

NANO - LECTURE 2



Nano Science and Nanotechnology

Properties of Nanomaterials

Dr. Mervat Kadhem

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- **Nanomaterials are more reactive as compared to bulk**
- **Melting point decreases in nanomaterials**
- **They can have different colors (optical properties) depending on size of nanoparticles**

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- **They can have different colors (optical properties) depending on size of nanoparticles**
- **Changes in electric and magnetic properties**
- **Mechanical and other properties also varies in nanomaterials**

Why different properties changes at Nanoscale?

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- The material properties of nanostructures are different from the bulk due to:
 - (i) The high surface area over volume ratio and **large fraction of surface atoms**
 - (ii) quantum effects are dominant at nanoscale (**quantum confinement**)

We will discuss these in next lectures on size effect and basic quantum mechanics (Particle in a box).

Properties of nanoparticles – appearance

Nanoparticles also interact differently with light.

**Normally, gold metal appears yellow in colour.
However, nanoparticles of gold in solution appear red
and blue in colour.**

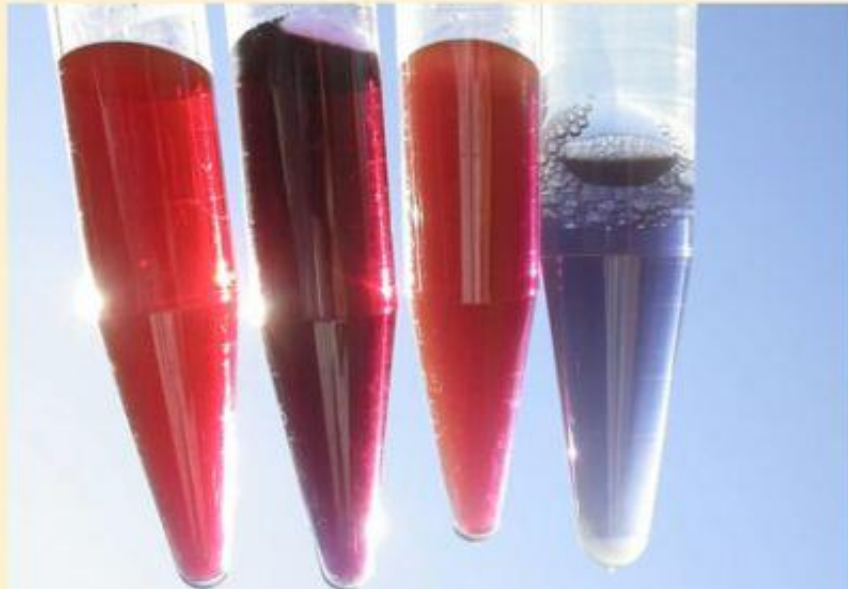


Properties of nanoparticles – appearance

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**Normally, gold metal appears yellow in colour.
However, nanoparticles of gold in solution appear red
and blue in colour.**

**Different-sized nanoparticles of gold give different
coloured solutions.**



Professor Michael Cortie

**Smaller nanoparticles appear red in solution, while
slightly larger nanoparticles appear blue, this is due to
the change in the energy band gap.**

Applications of Nanotechnology

- i. **Computer/Information Technology:/Communications:**
Large memories, Nanoelectronics, Bio-molecules as transistors,
- ii. **Medical and Health Care:**
Anti-cancer drugs, Bio-sensors, Implants, Dental Pastes/Ortho
- iii. **Energy:**
Solar cell, Fuel cell, Bio-fuels, Batteries
- iv. **Automobiles:**
Lubricants, Glass Coatings, Resins, Phosphors
- v. **Industry:**
Auto, Ceramic, Insulation, Phosphors, Hard Materials, Mechanical, Spray, Sensors
- vi. **Defense:**
Special Materials, Censors, Intelligent Clothing

Applications of Nanotechnology Continued

Vii. Cosmetics:

Skin Creams ,Anti aging creams

viii. Food & Agriculture:

Food Safety, Quality Assurance, water purification

ix. Water Treatment:

Nanofiltration , Clean drinking and Waste water

x. Environment:

Filters, anti toxicants ,nano catalysts for oil spills

xi. Textiles:

Special clothes ,wrinkle and stain free, antimicrobial socks

xii. Sports:

Sunglasses, Hockey sticks ,Rackets, Tennis and Golf balls

xiii. Aerospace:

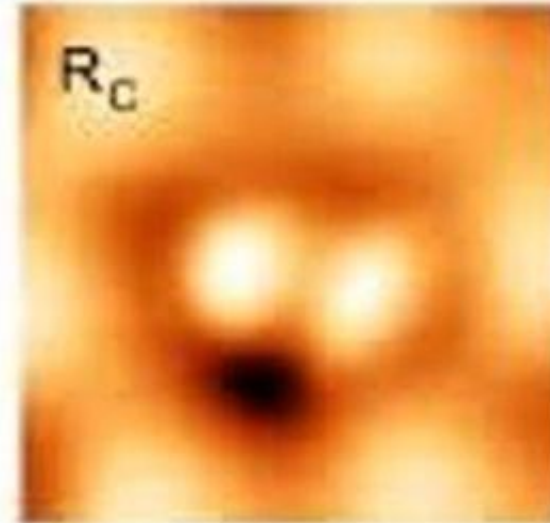
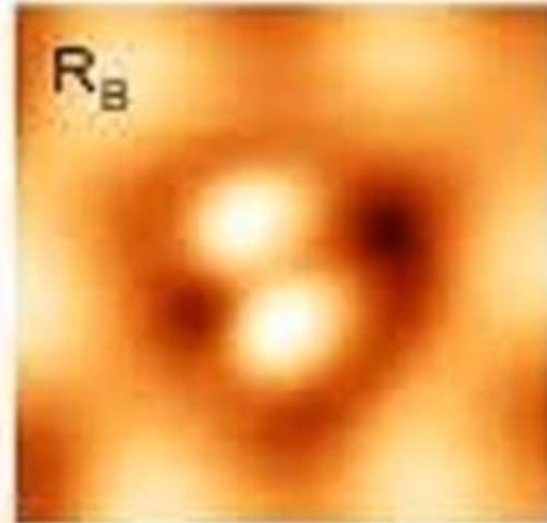
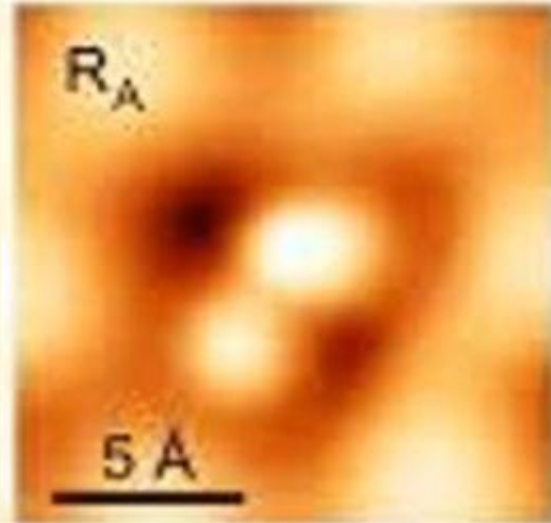
Communications, High strength light weight materials

Xiv. Oil and Gas Exploration:

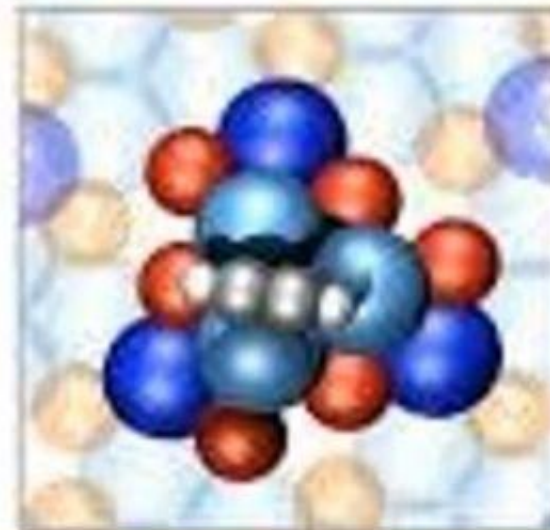
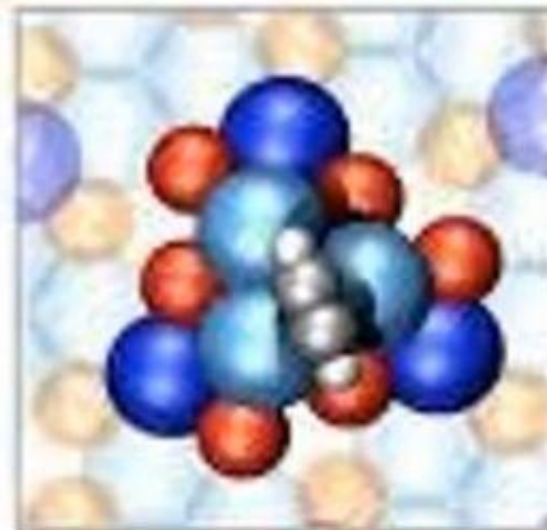
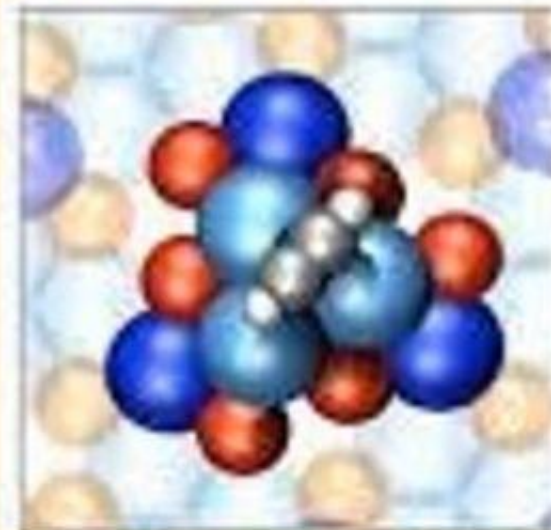
50% increase in extraction from existing oil wells by using nanotechnology techniques.

World's smallest Motor: 16 atoms

A molecular motor developed by a team of researchers from Switzerland consists of just 16 atoms. June 2020



Real Device image



Atomic arrangement

Image Source: Wikipedia

Moore's law: Every eighteen months, the number of components that can exist on an integrated circuit doubles

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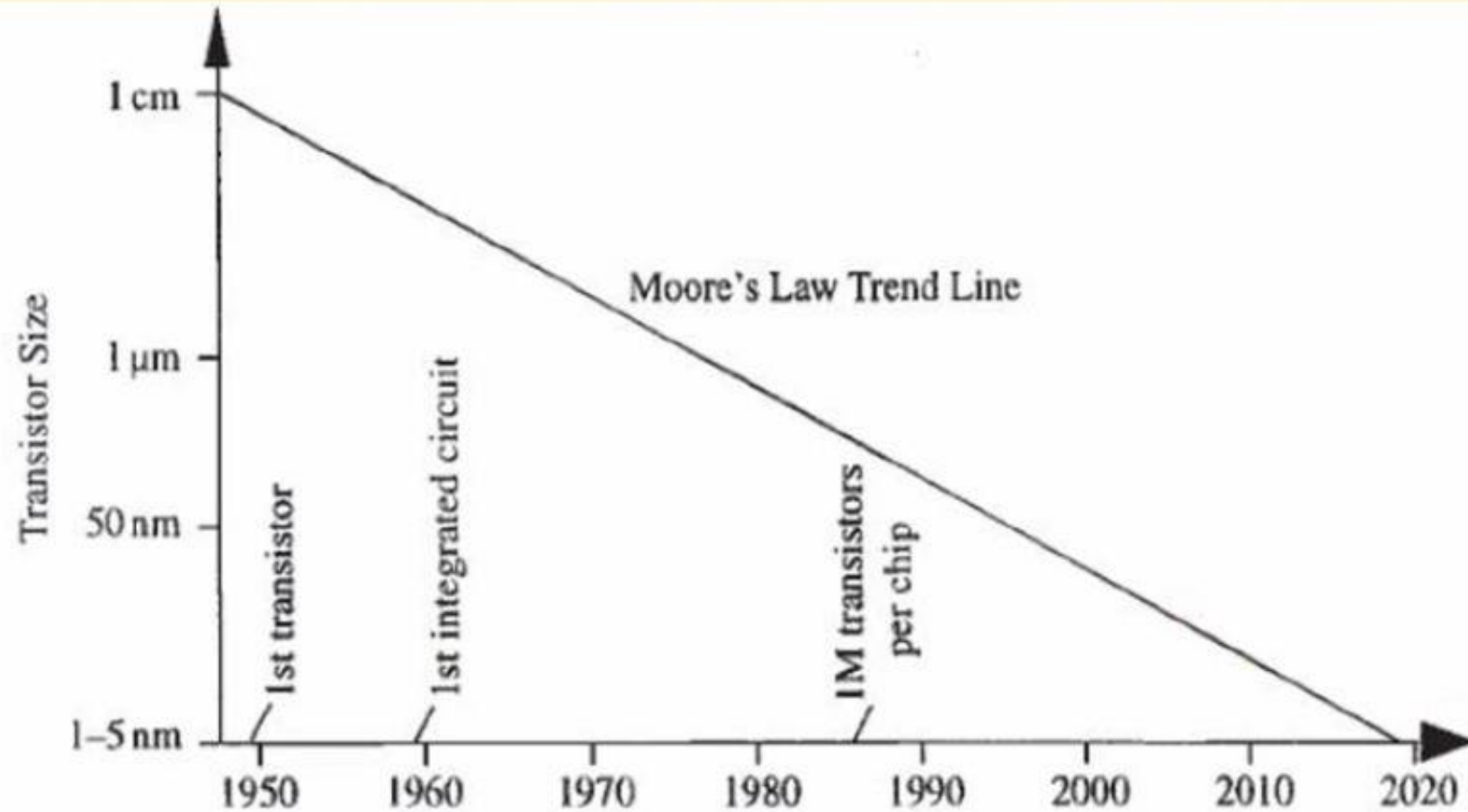
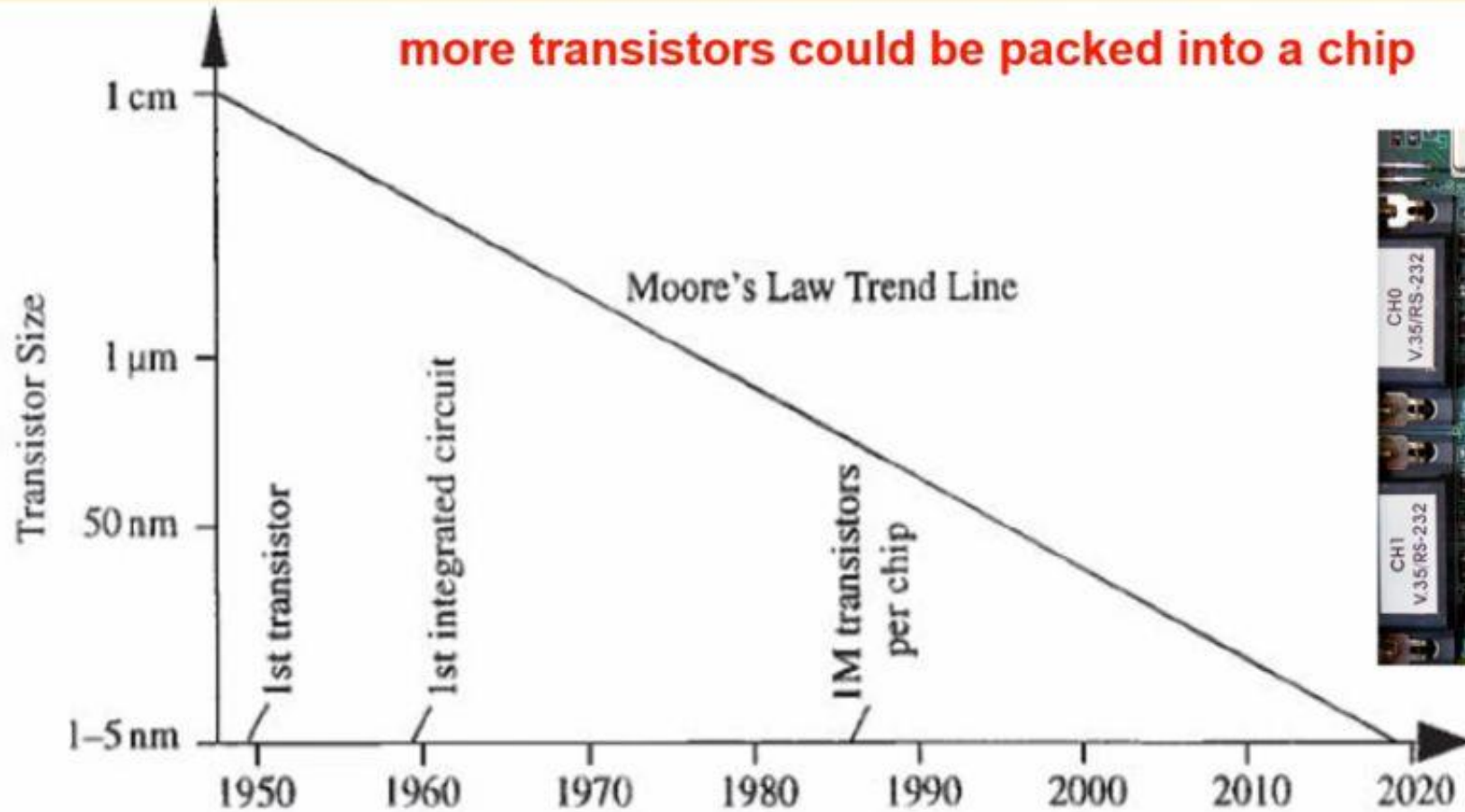


Fig. 1. "Moore's Law" plot of transistor size versus year.

Moore's law: Every eighteen months, the number of components that can exist on an integrated circuit doubles



But Moore suggested in 2007, that the size of transistor cant go beyond the atomic size (~ 0.1nm)

Fig. 1. "Moore's Law" plot of transistor size versus year.

Storage Technologies

Magnetic Storage



Optical Storage



Solid State Storage



1 Byte = 8 Bit

1 Kilobyte = 1,024 Bytes,

1 Megabyte = 1,048,576 Bytes,

1 Gigabyte = 1,073,741,824 Bytes



SSD



HDD

SSD (Solid State Drive)	HDD (Hard Disk Drive)
Semiconductor memories	Magnetic Memories
Faster	Slower
Shorter life span	Longer life span
expansive	Cheaper
Best for storing operating system, gaming apps etc	Best for storing extra data, movies, photos, documents etc.
Non mechanical (flash)	Mechanical (moving parts)

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

1. Elastic properties

- Nanomaterials, by virtue of their very high defect concentration, may have considerably lower elastic properties in comparison to bulk materials.

2. Melting point

- In other words, as the grain size is reduced, the melting point is lowered.
- It has been observed that nano-CdS of diameter ~ 2.5 nm melts at 600 K, much lower than the bulk melting point (1675 K).

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

3. Diffusivity

- nanocrystalline materials are expected to exhibit enhanced selfdiffusivity in comparison to single crystals or conventional polycrystals with the same chemical composition.
- This idea was confirmed by self-diffusion measurements in nanocrystalline Cu. The measured diffusivities in nanocrystalline Cu are about 14–20 orders of magnitude higher than lattice diffusion.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

4. Grain growth characteristics

- Nanocrystalline materials have a significantly larger surface area per unit volume fraction of grain boundaries compared to microcrystalline solids.
- the smaller the crystallite size, the larger in the surface area per unit volume.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **5. Enhanced solid solubility**
- hence the solubility may be enhanced (or reduced) in nanocrystalline materials in comparison to single crystals or glasses with the same chemical composition.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **6. Magnetic properties**

- The study of magnetic nanoparticles has seen a large research effort in recent years. The main driving force for this increased interest is their application potential in vital areas like ultrahigh density magnetic storage devices, magnetic random access memory (MRAM), magnetic semiconductors, etc.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **7. Electrical properties**

- Nanomaterials can hold considerably more energy than conventional coarse-grained materials because of their large grain boundary (surface) area.
- They are materials in which an optical absorption band can be introduced, or an existing band can be altered by the passage of current through these materials, or by the application of an electric field.
- Nanocrystalline materials are good candidates for separator plates in batteries because they can hold considerably more energy than conventional ones.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **8. Optical properties**

- Nanocrystalline systems have attracted much interest due to their novel optical properties, which differ remarkably from bulk crystals.
- Key contributory factors include quantum confinement of electrical carriers within nanoparticles, efficient energy and charge transfer over nanoscale distances and, in many systems, a highly enhanced role of interfaces.
- The linear and non-linear optical properties of such materials can be finely tailored by controlling the crystal dimensions, and the chemistry of their surfaces. Fabrication technology becomes a key factor for the applications.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **9. Thermal properties**

- In general, increasing the number of grain boundaries will enhance phonon scattering at the disordered boundaries, resulting in lower thermal conductivity.
- Thus, nanocrystalline materials would be expected to have lower thermal conductivity compared to conventional materials.

EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOUR

- **10. Mechanical properties**

- The mechanical behaviour of nanocrystalline materials is being widely researched, because of their radically different properties.
- The tensile, work hardening, fatigue and deformation behaviour of nanocrystalline materials are significantly different from that of their bulk counterparts due to the complex interaction of the defect structures.

SUMMARY

- The unique properties of nanomaterials arise from their small size and structural features such as large fraction of grain boundaries, triple junctions, etc.
- Initially, it was thought that the grain boundaries in nanomaterials are 'gas-like'; recently, there has been significant improvement in the understanding of the nature of grain boundaries in these materials.
- A number of unanswered questions remain on the extent of defects such as dislocations, disclinations, etc., which influence the properties of these materials significantly.
- The processing routes adopted to synthesize nanomaterials can significantly influence the grain boundary structure and the concentration of other defects in these materials, which in turn can influence their properties.

Thanks for Watching