Lecture 3

Characterization of Solid Particle

Properties of Nanomaterials

Nanomaterials have the structural features in between of those of atoms and the bulk materials. While most micro structured materials have similar properties to the corresponding bulk materials, the properties of materials with nanometer dimensions are significantly different from those of atoms and bulks materials. This is mainly due to the nanometer size of the materials which render them: (i) large fraction of surface atoms; (ii) high surface energy; (iii) spatial confinement; (iv) reduced imperfections, which do not exist in the corresponding bulk materials.
Due to their small dimensions, nanomaterials have extremely large surface area to volume ratio, which makes a large to be the surface or interfacial atoms, resulting in more "surface" dependent material properties.

The energy band structure and charge carrier density in the materials can be modified quite differently from their bulk and in turn will modify the electronic and optical properties of the materials.

Optical Properties

1. Optical properties

One of the most fascinating and useful aspects of nanomaterials is their optical properties.

Applications based on optical properties of nanomaterials include optical detector, laser, sensor, imaging, phosphor, display, solar cell, photo catalysis, photo electrochemistry and

biomedicine.

The optical properties of nanomaterials depend on parameters such as feature size, shape, surface characteristics, and other variables including doping and interaction with the surrounding environment or other nanostructures. Likewise, shape can have dramatic influence on optical properties of metal nanostructures.

Electrical Properties

2. Electrical properties

Electrical Properties of Nanoparticles" discuss about fundamentals of electrical conductivity in nanotubes and nano rods, carbon nanotubes, photoconductivity of Nano rods, electrical conductivity of nanocomposites. One interesting method which can be used to demonstrate the steps in conductance is the mechanical thinning of a nanowire and measurement of the electrical current at a constant applied voltage. The important point here is that, with decreasing diameter of the wire, the number of electron wave modes contributing to the electrical conductivity is becoming increasingly smaller by well-defined quantized steps.

In electrically conducting carbon nanotubes, only one electron wave mode is observed which transport the electrical current.

Mechanical properties

3. Mechanical Properties

Mechanical Properties of Nanoparticles” deals with bulk metallic and ceramic materials, influence of porosity, influence of grain size, super plasticity, filled polymer composites, particle-filled polymers, polymer-based nanocomposites filled with platelets, carbon nanotube-based composites. The discussion of mechanical properties of nanomaterials is, in to some extent, only of quite basic interest, the reason being that it is problematic to produce macroscopic bodies with a high density and a grain size in the range of less than 100 nm. However, two materials, neither of which is produced by pressing and sintering, have attracted much greater interest as they will undoubtedly achieve industrial importance.

Mechanical properties

These materials are polymers which contain nanoparticles or nanotubes to improve their mechanical behaviors, and severely plastic-deformed metals, which exhibit astonishing properties. However, because of their larger grain size, the latter are generally not accepted as nanomaterials. Experimental studies on the mechanical properties of bulk nanomaterials are generally impaired by major experimental problems in producing specimens with exactly defined grain sizes and porosities.

Filling polymers with nanoparticles or nano rods and nanotubes, respectively, leads to significant improvements in their mechanical properties. Such improvements depend heavily on the type of the filler and the way in which the filling is conducted. On the other hand, by using carbon nanotubes it is possible to produce composite fibers with extremely high strength and strain at rupture.

Magnetic properties

4. ***Magnetic properties***

Bulk gold and Pt are non-magnetic, but at the nano size they are magnetic. Surface atoms are not only different to bulk atoms, but they can also be modified by interaction with other chemical species, that is, by capping the nanoparticles. This phenomenon opens the possibility to modify the physical properties of the nanoparticles by capping them with appropriate molecules. Actually, it should be possible that non-ferromagnetic bulk materials exhibit ferromagnetic-like behavior when prepared in nano range. One can obtain magnetic nanoparticles of Pd, Pt and the surprising case of Au (that is diamagnetic in bulk) from non-magnetic bulk materials. This observation suggested that modification of the d band structure by chemical bonding can induce ferromagnetic like character in metallic clusters.

Selected Application of Nanomaterials

Nanomaterials having wide range of applications in the field of electronics, fuel cells, batteries, agriculture, food industry, and medicines, etc... It is evident that nanomaterials split their conventional counterparts because of their superior chemical, physical, and mechanical properties and of their exceptional formability.

Carbon nanotubes (CNTs) have chemical stability, good mechanical properties and high surface area, making them ideal for the design of sensors and provide very high surface area due to its structural network. Since carbon nanotubes are also suitable supports for cell growth, electrodes of microbial fuel cells can be built using of CNT.

Selected Application of Nanomaterials

Higher surface area available with the nanomaterial counterparts, nano-catalysts tend to have exceptional surface activity. For example, reaction rate at nano-aluminum can go so high, that it is utilized as a solid-fuel in rocket propulsion, whereas the bulk aluminum is widely used in utensils.

Nano chemistry also finds immense use in wastewater treatment and air purification devices. One class of filtration techniques is based on the use of membranes with appropriately sized pores, through which the liquid is allowed to pass.

Selected Application of Nanomaterials

Sensors made of nanocrystalline materials are extremely sensitive to a change in their environment. Some of the applications for sensors made of nanocrystalline materials are smoke detectors, ice detectors on aircraft wings and automobile engine performance sensors.

Food packaging can be improved by placing anti-microbial agents directly on the surface of the coated nanocomposite film. The incorporation of nanoscale clay particles in a polymer matrix can result in lower oxygen and water permeation with better recyclability. This can protect food from drying and spoilage (incurred by oxygen access).

Selected Application of Nanomaterials

In the field of medicine, nanotechnology finds application in diagnosis, therapeutics, prosthesis materials and tissue engineering. Nanomaterials have dimensions similar to those of biological molecules and hence they are useful for biomedical applications. By attaching different biomolecules to nanomaterials, they can be used in medical applications.

Insulation Aerogels are nanomaterials synthesized by the sol-gel process, which are porous, foam-like and extremely light-weight, and yet can withstand about 100 times their weight. They are currently being used for insulation in offices, homes