BASIC CONCEPTS OF NANOTECHNOLOGY

Muhamed Ashraf P.
ashrafp2008@gmail.com

ICAR- Central Institute of Fisheries Technology, Cochin, Kerala

Summary
Nanotechnology refers to objects that are one-billionth of a meter in diameter (nanometer). It is the emerging area of science and technology during the last 15 years. Among the nano materials nanotubes and powders were extensively used for various applications. Quantum dots are termedsynthetic atoms and it has immense potential in medicine as bio sensors. Nanomaterials were synthesized by either top-down or bottom up principles and its characterization the sophisticatedinstruments like SEM, TEM, XRD, AFM etc. were used. This article described in brief about various application in different fields of nanomaterials in research.

Introduction
Science and Engineering research are experiencing a boom in the field of nanotechnology. It has replaced the high temperature super conductivity and laser evolution. This has made a new revolution in science and technology. During 1974 a Japanese scientist Taniguchi introduced the term nanotechnology for everyday life in a conference of the Japan Society of Precision Engineering. Although the chemists were extensively carrying out research in nanotechnology last two centuries. In Yu's view, nanotechnology, when viewed broadly, encompasses a realm of scientific endeavors focused on the synthesis, exploration, and application of devices, materials, and technical systems whose operations are influenced by nanostructures—ordered fragments typically ranging in size from 1 to 100 nanometers. The implication of this definition on the term "nanotechnology" is understood not only as a technological process ofmanufacturing of nanomaterials, objects and systems of nano meter sizes, but it also refers to the activities associated with the construction and investigation of nano systems. The initial individual to highlight the significance and optimistic prospects of nanoparticle exploration was the Nobel Prize-winning American physicist, R. Feynman. In his lecture titled "There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics," presented on December 29, 1959, at the California Institute of Technology, Feynman addressed the challenge of controlling substance structure at the scale of ultra-small distances. Feynman emphasized the potential impact of having control over the arrangement of elements on a small scale. He stated that with such control, there would be a significantly expanded range of possible substance properties and diverse capabilities. Furthermore, Feynman suggested that developing the ability to observe and manipulate things at an atomic level could offer substantial assistance in addressing challenges in the fields of chemistry and biology. By the last decade of the 20th century, the scientific community began to realize the promise of nanotechnology, and as a result, nano research grew tremendously. Global governments invested huge amounts in this field and this had lighted new applications of nano materials for thebeneficial of the world.

Nanotechnology:

Nanotechnology involves entities measuring one billionth of a meter in diameter, referred to as a nanometer. Its fundamental concept is that materials, which exhibit specific properties at their regular sizes, manifest various beneficial properties and functions when they are at a nanoscale. Take sunscreen, for instance; at its standard size, it is a creamy and potentially messy lotion, while at the nano scale, it can be aerosolized and applied as a fine mist on the skin. The primary goal of nanotechnology is to augment surface area by generating exceedingly small particles, leading to increased interactions with other particles. In essence, nanotechnology encompasses the manipulation and fabrication of matter ranging in size from 1 to 100 nm.

Classification Of Nano Materials

Nanostructured materials can be categorized according to the recommendations put forth by the 7th International Conference on Nanostructured Materials. The classification includes:

- Nano particles
- Nano porous structures
- Nano tubes and nano fibers
- Nano dispersions
- Nano structured surfaces and films
- Nano crystals and clusters.

Among the above classification, nanoparticles, nano tubes, and nano fibers hold significant economic importance and find extensive applications.

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Carbon Nano Materials

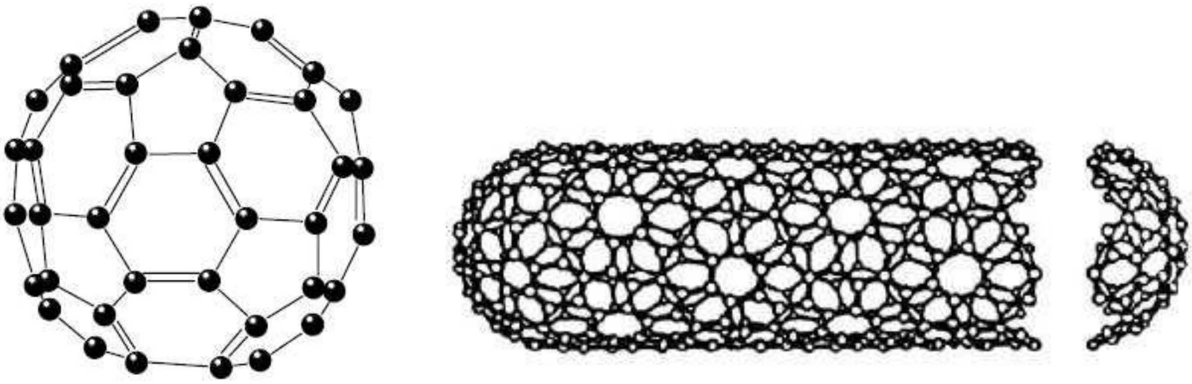

Fig 1. A) Fullerene C60 molecule B) A single layer nano tube model

Carbon nano materials, mainly fullerenes and carbon nanotubes are widely used for different applications. In 1985, Robert Curl, Harold Kroto, and Richard Smalley made the groundbreaking discovery of fullerene. Fullerene is a large molecule comprised of pentagons and hexagons, resembling footballs with an empty core (see Fig 1). The carbon atom count in fullerenes varies from 20 to several hundreds. Carbon nanotubes, unveiled by Sumio Lijima, exhibit quasi-one-dimensional tube structures formed by seamlessly wrapping the fundamental planes of a graphite hexagonal lattice into cylindrical shapes. Carbon nanotubes, whether single or multi-layered, have the capability of being opened and closed. In closed CNT the lid is half of fullerene molecule C60. The diameter of the CNTs varied from 0.5 (single layered) to 100nm in the case of multi layered structures. Nanotubes of SiC, BN, MoS, WS_2, V2O5, TiO2 etc. Owing to their topology, carbon nanotubes lack free chemical bonds; in spite of their diminutive sizes, they do not exhibit surface effects. Extensive research has been conducted on carbon nanotubes, with countries such as Japan engaging in commercial production, manufacturing hundreds of tons of CNTs.

Quantum Dots

Quantum dots are artificial atoms, whose properties can be controlled. Quantum dot is a conductor or semi conductor fragment having a three dimensional structure, with size of a few nanometers which can hold a certain number of electrons (around 100or less). An electron ina quantum dot is having many discrete quasy-stationary energy levels and it behaves as a particlein three dimensional potential box. Like atoms such system can transit from one energy level to another by emitting photons. The photon frequency can easily controlled by changing the size of the quantum dots. The most promising method of forming ordered arrays of quantum dots is based on the phenomenon of self-organization (self-assembling) of alien atoms on crystal surfaces and in solutions. If we succeed in creating quantum dots of the size of a few nanometers, then it will be possible to create single- electron devices working at room temperature. The operation of such devices would be based on a controlled movement ofindividual electrons.

Synthesis Of Nano Materials

Two commonly utilized methods for synthesizing nanomaterials are the top-down approach and the bottom-up approach. The bottom-up technique involves creating nanomaterials with the desired structure directly from the fundamental building blocks, such as atoms, molecules, and structural elements.Here we have to identify the desired materialin advance (eg, synthetic bone hydroxyapatite), ingredients like, titanium dioxide nanotubes, calcium phosphate, calcium hydroxide are placed together under ideal conditions in chlorides of sodium and potassium and magnesium carbonate/sulfate bath. Through a combination of self-direction and technical manipulation, molecules come together to form a complex product known as synthetic bone hydroxyl apatite. In a similar fashion, carbon nanotubes are created by directing simple carbohydrates (e.g., acetylene) through a volume containing catalysts at temperatures ranging from 600 to 800 degrees Celsius, resulting in the formation of CNTs on the catalysts.

The top-down approach involves the development of nanomaterials by reducing larger-sized particles to smaller sizes. Solid-state methods within these approaches transform insular materials into conductive substances. Atomic force microscopy facilitates the strategic placement of chemicals on materials to facilitate their modifications. The transformation of large materials into nanoscale dimensions imparts unique characteristics; for instance, nanosized aluminum exhibits the property of combustion. In the future, controlled nanoparticles of aluminum could potentially be employed to address conditions such as atherosclerotic plaques, calcifications in soft tissues, or tumors.

Equipments For Testing Nanomaterials

Nanotechnology holds the potential to transform diverse fields, including medicine, food science and technology, recreation and sport sciences, and civil engineering. Nanotechnology is an affordable technology eventhough it requires few number of costly equipments. A mere $500 investment can secure the essential chemicals, nanotubes, and nanoparticles required for basic work in a suitable laboratory. This is a modest expenditure when contrasted with the projected $1 trillion return in market shares anticipated from nanotechnology applications by 2015. Instruments employed for nanomaterial characterization encompass Transmission Electron Microscopes, Scanning Electron Microscopes and their variations like Scanning Tunneling Microscope, Near Field Scanning Optical Microscope, X-Ray Diffraction, Atomic Force Microscopes, FT Raman Spectroscope, UV-Vis Spectrophotometers, Particle size analyzers with zeta potential, among others.

The Characterisation of Nano materials

The characterization of nano materials is crucial as nanostructures exhibit intriguing physical and chemical characteristics. The effective utilization of nanotechnology necessitates a meticulous examination of their properties, encompassing mechanical, thermophysical, electrical, magnetic, optical, and chemical aspects. In-depth information on these properties can be found in various textbooks on nanotechnology.

Applications Of Nano Technology

1. **Electronics and instrumentation engineering**: CNTs used for compact sources for Roentgen radiation, luminescent lighting lamps, microwave radiation sources etc. CNTS used for preparing unique needle point of AFM and research is going on to develop modified nanotubes with specially selected functional groups at the needle points. In this case one can investigate not only the relief of a surface but also its chemical composition.

2. **Material science**: In the realm of material science, a significant application involves the creation of novel materials. CIFT is actively engaged in researching the formulation of new aluminum metal matrix composites through the inclusion of nano cerium oxide, nano samarium oxide, nano titanium oxide, and similar substances. Additionally, investigations have been conducted to manage the fouling of fishing gears employed in aquaculture and cages by applying nano materials. Manufacturing of fire-resistant materials by reinforcing nanomaterials in plastics. Development of thin anticorrosive coatings to protect the materials from degradation.

3. **Medicine and bio nanotechnology**: For the precise drug delivery, nanomaterials can be used when medications are transported to specific internal organs and tissues by carrier molecules. Synthesis of new biomaterials including substitutes for human body tissues, this will allow one to repair the human body.

The design of nanosensors and nano devices is instrumental in creating autonomous systems or those administered within the human body which facilitates identification of molecules with specific characteristics, such as cancer, and supports its subsequent treatment. Nanotechnology also plays a pivotal role in developing biomimetic mechanisms that enable the ongoing monitoring of a patient's health status. Furthermore, it facilitates communication with healthcare professionals and the execution of medical treatments as prescribed by physicians. Advancements in medical diagnostics and interventions fueled by nanotechnology have the potential to reshape practices in medical nutrition therapy. For instance, an engineered biodegradable material at the nanoscale, containing insulin, helps the individuals with type 1 diabetes mellitus provides flexibility to regulate their diet plans. This innovation releases insulin according to the requirement, responding to blood glucose concentrations. Ongoing research aims to gain a deeper understanding of the inflammatory processes associated with Crohn's disease and ulcerative colitis. This knowledge will pave the way for the direct application of anti-inflammatory agents derived from nanotechnology to the mucosal lining, thereby treating and preventing future attacks. The application of nano pharmaceuticals in resolving inflammatory bowel disease might expand food tolerances and choices for affected individuals. Nanotechnology is extending the horizons of cancer identification and potential treatment modalities. This includes improved diagnostic tools capable of detecting and visualizing very small tumors, Nano sensors identifying specific cancer markers in serum, and Nano shells delivering chemotherapy precisely to targeted locations. The transformative impact of nanotechnology on oncology suggests that future cancer treatments may be more targeted and of shorter duration, potentially influencing dietary interventions.

4. **Dietetics practice**: Examination and application of very small materials may sound better left to engineers, physicists, and chemists, but nanotechnology is expected to impact many aspects ofdaily life, including dietetics practice. Imagine an antibacterial nanomist, containing reactive nanoparticles so finely created so as to be unobtrusive to the human body, which can knock out *Escherichia coli* from fresh spinach or other foods at the point of harvest. Food packaging materials that detect *E coli* and other contaminants and that prevent spoilage are already being developed. These nanoproducts can transform purchasing, storage, and preparation specifications and hazard analysis critical control point activities in the food management arena.

5. **Food science**: Nanotechnology stands poised to reshape nutrient intake by expanding the array of enriched and fortified food products. This is expected to contribute to the growth of the functional food market, fueled in part by the proliferation of nutrient delivery systems facilitated by nanotechnology mechanisms. Antioxidant nutrients, for instance, can be incorporated into various nanomaterials such as nanocomposites, nanoemulsions, nanofibers, nanolaminates, nanofilms, or nanotubes. While the increased intake of micronutrients from an enhanced food supply holds potential benefits for the general population, vigilance by food and nutrition professionals is necessary to monitor against nutrient overconsumption and signs of toxicity in individuals. Micronutrient imbalances may also become more prevalent.

Social Issues

Societal implications of nanotechnology, like any emerging technology, remain uncertain. For instance, the consequences of the byproducts of nanoshells or nanoparticles used in cancer treatment entering circulation and healthy tissues are unclear. Questions arise regarding the need for medical treatment and nutrition therapy to address potential new diseases or conditions. Titanium dioxide nanoparticles, found in sunscreen, are susceptible to free radical formation when exposed to sunlight. Bement categorizes the societal impact of nanotechnology into three domains: environment, health, and safety; education; and ethical, legal, and other social issues. While nanotechnologists generally agree that nanoengineered DNA or subcellular nanoparticles are unlikely to have self-promulgation capabilities, concerns persist about the unregulated use of these nanomaterials in disease prevention and treatment. Maynard and colleagues advocate for the concurrent development of environmental and human health monitoring and alerting systems with specific nanotechnologies, challenging the "wait-and-see" approach. Broader issues encompass potential applications of nanotechnology in warfare, information transfer, security, and privacy, agricultural sustainability, and economic equity. The ethical and legal dimensions of nanotechnology necessitate public consideration, emphasizing the importance of raising awareness and understanding through public deliberations, discussions, and informed decisions by both the public and government for a promising future.

References

1. Yu. D. T (2007) Vestnik Rossiiskoi Akademii Nauk 77 (1), 3.
2. Andriyevsky R. A. and Khachoyan A. V. (2002) The Epilogue to the Book *Nanotechnologyin the Next Decade* (Mir, Moscow).
3. Smalley. R. (1997) Rev. Mod. Phys. 69 (3), 723.
4. Suzdalev, I. P. (2006) Nanotechnology: Physical Chemistry of Nanoclusters (Komkniga,Moscow).
5. Kobayasi N. (2005) An Introduction to Nanotechnology (BINOM, Moscow).
6. Likharev K. K. (2003) in *Nano and Giga Challenges in Microelectronics*, Ed. by J. Geer etal. (Elsevier, Amsterdam), 27.
7. Sysoev N.N., Osipov A.I and Uvarov A.V (2009) Nanotechnology and molecular physics.Moscow University Physics Bulletin. 64(1): 1.
8. Roco M. C. (2003) *J Nanoparticle Res*. 5:181-189.
9. Rao CNR, Muller A, Cheetham A K (ed) (2005) Chemistry of nanomaterials Vol 1 and 2.Wiley –VCH, Germany.

10. Smalley R. (1997) Rev. Mod. Phys. 69 (3), 723.

11. Grungberg P., Burgler D. E., Dassow H. (2007) Acta Mater. 55 (4), 1171.

12. Chechenin N.G. (2006) *Magnetic Nanostructures and their Application*, (Grant ViktoriyaTK, Moscow).

13. Vaddirajua S., Tomazosb I., Burgessc D. J., Jain F. C., Papadimitrakopoulosa F. (2010)

14. Biosensors and Bioelectronics 25 (2010) 1553–1565

15. Bhardwaj U., Papadimitrakopoulos F., Burgess, D.J. (2008). J. Diabetes Sci. Technol. 2(6), 1016.

16. Onuki Y., Bhardwaj U., Papadimitrakopoulos F., Burgess D.J. (2008) J. Diabetes Sci.Technol. 2 (6), 1003.

17. Wisniewski N., Reichert M. (2000). Colloids Surf. B: Biointerfaces 18 (3–4), 197–219.

18. Powell M.C., Kanarek M.S. (2006) Nanomaterial health effects—Part 2: Uncertainties andrecommendations for the future. *WMJ*. 105:18.

19. Peppas N.A., Kavimandan N.J. (2006) *Eur J Pharm Sci*. 29:183.

20. Arseneau K.O., Pizarro T.T., Cominelli F. (2000) *Curr Opin Gastroenterol*.16: 310.

21. Heuschkel R.B. (2000). *CurrOpin Gastroenterol*. 16: 565.

22. Macdermott R.P. (2007) *Inflamm Bowel Dis*. 13: 91.

23. Wamer W.G., Yin J.J., Wei R.R. (1997) *Free Radic Biol Med*. 23: 851.

24. Bement A.L. (2007) Testimony before the House Committee on Science hearing on fundamental nanotechnology research: The key to finding the promise and minimizing the peril. Available at: http://www.nfs.gov/about/congress/109/alb_nanotech_092106.jsp.