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ROLE OF NANO-SCIENCE AND TECHNOLOGY FOR ENVIRONMENTAL PROTECTION

Tata Kondala Rao and Y. L. N. Murthy*
Department of Chemistry, Govt. Degree College for Women, Srikakulam-532 001, A.P.
* Department of Organic Chemistry, Andhra University, Visakhapatnam-530 003, A.P.

ABSTRACT

The first part of the paper deals with construction of nano materials. People are interested in nano scale of less than 100 nm size because in this size properties of materials are very different than that of larger size of the same material. It is due to the larger surface area and quantum effects such as electrical and magnetic properties. Nano materials are constructed by "top down" or "bottom up" process. Nano-science and technology have brought revolution in several areas such as information, medicine, health, biology, environmental protection, agriculture and in other disciplines.

Second part of the paper deals that how nano-science and technology help in prevention of air, water, soil and ground water pollution. Particles in nano size act as antibacterial, antifouling and antidust catching nature. It also involves in increasing the oxygen content in atmosphere by decomposing water in presence of nano wires of titanium dioxide and ultra violet light which is analogous to photosynthesis. It can also help in self cleaning of porcelain tiles and making stain proof films etc. Nano-technology is applied to purify water from *E. coli* bacteria and green algae by nano titanium dioxide coated porcelain beads. Some nano particles react with pollutants in soil to transform them into harmless compounds and also act as herbicides.

INTRODUCTION

A nanometre (nm) is one thousand millionth part of a metre. For comparison, a single human hair is about 80,000 nm in width. A water molecule is about 0.3 nm across. People are interested in nanoscale which we define to be less than 100nm in size of particles and up to approximately 0.2nm because it is at this scale that the properties of materials can be very different from those at a larger scale.

Nano-science and technology are frontier interdisciplinary areas gradually developed since 1980s. Nano-science and technology have wide range of applications in information, materials, energy, environment, chemistry, biology, medicine, nanoelectronics, micromanufacture and nano defence etc. (Akira et al. 1999, Hagfelot & Gratzel 1995, Srivatsava & Patni 1989), and have become an important frontier of science and technology which draw great attention from scientists of whole world and show great potential of application. Nano-science and technology is widely expanded and deepen our understanding of the physical world, enable the production of materials and devices at atomic and molecular levels, and bring about technology revolution in many areas. Research and development in this new technology depends on the progress of theoretical and experimental studies in various disciplines, which will in turn provide new opportunities in these areas. In Environmental protection, nano-science and technology plays a major role. Some of the applications are already patent in Asian countries such as Japan and China etc.

Bacteria and viruses are decomposed on the tile surface due to the strong oxidizing properties of titanium dioxide, If you cover the walls and ceiling with these tiles, bacteria floating in the air in an operating room are also killed as they come in contact with the surface.

The paper in the Japanese style paper screen (shoji) has been treated with nano titanium dioxide so that it is self-cleaning (Fig. 1).

SCIENTIFIC GOALS OF NANO-SCIENCE AND TECHNOLOGY

Nano-science and technology are research areas that have developed rapidly in the recent years. They are still in the exploration stage, both theoretically and experimentally. The major research areas of basic research in nano-science and technology take exploring basic theories and developing new research methods and novel experimental techniques. The starting points advocate intercrossing multidisciplinary studies emphasizing on basic research and plans to achieve the goals.

PROPERTIES OF NANOMATERIALS

The properties of materials can be different at the nanoscale for two main reasons. First, nanomaterials have a relatively larger surface area as compared to the same mass of materials produced in a larger form. As the particle size decreases a greater proportion of atoms is found at the surface compared to these inside. For example, 20% of its atoms are at the surface when the particle size is 30nm. And 50% of its atoms when size is at 3nm. Fig. 2 shows that how size relates with surface area. Relation of percentage of atoms on surface with size is shown in Fig. 3. Fig. 4 shows the number of surface atoms in relation to total atoms with size of materials.

In addition, with surface area quantum effects begin to dominate the properties of matter as size is reduced to the nanoscale. These can affect the optical, electrical and magnetic behaviour of materials particularly as particle size approaches towards the nanoscale. These nanomaterials exhibit quantum effects such as lasers for optoelectronics and enhance mechanical and electrical properties. The properties of bulk materials are changed drastically and as the particle size approaches to nanoscale. For instance, the bulk ferromagnetic materials may turn into paramagnetic and bulk conductors may become insulators.

CLASSIFICATION

Nanomaterials are classified as one dimension (surface coatings), two dimensions (nanowires and nanotubes) and in three dimensions (nanoparticles).

Nanoscale in one dimension: They are thin films, layers and surface coatings. They are used for decades in the fields such as electronic device manufacture, i.e., in silicon. In integrated-circuit industry, for example, many devices depend on thin films for their operations. Monolayers (layers that are one atom or molecule thick) are also made and studied for their properties such as lubricant nature.

Nanoscale in two dimensions: Two dimensional nanomaterials such as nanotubes and nanowires have generated considerable interest among the scientists particularly because of their novel electrical and mechanical properties, for example, carbon nanotubes. They are few nanometers of diameter and several micrometers to centimetres long. They conduct electricity extremely well. These are used in sensors,

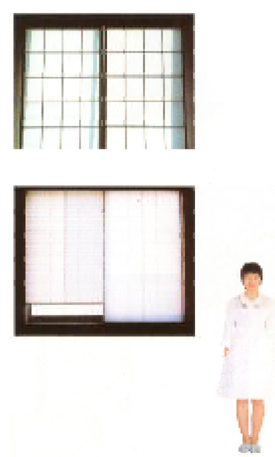

Fig.1: Self-cleaning paper in window blind and dress of nurses (Courtesy of MOLZA Corporation) and BKC, Inc Publishers).

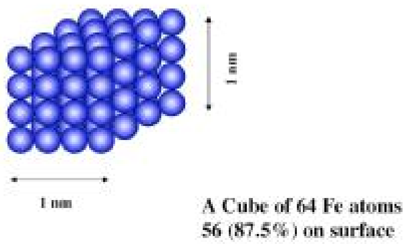

Fig. 2: Relation of size and surface area.

nanoelectronics and display devices. Similarly oxide based nanotubes (such as titanium oxide) are being used in catalysis, photocatalysis and energy storage.

Biopolymers such as DNA molecules can be coated in metal biocompatible sensors and small, simple motors. These self-assembly of organic backbone nanostructures are often controlled by weak interactions such as hydrogen bonds, hydrophobic or Van der Wall interactions.

Nanoscale in three dimensions (nanoparticles): They are less than 100nm in diameter. They exhibit new or enhanced properties compared with larger particles of the same material. Nanoparticles exist in the natural world such as in the products of volcanic activity and combustion, and in food cooking and vehicle exhausts.

Nanoparticles are of interest because of the new properties such as chemical and optical behaviour that they exhibit compared with larger particles of the same material. For example titanium oxide and zinc oxide become transparent at the nanoscale, and are able to absorb and reflect U.V light, and have found applications in sunscreens and new cosmetics, textiles, paints and in the methods of targeted drug delivery where they could be used to deliver drugs at a specific site in the body. Nanoparticles have large surface area and enhanced activity in potential applications such as catalysis.

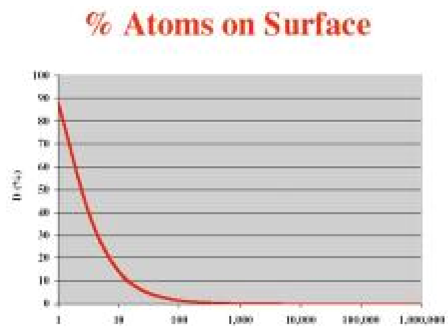

Fig. 3: % of atoms on surface in relation o size.

CONSTRUCTION OF NANOMATERIALS

Nano materials can be constructed by "top down" techniques producing very small structures from larger pieces of materials, for example, by etching to create circuits on the surface of a silicon microchip etc. They may also be constructed by "bottom up" techniques assembly, in which the atoms or molecules arrange themselves into a structure due to their natural properties (Figs. 5 and 6).

Methods of Synthesis

Several methods are used such as mechanical milling method, electric wire explosion method and microwave plasma method etc. for top down, and spraying pyrolysis method, coprecipitation method (Rao et al. 2006), sol gel method (Varma et al. 2005), citrate gel method and oxalate precursor method etc. for the bottom up. For example, a general method has been developed for the synthesis of crystalline metal

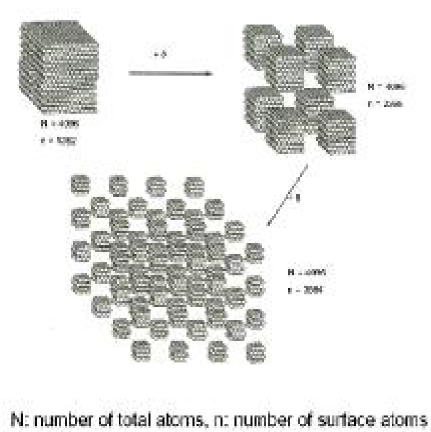

Fig. 4: Relation of surface atoms and total atoms with size of particles.

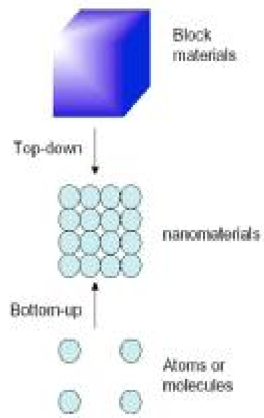

Fig. 5: Top down and bottom up methods for production of nano materials.

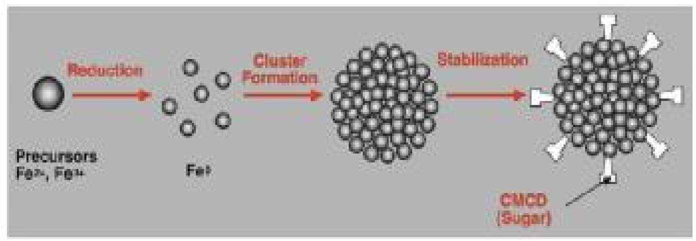

Fig. 6: Synthesis of nano materials. .

nanowires or nanotubes (such as bismuth nanotubes, tungsten nanowires) from smaller structures. In a typical process, inorganic composite precursors are prepared by reacting cationic or anionic surfactants with inorganic species under appropriate conditions. After treating these precursors by hydrothermal pyrolysis or other process, crystalline metallic nanotubes or nanowires are obtained.

PROTECTION OF AIR FROM POLLUTION

Air purification: Generally, air can be purified by ozone but during this process highly reactive radicles such as OH and O are produced. If titanium dioxide coated porcelain tiles or beads or door curtains are used they are more useful instead of using ozone because these nanomaterials under the dose of UV light cleans air from fouling gases, particulate matter (such as fly ash) and bacteria (Akira et al. 1999, Ollis & Al-Ekabi 1993). These are used in many countries such as in Japan, China etc. for air purification.

An analogue of photosynthesis is observed when nano titanium dioxide wires or tubes, taken as electrode (Zaban et al. 1998), and a piece of platinum is kept as opposite electrode and exposed to light of xenon lamp. Surprisingly oxygen gas bubbled up on the surface of titanium dioxide and hydrogen at platinum electrode which happened without passing electricity (Honda-Fujishima effect) (Akira et al. 1999). In other words water is decomposed into oxygen and hydrogen in the presence of nanotitanium dioxide (Rajeswar 1995), which helps enrichment of oxygen gas in nature

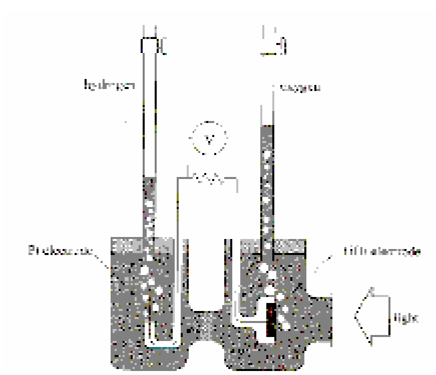

Fig. 7: Evolution of oxygen by photolysis of water by TiO_2 electrode system.

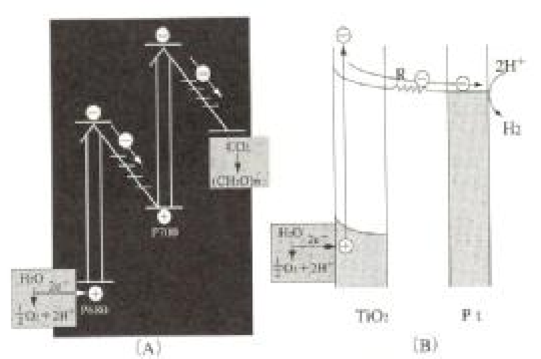

Fig. 8: Energy diagram (A): Photosynthesis in plants; and (B) Water photolysis by TiO_2-Pt electrodes.

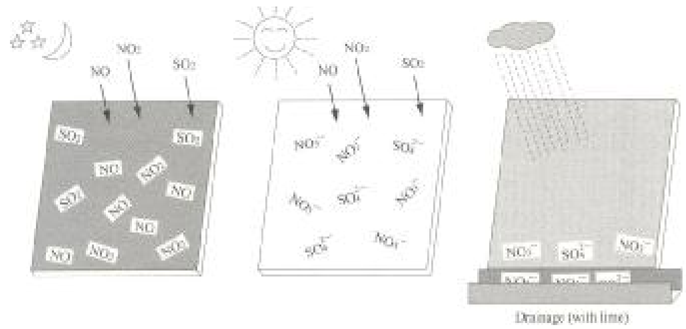

Fig. 9 Removal of nitrogen oxides and sulphur oxides from air by nano titanium dioxide coated tiles.

that further purifies the air and also increases the dissolved oxygen in water (Figs. 7 and 8).

Photocatalytic nanosubstance in air cleaners: Photocatalytic nanosubstances are used in air cleaners. Generally, they contain titanium oxide plus activated carbon. They trap pollutants and then destructed subsequently by irradiated titanium dioxide (Akira et al. 1999). They can be used to clean the air, the rooms, and inside of the cars, hospitals or even entire factory (Fig. 9).

Self cleaners: Self-cleaning and self-sterilizing of paper screens, paper windows and paper clothing (Akira et al. 1999) are used. For example, the paper screens have been treated with nanotitanium oxide, which has self cleaning action so the paper can be used to make the dresses for nurses as they act as self sterilizing. They are presently used in the hospitals of Japan. Nano titanium dioxide coated self-cleaning window curtains/paper clothes have three functions.

- It keeps itself clean.
- It helps keep the air in the office clean.
- It helps to kill bacteria in the office.

Military battle suits: Nonomaterial based 'battle suite' has been developed by the Institute of Soldier Nanotechnologies at MIT (Akira et al. 1999) is likely to be energy-absorbing material that will withstand blast waves and also act as sensor to detect or respond to chemical and biological weapons. There is speculation whether they could include certain nanomaterials they monitor physiology of a soldier who is still on the battlefield, and can give medical applications, such as splints for broken bones.

PROTECTION OF WATER FROM POLLUTION

Water purification: Nano-engineered membranes could potentially lead to more energy efficient water purification process (Ollis & Al-Ekabi 1993), notably in desalination by reverse osmosis etc. These applications would represent incremental improvement in technologies that are already available. They use specific nanoparticles.

Removal of *E. coli* bacteria: Ceramic beads covered with nano titanium dioxide are used in water purification (Akira et al. 1999) which kills bacteria and prevent the water also from green algae. These beads are easily removable from the water after completion of the purification (Fig. 10).

Removal of organic waste: Nanostructured ferroxanes or iron oxides ceramic membranes are used to purify the water from organic waste. Nano C60 is very efficient photocatalyst, which is 100 to 1000 times more efficient than equivalent commercially available titanium oxide materials.

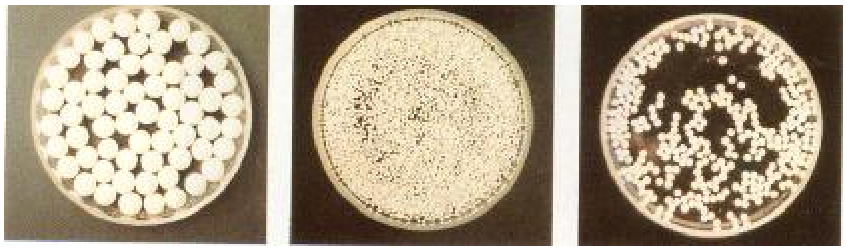

Fig. 10: Ceramic beeds covered with titanium dioxide to kill bacteria

Nano silver impregnated ceramic candles are used to get the protected water. It is now available in Andhra Pradesh with cheaper rates. This technique was developed by ARCI, Hyderabad.

Protection of soil and ground water from pollution: The potential of nanoparticles to react with pollutants in soil and ground water, and transform them into harmless compounds is being researched. In one study the large surface area and high surface reactivity of iron nanoparticles were used to transform trichloro ethylene, organo aromatic compounds and pesticides etc. into less harmful end products in ground water. It is also hoped that they could be used to transform heavy toxic

Fig. 11: Nano iron slurry and iron as electron donor.

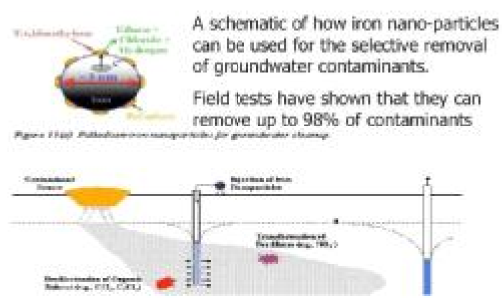

Fig. 12: Use of iron nanoparticles for removal of groundwater contaminants.

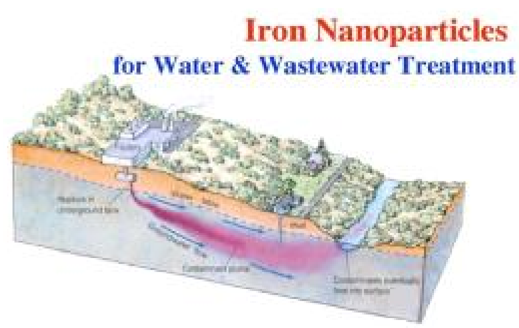

Fig. 13: Use of iron nanoparticles for water and wastewater treatment.

metals such as lead and mercury into bioavailable materials. Nano titanium dioxide was used and observed for its herbicidal action (Akira et al. 1999) (Figs. 11, 12 and 13).

OTHER APPLICATIONS OF NANO-SCIENCE IN THE PROTECTION OF ENVIRONMENT

Sanitary conditions in hospitals and other public facilities: In the summer of 1996 Japanese were shocked with the news of several deaths due to *E. coli* bacteria (Akira et al. 1999). They have been prevented from spreading by appropriate nano techniques and photocatalysis, which are sufficiently developed and adopted. They also achieved in maintenance of high level of sanitary conditions in hospitals and other public facilities. For this nano titanium dioxide coated tiles and sanitaryware are used.

Sunscreens and cosmetics: Nano-sized titanium dioxide (Akira et al. 1999) and zinc oxide are currently used in some sunscreens because they absorb and reflect ultraviolet rays and yet are transparent to visible light and so are more appealing to consumers. Nano-sized iron oxide is present in some lipsticks as a pigment.

Composites: Carbon nanotubes and nanoparticles of 10-100nm size act as fillers to rubber which reinforce the tyres (Akira et al. 1999). Carbon black falls within nano particle size. So the tyres are hard and less abrasive in nature.

Nano coatings on the surface: These are coatings with thickness controlled at the nano atomic scale. For example, recently developed applications of highly activated titanium dioxide acted as highly hydrophobic (water repellent) and antibacterial. The coatings based on nanoparticulate oxides catalytically destroy chemical agents, and scratch resistant hard coatings are significantly improved by nanoscale intermediate layers between the hard outer layer and substrate material so that stain proof plastic films are developed.

Paints: Incorporating nanoparticles in paints could improve their performance, for example, by making them lighter and giving them different properties. Thinner paint coatings (light weight) used for aircraft would reduce their weight, which could be beneficial to the environment. It may also substantially reduce the solvent content in paints, which reduces environmental pollution.

Nanoparticles produce sufficiently low cost fouling resistant coatings, which could be used in daily life such as piping for domestic and industrial water systems. Antifouling coatings could reduce the use of biocides, including chlorine etc. Nanoparticles in paints change colour in response to the change in temperature or chemical environment which results in reduction of infrared absorptive and so reduce heat.

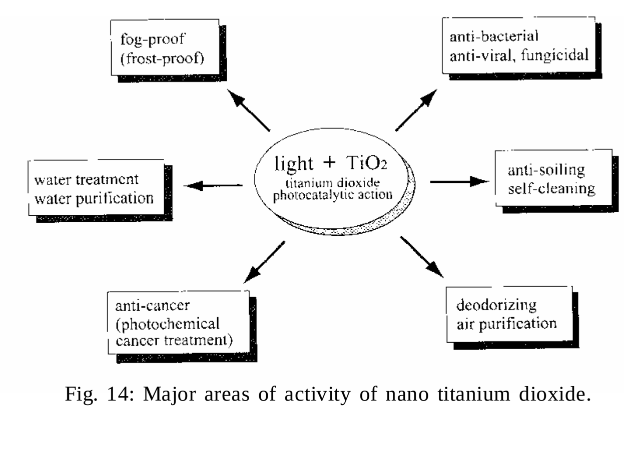

Fig. 14: Major areas of activity of nano titanium dioxide.

NO CONCLUSION BUT A CONTINUATION

Nano-sized metals or their composites have more activity towards environmental protection. Major areas of activity of nano titanium dioxide are as shown in Fig. 14.

Although many nanomaterials are

currently at the laboratory stage of manufacture, a few of them are being commercialized. It is not so amazing that government bodies, companies and university researchers are joining forces or competing to synthesize, investigate, produce and apply these amazing nanomaterials for environmental protection in addition to other nano applications.

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