

Emerging Materials: Nanomaterials

Assignment Project Exam Help

PRRE1003

Resources, Processes & Materials Engineering

<https://powcoder.com>

Add WeChat powcoder

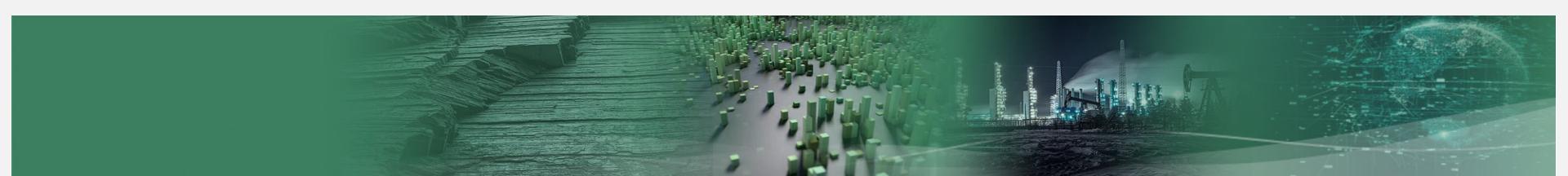
LECTURE 11

Irene Suarez-Martinez

I.Suarez-Martinez@curtin.edu.au



Curtin University



Electronic Warning Notice

COMMONWEALTH OF AUSTRALIA

Assignment Project Exam Help

WARNING

This material has been copied and communicated to you by or
on behalf of Curtin University under Part VB of the *Copyright
Act 1968 (the Act)*

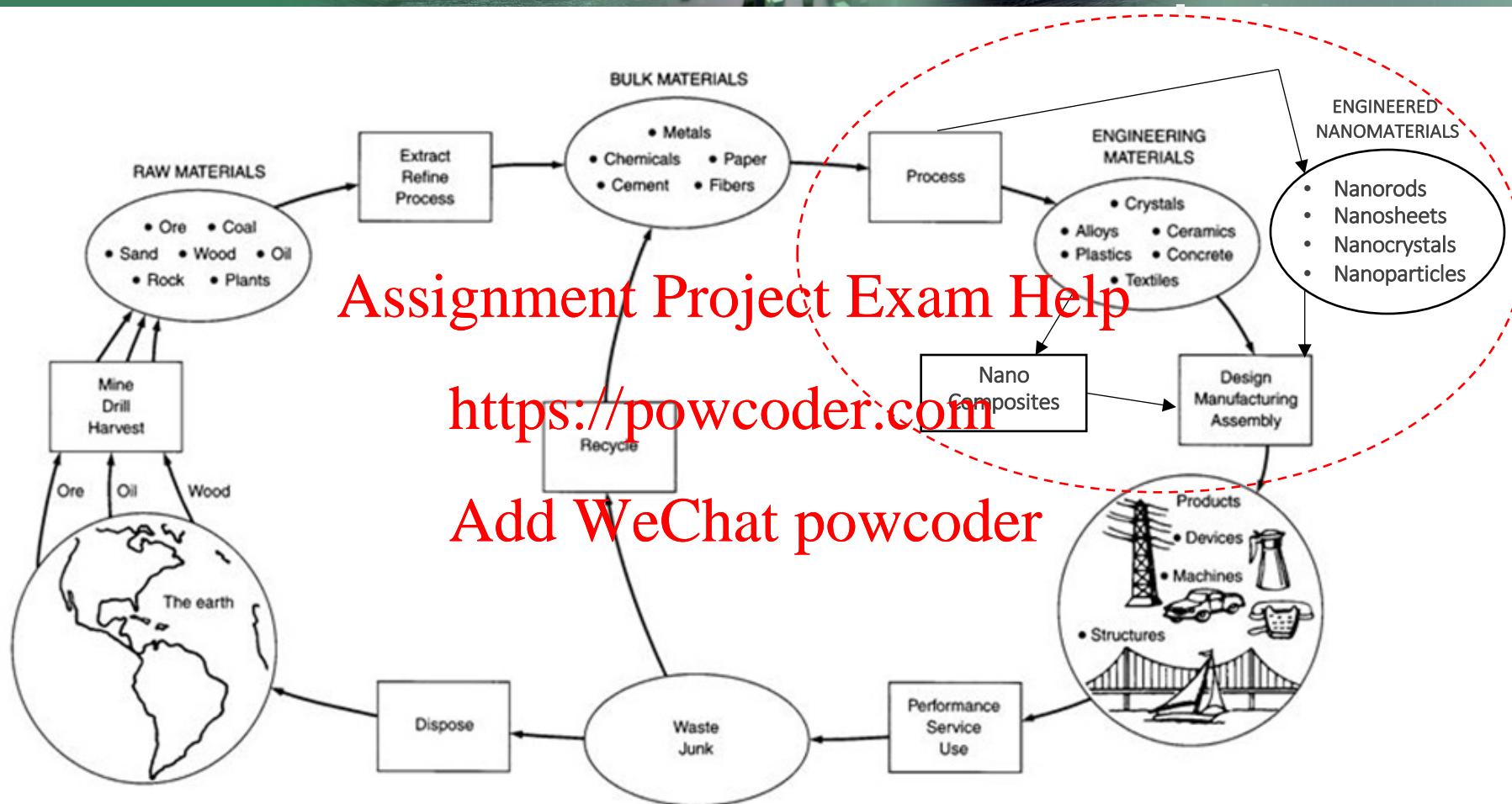
Add WeChat powcoder

The material in this communication may be subject to copyright
under the Act. Any further copying or communication of this
material by you may be the subject of copyright protection
under the Act.

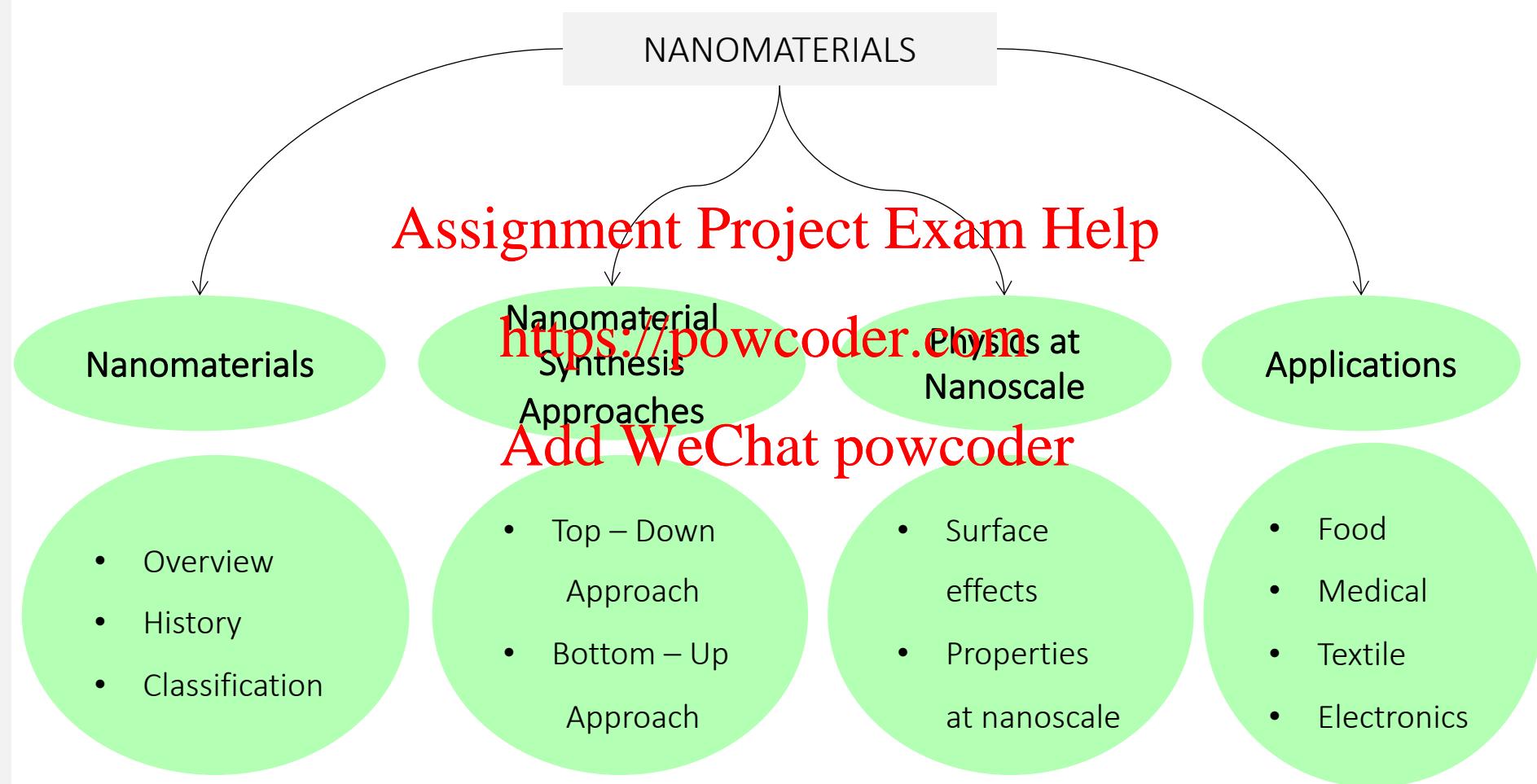
Do not remove this notice



Lecture Focus

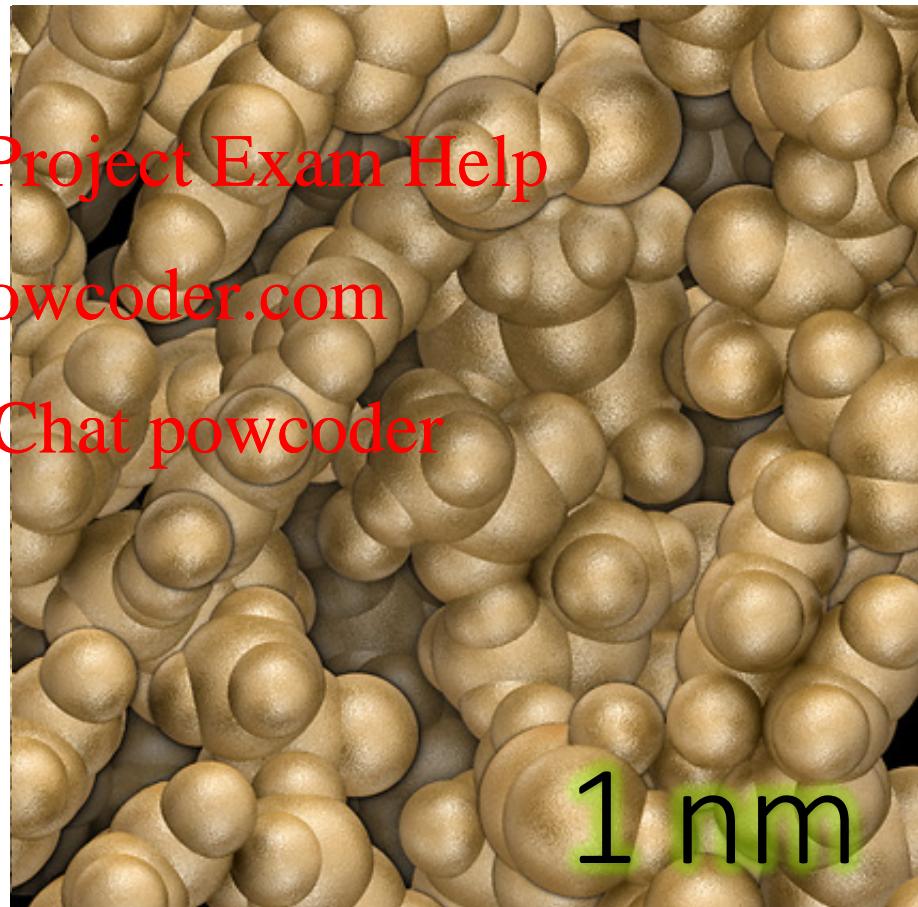
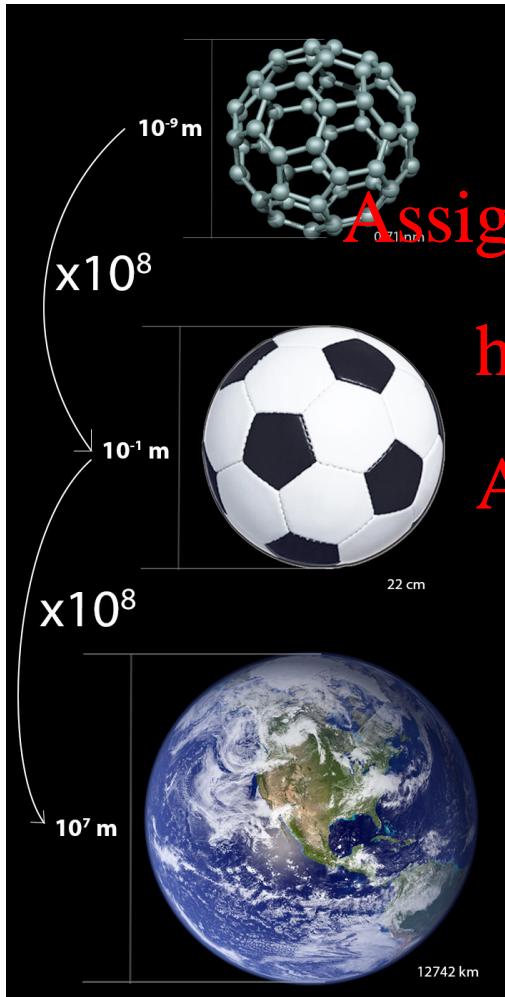


Reproduced from "Materials and Man's Needs", National Academy of Sciences, Washington D.C., 1974.



What is a nanometer?

A nanometre is *one billionth* of a metre. $1 \text{ nm} = 10^{-9} \text{ m}$



Assignment Project Exam Help

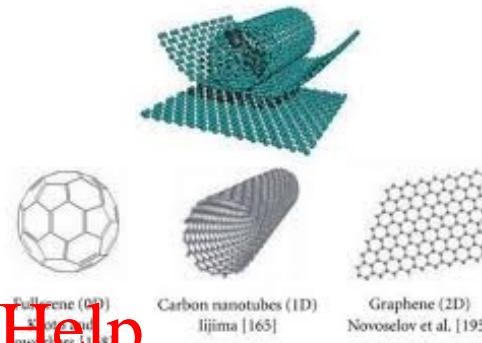
<https://powcoder.com>

Add WeChat powcoder

1 nm

Nanoscience & Nanotechnology

Nanomaterials can be defined as materials possessing, at minimum, one external dimension measuring 1-100nm.

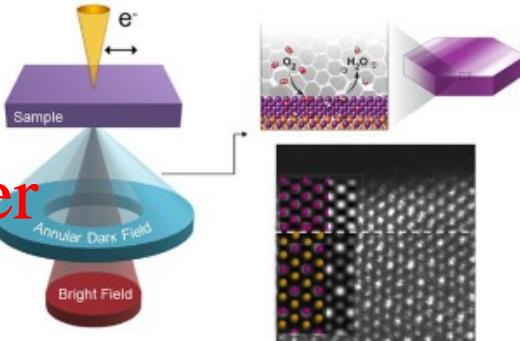


Assignment Project Exam Help

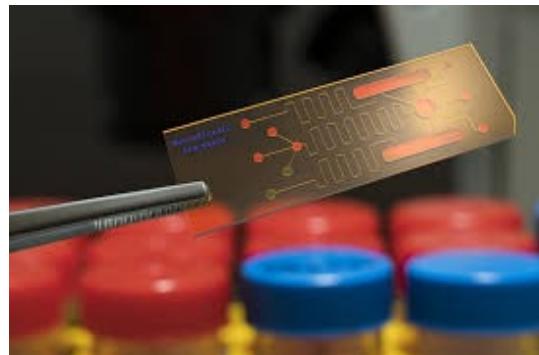
Nanoscience is the study of structures and materials on an ultra-small scale, and the unique and interesting properties these materials demonstrate.

<https://powcoder.com>

Add WeChat powcoder



Nanotechnology, is the design, production and application of structures, devices and systems at the nanoscale.



Early Nanotechnology



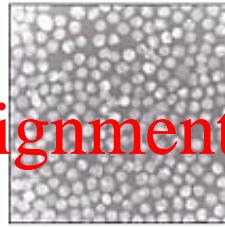
The First Nanotechnologists

Ancient stained-glass makers knew that by putting varying, tiny amounts of gold and silver in the glass, they could produce the red and yellow found in stained-glass windows. Similarly, today's scientists and engineers have found that it takes only small amounts of a nanoparticle, precisely placed, to change a material's physical properties.

Gold particles in glass

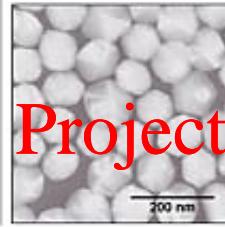
Size*: 25 nm
Shape: sphere
Color reflected:

100 nanometers =
0.0001 millimeter



Silver particles in glass

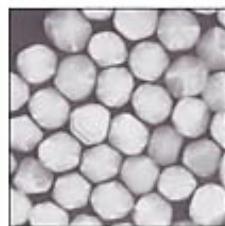
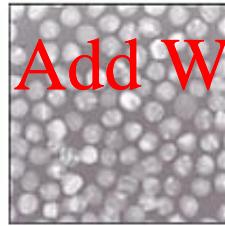
Size*: 100 nm
Shape: sphere
Color reflected:



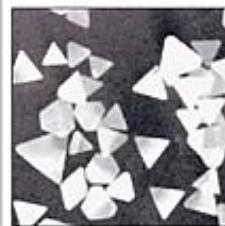
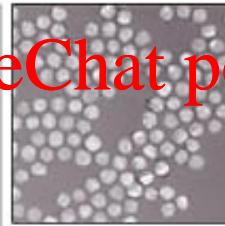
Size*: 50 nm
Shape: sphere
Color reflected:



Size*: 100 nm
Shape: sphere
Color reflected:



Size*: 40 nm
Shape: sphere
Color reflected:



Size*: 100 nm
Shape: prism
Color reflected:



Source: Dr. Chad A. Mirkin, Institute of Nanotechnology, Northwestern University

*Approximate

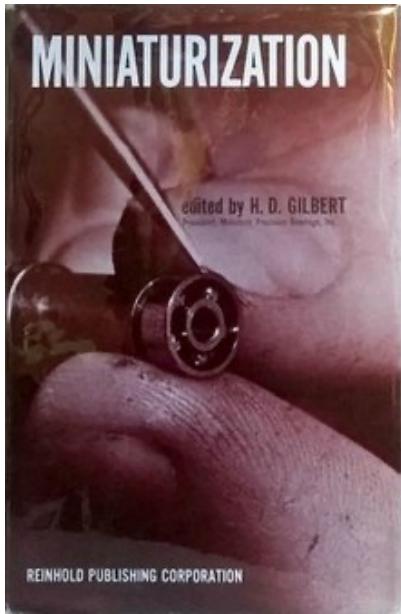
Further reading "Tiny Is Beautiful: Translating 'Nano' Into Practical" by Kenneth Chang on The New York Times 22nd Feb 2005. [(accessed on 10 May 2022)]; Available online:

<https://www.nytimes.com/2005/02/22/science/tiny-is-beautiful-translating-nano-into-practical.html>

13th century: "Damascus" saber blades contained carbon nanotubes and cementite nanowires



Analyzing Historical Context



"There's plenty of room at the bottom"
lecture by Richard Feynman at the
annual *American Physical Society*
meeting, *Caltech* (1959).

The Nobel Prize in Physics 1986



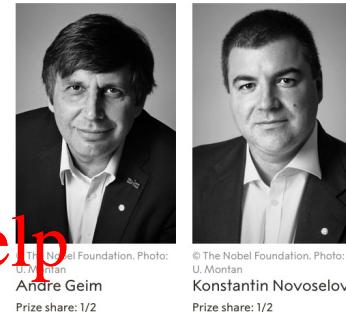
Assignment Project Exam Help

The Nobel Prize in Physics 1986 was divided, one half awarded to Ernst Ruska "for his fundamental work in electron optics and for the design of the first electron microscope", the other half jointly to Gerd Binnig and Heinrich Rohrer "for their design of the scanning tunneling microscope."

<https://powcoder.com>

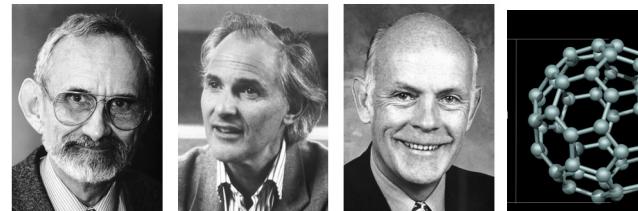
Add WeChat powcoder

The Nobel Prize in Physics 2010



The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov "for groundbreaking experiments regarding the two-dimensional material graphene."

The Nobel Prize in Chemistry 1996



The Nobel Prize in Chemistry 1996 was awarded jointly to Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley "for their discovery of fullerenes."



Significance of Nano-scale and Growth Outlook

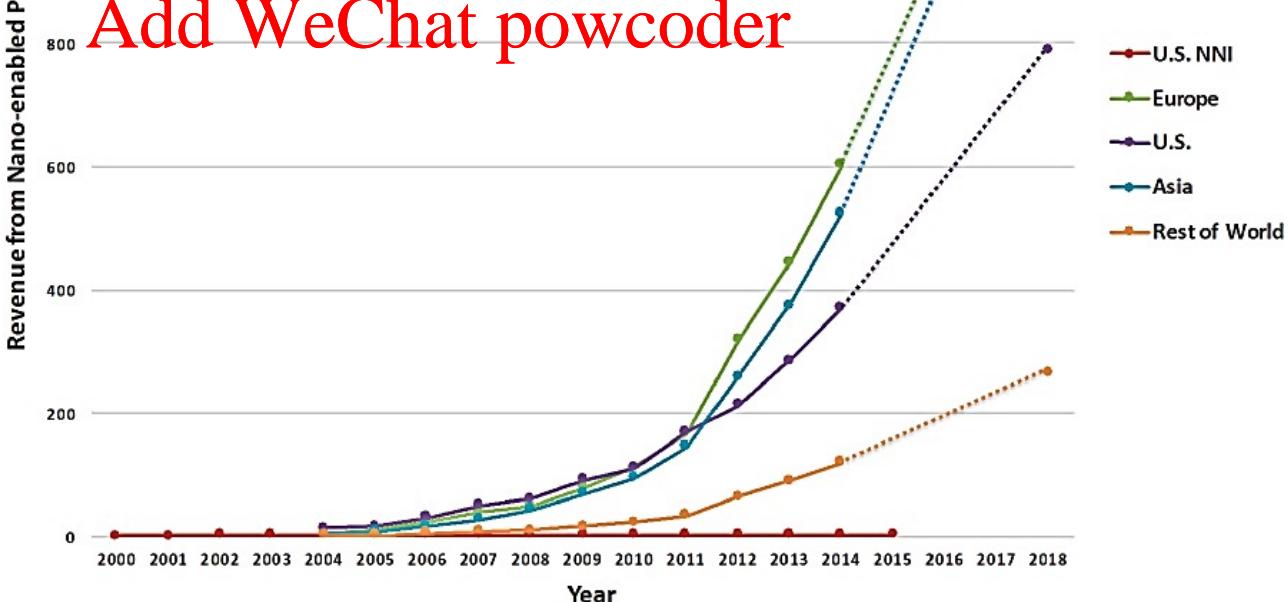
- The ability to see nano-sized materials has opened up a world of possibilities in a variety of industries and scientific endeavors.
- The global market for nanotechnology should grow from USD \$5.2 billion in 2021 to USD \$23.6 billion by 2026, at compound annual growth rate (CAGR) of 35.5% for the period of 2021-2026

Assignment Project Exam Help



<https://powcoder.com>

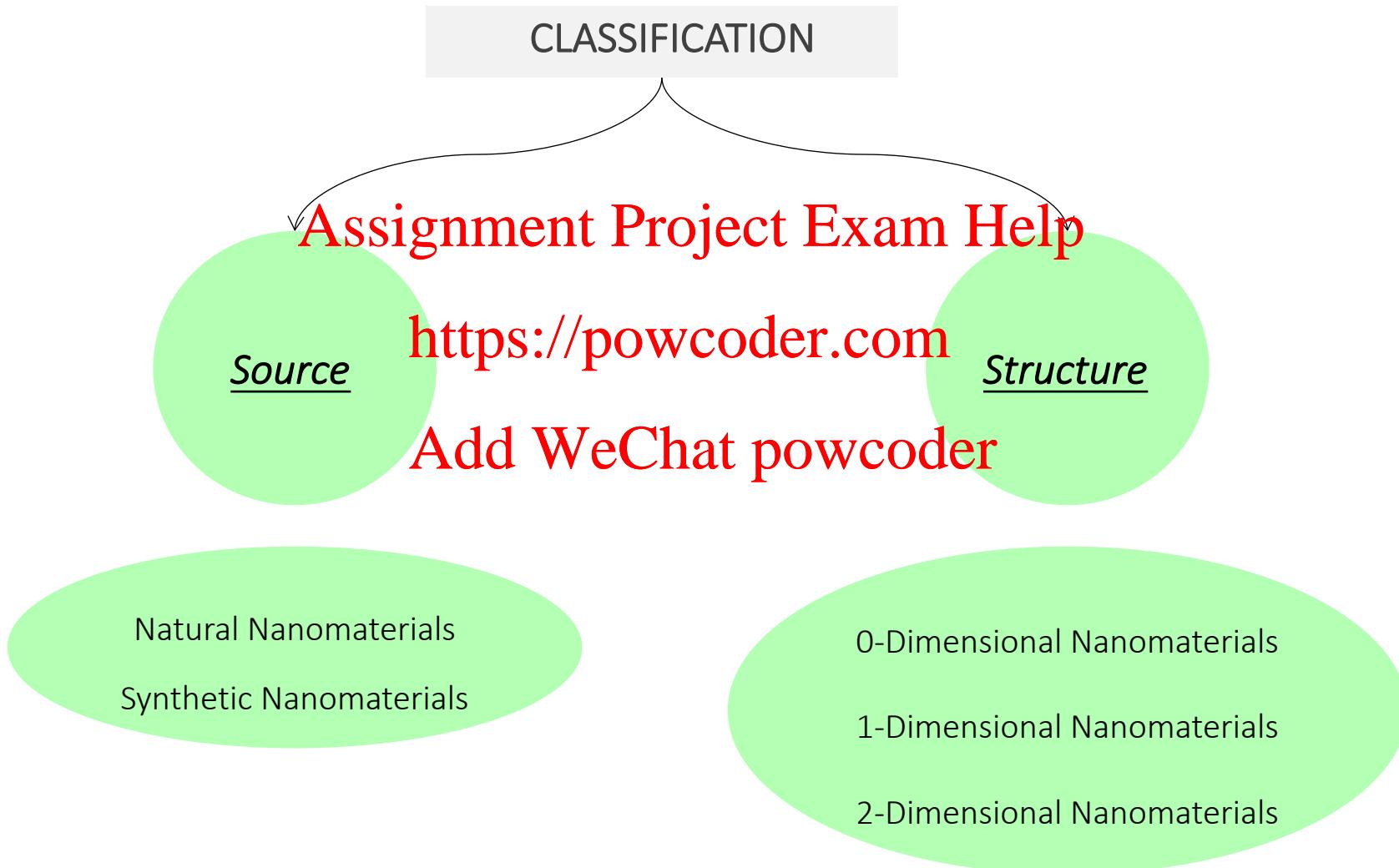
Add WeChat powcoder



\$34 billion
AUD by 2026



Classification of Nanomaterials



Source

Natural

A nanomaterial made by nature through (bio)geochemical or mechanical processes, without direct or indirect connection to a human activity or anthropogenic process.

Assignment Project Exam Help

- Nanoparticles including combustion products, forest

fires, volcanic ash (65% SiO₂, 18% Al₂O₃, 5% Fe₂O₃, 2%

MgO, 4% CaO, 4% Na₂O, and 0.1% S), ocean spray, and the radioactive decay of radon gas.

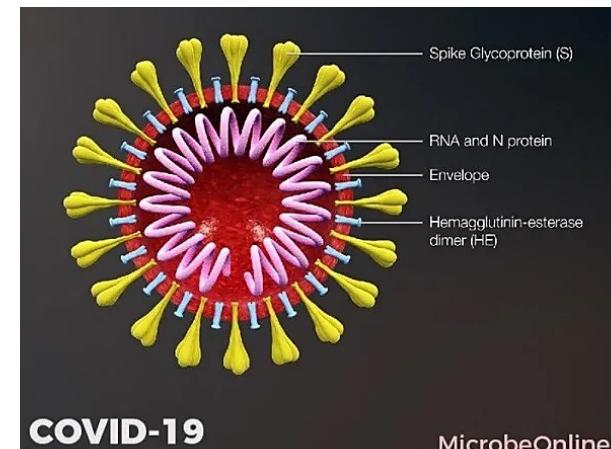
- Bacteria such as Shewanella and Lactobacillus species responsible for the fermentation of milk proteins.

- Coronavirus (125 nm) responsible for SARS disease.



<https://powcoder.com>

Add WeChat powcoder



Source

Synthetic

Two general categories: “incidental” and “engineered” nanoparticles.

- Incidental nanoparticles are the byproducts of human activities; have poorly controlled sizes and shapes.

Assignment Project Exam Help

- Soot nanoparticles (consist mainly of carbon) are commonly found in atmosphere.

<https://powcoder.com>

- Engineered nanoparticles are specifically designed and deliberately synthesized by human beings. They have very precisely controlled sizes, shapes, and compositions.

- Carbon nanomaterials such as fullerenes, carbon nanotubes, and graphene.

- Sun block that contains combinations of ZnO & TiO₂ nanoparticles including products from Neutrogena, Boots, Avon, The Body Shop, L'Oréal, Nivea..



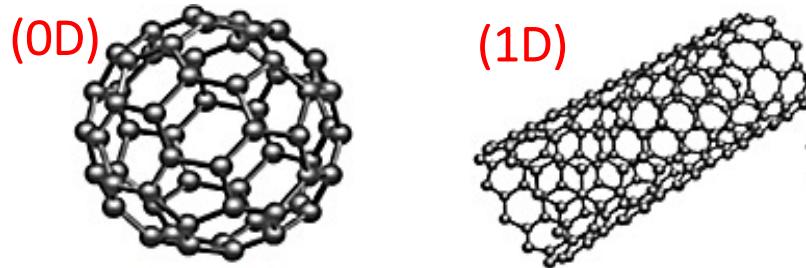
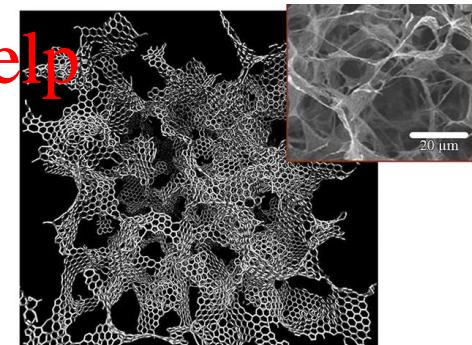
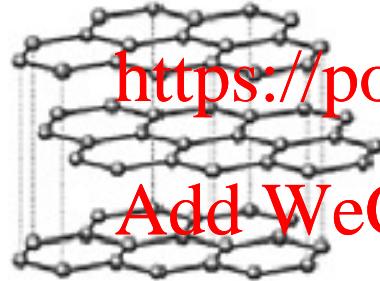
Structure

Regardless of a nanomaterial's origin, their size and shape, and not just their chemical composition and atomic structure, are fundamental to their properties; this makes them distinct from materials existing at the macroscale.

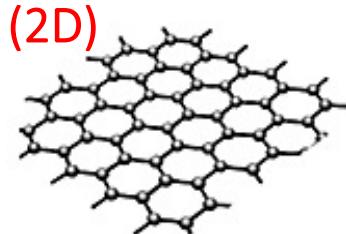
Assignment Project Exam Help

<https://powcoder.com>

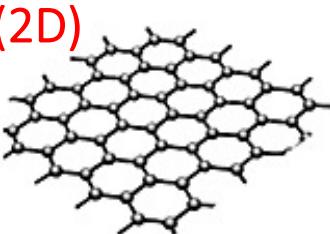
Add WeChat powcoder



FULLERENE



CNT

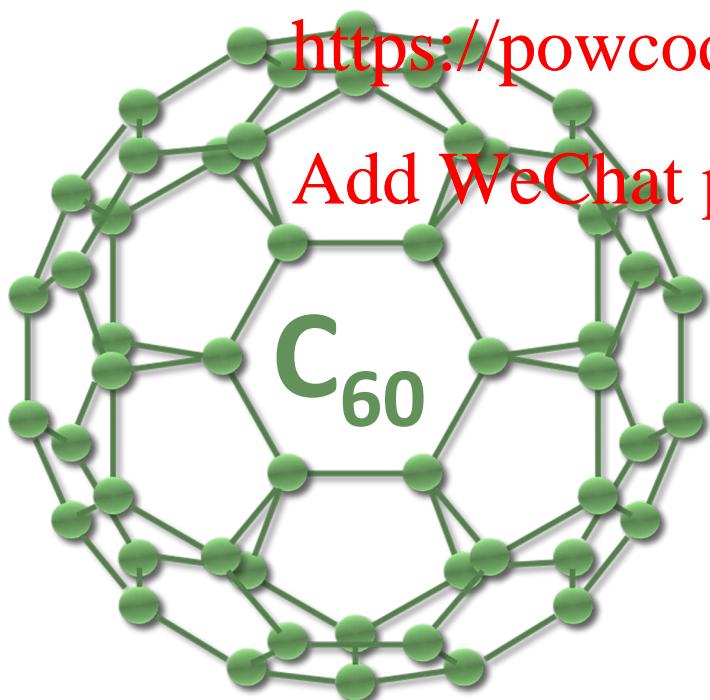


GRAPHENE

Nanomaterials of Zero Dimension (0D)

- A 0D structure is the simplest block that can be used for the design of nanomaterials.
- All three dimensions are in the nanometer regime and have a diameter less than 100 nm.
- Nanoparticles, nanocrystals, and nanoclusters correspond to this group.

Assignment Project Exam Help



<https://powcoder.com>

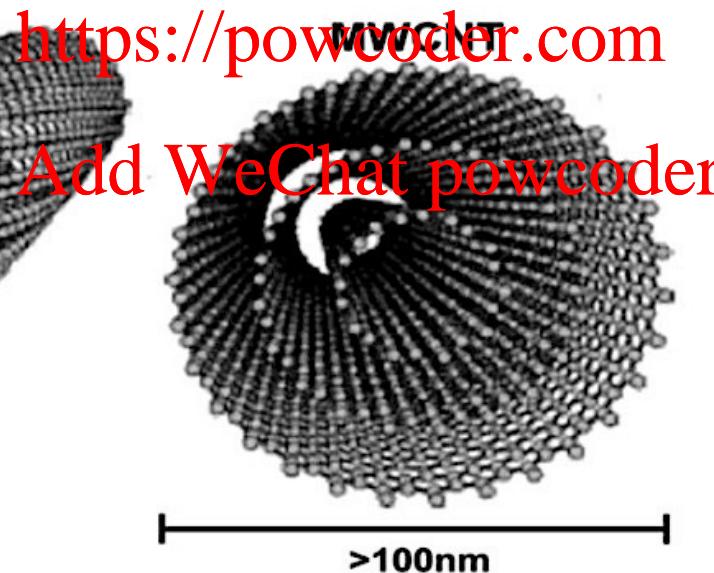
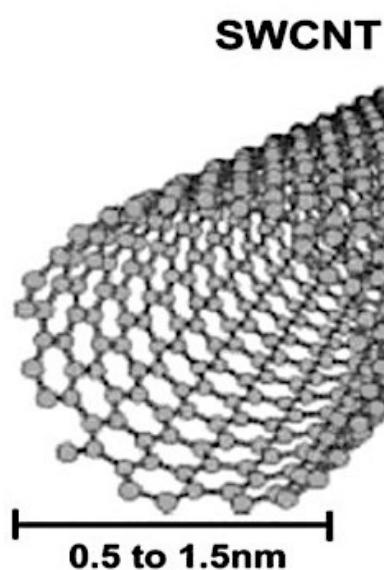
Add WeChat powcoder



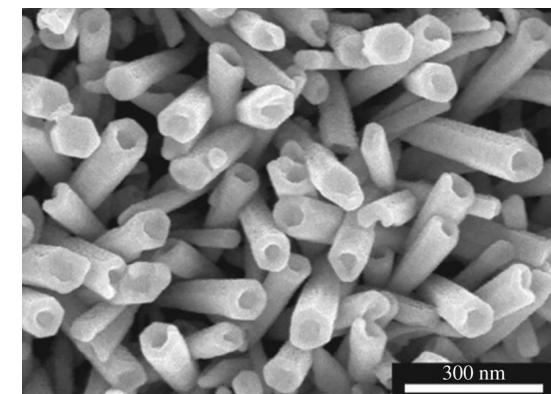
Nanomaterials of One Dimension (1D)

- They have a variable length, conserving two dimensions (height and width) in the nanometer regime; to these correspond the nanowires and nanotubes.

Assignment Project Exam Help



ZnO nanotubes from
<https://doi.org/10.1098/rsos.180510>



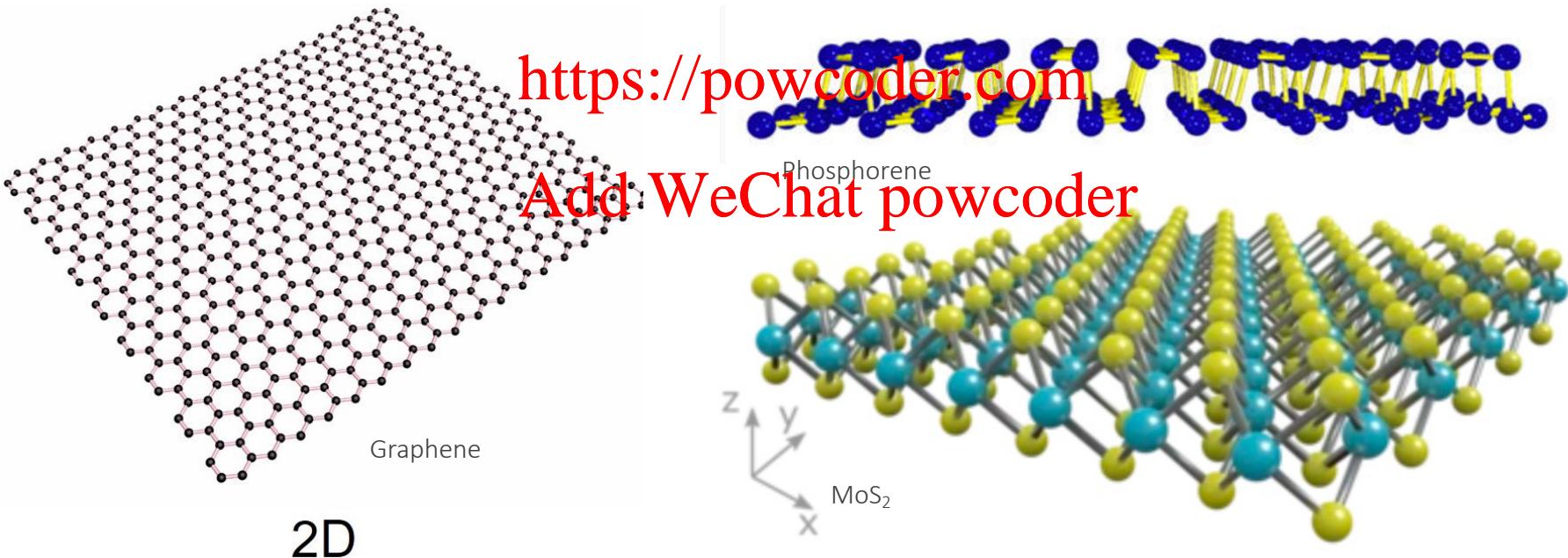
Nanomaterials of Two Dimension (2D)

- They have two of their dimensions not confined to the nanometer regime.
- They exhibit plate like shapes, nanosheets

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



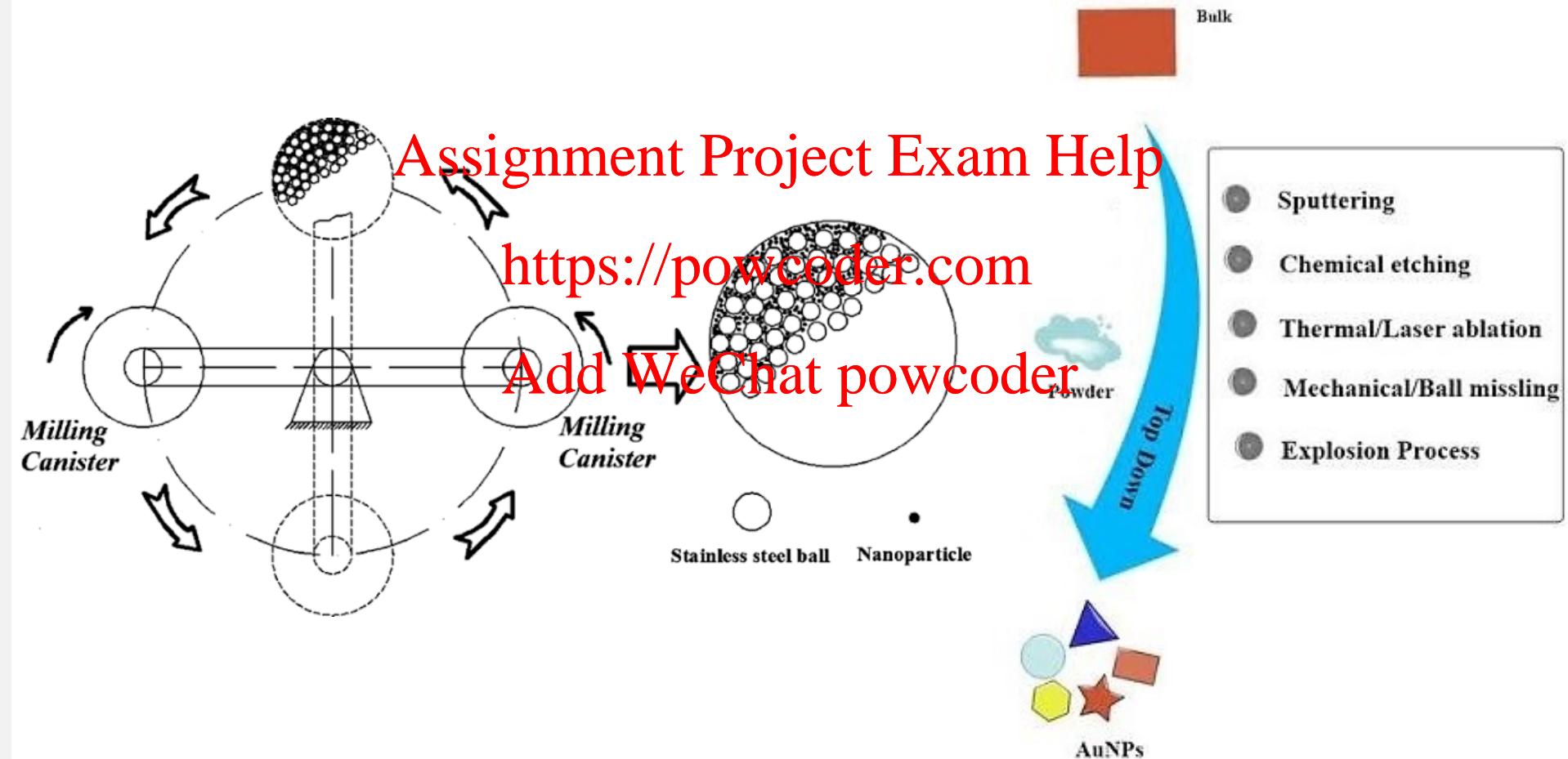
Learning Outcome Check

- What is the difference between (i) nanomaterials (ii) nanoscience and (iii) nanotechnology?
- What are the different classifications of nanomaterials, based on (a) source and (b) structure?
Assignment Project Exam Help
<https://powcoder.com>
- Given a range of nanomaterials, sort them according to source/structure.
Add WeChat powcoder
- Give an example each of the following nanomaterials: 0D, 1D, 2D and 3D.



Nanomaterial Synthesis Approaches

Top – Down Approach



Nanomaterial Synthesis Approaches

Top – Down Approach

Assignment Project Exam Help

<https://powcoder.com>

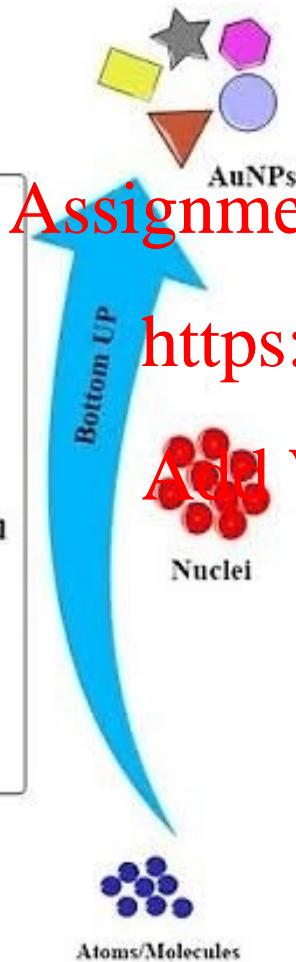
Add WeChat powcoder



Nanomaterial Synthesis Approaches

Bottom – Up Approach

- Atomic/ Molecular Condensation
- Vapour Deposition
- Sol-gel Process
- Spray Pyrolysis
- Chemical/Electrochemical Deposition
- Aerosol Process
- Bioreduction



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Physical Techniques

Physical Vapour Deposition (PVD)

- Sputtering
- Evaporation (laser, e-beam)
- Plasma etching
- Laser ablation

Chemical Techniques

Chemical Vapour Deposition (CVD)

- PECVD (Plasma-enhanced CVD)

- RF- PECVD (Radio Frequency Plasma Enhanced CVD)
- MPE-CVD (Microwave Plasma-enhanced CVD)

Self Assembled Monolayer

- Electrolytic deposition
- Sol-gel
- Pyrolysis



Nanomaterial Synthesis Approaches

Bottom – Up Approach

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

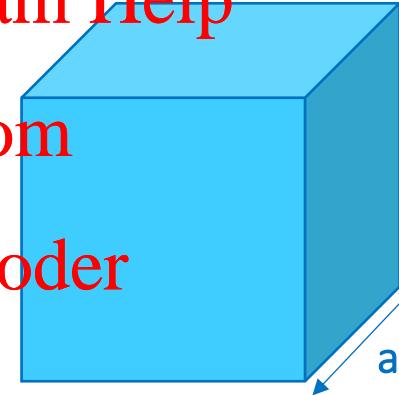
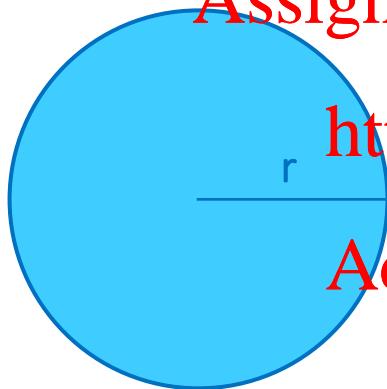
Surface Area to Volume Ratio (SAVR)

- The surface area to volume ratio for a material or substance made of nanoparticles has a significant effect on the properties of the material.
- Materials made up of nanoparticles have a relative larger surface area when compared to the same volume of material made up of bigger particles.

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



$$\text{SAVR Ratio} = \frac{3}{r}$$

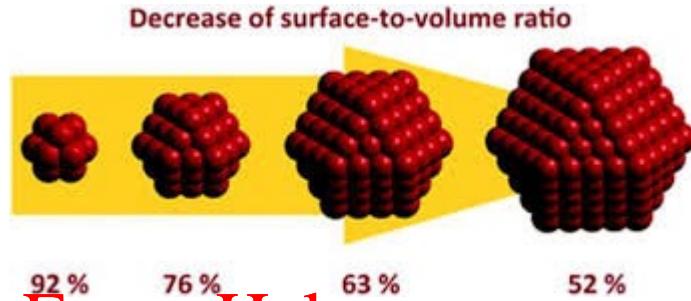
$$\text{SAVR Ratio} = \frac{6}{a}$$

TASK: Compare the SAVR for spherical particles of radius 30, 15, 3 and 1.

Compare the SAVR for cubic particles of side 30, 15, 3 and 1.

Surface Effects

Decrease in Surface to Volume Ratio



Assignment Project Exam Help

High S/V Ratio
leads to nanoparticles
being more
chemically reactive

<https://powcoder.com>

Properties

Variable

Add WeChat powcoder

It is also found that materials which are inert in their bulk form are reactive when produced in their nanoscale form.

Size-dependent properties

Chemical
Thermal
Mechanical
Optical
Electrical
Magnetic

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Properties of Nanomaterials

CHEMICAL

- Materials that are inert in their bulk form

Assignment Project Exam Help

become reactive at the nanoscale.

OPTICAL

- Semiconductors and many metals show

large changes in optical properties as a function of particle size.
<https://powcoder.com>

Add WeChat powcoder

THERMAL

- Altered melting points of conventional materials in nano regime



Chemical Properties

“When Gold is not noble”

Bulk Form

- Chemically inert;
- Regarded as a poor catalyst;
- Each gold atom is surrounded by twelve other atoms;
- Even the gold atoms at the surface have six adjacent gold atoms.



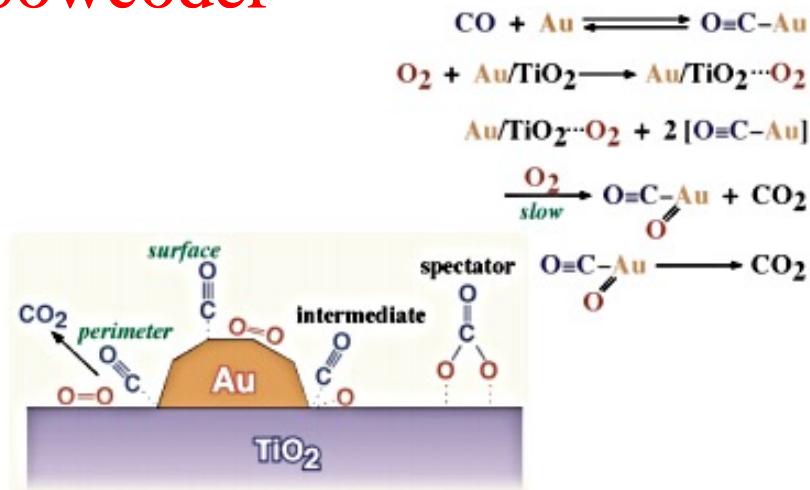
Nanoform

- Gold NPs below 10 nm in size;
- Great catalyst for oxidizing carbon monoxide;
- Gold forms crystalline shapes;
- The exposed atoms at the corners of the crystal are more reactive.

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



Optical Properties

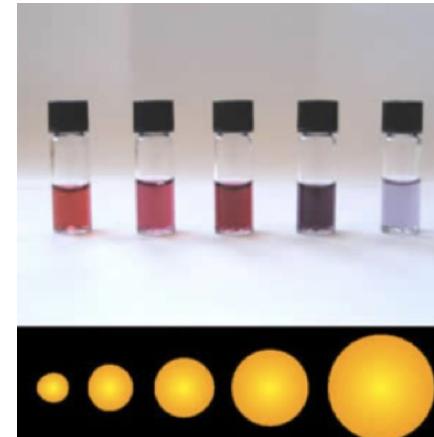
Bulk Form

- Yellow in colour, shiny because light reflects off their surfaces;
- Photons of light can't get through the electron clouds at the surface, therefore aren't absorbed by the electrons bound to atoms in metals;
- Photons are reflected back to the eye and which gives it that shiny bling quality.



Nano Form

- Electron cloud at the surface resonates with different wavelengths of light depending upon their frequency;
- Based on NP size, the electron cloud will be in resonance with a particular wavelength of light and absorb that wavelength;
- 90 nm size particles absorb colours on the red and yellow end of the colour spectrum: blue-green NP;
- 30 nm size particles absorb blues and greens, resulting in a red appearance.



Melting Temperature

$$E_{\text{Total}} = E_{\text{Bulk}} + E_{\text{Surface}}$$

Crystal Size Decreases (Bulk to Nano)

Surface atoms require less energy to move because they are in contact with fewer atoms

Assignment Project Exam Help

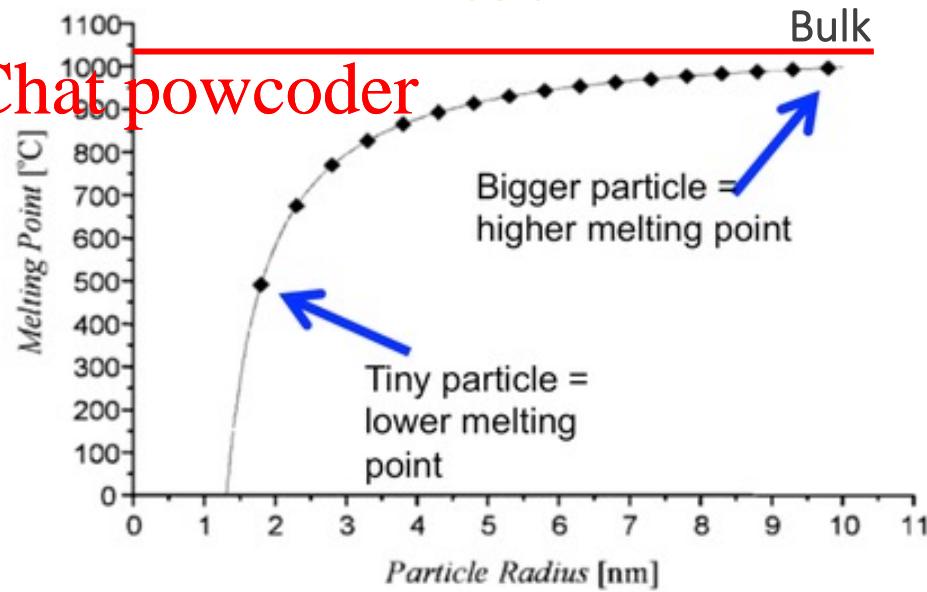
<https://powcoder.com>

Surface Energy Increases

Add WeChat powcoder



Melting Point Decreases



Learning Outcome Check

- ❑ Briefly describe the synthesis of nanomaterials with respect to Top-Down and Bottom-Up approaches.
- ❑ Calculate surface area to volume ratio (SAVR) for a sphere of radius r , and a cube of length a .
Assignment Project Exam Help
<https://powcoder.com>
- ❑ List 3 size-dependent properties of materials that change from bulk to nanosize particles. For each property, give an example.
Add WeChat powcoder

Applications of Nanomaterials

Food Industry

The ripeSense® sensor works by reacting to the aromas released by the fruit as it ripens. The sensor is initially red and graduates to orange and finally yellow.



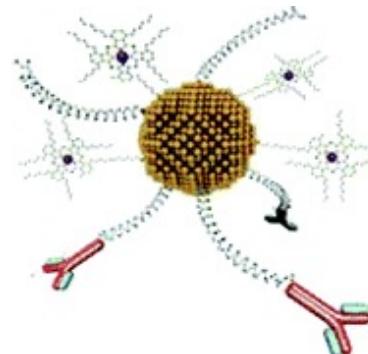
Assignment Project Exam Help

Now you can choose
your perfect pear by
its colour.

<https://powcoder.com>

Add WeChat powcoder

Gold nanoparticles as hyperthermia therapy: Au NPs produce heat when excited by light at certain wavelengths. When light is applied to a tumor containing gold nanoparticles, the particles rapidly heat up, killing tumor cells in a treatment also known



Applications of Nanomaterials

Textile Industry

Silver nanoparticles are added to clothing for their powerful ability to kill bacteria and fungi, and to prevent the nasty odors they cause

Assignment Project Exam Help

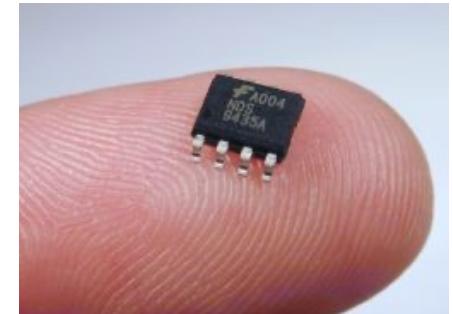


<https://powcoder.com>

Reinforced silk and other fibers
with carbon nanotubes to
improve strength and produce
“electronic yarn”

Electronics

Snapdragon 865 chip by Qualcomm used in android phones today / A13 bionic chip in iPhone 11 and beyond is based on a 7nm lithography process(N7P) and contains 8.5 billion transistors.



Learning Outcome Check

- Give an example of applications of nanotechnology in the following :
 - Textile
 - Food
 - Electronic
 - Biomedical

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



Lecture Summary

- ✓ Overview to nanomaterials and nano-technology
- ✓ Impact in the real world: Growth outlook
- ✓ Classification of Nano-materials
 - Based on Source
 - a) Natural
 - b) Synthetic
 - Based on Structure
 - a) 0- Dimension
 - b) 1- Dimension
 - c) 2- Dimension
- ✓ Nanomaterial Synthesis Approach
 - Top – Down Approach
 - Bottom – Up Approach

Assignment Project Exam Help

Surface Effects

<https://powcoder.com>

Add WeChat powcoder

✓ Properties of Nanomaterials

➤ Chemical

➤ Optical

➤ Thermal

✓ Applications of Nano-materials in various industries

