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NANO SCIENCE: AN OVERVIEW OF EMERGING TECHNOLOGY AND ITS BIOMEDICAL APPLICATIONS

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ABSTRACT
The recent advancement of nanotechnology in the field of biomedical sciences is rapidly growingwith applications of nanomaterials. With the discovery of their potential therapeutic ability in targeted drug delivery and manufacturing of ultrasensitive diagnostic equipments used in medicalsciences has attracted remarkable interest in nanomaterials and derived substances. Besides medical imaging in the form of bio imaging and bio sensors the nanomaterials are also used in heat transfer devices in the form of nano fluids. In many physiochemical devices these are used for bio imaging, bio sensors, ultrasensitive diagnostics etc. in the form of quantum dots, nano rods, nano clusters and graphene nanosheets.

KEYWORDS: Nano Materials, Targeted Drug Delivery, Quantum Dots.

Nanotechnology is an interdisciplinary study allowing to explore the new pathways to develop new materials with useful properties in day to day life. It is the understanding and control of matter having dimensions in the range 1 – 100 nm. The technique is basically related with the development of nanomaterials, devices and systems in advanced research and a rapidly emerging field for all the disciplines of Chemical, Biological and Physical Sciences. Initially this field had attracted scientists because of their size dependent physical and chemical properties.[1,2]

The technique is highly applicable in medical sciences and used to develop and design nanoparticles with efficiency to deliver drugs, heat and light in ultrasensitive as well as ultrasonic equipments and chemicals in the form of drugs, dyes etc. to specific types of cells i.e. target therapy, also called targeted drug delivery. The technology is also used in the treatment of hyperthermia, photoablation therapy, bioimaging and biosensors. Applications of nano sciencesis an emerging technology in the field of medical sciences and their fruitful combination is referred as nano drugs. These nano drugs are used for targeted therapy and nano shells are used to deliver drugs targeting the cancer cells. Nano materials have unique physiochemical propertiessuch as small size, large surface area and high reactivity.

Nanoparticles have dimensions in the range 1 – 100 nanometer.

Common terms in nano materials
Nano Shells
Quantum dots (QDs)
Confocal microscopy
Nano clusters (NCs)
Nano Dots
Clusters

Biomedical Applications
1. Using Quantum dots Fig.1
2. Immuno flouroscent biomarker imaging
3. Targeted drug delivery
4. Gold nanoshells and applications
5. Carbon nanotubes Fig. 2

In the last two decades, a number of nanoparticle based therapeutic and diagnostic techniques have been developed for the treatment of cancer, pain, asthama, allergy and many infectious diseases. The importance of them is using the unparallel freedom to modify the fundamental properties such as solubility, diffusivity, immunogenicity etc.[3,4] Nanotechnology is applied depending upon the types of reactions and the manner in which these proceed (top – down or top – up) and the medium in which they work (dry or wet). According to European Commission, a nanomaterial is defined as a natural incidental or manufactured substance containing particles, in an unbound state or as an aggregate or as an agglomerate where about50% or more of particles in the number – size Distribution 1 – 100 nm.[5]

Nanoparticles are classified on the basis of their construction like

(a) Carbon- based
(b) Metal- based
(c) Dendrimers Fig. 3
(d) Composites Fig. 4

The use of nanoscale agents is advantageous due to lesser toxicity, extended product life, moreconvenient routes of administration and reduced health care costs.[6] Carbon based Nano materials contain carbon and have hollow tubes, ellipsoids or spheres like structures.

Metal based have Metal atoms eg. Quantum dots, Nano gold, Nano silver and Metal based oxides. Dendrimers are another Nano materials having branched components, form polymers having surfaces with chain ends to facilitate chemical manipulation. Dendrimers create hollow cavities functioning during catalysis and are applied in biomedical research.[7] Now a days nanotechnology is a field of commercial exploration including fluorescent biological labels, drug and gene discovery, DNA structure probing, tissue engineering, tumour destruction via heating (hypothermia), MRI contrast enhancement and Phago kinetic studies.[8] Nitrogen - doped carbon nanotubes have bamboo like structures and are used for the treatment of cancer.[9] The functioning and application of nano materials are highly dependent on their structural pattern. The core components are basic building blocks for fabricating complex devices with desired functions. Chemistry plays central role in the development of novel nano structured materials providing synthesis of desired nano materials by synthetic route and structural manipulation, characterization, surface modification and processing into functional devices.

Engineered nano materials though provide great benefits, have potential effects on human healthand environment therefore small size make the material both promising and challenging The exposure to nano materials has shown health risks eg. cosmetics such as sunscreens though the skin absorption of nano materials depends on the quality of skin barriers (hair).[10]

Nano Shell: Metal nano shells (Fig. 5) are the gift from nanotechnology which has an inner dielectric core material made up of Silica and have an outer covering made up of thin metal layer specially gold. These are referred as gold nano shells exhibit optical properties typical of gold nanoparticles hence are used in biomedical imaging, drug delivery system in the therapy of several chronic diseases.[11] These have therapeutic applications and are used for fluorescence enhancement of weak molecular emitters, surface enhanced Raman spectroscopy etc.

These are used in the immuno assay procedures where nano shells are conjugated with antibodies that act as recognition sites for a specific analyte. Due to their large optical scattering cross sections these are also used as potential contrasting agents for photonics based imaging modalities via reflectance confocal microscopy and optical coherence tomography and help in early cancer detection. Due to nanoscale dimensions and dielectric functions at optical wavelengths surface plasmonic resonance gold nano shells convert LASER light into heat and kill the cancer cells. Technique is applicable both in vitro and in vivo.

Nano shells are the products of catalytic carbonization of organic polymers of thermosetting types eg. Furan resins, Phenol Formaldehyde resins with transition metals having a characteristichollow sphere shape. Nano shells show promising applications in biomedical imaging, target therapy, gene delivery, tissue welding, drug delivery systems and treatment of cancer cells in particular. The biomedical applications of nano shells via hypothermia where an alternative magnetic field is generated to heat them and kill the tumor cells at local level is now a promisingmedical technique. Nano shells effectively enhance the images from positron emission tomography (PET) or ultrasonography and give more clear picture of cells. The safe biocompatibility, stability, biovariability, optical tunable property and photo luminescent ability of different types of nano shells are continuously increasing their biomedical applications.[12] Nano shells particles being spherical nano composite materials, consist of concentric particles in which particles of one material are coated with a thin layer of another material using specialised procedures. Their functional potentiality differ with core materials in their properties and can be modified by changing either constituting material or core – to – shell ratio.[13,14]

Quantum Dots (QDs)

These are nano particles made up of semiconducting materials known as semiconductor nano crystals which are very tiny species having inner core made up of group II – VI elements eg. Cd -Te, Cd - Se or CdS, group II - V like In - P or In - As or group IV – VI such as Pb - Se. The outer shell is generally made up of ZnS. It also has a cap to improve functions in solution phase. The diameter of QDs generally ranges from 2 - 10nm. These differ with larger particles in optical and electronic properties. Quantum dots when exposed towards Ultraviolet light photoluminescence takes place with electronic excitation from valence bands to conductance bands generating semiconduction. These transitions occur at quantum mechanically allowed energy levels and are referred as Atomic spectra. For this reason quantum dots are also called artificial atoms.[15] Quantum dots have potential uses in many sensitive devices like Diodes, LASER amplifiers and Biosensors to enhance their efficiency. Quantum dots are referred as artificially synthesised nanoparticles with semiconductor properties having a wide range of applications in solar cells, biological labelling, display uses, composites, lighting and medical imaging. These also show effective applications in catalysis, photonics, electronics, information storage

imaging, medical equipments and sensors. However the efficiency of quantum dots needs a dependable technology to produce large scale nano crystals with consistency. M. Bawendi, L. Bruce and A. Ekimov succeeded to discover and develop quantum dots based Fluoresce technique in which quantum dots absorb light of one colour and reemit it instantaneously as another colour and the special feature is that their colour is determined by their size, though on nano scale.[16] Due to their atom like energy states these show remarkable optical properties and are used in fabricating optical probes for biological and medical imaging. The colloidal quantum dots are used in bio analytics and has emerged as one of the most promising areas of applications for the artificial nanoscale crystals.[17]

Clusters: Clusters is the oldest term used in biotechnological studies and has been used in the field of Chemistry since 1914 as shown in the WOS database describing Ion clusters in the gas phase.[18] With the development of nanoscience similar terms such as nano clusters and nano dots emerged. The current definition of clusters as recommended by IUPAC is as a number of metal centres grouped close together which can have direct metal bonding interactions or interactions through the bridging Ligand, but are not necessarily held together by these interactions.[19,20] Nano clusters term is applied to describe a metal particle, particularly a large metal clusters. Some show the quantum confinement effect, but with increase in size of nano clusters such an effect disappears and the nano cluster behaves as metal.[21] The size of nano clusters ranges less than 2 nm and when protective groups are added to the cluster core, the overall size may be larger than 2 nm.

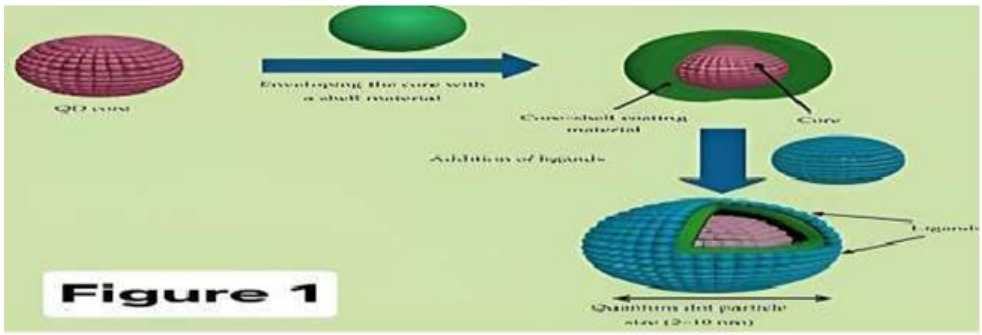
Nano Dots (NDs): These are used to describe luminescent noble metal clusters. Researchers have difference in opinion of the term, some interchange or mix nano dots and quantum dots, whereas others mix the terms nano particles and nano dots. Some focussed on photoluminescent properties of nano dots and others on plasmonic properties.[22] The size of nano dots ranges 2 - 20 nm.

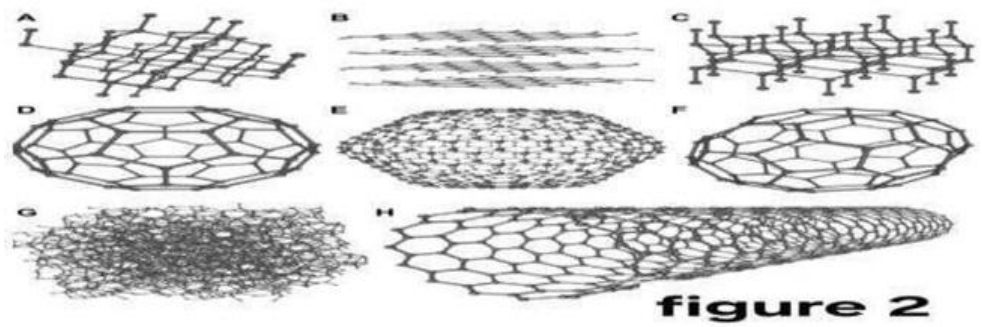
M. Bawendi, L. Bruce and A. Ekimov awarded Nobel prize in the year 2023 for their work on discovery and development of quantum dots. They studied the behaviour of quantum dots towards light and according to them quantum dots are fluoresce in nature and absorb one colour of light and instantaneously reemit it as another colour. The unique feature is that colour is determined by by their size within nano scale.

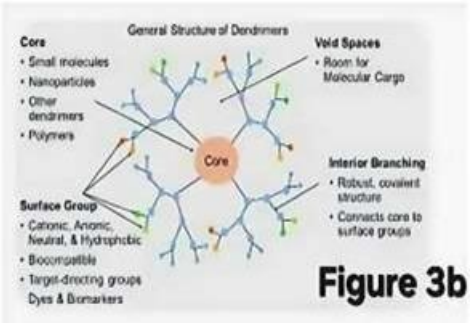
Carbon Dots: These are small nano particles made up of Carbon, may be crystalline or amorphous, mostly in sp^2 hybridisation state. In some cases sp^3 hybridisation is also reported.[23] Surface Engineering of Carbon nano dots is a key bridge to connect the C dots with biomedical applications. Recently the functionalization of Carbon nano dots towards bioimaging and biosensoring has been developed and applied with special focus on living cells and tissues.[24]

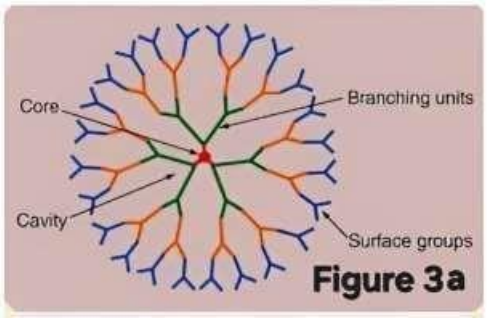
Confocal microscopy: Basic principle is related with the illumination and detection optics which are focussed on the same diffraction limited spot and moved over the sample to build the complete image on the detector. The idea of rejecting out of focus light in this manner was patented by Marvin Minsky (Minsky, 1957, 1988) and achieved by the use of illumination and detection where side pinhole apertures in the same conjugate image plane, making them confocal. The basic concepts of modern confocal microscope are the pinholes, the objective lenses and low noise detectors in common with the original design but also typically include fast scanning and LASER illumination.[25] Confocal microscopy is used in microbiology to study biofilms and antibiotic resistant strains of bacteria.

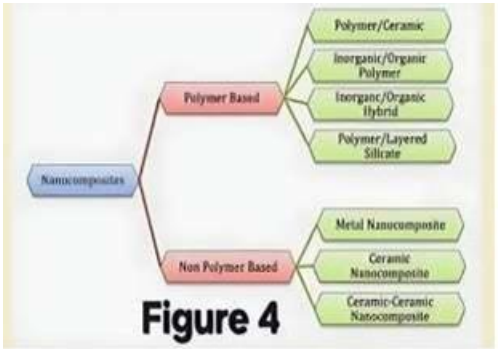
Applications in Medical Field: Extensively applied in health care industries as nano medicine, in novel diagnostic instruments, imagery and methodologies targeted medicinal products, pharmaceutical products, biomedical implants and tissue engineering. Uses of nanomedicine and nanotechnology is advantageous over traditional drug carriers specific forms have higher drug loading rate due to large surface area, better biocompatibility and targeted transformation providing the possibility for the treatment of a variety of diseases.[26] Due to good biocompatibility and biodegradability of nanomaterials these show comparatively lesser side effects when accumulated in human organs.[27] Carbon quantum dots are the widely used nanomaterials in medical field which are applied for bioimaging, drug delivery, gene delivery and cancer therapy. These are also used in daily life in photocatalysis, photosensors, solar energy conversion, light emitting diode (LEDs) etc. Carbon Quantum Dots possess special physiochemical and catalytic properties due to their smaller size and biocompatibility and serve as good drug delivering vehicles within the body. These have high biomedical applicability due to their lesser toxicity, high hydrophilicity, water solubility and chemical stability.

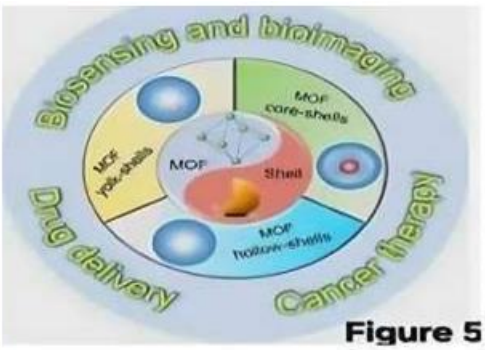












CONCLUSION

Nanoscience, the latest emerged technology has its own advantages and disadvantages. The effective use in targeted therapy, precise drug delivery, LASER amplifiers, in electronics and various Chemical industries makes it a field of interest. The high Surface area to volume ratio and various structural patterns enable the nanomaterials to effectively interact with target biomolecules, biosystems, various electrical and electronic applications, in many fields of physical and chemical sciences. The potential applications of nano materials in the field of medical sciences is possible because of their size as it facilitate the actions across the minute cellular structures. Sometimes the smaller size of nano materials proves hazardous due to improper penetrative route, inhalation during application process through cellular system resulting some unpredictable actions. The careful application of technology is just a gift for mankind in various aspects of life.

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