Overview of Nanotechnology: Applications and Challenges

OGWATA, C.M[1], ABANG, P. A[2]
[1, 2] Department of Electrical/Electronics Engineering, Federal polytechnic Oko, Anambra State

Abstract- Nanotechnology is the manipulation of matter on a near-atomic scale to produce new structures, materials and devices. The technology promises scientific advancement in many sectors such as medicine, consumer products, energy, materials and manufacturing. Nanotechnology refers to engineered structures, devices, and systems. Researching, developing, and utilizing these properties is at the heart of new technology. This paper presents the overview of this modern technology, evaluates the potentials and anticipated Risks associated with its application.

I. INTRODUCTION

Nanotechnology is a field of research and innovation concerned with building 'things' - generally, materials and devices - on the scale of atoms and molecules. A nanometre is one-billionth of a metre: ten times the diameter of a hydrogen atom.

Current knowledge of science at the nanometre scale is derived from many disciplines, originating with the atomic and molecular concepts in chemistry and physics, and then incorporating molecular life sciences, medicine and engineering. The observation and understanding of atomic and molecular behaviour from first principles was followed by the increasing ability to control and selectively modify properties of ever smaller pieces of matter in a functional way. Early examples here are the discoveries in self-assembly (Bain et al 1989) which culminated in current synthetic and supra-molecular chemistry (Gomez – Lopez et al 1996), the increasing knowledge about life's replication processes and the co-evolution of physical (Wuthrich 1995) and chemical methodologies. These have resulted in the portfolio of current molecular life sciences such as molecular motors and other functional entities (Mavroidis et al 2004, Clark et al 2004), including biomolecular and medical engineering and the emerging area of systems biology. On the other hand, manmade micro and nanoscale sensing devices originate from other domains in microscopy and device engineering but relate to biomedical applications (Ziegler 2004, Emerich and Thanos 2003).

The deviation of surface and interface properties from the bulk properties of larger amounts of materials led to the sometimes-unexpected significance of surface effects, including catalytic activity and wetting behaviour in material composed of nanosized entities, such as nanoparticles, composites and colloids (Kamat 2002). Quantum mechanical principles manifest themselves in the properties of surfaces of clusters of very small particles, especially those of the order of 1000 atoms or molecules and less. Composite materials (Schmidt 2000), with increasingly smaller characteristic sizes of the domains or phases, allowed for the design of materials with new and optimised physical and / or chemical properties. In electronic engineering, the miniaturization of devices has progressed well into the nanometre range with gate oxides in devices being routinely 25 nm thick. The recently increased public awareness of nanoscience is closely related to the availability of first real space images of atomic and molecular processes at surfaces through the invention of Scanning Probe Microscopies (Binnig and Rohrer 1985).

With the continuous development of nanotechnology, the possibility for the bottom-up production of nanoscale materials may result in some kind of self assembly of structures similar to the self assembly of phospholipid bilayers that resembles cellular membranes.

On the basis of current knowledge however, the spontaneous formation of artificial living systems through self assembly and related processes, suggested by some prominent commentators, is considered highly improbable. The combination of self replication with self perpetuation in an engineered nanosystem is extremely difficult to realize on the basis of current scientific knowledge.

II. THE NANOSYSTEM UNIT COMPONENTS AND STRUCTURE

- Nanospheres

Matrices, which have a particle size of 10–100 nm and which are prepared with natural or synthetic polymers and where the active substance is trapped in the particle, are called nanospheres. Figure 1 shows the structure of the nanospheres. Polymeric nanoparticles are divided into nanocapsules and nanospheres. The nanospheres may be crystalline and amorphous (Baysal, 2020). It is very advantageous because of its imprisonment, injection and dispersion properties (Niba et al, 2018).

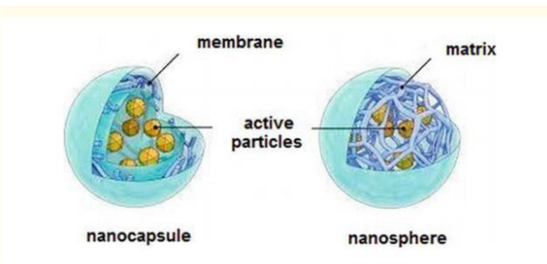

Fig1: structure of nano particle.

- Quantum dots

Quantum mechanics is the starting point of nanotechnology. These nano-sized semiconductor crystals are called quantum dots. Quantum dots are giant atomic structures that contain thousands of atoms. When substances are nano-sized, they act according to quantum laws. The most preferred quantum points due to their semiconductivity, optical, and electrical properties are CdSe, InAs, CdS, GaN, InGeAS, CdTe, PbS, PbSe, ZnS. The controllable size of the quantum dots leads to outstanding optical and electrical properties, as the size of the quantum dots changes, the wavelength and color of their radiation changes. Quantum points are revealed by the stimulation of electrons (Özada, 2016)

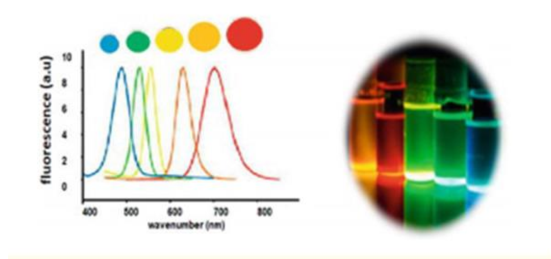

Fig 2: The wavelengths of quantum dots.

- Properties of Nanoscale Materials

Material properties depend on structure and composition, and can typically be engineered or modified by changing the relative influence of interfacial or interphase properties and the macroscopic bulk properties through the characteristic size or dimension of components and domains. This approach had already emerged centuries ago with steel alloys and has been so powerful that many engineering materials today are composites with micro to nanoscale domain sizes. Depending on the physical or chemical character of each domain, there is a complex interrelation between the structure and the composition of the material, which may relate to the bulk and surface properties of each ingredient and newly emerging properties localized at the interface. Selective chemical reactivity is quite common with nanocomposites, which gives the potential for disintegration of the material into one or the other component. Complex processes govern this behaviour, which clearly relates to nanoparticle release into the environment.

- Applications of Engineered Nanostructures and Materials

In materials science, nanocomposites with nanoscale dispersed phases and nanocrystalline materials in which the very fine grain size affords quite different mechanical properties to conventional microstructures are already in use. In surface science and surface engineering, nanotopographies offer substantially different properties related to adhesion, tribology, optics and electronic behaviour. Supramolecular chemistry and catalysis have led to novel surface and size dependent chemistry, such as enantioselective catalysis at surfaces. In biological sciences, fundamental understanding of molecular motors and molecular functional entities on the nanometre scale has been responsible for advances in drug design and targeting. Nanoscale functionalised entities and devices are in development for analytical and instrumental applications in Engineering, biology and medicine, etc.

Below are the areas of science and technology in which nanoscale structures are under active development or already in practical use

- Modern electronics components

The application areas in which these advances in nanoscience are making their biggest impact include electronic, electro-optic and optical devices. The transition from semiconductor (conventional and organic) technology to nanoscale devices has anticipated improved properties and resolution, e.g. fluorescence labelling, scanning probe microscopy and confocal microscopy. Data storage devices based on nanostructures provide smaller, faster, and lower consumption systems.

- Renewable and Sustainable Energy

The application of nanotechnology in the field of renewable and sustainable energy (such as solar and fuel cells) could provide cleaner and cheaper sources of energy. These would improve both human and environmental health.

- Medicine

In medicine, greater understanding of the origin of diseases on the nanometre scale is being derived, and drug delivery through functionalised nanostructures may result in improved pharmacokinetic and targeting properties.

- Consumer Products

A wide variety of functional nanoscale materials and functional nanoscale surfaces are in use in consumer products, including cosmetics and sunscreens, fibres and textiles, dyes, fillers, paints, emulsions and colloids.

- Pollution control

Tiny wastewater filters, for example, could sift emissions from industrial plants, eliminating even the smallest residues before they are released into the environment. Similar filters could clean up emissions from industrial combustion plants. And nanoparticles could be used to clean up oil spills, separating the oil from sand, removing it from rocks and from the feathers of birds caught in a spill.

- Agriculture

Tiny sensors offer the possibility of monitoring pathogens on crops and livestock as well as measuring crop productivity. In addition, nanoparticles could increase the efficiency of fertilisers, also, researchers in both developed and developing countries are developing crops that are able to grow under 'hostile' conditions, such as fields where the soil contains high levels of salt (sometimes due to climate change and rising sea levels) or low levels of water. They are doing this by manipulating the crops' genetic material, working on a nanotechnology scale with biological molecules.

- Risks and Concerns About Possible Effects on Human and Environmental Health

The exploitation of the properties associated with the nanoscale is based on a small number of discrete differences between features of the nanoscale and those of more conventional sizes, namely the markedly increased surface area of nanoparticles compared to larger particles of the same volume or mass, and also quantum effects. Questions naturally arise as to whether these features pose any inherent threats to humans and the environment. Bearing in mind that naturally occurring processes, such as volcanoes and fires, in the environment have been generating nanoparticles and other nanostructures for a very long time, it would appear that there is no intrinsic risk associated with the nanoscale per se for the population as a whole. As noted above, there is also no reason to believe that processes of self assembly, which are scientifically very important for the generation of nanoscale structures, could lead to uncontrolled self perpetuation. The real issues facing the assessment of risks associated with the nanoscale are largely concerned with the increased exposure levels, of both humans and environmental species, now that engineered nanostructures are being manufactured and generated in larger and larger amounts, in the new materials that are being so generated, and the potentially new routes by which exposure may occur with the current and anticipated applications.

Several non-governmental organisations are calling for greater risk evaluations, therefore concerns had been raised about the following aspects of nanotechnology:

- The toxicity of bulk material, such as solid silver, does not help predict the toxicity of nanoparticles of that same material.
- Nanoparticles have the potential to remain and accumulate in the environment.
- They could accumulate in the food chain.
- They could have unforeseen impacts on human health.
- The public has not been sufficiently involved in debates on the applications, uses, and regulation of nanotechnology.
- 'Grey goo': Tiny robots generated with nanotechnology could acquire the ability to self-replicate.
- If the rich countries are the main drivers of the development of nanotechnology, applications which benefit developing nations will be side-lined.
- Unless rapid action is taken, research into nanotechnology could progress faster than systems can be put in place to regulate its applications and their uses.

CONCLUSION

Nanotechnology is hailed as having the potential to increase the efficiency of energy consumption, help clean the environment, and solve major health problems. It is said to be able to massively increase manufacturing production at significantly reduced costs. Products of nanotechnology will be smaller, cheaper, lighter yet more functional and require less energy and fewer raw materials to manufacture.

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