ESP5403 Nanomaterials for Energy Systems

Introduction to Nanomaterials

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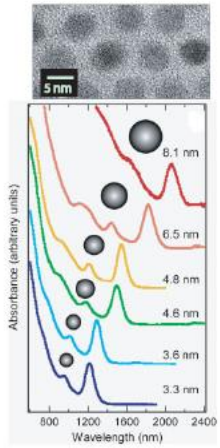
What is Nanomaterial?

Nanomaterials are commonly defined as materials with an average grain size **less than 100 nanometers**

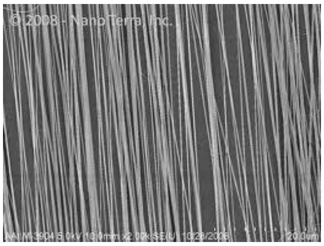
1 nm = 10^{-9} m

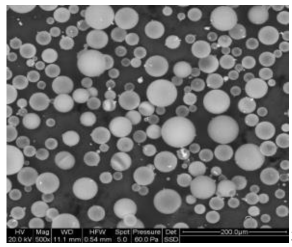
- The average width of a **human hair** is on the order of **100,000 nanometers**
- A single particle of **smoke** is in the order of **1,000 nanometers**

Nanomaterial Shapes



- Nanomaterials can be nanoscale in **zero dimensions** (quantum dots for solar cells)
- **One dimensions** (nanowire or nanofibers)
- **Two dimensions** (graphene sheets etc.,)
- **Three dimensions** (particles etc.,)





Why Nanomaterials ?

Nanotechnology exploits benefits of ultra small size, enabling the use of particles to deliver a range of important benefits or properties:

- Thermodynamics
- Electrical conduction
- Thermal conduction
- Mechanical properties

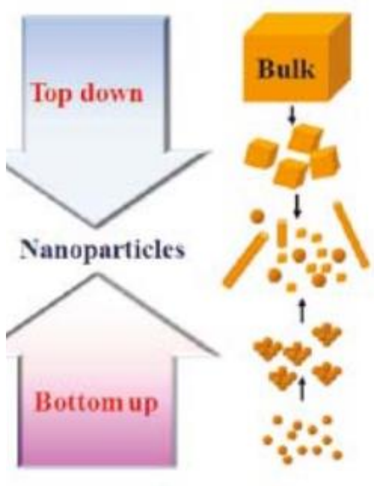
Energy systems:
Energy harvesting (solar cells, fuel cells and thermo-electrics)
Energy storage (lithium-ion batteries and supercapacitors)

Why?
Surface/interface contributions become enormously important.

- Behavior of nanomaterials may depend more on **surface area** than particle composition itself.
- Relative-surface area is one of the principal factors that enhance its reactivity, strength and electrical properties.

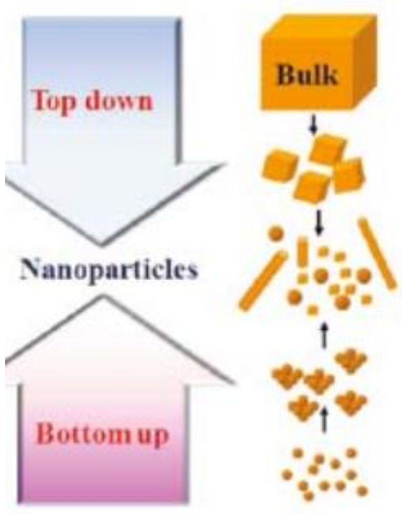
Approaches

- **Top-down** – Breaking down matter into more basic building blocks. Frequently uses chemical or thermal methods.
- **Bottoms-up** – Building complex systems by combining simple atomic-level components.



Methods for Creating Nanostructures

- **Mechanical grinding** example of (top-down) method
- **Wet Chemical** example of both (top-down) & (bottom up)



Topics to be covered (only for guidance)

Weeks 1, 2 and 3

1. Introduction to nanomaterials, semiconductor, ionic conductor and mixed conductor

Week 4

2. Nanomaterials synthesis: solid state and solution approaches, calcination and sintering; characterization of nanomaterials.

Weeks 5 and 6

3. Physical properties of nanostructured materials

3.1 Thermodynamics
3.2 Electrical conductivity
3.3 Thermal conductivity

Weeks 7, 8, 9 and 10

4. Energy conversion and storage using nanostructured materials

4.1 Solar Cells
4.2 Fuel cells
4.3 Thermo-electrics (Guest Lecture)
4.4 Rechargeable batteries
4.5 Supercapacitors

Weeks 11 and 12

5. Engineering aspects and challenges to be faced

5.1 Designing miniaturized devices: fuel cells and batteries
5.2 Safety issues

Weeks 13: Revision

Total Assessment: 100%

- **CA: 40%** (two quizzes)
- **Final Examinations: 60%**