# Nano scale Rare earth metal oxide semiconductor, Properties, preparation methods and its applications

**R. Thirumamagal1\*, U. Ashokan1, .A. Ayesha Mariam2**

1 Department of Physics, Ananda College, Devakottai.

2 P.G and Research Department of Physics, Kadhir Mohaideen College, Adhirmpattinam

# Abstract

The properties of metal oxide semiconductor materials change excessively when its size is reduced to nanoscale due to their large surface area or quantum size effect. The nanostructured metal oxide semiconducting materials reserves excellentredox property. In recent days rare earth lanthanides metals like (La, Ce, Pr, Nd ) have are a well-known catalyst for oxidation reactions as well as potential candidate as stabilizing agent of hydroxyapatitein the crystalline phase, one decided to generate a mixed hydroxide material that can be electrochemically activated generating metal oxide semiconductor compassing synergic catalytic effects for oxidation of hydroxyapatite and organic molecules. Metal oxide semiconducting nanostructed materials acts a vital role in the development of modern technology and lead to significant breakthrough in the semicodncutor industry like renewable energies, solar fuels, photovoltaic effect, eight emitting nano devices, and laser technology. Synthesized composites having good influence on the properties of sensing and inhibition ability on microbial activity.Modifying sensing materials is one kind of doping strategy to improve the sensing properties of metal oxide -based gas sensors. Metaloxide with hydroxyapatitienanocomposites revealed that the binary cytotoxicity of the composite mixture should mediate their direct contacts and the subsequent Cytotoxicity.

# Introduction

Nanoscience is the study of nanoscale materials: materials which exhibit remarkable, properties, functionalities and phenomena due to the influence of small dimensions. Technology refers to the practical application of knowledge- development, applications and commercial implications. Nanotechnology is based on manipulation, control, integration of atoms and molecular form of materials, structures, components, devices and systems at nanoscale. It is the application of nanoscience to industrial and commercial objectives.

Nanoscienceandnanotechnology are two research areas dealing with materials of nanoscale - and are multi-disciplinary areas integrating physics, chemistry, engineering and biology. Nanoparticles behave so very differently from when they are bound in larger units. Nanotechnology aims to make a study of these characteristics, to find laws of governing these characteristics, to integrate such knowledge, deriving theoretical model to describe them and to analyse the properties of them. Nanotechnology is engineering these objects at their molecular level by using different techniques. The purpose is to exploit the properties at the molecular level to be more efficient. It focuses on properties such as strength, lightness, electrical and thermal conductance and reactivity, to manufacture for useful items [1].

It employs two approaches 1, Top down approach and 2. Bottom up approach

Various concepts such as self-assembly, and molecular machines are also used in nanotechnology. Nanoparticles have unique properties compared with their bulk. Their properties can be controlled by simply tuning their sizes, shapes and compositions. These novelties are not just because of reducing their size; it comes from different ways that depends on type of material. Origins are: (i) Quantum size effect and (ii) Surface atom effect. **Quantum size effect**

Quantum confinement effect induces changes in bandgap energy and quantization of electronic energy level. When a particle size approaches the Bohr exciton radius, the energy gap becomes widened with the decreasing particle size and this property will enhance optical properties much.

**Surface atom effect**

The ratio of surface atom to bulk increases sharply with the decrease in particle size. This imperfect surface of nanoparticles provides surface defects that are even more active and can provide additional electronic states and reactivity i.e. when the size of the material decreases to nanoscale, total surface area per unit mass increases.

**Properties of Nanoparticles**

Due to their novel properties and varied potential applications, nanocrystalline materials with typical grain sizes <100 nm, are attracting and increasing attention from researchers all over the world [2]. Because of the small grain size of these materials, and consequently the large volume fraction of atoms in or near the grain boundaries, these materials exhibit properties that are often superior, and sometimes completely new, in comparison to those of conventional coarse-grained materials.

These can affect the optical, electrical and magnetic behaviour of the materials, particularly as the structure or particle size approaches the smaller end of the nano-scale. Materials that exploit these effects include quantum dots, and quantum well lasers for opto-electronics.

Nanoscience and nanotechnology have grown explosively in the last decade because of the increasing availability of methods of synthesizing of nanomaterials as well as tools for characterization and manipulation. Several innovative routes for synthesizing nanoparticles and nanotube assemblies are also now available. The size-dependent electrical, optical and magnetic properties of individual nanostructures of semiconductors metals and other materials and better understood. Besides the established techniques like electron microscopy, crystallography and spectroscopy, scanning probe microscopies have provided powerful tools for the study of nanostructures [3].

Nano structures constitute a bridge between molecules and infinite bulk systems. Individual Nano structures include clusters quantum dots nano crystals, nanowires and nanotubes, while collections of nonstructural materials involve arrays, assemblies, and super lattices of the individual nanostructures. The physical and chemical properties of nanomaterials can differ significantly from those of the atomic molecular or the bulk materials of the some composition are shown in Table 1.1 [4].

**Table -1.1 Nanostrcutures and their assemblies**

|  |  |  |
| --- | --- | --- |
| **Nanostructure** | **Si Size** | **Material** |
| Clusters, nanocrystals quantum dots | Radius 1-10nm | Insulators, semiconductors metals, magnetic materials. |
| Other nanoparticles | Radius  1-100nm | Ceramic Oxides |
| Nano biomaterials, Photosynthetic reaction center | Ra Radius 5-10nm | Metals, semiconductor oxides, sulfides, nitrides |
| Nanowires | Diameter  1-100nm | Carbon layered chalcogenide BN, GaN |
| Nanobiorods | Diameter  1-100nm | DNA |
| Nanotubes | Diameter 5nm | Carbon, layered chalcogenides Material BN,GaN |
| Two dimensional arrays of nanoparticles | Area  Several nm2-μm2 | Metals, semiconductors, Magnetic Materials |
| Surface and thin films | Thickness  1-100nm | Insulators, semiconductors metals, DNA |
| 3-dimensional super lattices of nanoparticles | Several nm in 3 dimensional | Metals, semiconductors, Magnetic Materials |

Some of the important concerns of materials scientists in the nanoscience area are

i. Nanoparticles or nanocrystals of metals and Semiconductors, nanotubes, nanowires and nanobiological systems.

ii. Assemblers of nanostructures and the use of biological systems, such as DNA as molecular nanowires and templates for metallic or semi conducting nanostructures.

iii. Theoretical and computational investigations that provide the conceptual framework for structure dynamics, response and transport in nanostructures.

iv. Application of nanomaterials in biology, medicine, electronics, chemical processes,

High - strength materials etc.

**Nanoparticles**

Nanoparticles are small clusters of atoms about 1 to 100 nanometers long. Nano derives from the Greek word nanos, which mean dwarf on extremely small. It can be used as a prefix for any unit like a second or a liter to mean a billionth of that unit. Nano particles are larger than an individual atom and a molecule but are smaller than bulk solid .Hence they obey neither absolute quantum chemistry nor laws of classical physics and have properties that differ markedly from those expected. The two major phenomena that are responsible for these differences, is the high dispersity of nanocrystalline systems. As the size of the crystal is reduced, the number of atoms in the surface of the crystal compared to the number of atoms in the crystal itself, increases. For example, a 4 nm (Cds) cadmium sulphide diameter has about 1500 atoms, of which about a third are on the surface which are usually determined by the molecular structure of the bulk lattice, now become increasingly dominated by the defect structures of the surface [5]

Template synthesis methods such as alumina-porous membranes and track-tched polycarbonate porous membranes, to electrochemically deposit metal nanparticles insides the pores has become popular in the recent years. These deposits have been studied in the context of a wide spectrum of scientific goals ranging from catalysis to magnetic properties and magnetic data storage. Attention has also been focused on the application of small metal particles in surface enhanced spectroscopy photo catalysis and selective solar absorbers studies with atomic absorption have shown that iron, nickel, cobalt and gold particles have equivalent areas per volume with particle radii in the range 3 to 5 nm. Magnetic measurements on iron, nickel and cobalt films-reveal them to the highly anisotropic with magnetization perpendicular to the surface of the film.. The unusual optical absorption of noble-metal nanoparticles such as copper, silver and gold embedded in a dielectric medium such as alumina renders them of interest for optical applications Electro Chemical nucleating also plays a role in nanoparticle fabrication of metal nanoparticles at template liquid interfaces [6].

To fabricate a metallic shell around a nanoparticle a variety of methods, such as the reverse micelle, thermal decomposition method. Photo-decomposition method and electrochemical displacement have been reported [7]. The displacement reaction can be carried out in neutral organic solutions or in an aqueous electrolyte through the use of hydrophilic surfactant groups extending from the metal core. The resulting magnetic core shell nanoparticles have potential applications in magnetic storage and also as drug-delivery systems. However, both the electro less and displacement depositions have one basic characteristic in common; no power supply is necessary to drive the deposition reaction. In brief, the displacement reaction deposition can be carried out with noble-metal ions reduced by the nanoparticles [8].

# Properties of Rare-Earth Metal Oxide Nanoparticles

Aseries of rare earth metal oxide (CeO2, Pr2O3, and Nd2O3) nanoparticles, which has been act as a vitamin for semiconductor industry and a ‘treasury’ of new born materials, has an inherently critical role in technical progress and the development of technical industries, and it is also widely applied in high-technology industries such as information and biotechnology [29]. The chemistry of rare earth differs from main group elements and transition metals because of the nature of the 4*f* orbitals, which are ‘buried’ inside the atom and are shielded from the atom’s environment by the 4*d* and 5*p* electrons.[29,30] These orbitals give rare earth unique catalytic, magnetic and electronic properties. These unusual properties can be exploited to accomplish new types of applications that are not possible with transition and main group metals.

**Nano particle preparation methods**

**Solution precipitation procession of nanoparticles**

Precipitating clusters of inorganic compound from a solution of chemical compounds has been an attractive proposition for researchers primarily because of the simplicity with which experiments can be conducted in a laboratory. This is especially true if the goal is to just have a nanocrystalline powder instead of a dispersible nanoparticulate powder. A major advantage of solution processing is the ability to form encapsulated nanoparticles, specifically with an organic molecule, for providing functionality to the nanoparticles improving their stability in a medium or for controlling their shape and size [14].

Solution processing can be classified into three major categories

1. Sol-gel processing
2. Precipitation Method
3. Hydrometallurgical method
4. Jet Nebulizer technique of Nps

**(i) Sol-Gel processing**

Sol-gel technique is one of the most popular solutions processing method for producing metal oxide nanoparticles. Over the years, solution precipitation and sol-gel processing have come to be used interchangeably mostly by people on the fringes of the technical community. There are distinct differences between two methods as will be made clear below. In sol-gel processing a reactive metal precursor such as metal alkoxide, is hydrolyzed with water and hydrolyzed species are allowed to condse with each other to form precipitates of metal oxide nanoparticles. The precipitate is subsequently washed and dried, which is then calcined at an elevated temperature to form crystalline metal oxide nanoparticles.

The hydrolysis of metal alkoxides involves nucelophilic reaction with water, which is as follows M(OR)y + xH2O+M(OR)y-x(OH)+xROH

**(ii) Precipitation**

Chemical and physiochemical methods of metal powder production allow great variations in powder properties. The wide variety of processing variables and production parameters currently available permit close control of particle size and shape. Powders made by reduction of oxides, precipitation from solution or from a gas, thermal decomposition, chemical embitterment, hydride decomposition and thermit reactions belong to this classification. The most widely used processes within this category include oxide reduction precipitation from solution and thermal decomposition.

The production of iron, copper, tungsten and molybdenum powders from their respective oxides is the well established commercial process. Detailed process descriptions for these oxide-reduced powders can be found in the articles “production of iron powder”. For the production of copper powder of refactory metal and carbide powders on a smaller scale, this oxide reduction process is used and also is used for production of cobalt and nickel powders as well.

Oxide-reduced powder grades of iron and copper compete with powder grades made by other processes. Oxide-reduced powders characteristically exhibit the presence of pores within each powder particle and thus are called sponge powders. This sponginess is controlled by the amount and size of the pores and accounts for the good compatibility and sinterability of such powders [15].

These chemical reactions can potentially control the mobility and toxicity of trace metals in soil systems.

**(iii) Hydrometallurgical method**

Production of metal powders by hydrometallurgical processing is based on leaching an ore or ore concentrate, followed by precipitating the metal from the leach solution. Although basic precipitation reactions have been known for more than 100 years, commercial use of this process did not flourish. Metal precipitation from solution can be accomplished directly by electrolysis cementation or chemical reduction. Indirect precipitation may be achieved by first precipitating a compound of the metal followed by heating, such as decomposition and reduction.

The most widely used commercial processor based on hydrometallurgy is copper cementation and the separation and precipitation of copper nickel and cobalt from their respective salt solutions by reduction with hydrogen.

In its simplest form, copper cementation recovers copper from acidic dump that reaches solutions as an impure powder precipitate. Due to the presence of significant amounts of iron and silicates, low apparent density and high green strength, such copper powders find use in P/M friction composite components. They are not used in conventional structural parts because of insufficient sintering activity.

**iv)Jet Nebulizer technique of NPs**

## 

## Figure 1.1 Experimental set up of Jet Nebuliser Technique

The Jet nebulizer contains three main parts as detailed in Figure 1.1, which can be easily dismantled and assembled. The first part is the bottom portion having an inlet for compressed air and micro air nozzle with a diameter of 0.5mm. This is the important part of this nebulizer. When air at high pressure applied through this nozzle, it acts like a jet air nozzle and air is relished from it with very high speed. This is the reason for the name as ‘Jet Nebulizer’. The second part is specially designed liquid sucking unit with a small hole and a striker target tip in the top portion and this is mounted on the first part of Jet air nozzle. Third one is the top portion having an outlet of 1cm diameter for the release of aerosols and also with a 1 cm diameter tube from top to bottom. The Figure 1.2 shows the photograph of Jet Nebulizer experimental set up.



Figure 1.2 Photograph of experimental technique

The chemical liquid which is to be sprayed should fill at the bottom portion of the Nebulizer. The filling of the liquid is poured through the opening of apex of top portion’s tube. When the compressed air applied to the bottom portion, it will be released through Jet air nozzle with very high speed. Now, the liquid in the bottom portion will make a move towards the junction of the Jet nozzle and the second portion through the capillary rise movement due to the vacuum produced at junction by the Jet nozzle speed of the air. While the liquid reaches the junction it mixed with the speedy air and subject to collide with striker target tip point. Due to this very high speed collision the fragmentation of the liquid starts and moved horizontally towards the walls of the first portion. Here the further fragmentation caused by second collision on the side walls and the liquid formed as aerosol sized droplets like mist, which moved towards the outlet. Due to the collision with the straighter target tip and horizontal movement of the liquid fragmentations a small vacuum created on the top portion of the tip and hence automatically the air will be sucked through the 1 cm diameter tube in the top portion of the Nebulizer. This air also added with the mist and moved towards outlet with very high speed.

The mist output coming out from the Nebulizer towards thorough the specially designed spray nozzle falls on the substrate which is placed inside the furnace maintained with the temperature range of 300°C to 500°C. The distance between the spray nozzle and the substrate optimized at 5 cm for better coating.

The quality of the film depends on various process parameters and hence it is essential to optimize each process parameter to get good quality films. In the present work the air flow rate and substrate to nozzle distance were optimized by trial and error method. When the distance between the substrate to nozzle changes, the thermal gradient in the vapour space changes, hence the thermophoretic force acting on the liquid droplet will also change. In the Jet nebulizer spray pyrolysis when the droplet (mist) approaches the substrate it should vaporize entirely just above the substrate: this is the deal condition for the best transportation of the species to the substrate. Assuming that the size distribution of all the droplets is the same, the thermal energy gained by the droplets will increase greatly with increasing substrate to nozzle distance. This results in the preheating of the droplets by carrier gas through heat radiation. It is known that preheating enhances the pyrolytic reaction. Therefore, it seems likely that, at a substrate to nozzle distance of 5 cm heterogeneous reaction takes place due to the pre-heating of the optimized droplet size and hence good quality films were obtained. Above 5 cm substrate to nozzle distance, the thermal energy gained by the droplet is very high. This causes the water molecule, which is the important oxidizing agent in the pyrolytic decomposition, to vaporize completely far away from the substrate. The particle melts and vaporizes (or sublimes) and a chemical reaction will occur in the vapour phase. This is a homogeneous reaction, because all the reactant molecules and product molecules are in the vapour phase. The molecules condense as microcrystallines, which form a powdery precipitate on the substrate. This powder disturbs the formation of the layer and leads to a reduction in transmission. In addition, the homogeneous reaction diminishes the deposition efficiency [16].

For the above, to optimize the distance between the spray nozzle and the substrate by trial and error method, starting from 10 cm to 2 cm, the distance gradually decreased from 10 to 7 cm, the mist is not able to reach the substrate due to heat waves. It means at that distance the mist fully vanished due to large amount of heat. Below 7cm only a light coating is possible. i.e. in this position only the fast moving mist particles can reach the glass substrate against the heat waves generated by the furnace in the form of vapour. By trial it is optimized at 5 cm. i.e. in the 5cm distance only a smooth vapour reach is possible to the substrate fully. Below 5 cm due to the fast movement of the mist, it is scattered by the substrate to outside.

In the static position of this spray nozzle, the substrate size may be 1cm x 1cm for coating. But here we used 2.5cm x 2.5cm substrate for coating. So a slight vertical and horizontal movement required for constant coating. .

The droplets (mist) hit the substrate, where the solvent is entirely vaporized leading to the deposition of a rough film in which the transmission decreases markedly. At the optimum air flow rate the size of the mist particle is also optimum. So the thermal energy gained by the droplet is in such a way that it vaporizes just above the substrate and gives a good quality transparent film. In the case of high air flow the mist particle size will be much smaller than the optimum size and the droplet vaporizes entirely well above the substrate. Hence the homogeneous reaction takes place in the vapour space which diminishes the deposition efficiency and the molecules condense as thermo crystallites. They form a powdery precipitate on the substrate resulting in the decrease in transparency in the present work it has been observed that 3.5 kg/cm2 is the optimum airflow rate which gives highly transparent, good quality films [17].

To optimize the compressor air pressure also by trail it was increased from 0.5 kg/cm3 to 4 kg/cm3. At last it is found that below 2 kg/cm3 air pressure the outflow of the chemical mist was very slow. Above 2 kg/cm3 only the chemical mist travelled vertically due to the pressure. At 3.5 kg/m3 only the smooth speed is achieved and it was reached to the substrate. Above 3.5 kg/m3 air pressure also suitable upto certain limit but it will damage the tube and nebulizer. For the smooth coating, the optimized constant air pressure is 3.5kg/cm3 (50 PSI).

A specially designed glass tube is used as a carrier tube for the chemical mist generated by the Jet nebulizer. So many tubes designed with various diameters and verified for the coating. In the lower diameter tubes the mist condensed again as liquid droplets and in the higher diameter tubes the speed of the mist is decreased. So finally by trial we achieved a fine high quality atomizing effect from the above mentioned size tube. In the above tube the spray nozzle glass walls cross section should be pure flat structure. i.e. the 7mm nozzle outlet must be as a perfect circle. Then only the spray outlet will be a stream lined. The heat waves from the furnace may affect the mist coming through vertical tube. So, it can be arrested by using Teflon tape rounded on the vertical tube. A new middle hole furnace is exclusively designed for this nebulizer spray with height of 30 cm and 10 cm hole diameter for better results, because in a long tube furnace, the heat waves can arrest the mist before reach the substrate. The Jet nebulizer’s spray rate measured for the optimum carrier gas pressure of 3.5 kg/m3. It is found that 0.75 ml/minute is the normal rate. The deposition parameters, optimized by many trials [18] are: air pressure = 3.5kg/cm2, nozzle to substrate distance = 5 cm, rate of spray = 0.75 ml/min. The ultrasonic type nebulizers are already used for thin film coating for various chemical solutions and some articles published for ultrasonic nebulizer thin film coating. This may be the first time of this type Jet nebulizer is used for thin film preparation. The following are the advantages of Jet nebulizer spray pyrolysis over the conventional spray pyrolysis

1. Relatively low temperature is enough to get good oxide films.
2. For device fabrications, less heating effect required.
3. Additional accessories like purette etc., are not required.
4. A small amount of precursor solution is required.
5. It also reduced the material quantity.
6. Very small,compact and convenient to spray.

**Commercial Production and use of Nanoparticles**

On the other hand, applications where a small amount addition has been able to change substantially the properties and performance of the end product are becoming increasingly popular. A number of such examples can be found in the area of functional coating [9].

**Application of Nano Materials**

Since nano materials possess unique beneficial chemical, physical and mechanical properties they can be used for a wide variety of applications. The applications include but are not limited to the following.

**Next generation computer chips**

The microelectronics industry has been emphasizing miniaturization, where by the circular such as transistors, resistors and capacitors are reduced in size. By achieving a significant reduction in their size, the microprocessor which contains these components can run much faster, thereby enabling computations at far greater speeds. However there are several technological impediments to these advancements, including lack of the ultra fine precursors to manufacture these components; poor dissipation of tremendous amount of heat generated by these microprocessors due to faster speeds, short mean time to failures [10]. **Better Insulation Materials**

Nanocrystalline materials synthesized by thecombustion sol-gel technique results in foam like structure called an aerogels. The porous aero gels are extremely light weight; yet, they can withstand 100 times their weight. Aero gels are composed of 3 dimensional, continuous networks of particles with filled at their interstices. Since they are porous and air is trapped at their interstices, aero gels are currently being used for insulation in offices, homes etc. By using aerogels for insulations heating and cooling bills are drastically reduced thereby saving power and reducing the attendant environmental pollution. They are also being used as materials for smart windows, which darken when the sun is too bright and they lighten themselves, when the sun is not shining too brightly [11].

**High-sensitivity sensors**

Sensors employ their sensitively to the changes in various parameters they are designed to measure. The measured parameters include electrical resistively, chemical activity, magnetic permeability, thermal conductivity and capacitance. All these parameters depend greatly on the microstructure of the materials employed in the sensors. The change in the sensors environment is manifested by the sensor material’s chemical, physical or mechanical characteristics are which suitably exploited for deduction. A reaction triggers a change in the sensor’s characteristics such as conductivity and capacitance. The rate and the extend of this reaction are greatly increased by a decrease in the grain size. Hence sensors made using nanocrystalline materials are extremely sensitive to the change in the environment. Typical applications for sensors made out of nanocrystalline materials are smoke detectors, ice detectors on air craft wings, automobile engine performance sensors etc.

**Large electro chromic display devices**

The reaction governing electrochromism is the double-injection of ions and electrons which combine with the nanocrystal. When the polarity is reversed, the colour in bleached. The resolution, brightness and contrast of these devices greatly depend on the tungsten acid gel’s grain size. Hence, nano materials are being explored for this purpose [12] in a larger way. It is also evident that nano materials out perform their conventional counter parts because of their superior chemical, physical and mechanical properties and their exception formability.

Many new applications are being discovered almost daily. They are much other applications and uses which are yet to be discovered. The nanomaterials of magnesium tin oxide belong to a category of wide band gap semiconductor material. These materials have shown reasonable performance in many fields like transparent electrodes for watch, solar cells etc.

**Cosmetics**

An area of nanoparticle technology that has incredible commercial potential is the cosmetic industry. Here there is a great demonstrated demand and the technology can be made simple, since the properties of color and light fastness are achieved by component mixing in the cosmetic preparation. The large markets for sunscreens and skin rejuvenation preparation promise additional revenues [13].

**Medical/Pharmacology**

Overall, much of the demand for nanoparticulate dispersions and coatings comes from the cosmetic and pharmaceutical industries in particular, liquid dispersion preparations will be widely used to apply topical coatings to the human epidermis because they can be absorbed faster and more completely than conventional coatings [14]

**Micro electro mechanical systems**

Although MEMS technologies will support the semiconductor industry in particular, there are many other applications being explored, such as in medicine, ceramics, thin films, metal alloys and other proprietary applications. In the United States a particular focus is seen in applying sputtering coatings to achieve MEMS technology in concert with these applications.

**Printing**

In the areas of image capture/image output addressed by ink jet technology nanoscience can help control the properties of the ink’s themselves.

**Semiconductors**

One form of bottom up technology that is receiving considerable attention is thin film for the semiconductor industry.

**Biological applications**

Nanosizedhydroxyapatite (HA) is the main component of mineral bone. Living bone constantly undergoes a coupled resorptive-formative process known as bone remodeling. The process involves simultaneous bone removal and replacement through the respective activities of osteoblasts and osteoclasts, with the accompanying vascular supply and a network of canaliculi and lacunae. HA possesses exceptional biocompatibility and bioactivity properties with respect to bone cells and tissues, probably due to its similarity with the hard tissues of the body.

Semiconductor Nanomaterials for Hydrogen

Production

The extensive use of fossil fuel over the last 150 years has

caused a rise in urban ill-health, economic dependence,

political unrest and many cases of warfare [25]. A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [26], and a parallel

Swedish study reported that pollution can increase the risk

Semiconductor Nanomaterials for Hydrogen

Production

The extensive use of fossil fuel over the last 150 years has

caused a rise in urban ill-health, economic dependence,

political unrest and many cases of warfare [25]. A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [26], and a parallel

Swedish study reported that pollution can increase the risk

Semiconductor Nanomaterials for Hydrogen

Production

The extensive use of fossil fuel over the last 150 years has

caused a rise in urban ill-health, economic dependence,

political unrest and many cases of warfare [25]. A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [26], and a parallel

Swedish study reported that pollution can increase the risk

For Hydrogen Production

The extensive use of fossil fuel over the last 150 years has

caused a rise in urban ill-health, economic dependence,

political unrest and many cases of warfare [25]. A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [26], and a parallel

Swedish study reported that pollution can increase the ris

A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [

A recent study initated that more deaths are caused by car emissions than by car accidents. [26]. Investgations also shown a substantial increase in the concentrations of carbon oxide and other green house gases. Developing environmental concerns are advised to the extensive use of non-sustainable fossil fuels (oil, natural gas, and coal) and a constant increasing of energy demand. Hydrogen is a promising alternative fuel, since it is completely pollution free and can readily be produced from renewable energy resources, thus eliminating the net production of green house gases. Photocatalytic hydrogen production from water is one of the promising techniques because it is based on photon (or solar) energy, which is a clean, perpetual source of energy, and mainly water, which is a renewable resource. It is an environmentally safe technology. The photochemical conversion of solar energy into a storable form of energy, i.e. hydrogen, allows one to deal with the intermittent character and seasonal variation of the solar influx. However, it requires a photocatalyst that should possess chemical stability, corrosion resistance, visible light harvesting and suitable band edges.

Conclusion

Semiconductor nanomaterials are advanced materials for various applications which have been discussed at length. The unique physical and chemical properties of semiconductor nanomaterial make it suitable for application in emerging technologies, such as nano electronics, nanophotonics, energy conversion, non-linear optics, miniaturized sensors and imaging devices, solar cells, detectors, photography and bio-medicine. There are three key steps: materials preparation, properties, characterization and devices fabrication. The preparation of nanomaterials is being advanced by numerous physical and chemical techniques. The purification and size selected techniques developed can produce nanocrystals with well-defined structure and morphology.

Hydrogen is a promising alternative fuel, since it

is completely pollution-free and can readily be produced

from renewable energy resources, thus eliminating the

net production of greenhouse gases.

Semiconductor Nanomaterials for Hydrogen

Production

The extensive use of fossil fuel over the last 150 years has

caused a rise in urban ill-health, economic dependence,

political unrest and many cases of warfare [25]. A recent

European study revealed that more deaths are caused by

car emissions than by car accidents [26], and a parallel

Swedish study reported that pollution can increase the risk

Hydrogen is a promising alternative fuel, since it

is completely pollution-free and can readily be produced

from renewable energy resources, thus eliminating the

net production of greenhouse gases.

**References**

[1]. Slimonis F. Faber A.J and Hoogendom C.J, Porcelain enamelledabsorbens, coated by spectra tin oxide, J. Sol. Eng 23 (1987), 109

[2]. Wheat CRC Hand Book of +chemistry and physics 65th edition, CRC press Bocaration (1985)

[3]. Nathail Hall, Dictionary of metal finishing chemicals, Ch Eng, Metals and plastics, (1963), 82

[4]. Wang, Zhong Lin, and XiangdongFeng, Polyhedral shapes of CeO2nanoparticles,  The Journal of Physical Chemistry B107, no. 49 (2003),13563

[5]. Zhang, F.; Chan, S.-W.; Spanier, J.E.; Apak, E.; Jin, Q.; Robinson, R.D.; Herman, I.P,Cerium oxide nanoparticles: Size-selective formation and structure analysis,Appl. Phys. Lett. 80, (2002), 127

[6]. Adachi, G.; Masui, T, In Catalysis by Ceria and Related Materials; Trovarelli, A. (Editor); Imperial College Press: London, (2002), Chapter 3

[7]. Rodriguez, J.A.; Wang, X.; Hanson, J.C.; Liu, G.; Iglesias-Juez, A.; FernándezGarcía, The behavior of mixed-metal oxides: Structural and electronic properties of Ce1−xCa*x*O2 and Ce1−xCa*x*O2−x, M. J. Chem. Phys., 119, (2003), 5659

[8]. Kossoy, a.; Feldman, Y.; Wachtel, E.; Gatsman, K.; Lubomirsky, L.; Fleig, J.; Meier, J.; Metal Oxide Nanoparticles,Phys. Chem. Chem. Phys., 8, (2006), 111

[9]. Shelef, M.; Graham, G.W., Why rhodium in automotive three way catalysists? Catal. Rev. –Sci. Eng., 36, (1994), 433

[10]. Trovarelli, A,Catalytic properties of Ceria and CeO2 containing materials, Catal. Rev.Sci.,Eng., 38, (1996), 439

[11]. Martínez-Arias, A.; Fernández-García, M.; Ballesteros, V.; Salamanca, L.N.; Conesa, J.C.; Otero, C.; Soria, J. Langmuir,Metal oxide Nanoparticles, 15, (1999), 4797

[12]. Rochford, Jonathan, and Elena Galoppini., Zinc(II) Tetraarylporphyrins Anchored to TiO2, ZnO, and ZrO2 Nanoparticle Films through Rigid-Rod Linkers*,*Langmuir 24, no.10 (2008): 5366

[13]. Verma, Sandeep, PrasenjitKar, Amitava Das, Dipak K. Palit, and Hirendra N. Ghosh, Interfacial Electron-Transfer Dynamics on TiO2 and ZrO2 Nanoparticle Surface Sensitized by New Catechol Derivatives of Os(II)-polypyridyl Complexes:  Monitoring by Charge-Transfer Emission,The Journal of Physical Chemistry C 112, 8 ,(2008): 2918

[14]. Kim, Hyung Hwan, Jong Bo Park, Min Ji Kang, and Young Hwan, Surface-modified silk hydrogel containing hydroxyapatitenanoparticle with hyaluronic acid–dopamine conjugate, Park. International journal of biological macromolecules 70, (2014): 516

[15]. Meena, Ramovatar, Kavindra Kumar Kesari, MadhuRani, and R. Paulraj, Effects of hydroxyapatitenanoparticles on proliferation and apoptosis of human breast cancer cells (MCF-7), Journal of Nanoparticle Research 14, 2, (2012),712

[16] Shanti S, Subramanian C, Ramasamy P, Metal sulfide thin films by chemical spray pyrolysis, Materials science and Engineering , B57,(1999) 127

[17]. Shen-ChihShen, Yu-Jen Wang, Yung-Yue Chen., Design and fabrication of medical micro-nebulizer, Sensors and Actuators A:Physical 144(1), (2008), 135

[18]. Manoj P.K, Gopchandran K.G, Peter koshy,.Vaidyan,Benny Joseph V.K,Growth and characterization of indium oxide thin films prepared by spray pyrolysis, Opt. Mater. 28,(2006), 1405

[19] Wu, Hsi-Chin, Tzu-Wei Wang, Jui-Sheng Sun, Wen-Hsi Wang, and Feng-Huei Lin, A novel biomagneticnanoparticle based on hydroxyapatite,Nanotechnology 18, 16, (2007), 165601.

[20]. Fujii, Syuji, Yuki Miyanari, Taiki Nishimura, Yuichi Yokoyama, ShoHamasaki, Masahiro Okada, Tsutomu Furuzono, Shojiro Matsuda, Hideki Takamori, and Yoshinobu Nakamura, In vitrodegradation of hydroxyapatitenanoparticle-coated biodegradable microspheres, Polymer degradation and stability 98, 1, (2013), 377

[21]. Hu, Yang, ShengwenZou, Weike Chen, Zhen Tong, and Chaoyang Wang,Mineralization and drug release of hydroxyapatite/poly(l-lactic acid) nanocomposite scaffolds prepared by Pickering emulsion templating, Colloids and Surfaces B: Biointerfaces ,122, (2014), 559

[22]. Nie, Hemin, and Chi-Hwa Wang, Fabrication and characterization of PLGA/HAp composite scaffolds for delivery of BMP-2 plasmid DNA,Journal of controlled release 120, (2007), 111, 1

[23] Fujii, Syuji, Masahiro Okada, Taiki Nishimura, Hayata Maeda, Tatsuya Sugimoto, Hiroyuki Hamasaki, Tsutomu Furuzono, and Yoshinobu Nakamura, Hydroxyapatite-armored poly(ε-caprolactone) microspheres and hydroxyapatite microcapsules fabricated via a Pickering emulsion route,Journal of colloid and interface science , 374, (2012), 1, 1

[24] JiHoon Lee, II Tae Kim, RinaTannenbaum, MeishaL.Shofner, Synthesis of polymer-decorated hydroxyapatitenanoparticles with a dispersed copolymer template, J.Mater.Chem., 22, (2012),11556

[25] L.Mohan, D.Durgalakshmi, M.Geetha, T.S.N.Sankaranarayanan, R.Asokamani, Electrophoretic deposition of nanocomposite (HAp+TiO2) on titanium alloy for biomedical applications, ceramics international, 38, (2012),3435

[26] FaheemA.Sheikh, Muzafar A. Kanjwal, Hak Yong Kim, Hern Kim, Fabrication of Titanium dioxide nanofibers containing hydroxyapatitenanoparticles, Appl. Surf. Sci., 257, (2010), 296

[27] Hsien-Te Chen, Chi-Jen Chung, Tsai-Ching Yang, Chin-Hsin Tang, Ju-Liang He, Microscopic observations of osteoblast growth on micro-arc oxidized β titanium, Appl. Surf. Sci. 266, (2013), 73

[28]. Kaviyarasu, K., Mariappan, A., Neyvasagam, K., Ayeshamariam, A., Pandi, P., Palanichamy, R.R., Gopinathan, C., Mola, G.T. and Maaza, M., ,Photocatalytic performance and antimicrobial activities of HAp-TiO2nanocomposite thin films by sol-gel method, Surfaces and Interfaces, 6(2017), pp.247

[29] Hu, Z., Haneklaus, S., Sparovek, G. &Schnug, E. Rare earth elements in soils. Commun. Soil Sci. Plant. Anal. **37**, 1381–1420 (2006).

[30]Bouzigues, C., Gacoin, T. &Alexandrou, A. Biological applications of rare-earth based nanoparticles. Acs Nano **5**, 8488–8505 (2011).