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Survey on Nanotechnology

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ABSTRACT

Nanotechnology is a field where scientific knowledge and ideas emanating from the sub-atomic, atomic and molecular levels are applied in the manufacture of new and smart materials. Nanotechnology makes use of the novel properties exhibited by materials in the nanoscale. Nanocrystalline materials have microscopic grain sizes of up to 100 nm with remarkably distinct optical, electrical, chemical and mechanical properties different from those of the bulk material. Nanoparticles can be used to develop materials with unique properties since the number of atoms on the surface of a particle in the nanoscale is comparable to that inside the particle. Hence in order to meet the advanced technological demands in the areas such as electronics, catalysis, ceramics, magnetic data storage, structural components etc., it is important to make use of materials in the nanometer scale.
Nanotechnology is a rapidly growing field of science which encompasses researchers and scientists from the areas of biology, chemistry, engineering, materials science and physics. This technology provides the basis for research and manufacture of materials in the 21st century. In addition, this interdisciplinary technology will provide a strong platform for the growth of pharmaceutical industry, medical diagnosis, materials industry and the overall economy of the country which will eventually enhance creation of job opportunities, food security, good health and affordable housing.
It promises improved efficiency in ICT equipment used in computing, data storage (chips) and communications (fibre optics). It can be used to develop renewable energy sources such as solar cells and panels. It can also be utilized to synthesize filters that can be used to get rid of pollutants; contaminants, harmful salts and viruses in water and sewerage systems and for the diagnosis and treatment of diseases including cancer and to restore damaged human organs or tissues using engineered tissue.

Key Words: *Materials, Manufacture, Nanoscience, Nanoscale, Technology*

1. INTRODUCTION

Nanotechnology is a broad field of study that involves the science, engineering and technology of materials whose dimensions lie in the range of approximately between 1 and 100 nanometers, known as the nanoscale. It cuts across engineering, biology, physics, medicine and chemistry fields. Nanotechnology entails the process of designing, engineering, controlling and manipulating material at the nanoscale with the aim of fabricating new and improved functional materials, products, devices and systems for industrial application [1]. Materials in the nanoscale display chemical and physical properties such as electrical conductance, chemical reactivity, magnetism, optical, strength, thermal effects etc. different from those of the bulk due to their large surface area to volume ratio and thus can be used for a broad range of applications in the creation of various types of novel nanomaterials and devices such as nanotubes, nanowires, nanorods, nanoparticles, nanopowders, quantum dots, nanofibres etc.

Nanotechnology applications use fewer raw materials, save time and energy to create smaller, lighter, cheaper, faster and smart functional devices [1]. Nanotechnology has potential applications in various sectors including but not limited to, health care, energy, construction, transport, textiles, consumer products and agriculture. It has been reported that cement materials with better properties of such as reduced thermal transfer rate of fire retardant and insulation and Increased sound absorption can be manufactured using this technology [2]. In the automobile industry vehicles are fitted with strong and light plastic nanomaterials as shock absorbers in the car and to provide resistant to rust [3].

In addition, research in nanotechnology presents new scientific advances to improve on how to measure, monitor and manage our environment so as to minimize and eventually eliminate pollution or mitigate effects of climate change [4]. It is one of the interdisciplinary technologies which promise to have positive implications for health, wealth and security in the coming decades. This technology is thought to be the primary driver of the economy in the 21st century and beyond.

The objective of this article is to provide a brief survey on the significance of nanotechnology in the development of a country's manufacturing, construction, security and automobile industries in line with the country's Sustainable Development Goals (SDGs). It also intends to communicate and create awareness of the benefits of nanotechnology to the nation's growth and

development and attainment of the United Nations Millennium Development Goals (UNMDGs) [5]. Finally, this article looks into the methods of preparation of nanomaterials and the role and types of equipment and techniques used to investigate or characterize properties of the synthesized nanomaterials.

2. NANOTECHNOLOGY APPLICATIONS

2.1 Civil Engineering and Construction

The area of civil engineering and construction can benefit a lot from advances in nanotechnology. This technology can be applied right from the design stage throughout the construction process. This is possible due to the novel properties exhibited by nanotechnology by-products which include Light, Strong, easy to maintain and low cost, reduced heat transfer rate and increased insulation, sound proof and translucency of glass and glare free glasses. Some of these applications include; Strengthening of concrete products using nanoparticles, carbon nanotubes, nanofibers and therefore increase durability and also to reduce pollution, reducing or preventing conduction and radiation of heat by production of better insulation materials, manufacture of cheap and stronger stainless steel that can withstand corrosion and effects of weather, coating surfaces using special paints and thin films which have auto-cleansing (dirt protection) and reflectance or absorbance properties [6]. Due to the favorable properties such as strength, corrosion resistance and ability for welding, steel has become a major material in the construction industry. The American Iron and Steel Institute and the U.S. Navy developed new, low carbon, high performance steel (HPS) for application bridges [7]. By incorporating copper nanoparticles in the steel grain boundaries, the new steel with higher corrosion-resistance and weld ability was developed [2].

It has been reported that addition of nanoscale materials into cement could improve its performance for instance adding small amount of carbon nanotube (0.01) by weight could increase its overall strength [8]. Nano-silica (SiO_2) significantly improves the compressibility of concrete and fills the pores between large fly ash and cement particles to enhance pore size distribution [9]. Research on the application of nanotechnology in glass materials reports that Titanium dioxide (TiO_2) nano-thin films can be used in coating glasses. The TiO_2 film is hydrophilic and reacts with pollutants in air via photo-catalysis and prevents the glass from fouling and also have self-cleaning properties when it comes in contact with rain water [6]. Some gelatinous crystalline nanomaterials can also be used as wall linings to thermal insulate inner surfaces of buildings and offices from extremes heat and cold. In addition, some cutting and drilling tools, can be produced from nanomaterials such as tungsten carbide and titanium carbide which are characterized by high hardness compared to normal materials [3].

2.2 Medicine and Health Care

Nano-medicine is a comparatively new field of nanoscience and technology. It makes use of nanosized materials in biological tests which are used as tags and labels thus enabling tests be performed quickly and efficiently which help early detection and prevention of disease, diagnosis, treatment and follow-up [10]. Other applications include fluorescent labels used as biological detectors of pathogens, tumors and protein, investigating DNA structure, drug delivery, tissue engineering etc. [11].

Medical nanotechnology brought many improvements in clinical procedures since it has enabled application of micro-devices in medical treatments and surgery. Nanobiosensors and actuators embedded in Medical Nanorobots provides new medical tools for doctors in surgery and pervasive medicine [12]. In medical practice nanosized chips can be used for biomedical research and DNA analysis. The chips are made of an inert base which comprises thousands of single strand DNA molecules with varied base sequences. This helps in the identification of DNA from a tissue sample that has been labeled with a fluorescent material [13]. Early diagnosis and treatment of diseases can be made possible and easy by application of molecular scale nano-probes which make use of imaging techniques with enhanced signal sensitivity, better spatial resolution and the ability to relay information on biological systems at molecular and cellular levels. These nanodevices can be designed to interact with cells and tissues and include magnetic resonance imaging (MRI) and positron emission tomography (PET) [14]. Silver nanoparticles used in the linings inside refrigerators helps kill germs keeping food fresh for a long time, and makes laundry easy with washing machines [3].

2.3 Environment

Ensuring environmental sustainability is one of the UN MDGs. Nanotechnology has numerous benefits in the environmental sector including early environmental treatment and remediation, stronger and lighter nanomaterials, smaller, more accurate and more sensitive sensing and monitoring devices [15]. It has been reported that nanoparticle of TiO_2 can be used in auto-cleaning systems for photocatalytic degradation of air pollutants, as Nano-catalysts for more efficient, cheaper and better-controlled catalytic converters, Nano-sensors for detecting toxic materials and leakages in the environment [16]. Another research, microporous crystalline hydrated aluminosilicates known as zeolites, acting as redox catalysts and sorbents, can remove atmospheric pollutants, such as engine exhaust gases and ozone-depleting CFCs [17].

Iorio et al explored the potential application of polymerin, the polymeric, dissolved organic matter from olive oil wastewaters, aimed at remediating hydrophobic organic compounds (HOCs) point-source pollution [18]. They concluded that Polymerin sorption on Al_2O_3 significantly depended on particles size, Polymerin sorption increased with surface area and zeta

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potential of nanoparticles compared to micro-particles. Therefore, use of Polymerin along with Al_2O_3 nanoparticles in water treatment could give both economic and ecologic advantages.

The phenomena of thermoluminescence (TL) and optically stimulated luminescence (OSL) have been extensively applied for measurement of radiation doses from ionizing radiations such as x-rays, γ-rays and β particles. Dosimeters based on luminescence phenomenon are also used for measurement of radiation doses from neutrons. Dosimetric nano-phosphors have been developed by various laboratories and commercial manufacturing companies for their use in environmental monitoring and detection of radiation doses [19]. A recent research by Chithambo et al on thermal luminescence of $SrAl_2O_4:Eu^{2+}$, Dy^{3+} nano-phosphors found that free electrons trapped at Dy^{3+} caused formation of Dy^{2+} cations whereas holes concomitantly transferred to Eu^{2+} converting these to Eu^{3+} following ionization of the sample with beta irradiation [20]. In developing countries carbon nanotubes (CNTs) can be used in purification and desalination of drinking water. Carbon nanotube are also used in the manufacture of air filters, to get rid of the carbon dioxide emissions from factories and industries in addition, it has been found that the use of silver nanoparticles in air filters kills 99% of flu viruses and gets rid of bad smells in the air [3].

2.4 Computer monitors and TV screens

Computer monitors, television and mobile phone screens make use of phosphor nanomaterials in form of quantum dots called pixels to display images. In particular, it has been reported that using nanomaterials such as zinc selenide (ZnSe), zinc sulfide (ZnS), cadmium selenide (CdSe) and cadmium sulfide (CdS) in the manufacture of display screens helps to improve clarity and quality of images in addition to reducing the cost of production [3].

Rare earth doped aluminates constitutes a group of luminescence nanomaterials suitable for manufacture of lighting and display devices due to their high stability and brightness [21]. The intense emission of Eu^{2+} makes these nanophosphors find important industrial applications such as, the tri-color low pressure mercury fluorescent lamps. Comprehensive research on large-scale lighting devices and flat panel displays has been made significantly easy by the discovery of the plasma display panel (PDP) and light-emitting diodes (LEDs) [22]. Plasma display panels (PDPs) have many advantages such as a wide viewing angle, fast response, large screen, low energy consumption and high scalability which gives them considerable popularity [23].

2.5 Security

Peace and security is of paramount importance for any country. A lot of research is currently being undertaken on the use of nanotechnology for military purposes. Nanoparticles are used for the identification and targeting of enemy areas by the military [24]. Tubes of carbon nanoparticles embedded in polymer are used as radiation - proof to protect military electronic gadgets, radios and vehicles in the battlefield from radiation that comes from bombs since it is a good conductor of electricity and hence not affected by electromagnetic energy. Military cloths can also be made from nanomaterials tailored in such a way as to provide protection from harsh weather, nuclear and chemical or biological hazards. Nanotechnology can as well be applied in cyber security and the manufacture of smart computers protected with encryption and decryption functionalities [3].

Luminescent nanophosphors have also been applied in the manufacture of textiles for sports-wear and road safety. For instance, Strontium Aluminate phosphors, $SrAl_2O_4:Eu^{2+}$, Dy^{3+} have been reported to exhibit broad band yellow-green persistent luminescence for long hours and can withstand environmental degradation which makes it suitable for incorporation into clothes [25]. Recently, clothes have been manufactured using installed nanoparticles such as silicon particles, which makes them resistant to odor and dyes [3].

3. TECHNIQUES AND EQUIPMENT FOR THE SYNTHESIS OF NANOPARTICLES

Several methods have been used to manufacture nanoparticles both in small scale and large scale (industrial). The choice of method is determined by the type of nanoparticles and the application for which they are being made. Nanoparticles can be prepared in different forms; powder, single crystals, liquid, thin films, sprays, etc. Some of the common methods include combustion, solid state reaction, Chemical Bath Deposition (CBD) [26], pulsed laser deposition (PLD) [27], Physical Vapor Deposition (PVD) or Chemical Vapor Deposition (CVD) [28], spin coating, sputtering, epoxide-catalyzed sol-gel methods [29] and precipitation method [30].

The synthesized nanoparticles can be characterized by use of various spectroscopic techniques which go together with different types of equipment. The choice of technique depends on the property to be investigated. For instance, the structure and purity of the nanoparticles can be investigated by using Bruker-AXS D8 Advance X-ray diffractometer (Bruker Corporation of Germany) operating at 40 kV and 4 mA using Cu Kα = 0.15406 nm. The morphologies of the particles can be obtained by using a Shimadzu Superscan SSX-550 scanning electron microscope (SEM) coupled with an energy dispersive x-ray spectrometer (EDS) for elemental composition. For analysis of chemical state, molecular bonding and binding energy of the samples, X-ray photoelectron spectroscopy (XPS) is done using PHI 5000 Versa probe - Scanning ESCA Microprobe. Absorption spectra are

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recorded using a Perkin Elmer Scan - Lambda 950 UV-Vis spectrophotometer. The photoluminescence (PL) excitation and emission spectra are measured at room temperature using a Cary Eclipse luminescence spectrometer (model LS-55) with a built - in 150W xenon flash lamp as the excitation source and a grating to select a suitable excitation wavelength. Others include Raman spectroscopy, Fourier Transform Infra-Red (FTIR) spectroscopy, Auger Electron Spectroscopy (AES), Time of Flight- Secondary Ion Mass (ToF-SIMS) spectroscopy [31].

2. RECOMMENDATIONS

It is highly recommended and emphasized that governments and other relevant authorities and stakeholders focus on the importance of support for nanotechnology and related science and research needs so as to facilitate the attainment of the United Nations Millennium Development Goals (UNMDGs). The following strategies are suggested:

- Fund and facilitate of long-term research in nanoscience and nanotechnology that will enable the understanding of the synthesis and characterization of nanomaterials and fabrication or manufacture of devices for application in various sectors.
- Train and support the required human resource and institutions that will enable development of new industries, and commercialization of innovations.
- Develop and maintain requisite physical infrastructure to enable the development of first-class basic research and exploration of nanotechnology applications.
- Spur and support new technological developments such as smart and advanced materials for advanced manufacturing and for information and communication technologies (ICT), nano-biotechnology materials and precious metal-nanoparticles for mining resources industries etc.
- Establish annual funding in the country's budget to support the implementation of the nanotechnology strategy
- Initiate and encourage collaboration among the different disciplines or fields of study and among various institutional for the advancement of nanoscience and nanotechnology.

3. CONCLUSION

This paper has outlined the benefits and applications of nanotechnology. Based on the information highlighted in this article, it is hereby concluded that nanotechnology can provide a number of promising developments that can be utilized to spur the economy and overall growth of the country by creation of jobs, ensuring food security, good health and affordable housing.

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