Nano materials, quantum dots synthesis and applications

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Abstract:

Nanomaterials are defined as engineered materials with a least one dimension in the range of 1-100nm. Particles of "nano" size have been shown to exhibit enhanced or novel properties including reactivity, greater sensing capability and increased mechanical strength. The nanotechnique offers simple, clean, fast, efficient, and economic for the synthesis of a variety of organic molecules, have provided the momentum for many chemists to switch from traditional method. In the present article an attempt was made to focus on what is nanomaterials, how is it generated and what importance may it have.

Keywords: Nanomaterials-synthesis, properties, applications

Introduction

Nano-sized particles ranging below several 10 nm are of great interest, because of the chemical and physical behavior of the particles arising from the quantum size effect which are remarkably different from those in bulk form giving the great potential for use in applications in the electronic, chemical and mechanical industries, as well as in the related technologies using catalysts, drug carriers, sensors, pigments, also as well as in optical, magnetic and electronic materials. The usage of the unagglomerated particles with sharp size distribution is preferred for practical applications and technologies, especially for compacting or self-arranging the particles. A number of techniques for the preparations of nanoparticles that satisfy this requirement have been developed via gas and liquid phase processes. To be industrially relevant, the process needs to be low-cost and involve both continuous operation and a high production rate. In this presentation, synthesis of nanoparticles will be introduced followed by the explanation of the outline on the synthesis of nanoparticles via different processes and nanoparticle-based nanostructured materials investigated for various applications. The model materials used include: noble metals, phosphors, quantum dots and luminescent semi-conductor materials.

Nanotechnology and nanomaterial synthesis:

If the task of any technology is to establish physical, chemical, mechanical and other laws with the purpose to discover and implement the most efficient manufacturing processes, then we have to admit that the nanotechnology is still at the early stages of development. In 2001, the Science magazine named nanotechnology ''The Breakthrough of the Year''[1], and indeed, there is a number of very promising findings. In the same time, the Scientific American magazine voiced skepticism, which is always present in science. In the special issue, partially devoted to nanotechnology, Gary Stix, a special projects editor, noted that the word ''nanotechnology'' sounds more like and science-fiction one that its scientific equivalent ''applied mesoscale

materials science''[2]. He also advised to ''discard the overheated rhetoric that can derail any big new funding effort.'' It is also indicative that the nanotechnology is not profitable as yet. However, declaring nanotechnology ''enabling and potentially disruptive'' should be regarded as a scientific advertising and the reality of the near future.

There are various points of view as to what directions the nanotechnology is most likely to take. In[3] five major areas within the nanotechnology were identified: (a) molecular nanotechnology; (b) nanomaterials and nanopowders; (c) nanoelectronics; (d) nano-optics and nanophotonics; (e) nanobiomimetics. In the authors' opinion, the last three areas deal with the application of nanomaterials. Therefore, the concept of a nanomaterial should be discussed fully and comprehensively. However, this discussion has not taken place yet, at least not in the context of the mechanics of materials. This is due to the fact that the overwhelming majority of studies on nanomaterials is carried out within chemistry and molecular physics, because it is primarily chemists and physicists who had experience in working with substances on atomic, molecular and macromolecular levels.

Apart from molecular nanotechnology, there are several well-known manufacturing methods to produce nanomaterials[4,5] as shown in flow chart. Synthesis is the most important step in the studies of nanoparticles.. Looking at the chemical formula of most of the phosphors one may feel that the synthesis of the luminescent materials should be straight forward as the host materials are well-known. However, in practice the synthesis of the phosphors with desired characteristics can be quite tricky. The difficulties arise as one has to consider several aspects such as the incorporation of the activators at the desired sites, elimination of the unwanted impurities, specific grain size and morphology suitable for the application, cost of production, batch, etc.

Synthesis of Nanomaterials:

a) Chemical vapour deposition: According to this technique, a material is placed in a vacuum, heated up until it vapourises and then deposited on the hard surface. Deposition can be either direct or accompanied by a chemical reaction between the material being deposited and the material of the hard surface. The latter usually leads to formation of oxides or carbides of metals on the metal surface, if oxygen and carbon are present in it. [6,7]

b) Electro-deposition or galvanization: This is a well-known and long-established technique. In nanotechnology, between one and several atomic layers need to be deposited. Nanogalvanisation is also used to produce dispersive nanomaterials. For example, polymeric membranes, with pores from 10 to 100 nm in size become conductor materials when filled with atoms of metals. Such nanocomposite exhibits adaptable properties and behave as smart materials.[8]

c) Sol–gel synthesis: Gels are suspensions of disperse particles, which form spatial lattice in a dispersive liquid. The hold the shape like materials and may form by coalescence of sol particle. If the particles in the suspension are rather small and in Brownian motion, then such suspension is termed a sol. A sol–gel is a shape-holding suspension of colloidal particles in a liquid.

Nanoparticles form a sol–gel in four stages, including hydrolysis; condensation and polymerization of monomers; particle growth; and agglomeration of the particles and formation of a gel. The sol–gel synthesis is used to produce nano-films. [9-14].

d) Arc plasma sprays or plasma arcing: This plasma ionisation scheme includes two electrodes to generate potential difference. If the electrodes are in a gas medium, the gas loses electrons and becomes ionised, forming plasma. To produce, for example, a nanotube film, carbon electrodes are used, of which one generates carbon cations and the other receives them to form nanotubes. [6]

e) Solvothermal process: Precursors are dissolved in hot solvents (e.g., n-butyl alcohol) and solvent other than water can provide milder and friendlier reaction conditions If the solvent is water then the process is referred to as hydrothermal method.[15,16]

Properties of Nanomaterials:

Two principal factors cause the properties of nanomaterials to differ significantly from other materials: increased relative surface area, and quantumeffects.

a) Optical Properties: Nanoparticles often possess unexpected optical properties as they are small enough to confine their electrons and produce quantum effects.[19] For example gold nanoparticles appear deep-red to black in solution. Nanoparticles of yellow gold and grey silicon are red in color. Gold nanoparticles melt at much lower temperatures (~300 °C for 2.5 nm size) than the gold slabs (1064 °C);.[21] Absorption of solar radiation is much higher in materials composed of nanoparticles than it is in thin films of continuous sheets of material. In both solar PV and solar thermal applications, controlling the size, shape, and material of the particles, it is possible to control solar absorption.17,[9][20][21]

b) Electrical properties: The electrical properties of nanomaterials vary between metallic to semiconducting materials. It depends on the diameter of the nanomaterials. The very high electrical conductivity of nanomaterial is due to minimum defects in the structure.

c) Thermal conductivity: The thermal conductivity of nanomaterials are very high, is due to the vibration of covalent bonds. Its thermal conductivity is 10 times greater than the metal. The very high thermal conductivity of nanomaterial is also due to minimum defects in the structure.

d) Mechanical properties: Nanomaterials are very strong and withstand extreme strain. Most of the materials fracture on bending because of the presence of more defects, but nanomaterials possesss only few defects in the structure.

Applications of Nanomaterials: Below we list some key applications of nanomaterials. Most current applications represent evolutionary developments of existing technologies: for example, the reduction in size of electronics devices

a) Sunscreens and Cosmetics: The traditional chemical UV protection approach suffers from its poor long-term stability. A sunscreen based on mineral nanoparticles such as titanium dioxide offer several advantages. Titanium oxide nanoparticles have a comparable UV protection property. Nanosized titanium dioxide and zinc oxide are currently used in some sunscreens, as

they absorb and reflect ultraviolet (UV) rays and yet are transparent to visible light and so are more appealing to the consumer. Nanosized iron oxide is present in some lipsticks as a pigment. The use of nanoparticles in cosmetics has raised a number of concerns about consumer safety.

b) Paints: Incorporating nanoparticles in paints could improve their performance, for example by making them lighter and giving them different properties. Thinner paint coatings ('lightweighting'), used for example on aircraft, would reduce their weight, which could be beneficial to the environment.

c) Displays: The huge market for large area, high brightness, flat-panel displays, as used in television screens and computer monitors, is driving the development of some nanomaterials. Nanocrystalline zinc selenide, zinc sulphide, cadmium sulphide and lead telluride synthesized by sol gel techniques are candidates for the next generation of light-emitting phosphors.

d) ***Lamp Phosphor: Mercury Free-lamp:*** Phosphor material finds wide applications ranging from fluorescent lamp to luminescence immunoassay. This material essentially converts one type of energy into visible radiation. In fluorescent lamp, phosphor materials convert UV radiation into visible radiation. Lamp phosphors are mostly white in colour and they should not absorb the visible radiation.

e) Other Applications: Some of the major applications of nanomaterials are: medicine, energy, sensors of gas, food, agriculture, and constructions etc. Some commercial products on the market today utilizing nanomaterials include stain resistant textiles and reinforced tennis rackets. Companies like Kraft foods are heavily funding nanomaterials based plastic packaging. Food will stay fresh longer if the packaging is less permeable to atmosphere. Coors Brewing company has developed new plastic beer bottles that stay cold for longer periods of time.

Advantages of nanomaterials:

Following are the advantages of Nanophosphor over Submicron /micron phosphor:

Superior emitter; Nanophosphor has controlled particle size, size distribution, shape, and crystallinity; Nanophosphor produces high luminescence efficiency; Nanophosphor has high luminescence intensity because of ideal surface passivation and agglomeration of particle; Ability to withstand high temperature; Degradation behavior is less; The advantage of inorganic capping is that they saturate dangling bonds and substantially reduce nonradiative centers (dead layer); Nanophosphor have major advantages in reducing loss due to internal scattering, total internal reflection etc. Nanophosphor are tunable and chemically stable;. The uniqueness of semiconductor Nanonmaterials lies in the tunability of the optical absorption and emission properties over a range of wavelength by control of the crystallite size. It is also possible to introduce trap states within the band gap to act as luminescent centers.

Discussion:

Nanotechnology is a powerful innovative tool in the hands of the researchers, so it not a managerial profession. Most of the organizations connected with Nanotechnology are engaged in the research to find out new structure and studying the properties of Nano particle. So, a good background of physics and chemistry is called for. One must understand at nano level we are dealing with manipulation of atoms and molecules and their arrangement, many factors which

need to be taken care of on worldly (normal) scale devices do not apply to on nano scale devices. Likewise factors which can be ignored on normal scale may play important role at nano scale. So an open mind, analytical skill, mathematics, computer programming skills in simulation and algorithm development and implementation would be an asset and one should put lot of effort in developing them. If we think of application, then we need to also have a background and expertise in the field we would like to apply Nanotechnology. Medicine and electronics are the two major areas where we would be seeing lot of activity in this field.

At this stage it is difficult to say what actually would be achieved by Nanotechnology. It's a gamble with a calculated risk. The Nanotechnology has existed for now more than 30 years, it was not in the lime light and not taken seriously by researchers. But with the development and breakthrough achieved in recent years in electron microscope etc, substantial progress could be made in Nano science and devices. It may take longer than that, put possibly our survival demands that we prepare now for the earliest possible development scenario. Nanotechnology has pushed the limits further.

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