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A basic idea on synthesis, characterization and applications of nanoparticles

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Abstract: Nanoparticles have been synthesized by different chemical and physical methods. The optical and size dependent properties of quantum dots were analyzed in the presence and absence of different capping agents in aqueous solution. The nanoparticles have been characterized by X-ray diffraction, UV–Vis spectrophotometer, Photoluminescence, and Fourier-transform infrared spectroscopy measurements. Quantum dots with small grain size were observed in XRD and decrease in particle size of the same with increase in band gap is deduced through UV–Vis and XRD studies. The FT-IR spectrum confirms the interaction of different groups. In this paper I shall discuss about the different type of properties of nanoparticles.

Keywords: Nanoparticles, optical, size dependent properties.

I. INTRODUCTION

Nanometre sized nanoparticles, wires and belts have a wide range of electrical and optical properties and variable mechanical stability and phase-transition mechanisms to demonstrate a sensitive dependency on size, shape and structure. A fracture of research performance has been emerged in the synthesis and characterization of semiconductor nanoparticles for size dependent optical properties [1-5].

II. TECHNIQUES FOR SYNTHESIS OF NANOMATERIALS

There are two general approaches for the synthesis of nanomaterials: Top- down & Bottom–up techniques. A brief review of Top-down and Bottom-up techniques of synthesis of nanostructured materials are discussed in the following sections:

Top-down techniques

Top-down approach involves the breaking down of the bulk material into nanosized structures or particles. Top-down synthesis techniques are extension of those that have been used for producing micron sized particles. Top-down approaches are naturally simpler and depend either on removal or division of bulk material or on smallness of bulk fabrication processes to produce the required structure with appropriate properties. The biggest difficulty with the top-down approach is the imperfection of surface structure.

Bottom-up techniques

The different approach, which has the potential of creating less misuse and thus the more inexpensive, is the 'bottom-up'. Bottom-up approach refers to the build up of a material from the bottom: atom-by-atom, molecule-by-molecule, or cluster-by cluster. Many of these techniques are still under development to be used for commercial production of nanopowders. Oraganometallic chemical route, revere-micelle route, sol-gel synthesis, colloidal precipitation, hydrothermal synthesis, template assisted sol-gel, electrodeposition etc. are some of the well- known bottom–up techniques reported for the preparation of luminescent nanoparticals.

Nanoparticles have attracted great interest in recent years because of their unique chemical, physical, optical, electrical and transport properties which are different from those of either the bulk materials or single atoms [6, 7]. Due to the vast surface area, all nanostructured materials posses a huge surface energy and thus, are thermodynamically unstable or metastable. One of the great challenges in fabrication and processing of nanomaterials is to overcome the surface energy and to prevent the nanomaterials from growth in size determined by the reduction of overall surface energy. Due to high surface energy of the nanoparticles, they are awfully reactive and most systems without protection or passivation of their surfaces undergo aggregation [8]. Organic stabilizers are usually used to prevent nanoparticles from aggregation by capping their surfaces [9].

Chemical reactions for material synthesis can be carried out in the solid, liquid, or gaseous states. The more conventional solid-state synthesis approach is to bring the solid precursors into close contact by grinding and mixing and subsequently to the heat treatment at high temperatures to facilitate diffusion of atoms or ions in the host material by chemical reaction. The diffusion of atoms depends on the temperature of the reaction and grain boundary contacts.

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Low reaction temperatures also discourage detrimental grain growth. Many materials can be synthesized in aqueous or non aqueous solutions. But the wet-chemical synthesis of extrinsic semiconductor nanomaterials faces new problems that are not encountered in bulk materials. The synthesis parameter such as temperature, pH of the solution, reactants concentration and reaction time should be ideally correlated with factors such as supersaturation, nucleation and growth rates, surface energy and diffusion coefficients, in order to ensure the reproducibility of reactions.

Characterization techniques:

X-ray diffraction (XRD)

X-ray diffraction (XRD) is a high-tech, non-destructive technique for analyzing a wide range of materials. Each crystalline solid has its unique characteristic X-ray diffraction pattern which may be used as a fingerprint for its identification [10]. Once the material has been identified, X-ray crystallography may be used to determine its structure. The phenomenon of the x-ray diffraction by crystals results from a scattering process in which x-rays are scattered by the electrons of the atoms without change in wavelength. As the wavelength of X-rays is close to atomic size, they get diffracted by atoms and ions. If the atoms or ions are arranged in a particular fashion then the diffracted X-rays interfere constructively or destructively with each other depending on the path difference [11].

Spectroscopic studies

Investigations of optical properties of semiconducting materials are essential for proper application in semiconductor devices. The fundamental optical properties, which have been investigated, are reflectance, transmittance and absorption of light at various wavelengths.

Optical absorption

The measurement of absorption spectra is the direct method for interested the band structure of semiconductors. In the absorption, a photon of known energy excites an electron from a lower to a higher energy state. In other manner we can say that absorption is also resulted from contact between atoms and electromagnetic radiations.

Transmission electron microscopy

Electron microscopes make images of material microstructures with much higher magnification and resolution than light microscopes. The high resolution of electron microscopes results from short wavelengths of the electrons used for microscope enlightenment. The wavelength of electrons in electron microscopes is about 10,000 times shorter than that of visible light. The resolution of electron microscopes reaches the order of 0.1 nm if lens aberrations can be minimized. Such high resolution makes electron microscopes enormously useful for useful ultrafine details of material microstructure [12].

Scanning electron microscopy

The scanning electron microscope (SEM) is the most commonly used type of electron microscope. It examines microscopic structure by scanning the surface of materials, similar to scanning confocal microscopes but with much higher resolution and much greater depth of field. An SEM image is formed by a focused electron beam that scans over the surface area of a specimen; it is not formed by instant illumination of a whole field as for a TEM. Possibly the most important characteristic of an SEM is the three-dimensional look of its images because of its large depth of field. An SEM is comparatively easily operated and maintained, compared with a TEM. In addition, an SEM system enables us to obtain chemical information from a specimen by using different techniques, including by equipping the x-ray energy dispersive spectrometer (EDS). This introduces the basic working principles and character of an SEM for microstructural and surface morphology examination [12].

III. APPLICATIONS OF NANO MATERIALS

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. Only some potential applications of nanomaterials in different field of science and technology are given below:

Fuel cells

A fuel cell is an electrochemical energy conversion device that converts the chemical energy from fuel and oxidant directly into electricity. The heart of fuel cell is the electrodes. The performance of a fuel cell electrode can be optimized in two ways; by improving the physical structure and by using more active electro catalyst. A good structure of electrode must give sufficient surface area to help gas transport and offer good electronic conductance. In this fashion the structure should be able to reduce losses.

Carbon nanotubes

Carbon nanotubes 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. Due to three-dimensional architectures and puffy electrode surface area for the entry of growth medium, bacteria can grow and propagate and get powerless.

Catalysis

Higher surface area available with the nanomaterial counterparts, nano-catalysts tend to have exceptional

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surface activity. Catalysts assisting or retarding the reaction rates are dependent on the surface activity and can very well be utilized in manipulating the rate-controlling step.

Phosphors for high-definition TV

The resolution of a television, or a monitor, depends greatly on the size of the pixel. These pixels are essentially made of materials called phosphors, which glow when struck by a stream of electrons inside the cathode ray tube. The resolution improves with a reduction in the size of the pixel or the phosphors.

Next generation computer chips

The microelectronics industry has been emphasizing smallness such as transistors, resistors, and capacitors, are reduced in size. By achieving an important reduction in their size which contain these components thereby enabling computations at far greater speeds. Nanomaterials help the industry break these barriers down by provided that the manufacturers with nanocrystalline starting materials, ultra-high purity materials, materials with better thermal conductivity, and longer-lasting, strong interconnections.

IV. CONCLUSION

I have discussed a general idea on synthesized nanoparticles by top down and bottom approaches, and characterization techniques such as XRD, optical absorption, TEM, SEM and applications as a fuel cell, catalysis etc. in this paper.

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