Nanotechnology for Energy

- Preparation, processing and patterning of nanomaterials for energy systems

from practical engineering approaches

- in bulk
- at a large (industrial) scale
- with low cost
- study the life cycle
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  - Nanomaterial synthesis
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Energy and the Environment

➢ Global Warming

Figure 1b  Increased CO₂ Emissions Causing a Rise in Atmospheric CO₂ Associated with a Rise in Global Temperature (Sources: CO₂ data from Ethridge et al. 2001, Keeling and Whorf 2002; temperature data from Jones et al. 1998, Peterson and Vose 1997)
Global Warming and Energy Needs

\[ C_xH_y + \text{coal} + 0.25y\ O_2 \rightarrow xCO_2 + 0.5yH_2O + \text{Energy} \]
Energy Needs

- The oil production will peak soon
- The major player will be still fossil fuels (oil, coal, natural gas, oil sand, etc.) before 2050
- The portion of ‘renewable fuels’, however, will increase dramatically …
Life Cycle of Energy Devices

- Raw Material Synthesis
- Components Manufacturing
- Module & Device Assembly
- Installation & Use
- Waste Disposal & Recycle
LEER Projects on Nano-based Energy Devices

- Flame synthesis of single walled carbon nanotubes
- Fabrication of CNT based electrodes
- Development of nanothermite for packaging
- Towards 3D solar harvesting devices

Plasma gasification for E-waste
Projects on Energy Devices

➢ Our Ultimate Research Goals

- Focus on large-scale, low-cost production and processing of nanomaterials
- Develop packaging and patterning technologies for bulk materials (vs. individual ones) e.g., printing and electrophoretic deposition
- Contribute to
  - improve today’s energy systems
  - develop future energy systems
Nanomaterial Synthesis

- Large-scale Synthesis of Nanoparticles and Carbon Nanotubes

Input: Gas-phase chemicals
Processes: in aerosol phase (weak dependence on geometry)
Output: material containing 25% SWCNTs

Wen et al. (2008) Carbon
Nanomaterial Synthesis
Fabrication of Nano-electrodes

Approach 2: Electrophoretic Deposition
Approach 2: Electrophoretic Deposition

<table>
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<tr>
<th>Sample #</th>
<th>Description</th>
<th>Capacitance (Cp) uF</th>
<th>Internal Resistance (R) Ohms</th>
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<tr>
<td>1</td>
<td>Electrolyte Only</td>
<td>0.58</td>
<td>450.00</td>
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<tr>
<td>2</td>
<td>Bare Ni</td>
<td>12.00</td>
<td>42.00</td>
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<tr>
<td>3</td>
<td>Drop Coated</td>
<td>25.00</td>
<td>1.22</td>
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<td>4</td>
<td>SWCNT EPD Coated 20V - 3min</td>
<td>3.50</td>
<td>45.00</td>
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<tr>
<td>5</td>
<td>SWCNT EPD Coated 30V - 3min</td>
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<td>6.50</td>
</tr>
</tbody>
</table>

Super Capacitors w/ Solid Electrolyte
**LEER Projects on Nano-based Energy Devices**

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Energetic Nanomaterials

- Replacing gold wire by copper wire
- Example Reaction

$$4\text{Al} + 3\text{CuO}_2 \rightarrow 2\text{Al}_2\text{O}_3 + 3\text{Cu} + \text{Heat}$$

Wire welding
Energetic Nanomaterials

Objective: to investigate the thermodynamic properties and trigger mechanism of the coated Al-CuO thermite for Cu-Cu wire bonding applications
Nanothermite for Electronic Packaging

➢ Novel Core-Shell Nanothermite

Wen et al. (2010) submitted
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3D Dye Sensitized Solar Cells

- Hydrothermal Synthesis of ZnO and TiO$_2$ Nanowires
  - tunable geometries
  - tunable diameters
  - tunable length
  - tunable thickness
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Plasma gasification for E-wastes
Plasma Enhanced Gasification for E-waste

➢ the Current Technology

Hundred of workers in Shanghai sort through piles of scrap from North America and Europe for metal to be melted down for the auto industry in Japan.
Plasma Enhanced Gasification for E-waste

» Plasma Gasification vs. the Current Technology
Summary

- Solar energy will be the ultimate solution to the energy crisis
- Electricity and hydrogen need to be generated from solar resources and biomass
- Nanotechnology will find its killer applications in developing novel energy devices
- Technical breakthroughs will be evaluated by both energy conversion efficiencies and material and manufacturing costs