bin Hu (APL 2005)

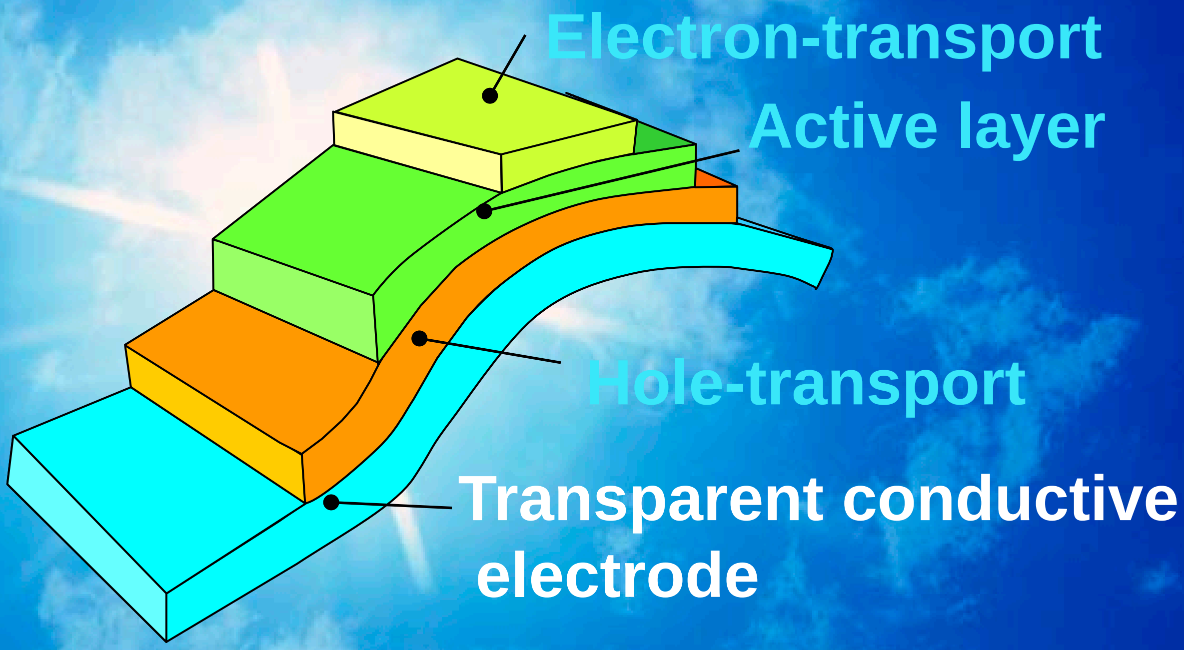
Demonstrated 7 times Higher Photocurrent for Mixed Bulk Heterojunction OPV

Structure bulk and interface assessment (SNS)

Environmental chamber -1(CNMS)
Environmental chamber-2 (SNS)

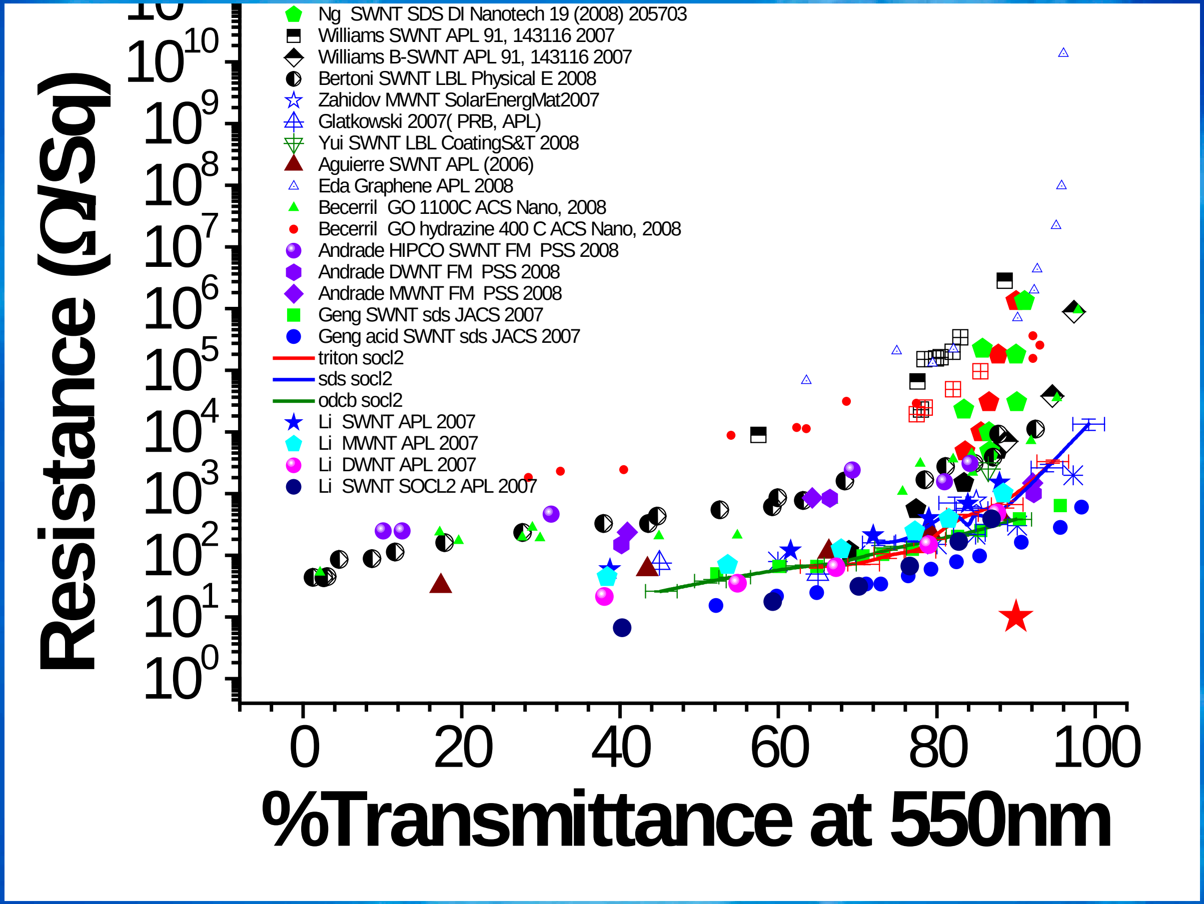
Combine benefits of nanomaterials and polymers to control nano morphology of OPV. Correlate PV structure (SNS) and Property (CNMS)

Nanomaterial based Transparent conductive electrodes

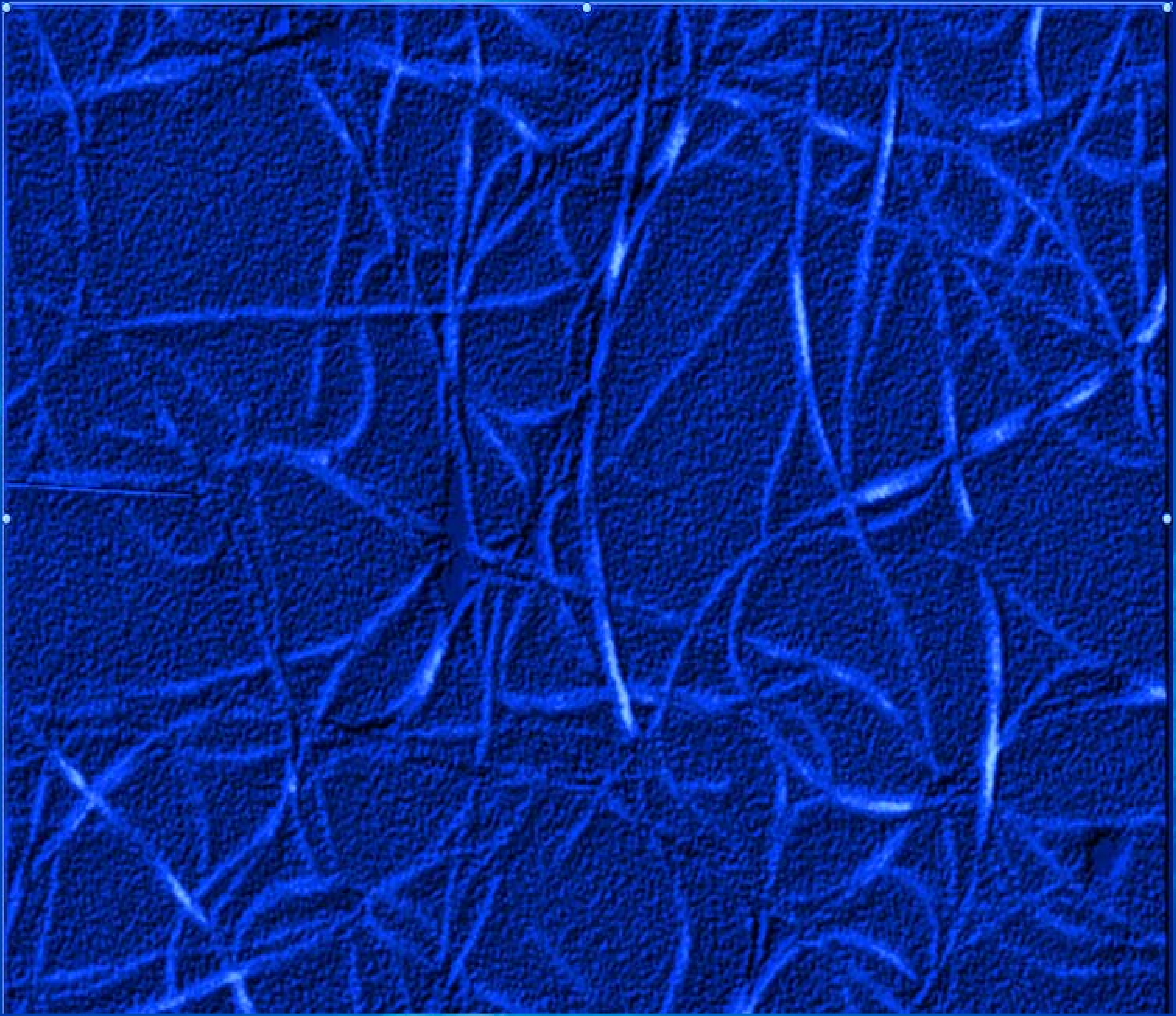


Current standard- ITO (indium Tin Oxide)

Opto-Electrical Properties of Carbon Nanotube-Based TCE

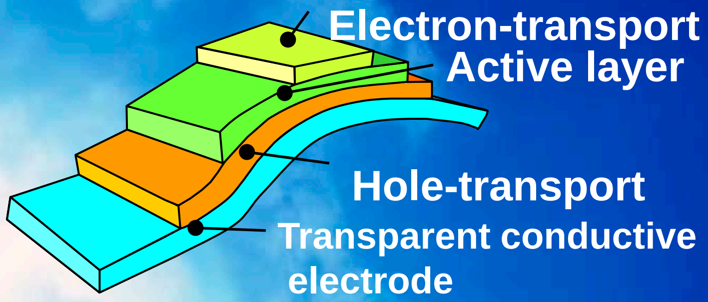


…are getting better getting close to the properties of Indium Tin Oxide TCE



SWNT transparent conductive electrode under electron microscope

Unfolding Structure of Interfaces in Organic Photovoltaic

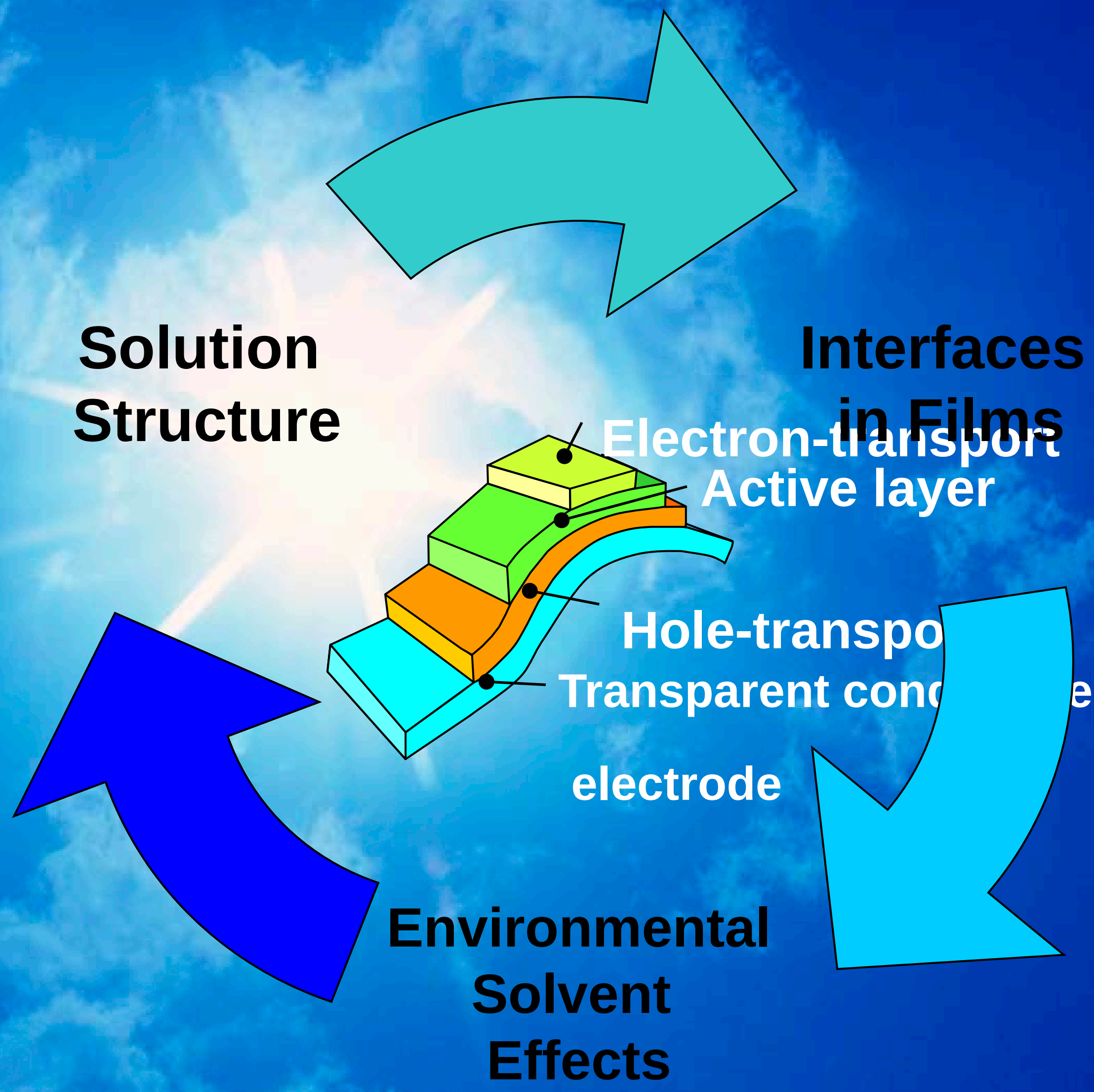


- **Why neutrons?**
  - **Non destructive**
  - **Matches the vertical spatial scale of OPV (sub nm to 10th of nanometers) which could be probed using neutrons.**
  - **Averaged over macro-scale lateral area**
  - **Possibility to contrast interface of interest with isotopes (D)**
  - **Applicable to powers/solutions/films relevant to OPV**
  - **In situ monitoring of structural change during accelerated aging (without adding more structural damage like with Xray)**

- **Goal: Develop control of structural and function of nano-interfaces**

Structure-Property Relationship of Interfaces in Organic Photovoltaics (Lifecycle of interfaces)

GOAL: Develop understanding of interfacial structure by neutron reflectometry and scattering and compare it with interface functionality



Collaborations

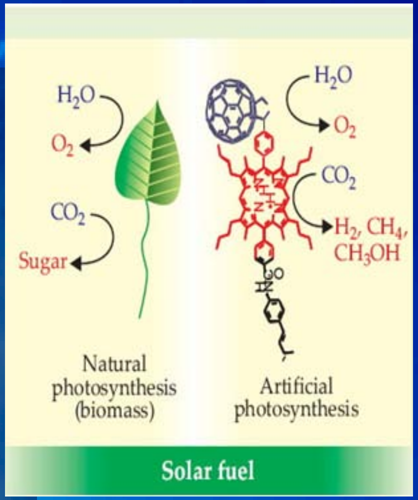
- Advanced characterization of PSI assembly and photo-activity in artificial photosynthesis systems with Bamin Khomami (UTK)

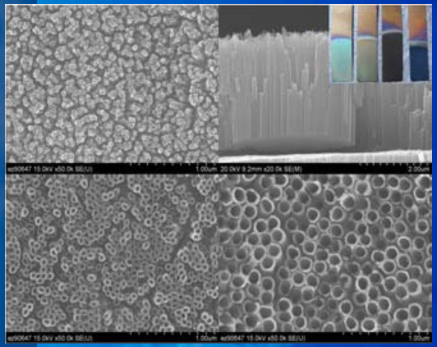
- Nanomaterials for OPV, Magnetic field effect of the dynamics of the excited state in OLED and OPV with Bin Hu(UTK)

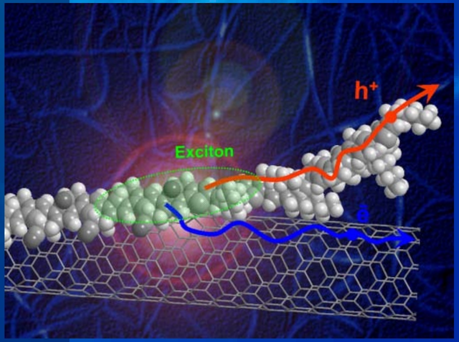
- Effect of material assembly on structure and properties of OPV Mark Dadmun (UTK)

- Towards perfect interface using nanostructures with Prof. M Hickner (Penn State)

- Effect of band gap narrowing on electro-optical functionality of TiO2 Parans Paranthaman (ORNL)







Sustainable Energy Future

Organic PhotoVoltaics

Third workshop

Sustainable Energy Future: Focus on Organic Photovoltaics

New Directions in Organic Photovoltaics: From Materials to Architectures.
Prof. David Carroll, Wake Forest University

Molecular Engineering of Conjugated Polymers to Reach Higher Efficiency "Plastic" Solar Cells
Prof. Wei You, University of North Carolina at Chapel Hill

Transparent Conducting Electrodes made from Networks of Single-walled Carbon Nanotubes for Organic Photovoltaics
Dr. Jeff Blackburn, National Renewable Energy Laboratory

A Case Study of Poly(3-hexylthiophene)-fullerene Derivative Bulk Heterojunction photovoltaics
Prof. Paul R. Berger, The Ohio State University

Polymer-based Photovoltaic Cells Incorporating Inorganic Nanocrystals
Prof. Jiangeng Xue, University of Florida

Carbon Nanotube (CNT) Network Transparent Electrodes for Organic Solar Cells
Dr. Chunming Niu, Unidym

Magneto-Optical Studies of Internal Photovoltaic Processes in Organic Solar Cells
Prof. Bin Hu, University of Tennessee Knoxville

Interfaces in Organic Photovoltaics
Prof. Bernard Kippelen, Georgia Institute of Technology

Fundamentals of Impedance Spectroscopy and Data Interpretation
Prof. Rosario Gerhardt , Georgia Institute of Technology

Impedance and Photo-Electrochemical Techniques in Renewable Energy Research
Dr. Carl-Albrecht Schiller, Zahner, Germany

September 15-16, 2010

Locations: C156, CLO (September 15th)
L282, CNMS (September 16th)

September 15-16th 2010

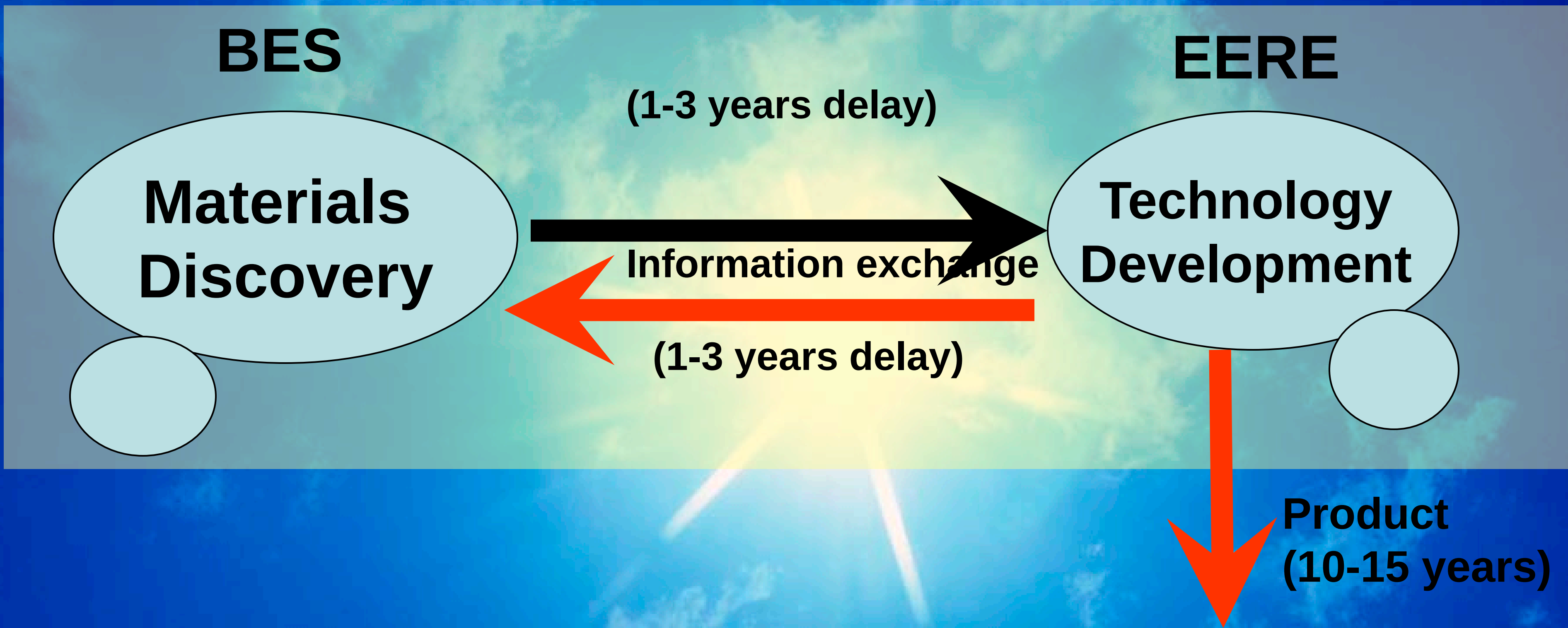
Sustainable Energy Future: Focus on Organic Photovoltaics

The goals of this workshop are to:

- *Review the current state of research activities in nanomaterial-based organic photovoltaics*
- *Introduce in-house capabilities for material synthesis and measurements at CNMS and its current R&D efforts*
- *Facilitate discussions of user research proposals and opportunities for collaboration among attendees*
- *Introduce advanced techniques to characterize photovoltaic cells.*

Wednesday, September 15, 2010		Location: CLO, room C156
8:00 - 8:40 a.m.	Dr. David Carroll	New Directions in Organic Photovoltaics: From Materials to Architectures
8:50 - 9:30	Dr. Wei You	Molecular Engineering of Conjugated Polymers to Reach Higher Efficiency "Plastic" Solar Cells
9:40 - 10:20	Dr. Jeff Blackburn	Transparent Conducting Electrodes made from Networks of Single-walled Carbon Nanotubes for Organic Photovoltaics
10:30 - 11:00	Break	
11:00 - 11:40	Dr. Paul R. Berger	A Case Study of Poly(3-hexylthiophene)-fullerene Derivative Bulk Heterojunction Photovoltaics
12:00 - 1:00 p.m.	Lunch	Presentations: Jim Browning (Neutron), Kunlun Hong (Polymer), and Kai Xiao (Organic Nanowires)
1:10 – 1:50	Dr. Jiangeng Xue	Polymer-based Photovoltaic Cells Incorporating Inorganic Nanocrystals
2:00 - 2:40	Dr. Chunming Niu	Carbon Nanotube (CNT) Network Transparent Electrodes for Organic Solar Cells
2:50 - 3:30	Dr. Bin Hu	Magneto-Optical Studies of Internal Photovoltaic Processes in Organic Solar Cells
3:40 - 4:00	Break	
4:00 - 4:40	Dr. Bernard Kippelen	Interfaces in Organic Photovoltaics
4:50 - 5:50	Discussions	
Thursday, September 16, 2010		**Location : CNMS, room L282**
8:00 - 9:40	Dr. Rosario A. Gerhardt	Fundamentals of Impedance Spectroscopy and Data Interpretation
9:50 – 12:00 p.m.	Dr. Carl-Albrecht Schiller	Impedance and Photo-Electrochemical Techniques in Renewable Energy Research
12:00 - 1:00	Lunch	
1:00 – 5:50	Dr. Carl-Albrecht Schiller	Demonstrations of Advanced PV Testing

Strong, but disconnected efforts of BASIC and APPLIED Sciences



10-15 years technology development cycle is too long.
<u>Hard to compete internationally</u>

Cooperative Basic and Applied Sciences Effort

This is a successful model of structuring research and technology development in Japan, Korea, England, Ireland, Germany,Russia.

Building on the foundation of strong BES and EERE programs at ORNL for Accelerated material discovery and technology development effort in PV

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