



NanoScience-NanoTechnology module

ID student-NST introduction

NanoScience-NanoTechnology (NST)

How would you define Nanoscience-Nanotechnology?

NanoScience-NanoTechnology (NST)

Fundamental concept: Properties relate not only to structure, but also to size.

(Kumar & Kumbhat 2016)

Definition: “The study of phenomena and manipulation of materials at atomic, molecular, and macromolecular scales, where properties differ significantly from those at a larger scale”

(The Royal Society and The Royal Academy of Engineering 2004)

NanoScience-NanoTechnology (NST)

NST framework:

- 1) Foundational science content
- 2) Applying the foundational science content
- 3) Epistemological knowledge: moving forward/generating new knowledge
- 4) NST & Society

(Stevens et al. 2009)

NanoScience-NanoTechnology (NST)

What science concepts do you regard as foundational for NST?

Word cloud: Choose up to 3 words/phrases!

NST: Fundamental concepts

□ Size & Scale

- Magnitude units, orders of magnitude,
- Proportionality: Surface-related and volume-related properties, $\frac{S}{V} \sim \frac{1}{r}$
- Shape: affects $\frac{S}{V}$

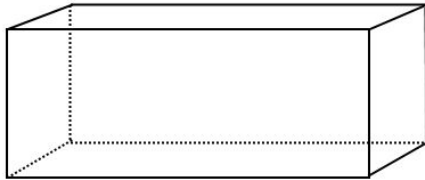


Image: Stevens et al. 2009

Dimensions (cm)	Surface Area (cm ²)	Volume (cm ³)	S/V (cm ⁻¹)
10 x 10 x 10	600	1000	0.60
20 x 10 x 5	700	1000	0.70
50 x 10 x 2	1240	1000	1.24
100 x 10 x 1	2220	1000	2.22

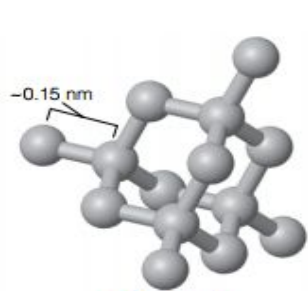


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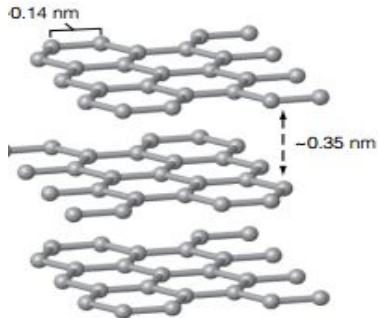
NST: Fundamental concepts

Structure of matter

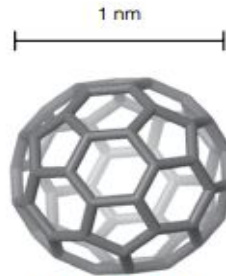
- Type & arrangement of atoms, structure → properties in the macroscale



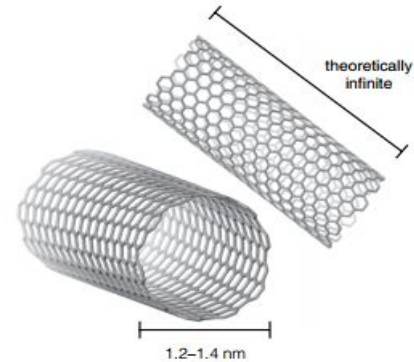
a. Diamond



b. Graphite



c. C₆₀ Buckyball



d. Single-Walled Nanotube

Image: Stevens et al. 2009

NST: Fundamental concepts

□ Structure of matter

- The structural advantage of nature: Biomimetics
 - Renewable resources
 - Aqueous environments
 - Near ambient temperatures
 - Biodegradable-sustainability

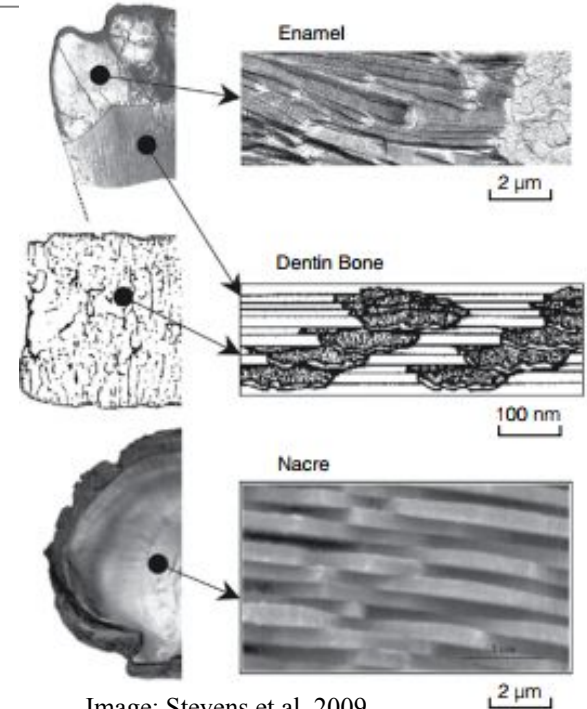


Image: Stevens et al. 2009

NST: Fundamental concepts

□ Forces & interactions:

too weak in the nanoscale, apparent results in the macroscale

- Specificity

Soap & oil/grease (hydrophobic)

Water & sugar (hydrophilic)

- Controlling conditions: temperature, ions concentration, polarization of the solvent,

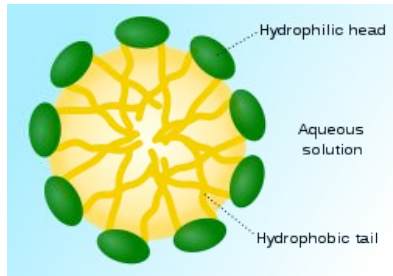


Image: https://commons.wikimedia.org/wiki/File:Micelle_scheme-en.svg

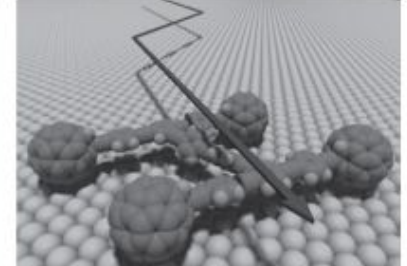
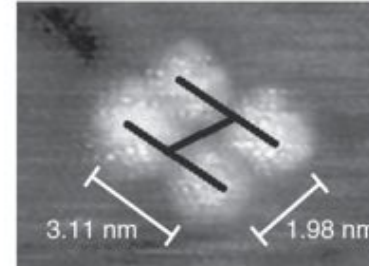
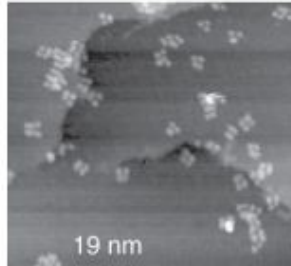
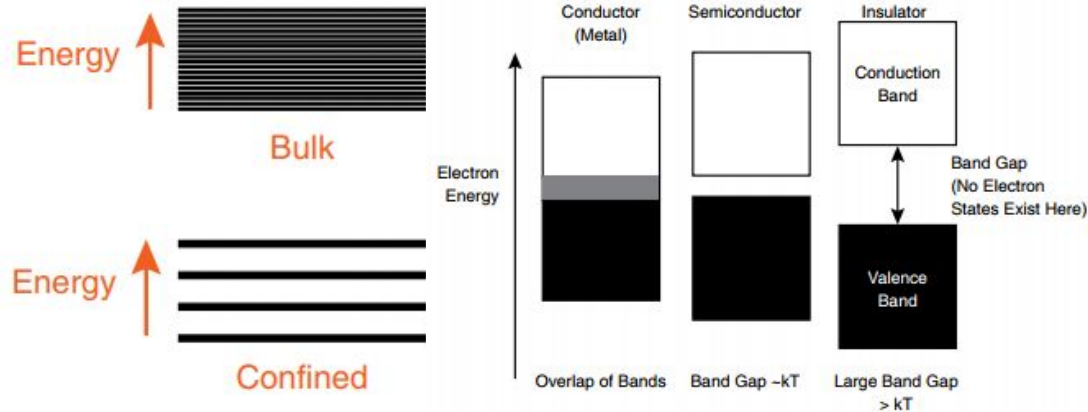


Image: Stevens et al. 2009

NST: Fundamental concepts

Quantum effects

- e.g. Conductivity, optical properties



Images: Stevens et al. 2009

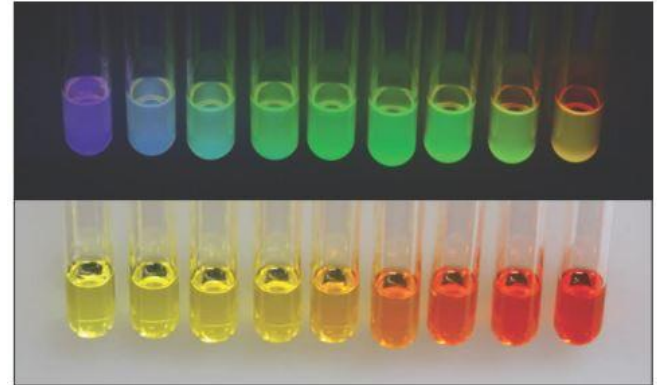


Image: An example of CdSe nanoparticles
(Reused from Nordell et al. 2005)

2) Applying the foundational science content

What revolutionary phenomena can you think that are used in NST applications?

Word cloud: Choose up to 3 words/phrases!

2) Applying the foundational science content

- Size-dependent properties
 - Surface-related properties
 - Rate of reaction, capillary action, adhesion
 - Volume-related properties
 - Conductivity, optical & magnetic properties, reactivity

2) Applying the foundational science content

□ Size-dependent properties

e.g. Au nanoparticles

- Change colour (2-100nm)
- Loses electrical conductivity ($\sim 10\text{nm}$)
- Melting point is halved (2nm)
- Catalyst ($< 6\text{nm}$) in low temperatures



Image: Xiong et al. 2014

3) Moving NST forward

Can you reflect on what is needed in order to generate new NST knowledge?

Word cloud: Choose up to 3 words/phrases!

3) Moving NST forward

□ Instrumentation

- Study the nanoworld
- Manipulate the nanoworld
- Optical microscope ($\sim 10^{-7}$ m)
- Scanning Electron Microscope (SEM) ($\sim 10\text{nm}=10^{-8}\text{m}$)
 - e beam and backscattered e
- Scanning probe microscope (SPM):
 - Scanning Tunneling microscope (STM) ($\sim 0,2\text{nm}$)
 - Atomic Force Microscope (AFM) ($\sim 0,1\text{nm}$)

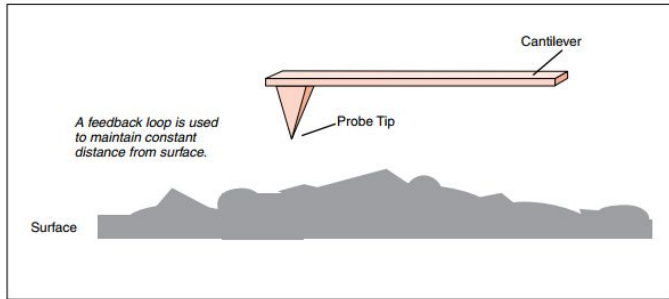


Image: Stevens et al. 2009

3) Moving NST forward

□ Modelling/simulations

- Targets too small to see & too complex
- Models (physical/digital) useful to learn science, to “doing” science, to learn *about* science
- Aim: describe / explain / predict / communicate phenomena



- Simulation: one representation of a model with predefined variables and set conditions in order to explore a specific target

Images: Stevens et al. 2009

4) NST & Society

Name some reasons why NST is relevant to societal issues

Word cloud: Choose up to 3 words/phrases!

4) NST & Society

Broad range of applications:

- ✓ Healthcare (e.g. Ag nanoparticles, drug delivery etc.)
- ✓ Renewable and sustainable energy (e.g. solar panels)
- ✓ Water purification
- ✓ Building materials (e.g. TiO₂ paint)
- ✓ Electronics
- ✓ Data storage
- ✓ Cosmetics (e.g. sunscreen)

4) NST & Society

Potential Risks:

- ✓ Size: penetrate biological barriers: Human health issues
- ✓ New materials: Environmental and Waste management issues
- ✓ Private safety issues
- ✓ ...

Too soon: Long-term effects unknown...

- *The long-term safety and health of human beings and the environment*
- *The impact on the economic and social wellbeing of society*

4) NST & Society

Need for:

- ✓ Balance of costs – benefits
- ✓ Evaluation of scientific claims based on evidence
- ✓ Informed decision making

References-Sources

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