CONTACT: Research in Power Generation and Storage for the Air Force

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University of Texas at Dallas

Jack Agee
Director, CONTACT Program
Rice University

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Fort Worth, TX

AGENDA

- CONTACT Program
- Supercapacitors……*UT Dallas*
- Hybrid Tandem Solar Cells with Carbon Nanotube Interlayers……*UT Dallas*
- Organic-Inorganic Hybrid Materials for Solar Cells ……*UT Austin*
- Armchair Quantum Wire……*Rice University*

What is CONTACT?

Consortium for Nanomaterials for Aerospace Commerce and Technology

- Partnership of the following institutions:
  - **U.S. Air Force Research Laboratory**
  - **University of Texas at: Arlington, Austin, Brownsville, Dallas, and Pan American**
  - **Rice University**
  - **University of Houston**
- Basis for cooperative nanotech research in Texas to provide breakthrough technological solutions
- Strengthened by cross-cutting intellectual collaborations and the availability of state-of-the-art equipment
- Focused on tech transfer to aerospace, commercial, and defense sectors

CONTACT Project Descriptions

CONTACT is focused on the following areas of interest to the Air Force and aerospace industry:

1. **Adaptive Coatings and Surface Engineering**
   - Nano coatings (reduce drag, corrosion, repair cracks)
   - Thermal control, space environment resistant satellites
   - Nanoparticle enhanced composites – structures
2. **Nano Energetics**
   - High energy propellants and explosives
   - Use nanoparticles to control the burn rate
3. **Electromagnetic Sensors**
   - Devices for optical sensing, communications
   - Ultraviolet, visible, infra-red, terahertz frequencies
4. **Power Generation and Storage**
   - Solar cells, magnets, next generation batteries, capacitors
   - Enable directed energy weapons, compact power generators

Research in power generation and storage for the Air Force

Novel Composite Carbon Nanofibers for Supercapacitor Electrodes

John P. Ferraris[1,2,3]

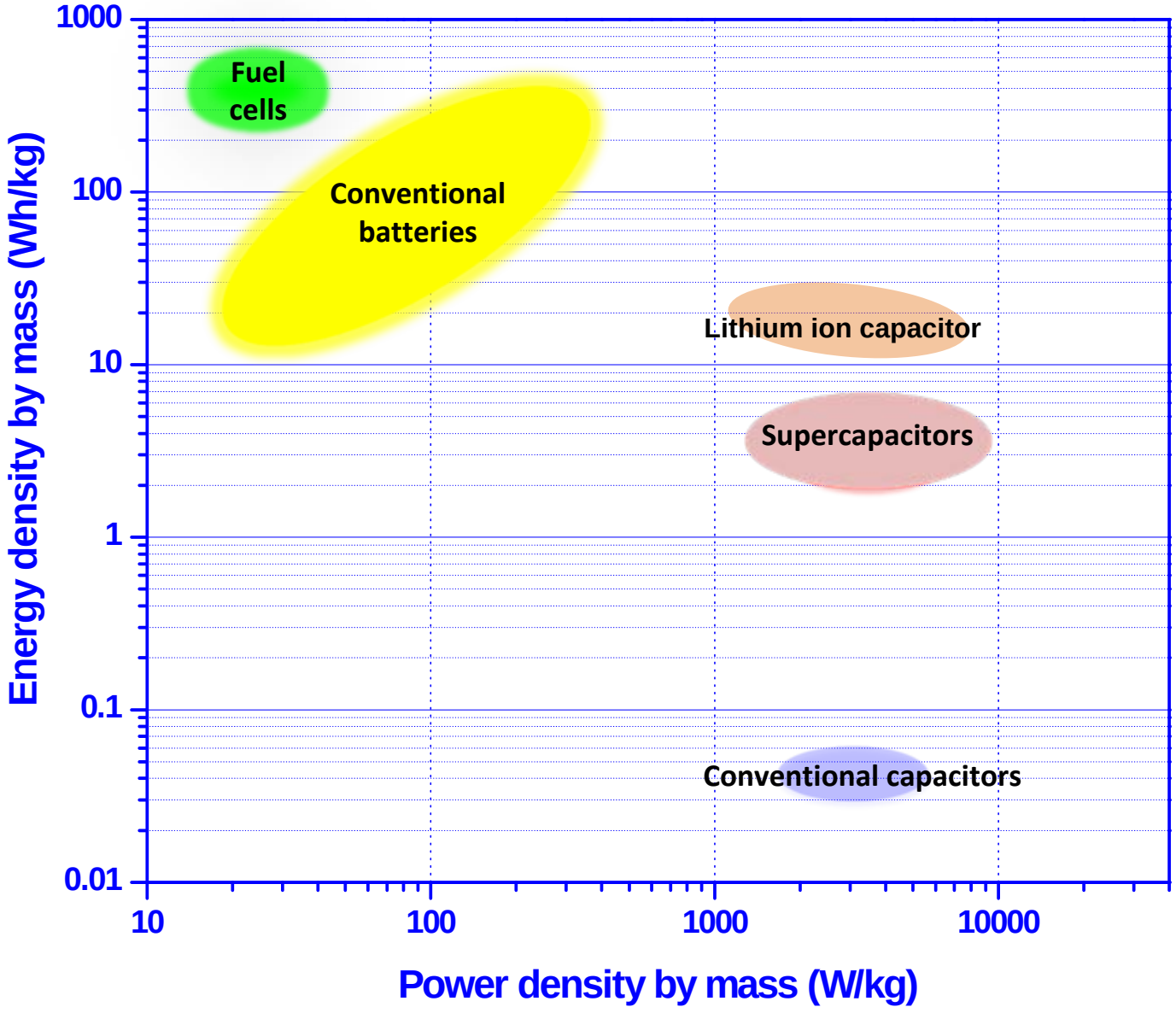
The University of Texas at Dallas

[1]Department of Chemistry
[2]The Alan G. MacDiarmid NanoTech Institute
[3]Solarno, Inc.

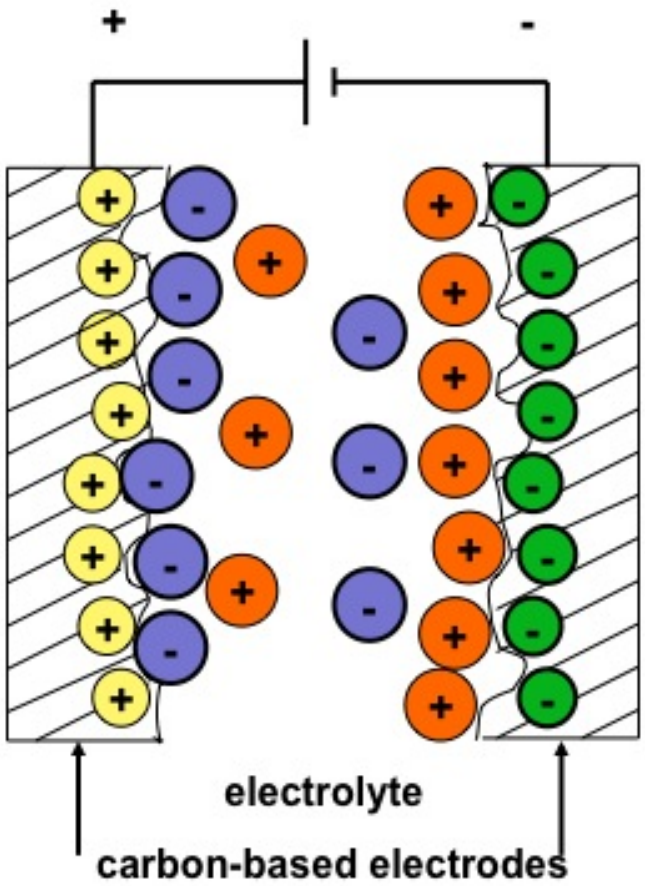
Supercapacitors

John Ferraris *-University of Texas at Dallas*

- Energy storage devices
- Strategies to increase energy and power densities in supercapacitors; electrodes and electrolytes
- Electrospinning of nanofibrous polymers
- Adding templated carbon precursor: metal-organic framework-5 containing furfurol


Fuel cells
Conventional batteries
Lithium ion capacitor
Supercapacitors
Conventional capacitors
1000
100
10
1
0.1
0.01
10
100
1000
10000
Energy density by mass (Wh/kg)
Power density by mass (W/kg)

Strategies for increasing energy and power densities in supercapacitors



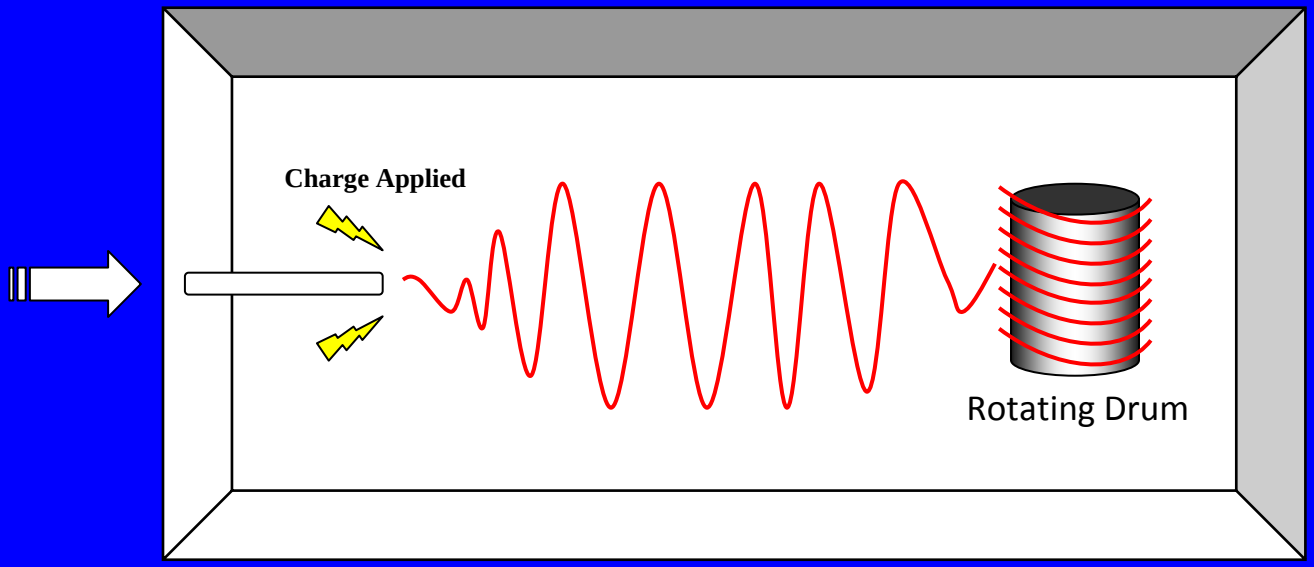
Electrode:

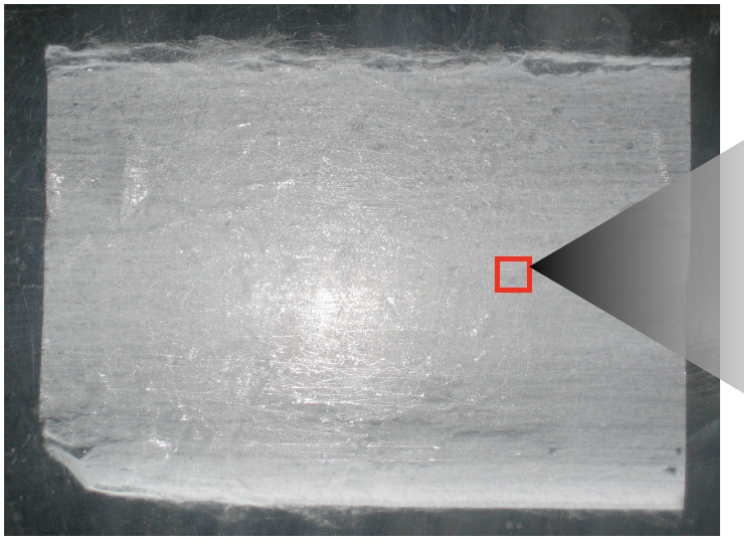
- increase effective surface area: mesopores >> micropores
- Increase conductivity
- decrease contact resistance

Electrolyte:

- highly conducting
- wider electrochemical window
- (>3V)

Electrostatic Deposition (Electrospinning) of Nanofibrous Polymers



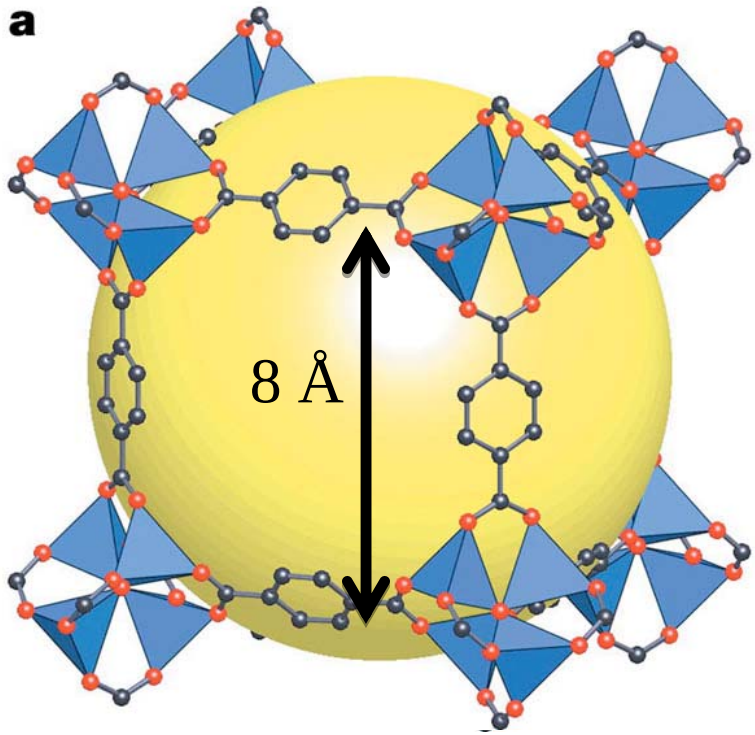


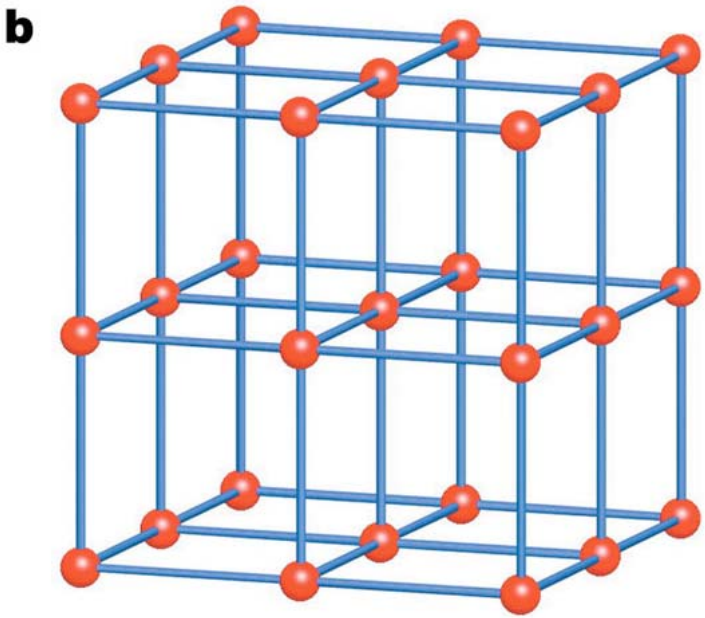
RESEARCH RATIONALE

E-spun composite polymer fiber containing dispersed templated carbon precursor

Carbon fiber matrix incorporating high surface area carbon (No binders required)

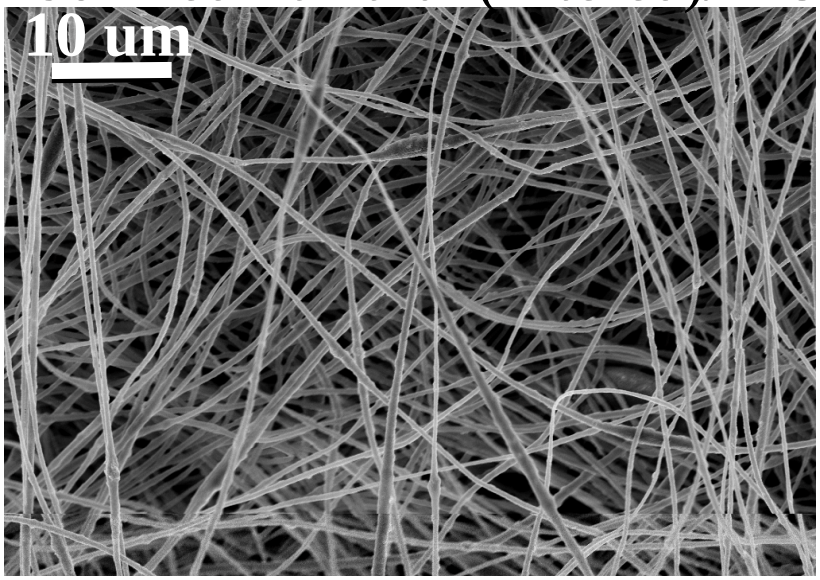
Templated Carbon Precursor: Metal-organic framework-5 (MOF-5) containing Furfural

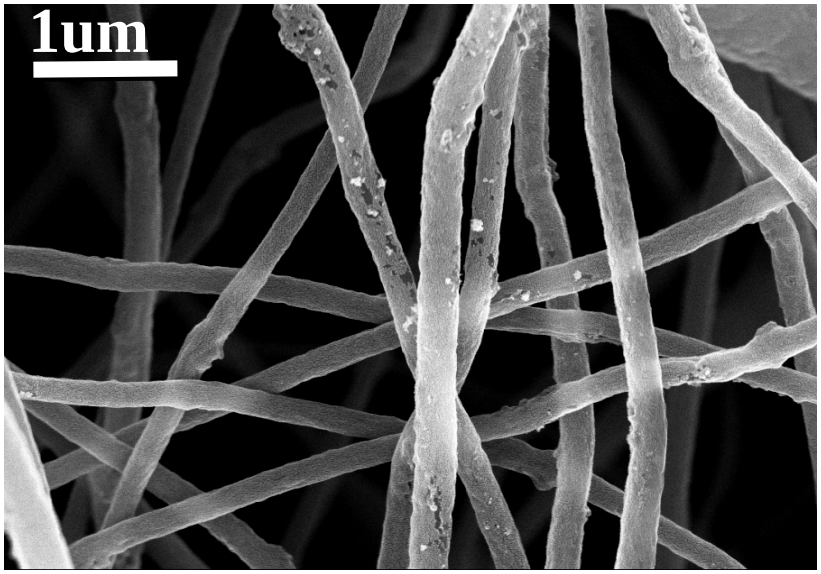




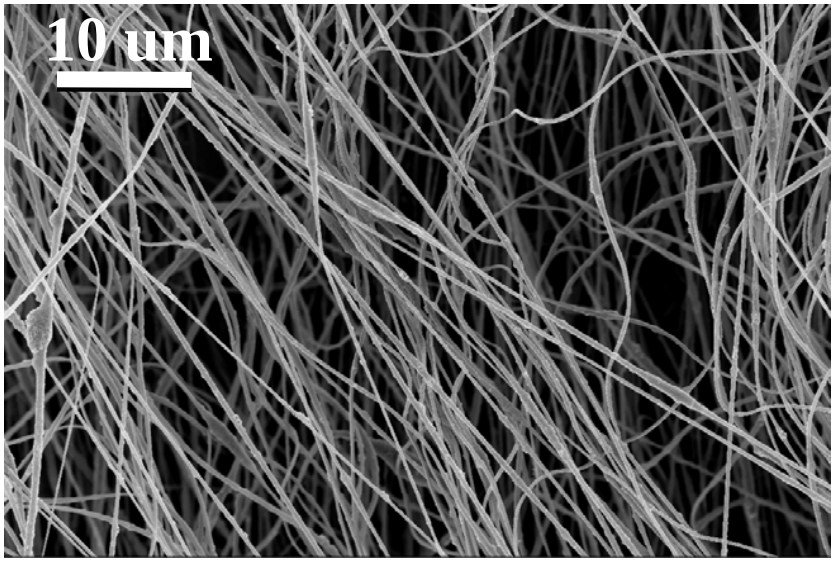
Yaghi, O. M., O'Keeffe, M. , Ockwig, N. W., Chae, H. K., Eddaoudi, M., Kim, J., *Nature* **2003** 423, 705-714 doi:10.1038/nature01650

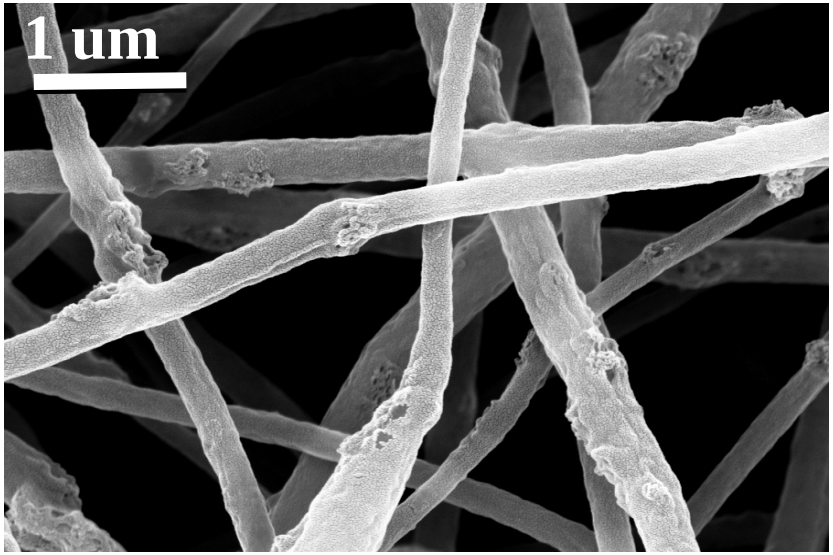
Carbonized Furfural (filtered)/MOF-5/PAN



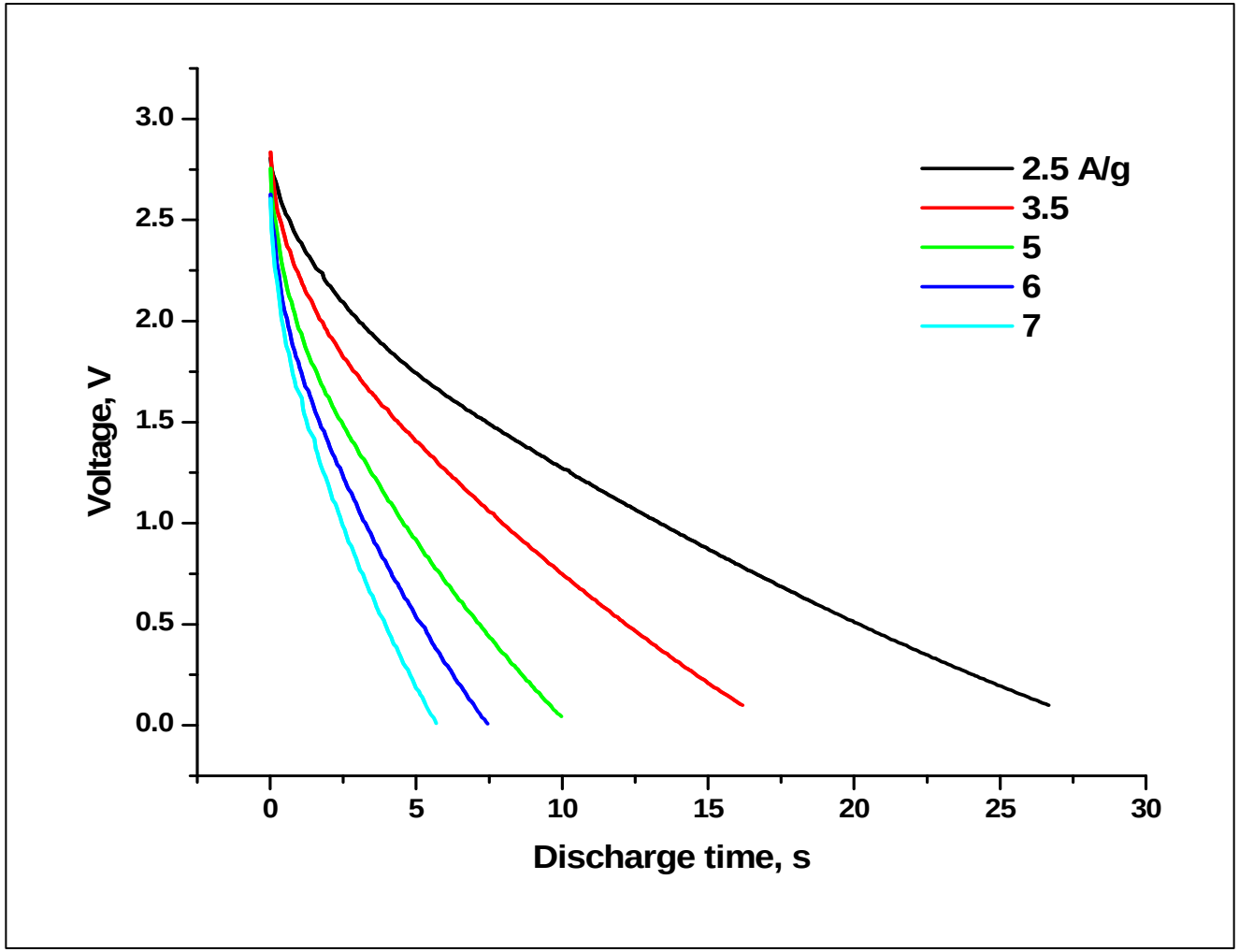


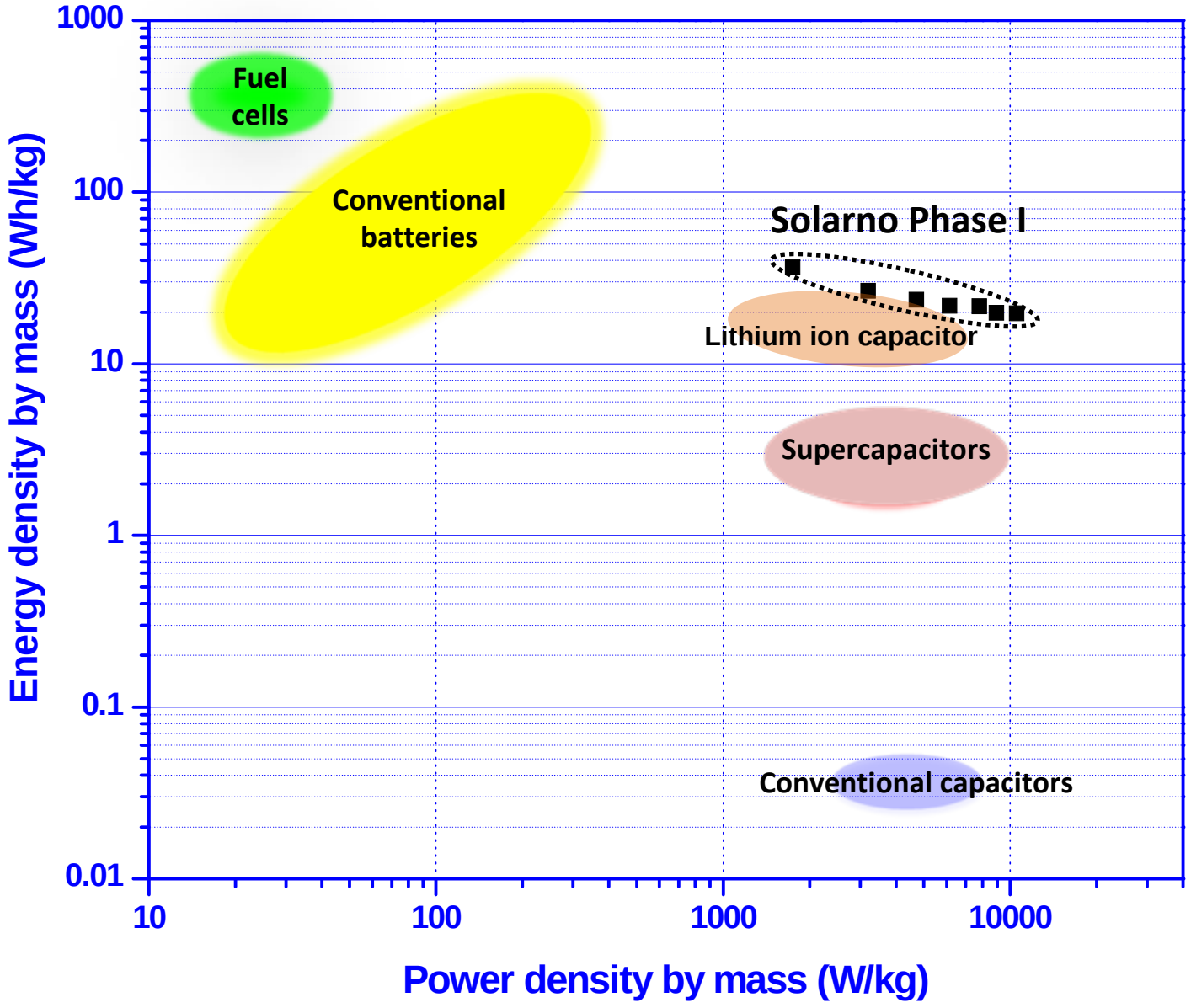
Carbonized Furfural(Vapor deposited)/MOF-5/PAN





Charge/discharge for Furfural(filtered)/MOF-5/PAN in EMITFSI




Fuel cells
Conventional batteries
Solarno Phase I
Lithium ion capacitor
Supercapacitors
Conventional capacitors
1000
100
10
1
0.1
0.01
10
100
1000
10000
Energy density by mass (Wh/kg)
Power density by mass (W/kg)

The Supercapacitor Group @ UTD

Funding

- CONTACT
- NSF STTR to SOLARNO/UTD

Research in power generation and storage for the Air Force

Hybrid Tandem Solar Cells with Carbon Nanotube Interlayers: DSC/OPV Parallel Tandems

Anvar Zakhidov[1,2,3]

The University of Texas at Dallas
[1]Nanotech Institute
[2]Department of Physics
[3] SOLARNO Inc.

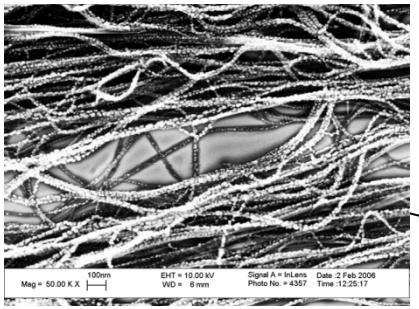
Hybrid Tandem Solar Cells with Carbon Nanotube Interlayers

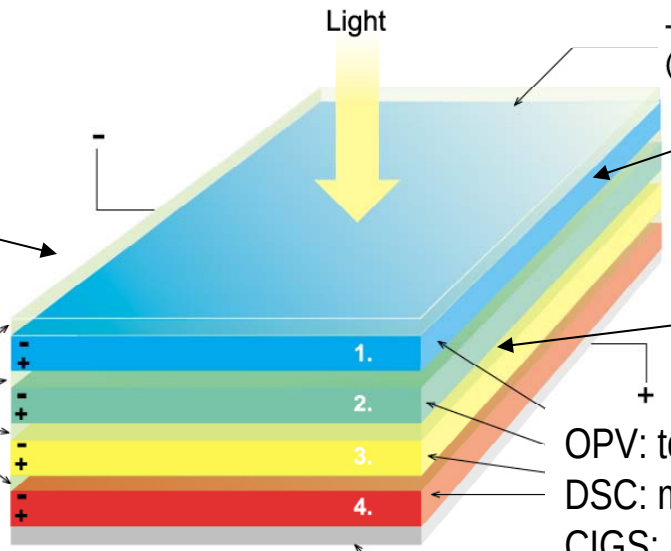
Anvar Zakhidov *-University of Texas at Dallas*

- Schematic of a thin film hybrid tandem solar cell
- Newest results for organic photovoltaic (OPV)-dye sensitized solar cells (DSC) tandem including efficiency and absorption profile
- Future plans

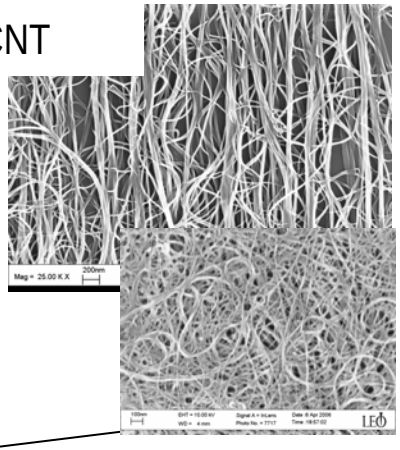
Basic Architecture of Thin Film Hybrid Tandem for CONTACT program

Transparent interconnects
by T-CNT networks functionalized by
metal coatings and single wall CNTs





Multiwall CNT



Top Contact
(transparent)

Transparent
Interconnect

Single wall CNT
on T-MWCNT

OPV: top cell, Eg = 2 eV
DSC: middle cell 1, Eg = 1.65 eV
CIGS: bottom cell Eg = 1 eV

Reflector +
Collector

A flexible hybrid tandem solar cell based on transparent carbon nanotube networks as interlayers between DSC, CIGS and OPV for maximal collection and recombination of charges.

Today OPV-DSC tandem will be described for the CONTACT program

Summary

1) We demonstrated a parallel tandem of DSC/OPV:
"Dye sensitized - Organic photovoltaic cell with:

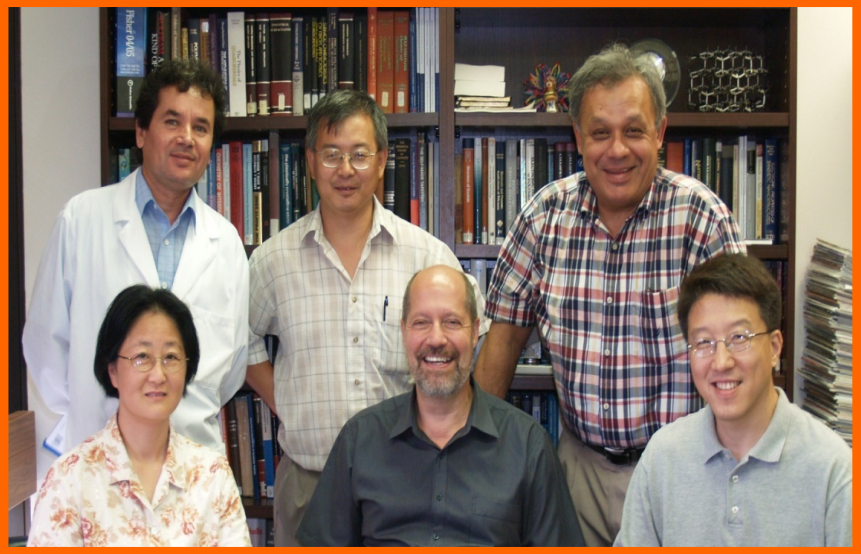
- Increase of photocurrent, and enhanced power efficiency (~7 % presently and 13-14 % predicted for optimized)
- Enhanced spectral sensitivity
- Semi-Monolithic design incorporating a MWCNT interlayer and Inverted OPV with SWCNT cathode
- Filled 2 patents (by Solarno/UTD) and awarded Phase II STTR program by DOE on development of Hybrid tandems

2) From our model we demonstrated advantages of parallel architecture and need to improve conductivity of both MWCNT interlayer and inverted SWCNT cathodes;
In order to achieve 14-16 % in DSC/OPV tandem

3) Future Plans: to create Inorganic/Organic Parallel tandem of Si-OPV and Si-DSC type (partnership with Euro-Asia Center for Advanced Technologies). Total efficiency predicted ~ 20-25 %

"Science is People!"

Alan MacDiarmid, 2000 Nobel Laureate in Chemistry



UTD Nanotubes Team:

Ali Aliev, Sergey Lee, Anvar Zakhidov, Mei Zhang, Ray Baughman, Shaoli Feng

UTD Nano Energy and Nanophotonics:

Yuen Jung, Chao Chen, Alex Cook, Raquel Ovalle, Anvar Zakhidov, Alex Kuznetsov, Josef Velten, Dean Hsu, Brian Wang, Kamil Mielczarek

Funding

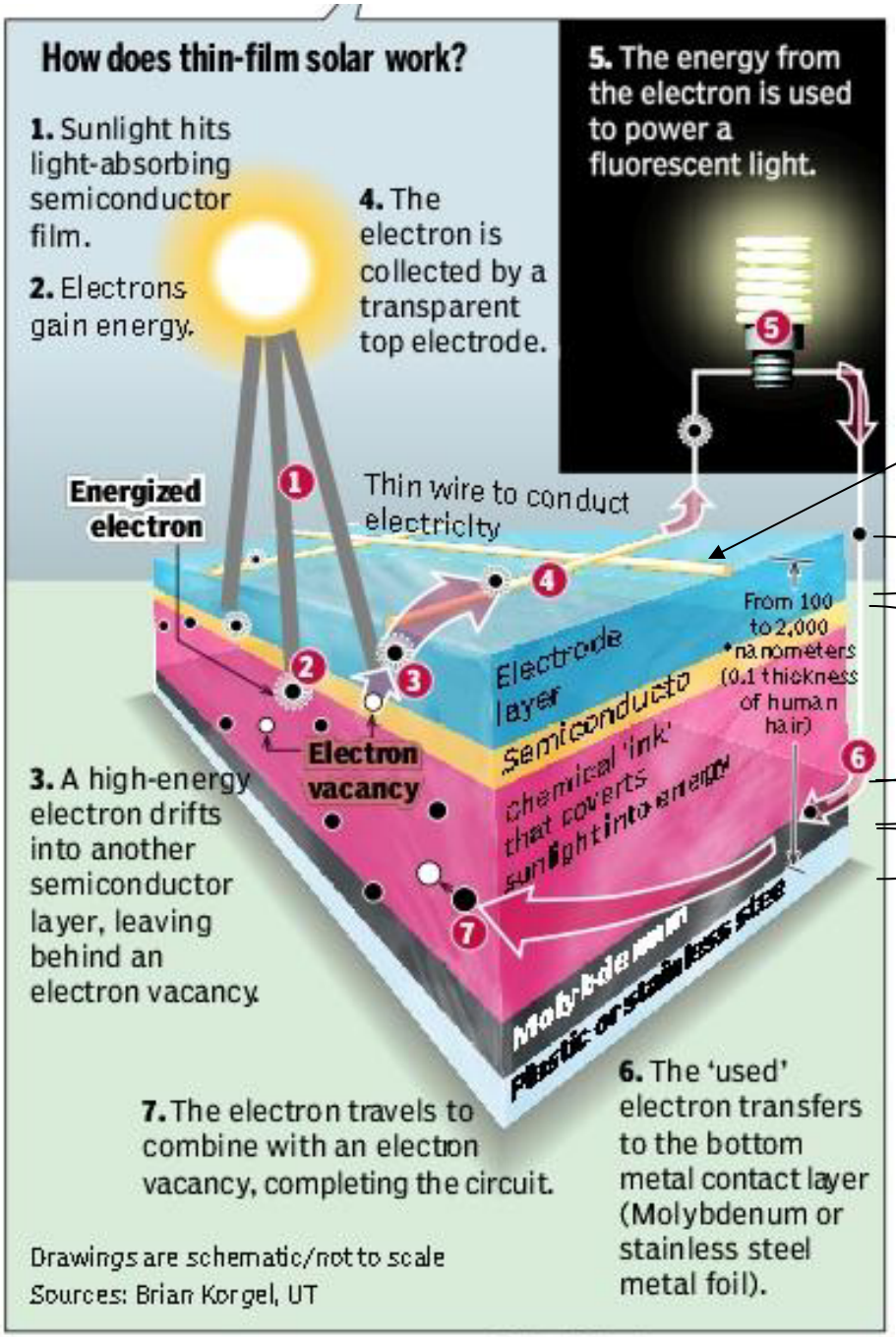
- CONTACT (AFRL/Rice Strategic Partnership for Commercialization of Nanotechnology)
- Texas Advanced Technology Program,
- STTR by DOE and NSF to SOLARNO/UTD
- Robert A. Welch Foundation

Electronic Devices through Organic-Inorganic Hybrid Materials and Processing Development

B. A. Korgel, A. J. Bard, A. Dodabalapur, and D. Vandenbout

-University of Texas at Austin

- Synthesis and characterization of $Cu(In,Ga)Se_2$ and creating a stable photovoltaic material
- Schematic of a thin film solar cell
- Lowering the cost of solar energy
- Spray-on $CuInSe_2$ inks and its challenges
- Si nanowires



Metal

n-type semiconductor

Nanocrystal ink

Metal

Glass or plastic support

To Lower the Cost of Solar Energy…

Change the way solar cells are made

Slow, high temperature vacuum processes

Print like newspaper

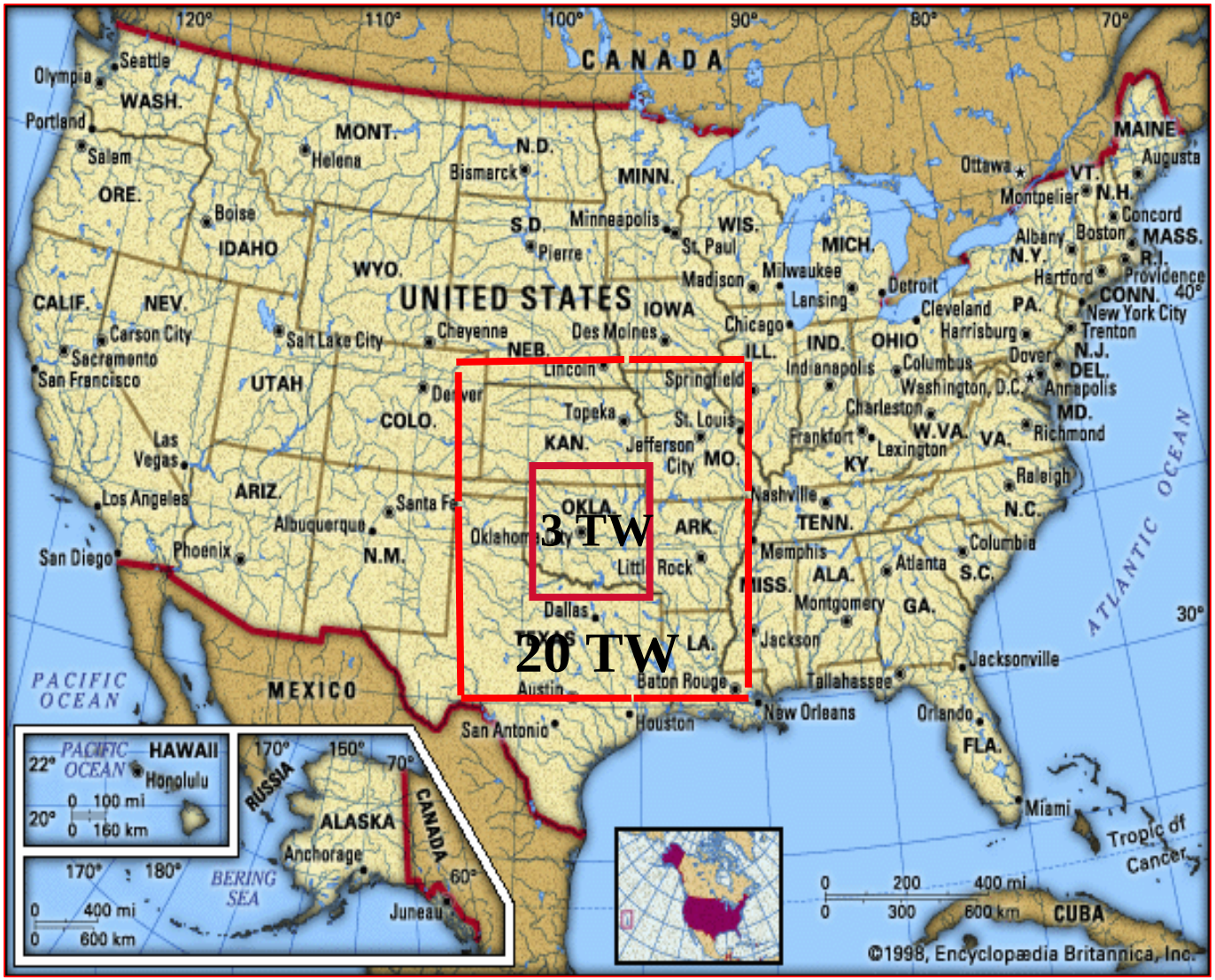
Photovoltaic Paints…?

Armchair Quantum Wire

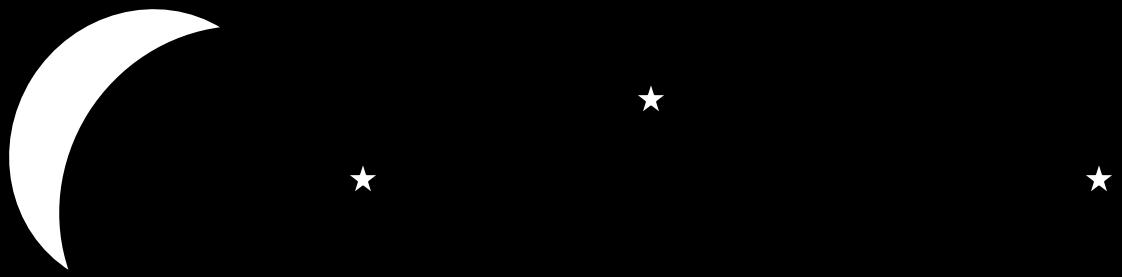
Wade Adams *-Rice University*

- Potential and challenges of solar energy
- Revolutionizing power grid technology
- Characteristics and synthesis of single-wall carbon nanotube (SWCNT) quantum wire
- Strategies for developing large quantities of Armchair SWCNT

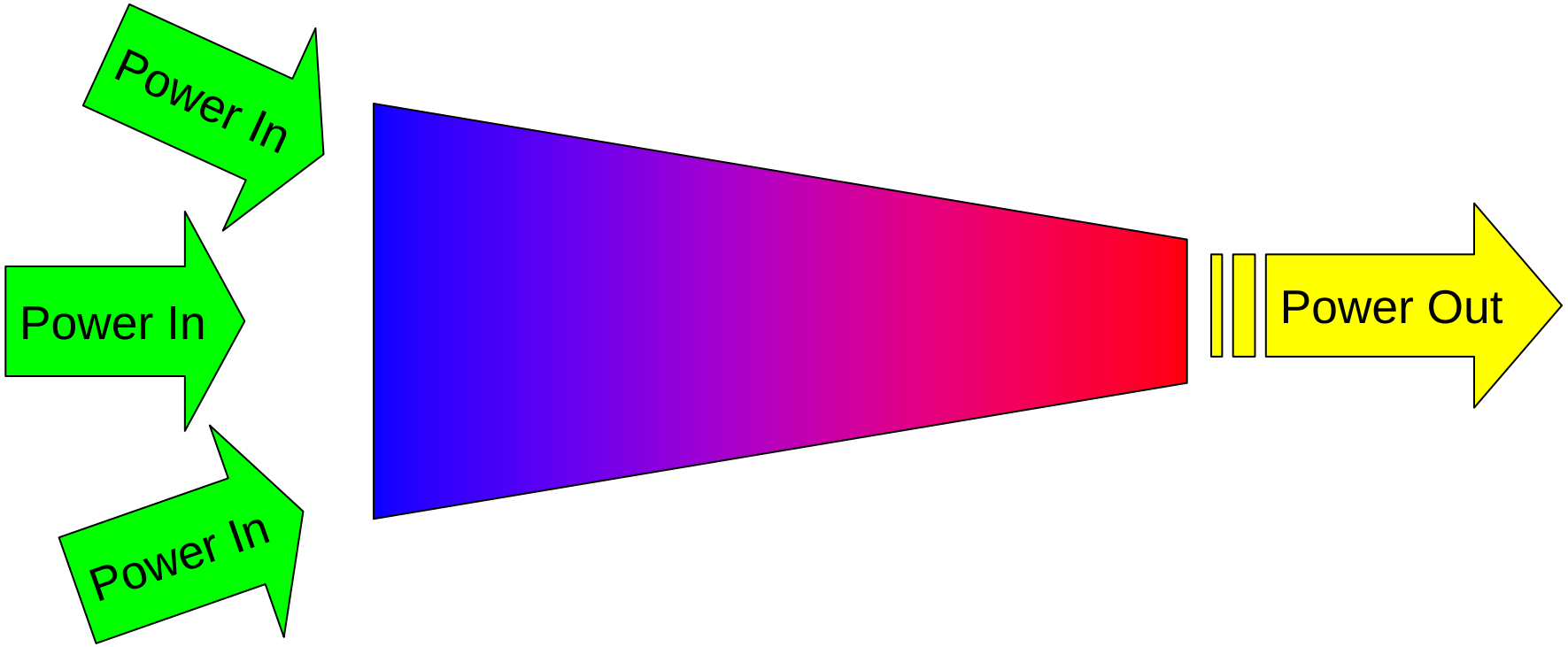
Solar energy could power the country



Nathan S. Lewis, California Institute of Technology

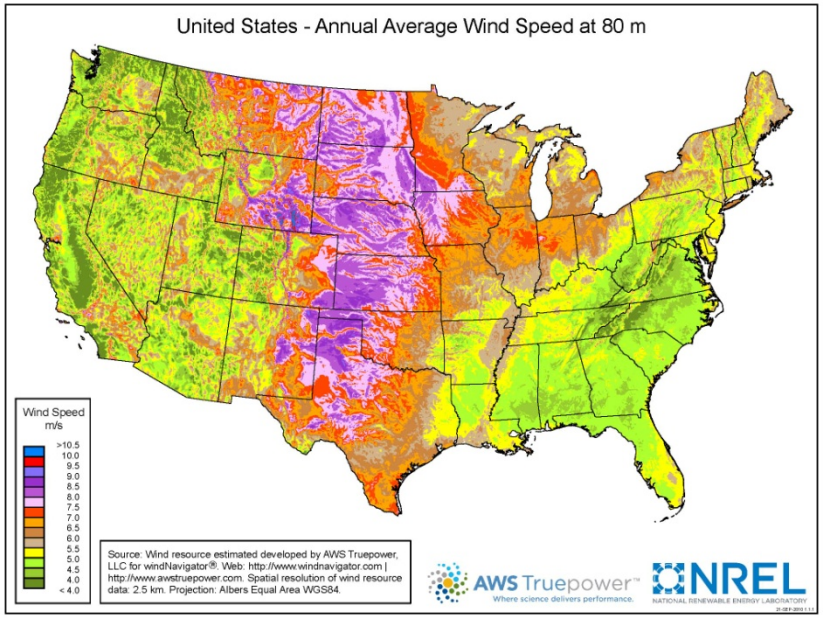


And distance:



Transmission lines lose approximately 8% of electricity every 200 miles.

Wind is important, but…

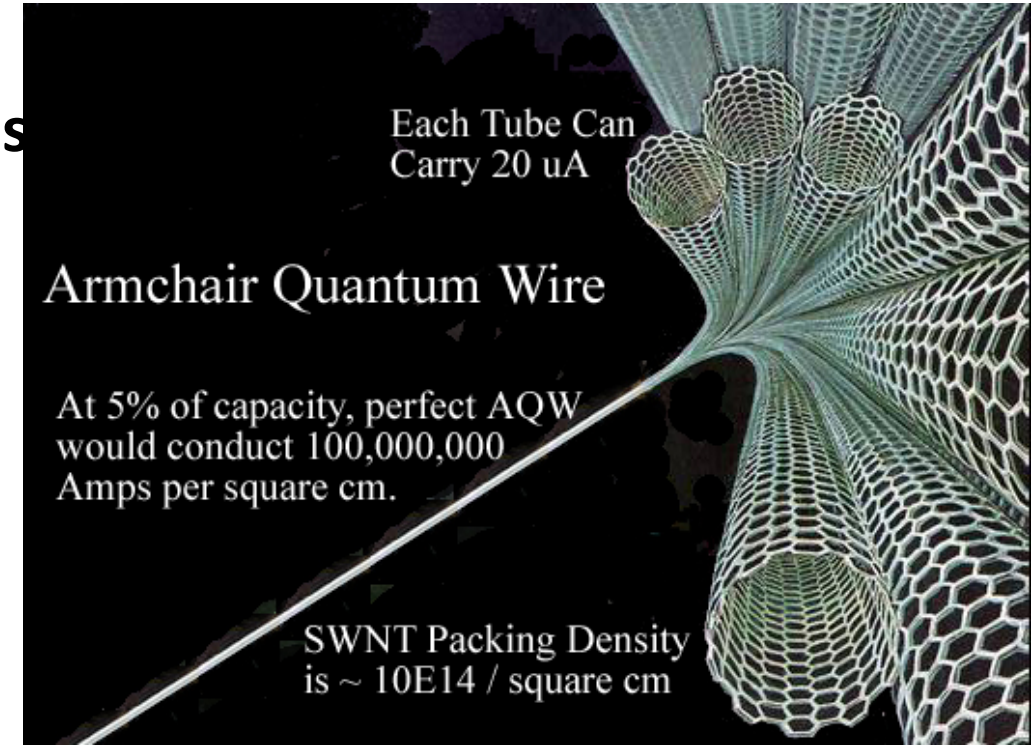


…it’s also a long way from the market.

SWCNT* Quantum Wire

- **Expected Features**
  - 1-10x Copper Conductivity
  - 6x Less Mass
  - Stronger Than Steel
  - Zero Thermal Expansion

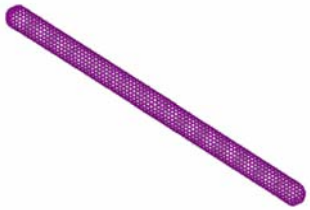
- **SWCNT Technology Benefits**
  - Type & Class Specific
  - Higher Purity
  - Lower Cost
  - Polymer Dispersible

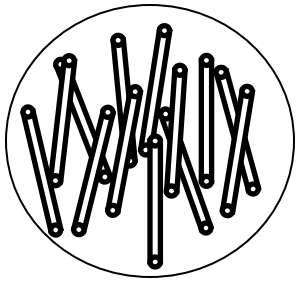


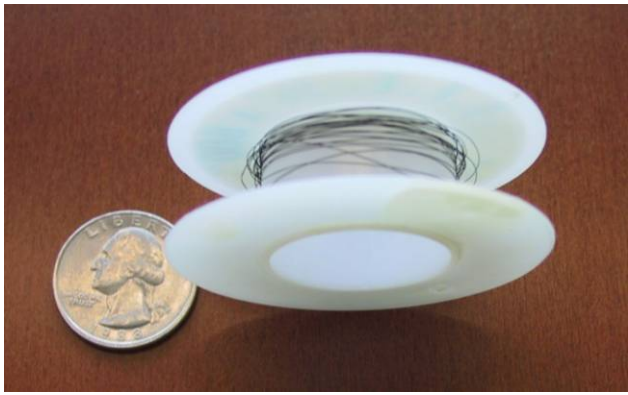
***Single-Wall Carbon Nanotube**

Making the AQW

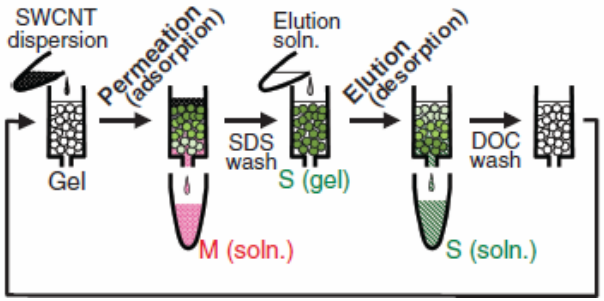
- What needs to be done:
  - Go from single SWCNT
    - to macroscopic material
  - All-armchair SWCNTs
    - preferably all same diameter
  - Large quantity
  - Align and transform into fiber







3 Routes to Large Quantities of Armchair SWCNT



- Sort Large Quantities of SWCNTs
- Sort Small Quantities of SWCNTs
- Amplify
- Grow Only Armchair SWCNTs (catalyst tuning)