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Review on History and Evolution of Nanoparticles and Applications in Various Fields

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Abstract: ***One of the most exciting innovations of the 21st century is nanotechnology. Nanoscience is a combination of physics, materials science, and biology that deals with atomic and molecular scale. The top-down approach includes the breakdown into nanosized structures or particles of bulk material. The 'bottom-up' is the alternative approach, which has the opportunity to produce less waste and also more economically. By using natural asbestos nanofibers more than 4,500 years ago, humans have already manipulated ceramic matrix reinforcement. The synthesis of a colloidal Au nanoparticle solution was reported by Michael Faraday in 1857, which was the first scientific explanation to report nanoparticle preparation and initiated the history of nanomaterials in the scientific arena. Carbon-based materials became the foundation of almost every field of science and engineering after the discovery of' graphene. Important advancements in the field of nano-oncology have also been made by enhancing the effectiveness of conventional chemotherapy drugs for a plethora of aggressive human cancers***
Keywords: Nanotechnology, top-bottom approach, drug delivery

I. INTRODUCTION

A Greek prefix meaning 'dwarf' or anything very small is referred to as the prefix 'nano' and represents one thousand millionths of a meter (10-9 m). We should differentiate nanoscience and nanotechnology from each other. Nanoscience is the analysis of structures and molecules on nanometer scales ranging from 1 to 100 nm, and the technology that uses it is called nanotechnology [1] in practical applications such as devices etc. The evolution of nanoscience can be traced back to the time in the 5th century B.C. of the Greeks and Democritus, when scientists considered the question of whether matter is continuous, and thus indefinitely divisible into smaller parts, or made of small, indivisible and indestructible particles, now called atoms by scientists.

One of the most exciting innovations of the 21st century is nanotechnology. It is the ability to transform the theory of nanoscience to useful applications across the nanometer scale of observing, measuring, manipulating, assembling, managing and manufacturing matter. "In the United States, the National Nanotechnology Initiative (NNI) describes nanotechnology as a nanoscale science, engineering and technology (1 to 100 nm) where specific phenomena allow new applications in a broad range of fields, from chemistry, physics and biology to medicine, engineering and electronics"[2].

We should differentiate nanoscience and nanotechnology from each other. Nanoscience is a combination of physics, materials science, and biology that deals with atomic and molecular scale material manipulation, while nanotechnology is the ability to measure, manipulate, assemble, monitor, and generate matter on a nanometer scale. There are several reports available that have given the history of nanoscience and technology, but no study is available that summarizes the revolutionary events of nanoscience and technology from the beginning of that period. It is therefore important to summarize the key events in nanoscience and technology in order to fully understand their progress in this area.

II. THE CREATIVE PIONEERS OF NANOTECHNOLOGY

Richard Feynman, the American physicist and Nobel Prize laureate, presented the idea of nanotechnology in 1959. Feynman gave a lecture entitled "There's Plenty of Room at the Bottom" at the California Institute of Technology during the annual meeting of the American Physical Society (Caltech). "Feynman hypothesized in this lecture, "Why can't we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin? ', and identified the vision of the use of machines for building smaller machines, down to the molecular level [3]. This new idea has shown that the theories of Feynman have been proven correct, and he is considered the father of modern nanotechnology for these reasons. "In 1974, Norio Taniguchi, a Japanese scientist, was the first to use and describe the term "nanotechnology" after fifteen years as: "nanotechnology consists mainly of the processing of material separation, consolidation and deformation by one atom or molecule"[4].

III. PREPARATION METHODS

Two methods were created to explain the various possibilities for the synthesis of nanostructures after Feynman discovered this new area of research that captured the attention of many scientists. These methods to production come into two categories: top-down and bottom-up, which vary in consistency, speed and cost levels.

A. Top-down Approach

The top-down approach includes the breakdown into nanosized structures or particles of bulk material. Top-down methods of synthesis are an extension of those used to generate micron-sized particles. Top-down methods are generally simpler and rely either on bulk material removal or division or on miniaturization of bulk manufacturing processes to achieve the desired structure with adequate properties. For the top-down approach, the main issue is the imperfection of the surface structure. Lithographic nanowires, for example, are not smooth and can contain a lot of impurities and structural defects on their surface. High-energy wet ball millings, electron beam lithography, atomic force manipulation, gas-phase condensation, aerosol spray, and so on are examples of such techniques.

B. Bottom-up Technique

The 'bottom-up' is the alternative approach, which has the opportunity to produce less waste and also more economically. The bottom-up method refers to the construction from the bottom of a material: atom-by-atom, molecule-by-molecule, or cluster-by-cluster. Many of these methods are either being developed or are only beginning to be used to manufacture nanopowders commercially. Some of the well-known bottom-up techniques mentioned for the preparation of luminescent nanoparticals are the Oraganometallic chemical route, revere-micelle route, sol-gel synthesis, colloidal precipitation, hydrothermal synthesis, template assisted sol-gel, electrodeposition etc.

The British Standards Institution [5] has recently suggested the following definitions for the scientific terms used:.

1) *Nanoscale:* The size range is roughly 1 to 1000 nm.
2) *Nanoscience:* The nanoscale science and analysis of matter that deals with the understanding of its size and structure-dependent properties and compares the appearance of variations associated with individual atoms or molecules or bulk content.
3) *Nanotechnology:* Nanoscale processing and control of matter by the use of scientific expertise in different industrial and biomedical applications.
4) *Nanomaterial:* Material in the nanoscale dimension with some internal or external structures.
5) *Nano-object:* Material with one or more dimensions on the peripheral nanoscale.
6) *Nanoparticle:* Three external nanoscale dimensions of a nano-object. Instead of nanoparticle (NP), the terms nanorod or nanoplate are used when a nano-longest object's and shortest axis lengths are distinct.
7) *Nanofiber:* If in a nanomaterial there are two identical exterior nanoscale dimensions and a third larger dimension, it is referred to as nanofiber.
8) *Nanocomposite:* Multiphase structure in the nanoscale dimension with at least one step. Nanostructure: Composition in the nanoscale area of interconnected constituent parts. Nanostructured materials: materials containing the nanostructure of the interior or surface.

IV. HISTORY OF NANOMATERIALS

By using natural asbestos nanofibers more than 4,500 years ago, humans have already manipulated ceramic matrix reinforcement [6]. More than 4000 years ago, the Ancient Egyptians have used NMs based on a synthetic chemical process to synthesize PbS NPs of around 5 nm in diameter for hair dye [7]. "Similarly, the first synthetic pigment prepared and used by Egyptians using a sintered mixture of nanometer-sized glass and quartz around the 3rd century BC was "Egyptian blue"[8]. A multifaceted mixture of $CaCuSi_4O_{10}$ and SiO_{22} is Egyptian blue (both glass and quartz). The widespread use of Egyptian blue for decorative purposes was found in ancient geographical regions of the Roman Empire, including countries such as Egypt, Mesopotamia, and Greece, during archaeological explorations

The synthesis of metallic NPs by chemical methods dates back to the 14^{th} and 13^{th} centuries BC, when metals were used by Egyptians and Mesopotamians to manufacture glass, which can be cited as the beginning of the age of metallic nanoparticles [9]. The earliest examples of synthetic NMs in a practical application may be such materials. Red glass that is colored by surface plasmon excitation of Cu NPs [10] has been found in Frattesina di Rovigo (Italy) since the late Bronze Age (1200-1000 BC). Similarly, Cu NPs and cuprous oxide (cuprite Cu_2O) [11] have been recorded in Celtic red enamels originating from the 400-100

BC period. Nevertheless, the most popular example of ancient metallic NP use is a Roman glass workpiece. The Lycurgus Cups are a Roman glass cup from the 4th century, made of dichroic glass with various colors: red when a light passes from behind and green when a light passes from the front [12]. Recent studies have shown that Ag-Au alloy NPs is stored in the Lycurgus Cups, with a 7:3 ratio in addition to around 10 percent Cu [13]. Later, red and yellow stained glass used in churches of the medieval era was developed by adding colloidal Au and Ag NPs [9], respectively.

Mesopotamians began using glazed ceramics for metallic luster decorations during the 9th century [14]. Due to the presence of distinct Ag and/or Cu NPs isolated inside the outermost glaze layers, these decorations displayed impressive optical properties. Such decorations are an example of nanoparticles of metal exhibiting iridescent bright green and blue colors under complex conditions of reflection. A double layer of Ag NPs (5–10 nm) in the outer layer and larger ones (5–20 nm) in the inner layer were revealed by TEM analysis of these ceramics. A similar technique was used in the mid-19th century to manufacture the popular Satsuma glass in Japan. The absorption properties of Cu NPs have been helpful in brightening the ruby colored Satsuma glass [15]. In addition, the best examples of natural NM use since ancient times are clay minerals with a thickness of a few nanometers. It was recorded that clay was also used to bleach wool and clothes in Cyprus in 5000 BC [16].

The synthesis of a colloidal Au NP solution was reported by Michael Faraday in 1857, which was the first scientific explanation to report NP preparation and initiated the history of NMs in the scientific arena. He also revealed that Au colloids have different optical characteristics compared to their respective bulk counterparts. This was probably one of the earlier reports which observed and identified quantum size effects. Later, the explanation behind the particular colors of metal colloids [17] was explained by Mie (1908). In the 1940s, SiO_2 NPs were manufactured as rubber reinforcement replacements for carbon black [18].

V. MODERN ERA OF NANOTECHNOLOGY

From the early ideas of Feynman until 1981, when physicists Gerd Binnig and Heinrich Rohrer developed a new form of microscope at the IBM Zurich Research Laboratory, the Scanning Tunneling Microscope (STM)[19,20], there has been development in nanotechnology. In 1986, "for their design of the STM," Binnig and Rohrer received the Nobel Prize in Physics. This discovery has led to the development of atomic force microscopes (AFM) and scanning probe microscopes (SPM), the tools of choice for researchers in nanotechnology today [21,22]. At the same time, Robert Curl, Harold Kroto, and Richard Smalley discovered in 1985 that carbon can also exist in the form of fullerenes or buckyballs [23], very stable spheres. When graphite is evaporated in an inert atmosphere, carbon balls with the chemical formulas C60 or C70 are formed. A new carbon chemistry has now been developed and metal atoms can be enclosed and new organic compounds can be formed. A few years later, in 1991, Iijima et al. observed by transmission electron microscopy (TEM) hollow graphite tubes or carbon nanotubes forming another member of the fullerene family [24]. In several nanotechnological applications, the strength and versatility of carbon nanotubes make them potentially useful. As field emitters, energy storage materials, catalysis, and molecular electronic components, they also have potential applications.

In 2003, in their washing machines, air conditioners, refrigerators, air purifiers and vacuum cleaners, Samsung launched antibacterial technology with the trade name Silver NanoTM, using ionic Ag NPs [25]. In auto manufacturing, NPs and NSMs are commonly used as fillers in tires to improve road adhesion, fillers in the car body to improve rigidity, and as transparent layers used for heating, mist and ice-free window panes [26]. By the end of 2003, for both metallic and non-metallic paint finishes, Mercedes-Benz had introduced an NP-based clear coat into series production. The coating increases the resistance to scratch and improves the shine. Ultrastable suspensions of small magnetic NPs with superparamagnetic properties are liquid magnets, so-called ferrofluids [27]. The liquid is macroscopically magnetized when a magnetic field is applied, which leads to the alignment of NPs in the direction of the magnetic field [28]. Recent research has focused on the development of enhanced Earth-based adaptive optic and magnetic mirror astronomical telescopes with the shape-shifting capability of ferrofluids[29,30]. TiO_2 NPs are commercially used in dye-sensitization capable solar cells [31].

In 2004, Xu et al. accidentally identified a new class of carbon nanomaterials called carbon dots (C-dots) with a size below 10 nm during the purification of single-walled carbon nanotubes [32]. Due to its benign, abundant and inexpensive existence, C-dots with interesting properties have steadily become a rising star as a new nanocarbon member [33]. The possession of such superior characteristics as low toxicity and strong biocompatibility makes C-dots favorable materials for bioimaging, biosensor and drug delivery applications [34-39]. C-dots can also offer exciting opportunities for catalysis, energy conversion, photovoltaic devices and nanoprobes for sensitive ion detection [40-43], based on their excellent optical and electronic properties. Carbon-based materials became the foundation of almost every field of science and engineering after the discovery of' graphene' in 2004.

VI. PHYSIOLOGIC AND BIOLOGIC CHARACTERISTICS OF NANOPARTICLES

Pharmacologically active cancer drugs enter the tumor tissue with low specificity and dose-limiting toxicity during chemotherapy. Oral and intravenous (iv) pathways provide conventional drug delivery methods. These methods have many drawbacks; for example, oral administration of tablets or capsules can lead to disorderly pharmocokinetics due to exposure of these agents to the body's metabolic pathways [44]. This can lead to the administration of greater doses than required, which can also lead to increased toxicity [45]. Traditional IV paths are also much more complicated. Some traditional iv medications have a low specificity, resulting in adverse effects on healthy tissues. To solve some of these issues, nanoparticle drug delivery, using biodegradable polymers, offers a more effective, less harmful solution. In 1975, Ringdorf proposed a polymer-drug conjugate model that could boost the delivery of an anticancer model [46]. He suggested that a polymer-drug conjugate model's pharmacological properties could be controlled by modifying the polymer's physical and chemical properties. For instance, by incorporating solubilizing moieties into the polymer, an insoluble drug can be rendered water soluble, thereby enhancing its bioavailability and biodegradability. Passive and active [47], the delivery of the drug to the target tissue can be accomplished mainly in two ways.

VII. MEDICAL USE OF NANOPARTICHES

Nanoparticles for bioimaging Many molecular imaging techniques have been documented for in vitro and in vivo biological specimens, such as optical imaging (OI), magnetic resonance imaging (MRI), ultrasound imaging (USI), positron emission tomography (PET) and others [48,49]. Bioimaging technologies are advancing the current production of luminescent and magnetic nanoparticles [50,51]. Two distinct forms of nanoparticles have been used extensively for imaging: OI luminescent nanoparticles and MRI magnetic nanoparticles. Dual-mode nanoparticles for OI and MRI simultaneous imaging are also available [52,53].

VIII. NANOPARTICLES AS DRUG DELIVERY SYSTEMS (DDSS)

DDSscan improves the efficacy of many main "free " drug properties such as solubility, in vivo stability, pharmacokinetics, and biodistribution [54]. Due to their advantageous characteristics, as previously stated, nanoparticles can be used as a possible DDS in this aspect. Mixed monolayer covered gold clusters were used for in vitro delivery of a hydrophobic fluorophore (BODIPY) as an example of cellular delivery (BODIPY is a class of organic fluorescent dyes that have recently become interesting for organic photovoltaics due to their high tuneable infrared absorption and high stability); a hydrophobic drug analogue[55]. The cationic surface of the nanoparticles facilitated cell membrane penetration, and intracellular glutathione (GSH) was activated by the payload release, depending on ca. 1,000 times higher GSH intracellular concentration relative to the extracellular environment. Fluorogenesis has identified the release of the dye upon release of the dye from the quenching nanoparticle. Fluorophore mediated release was observed in mouse embryonic fibroblast (MEF) cells containing approx. GSH levels are 50 percent lower than Hep G2; esterases process GSH monoethyl ester (GSH-OEt) to GSH by incubation, transiently rising intracellular GSH concentrations. Lin et al. have shown that thiols such as dihydrolipoic acid (DHLA) and dithiothreitol (DTT) can also serve as stimuli in mesoporous silica nanoparticles to dissolve porous caps and thus release trapped molecules within the pores [56,57]. The pores were capped with removable nanoparticles of cadmium sulfide (CdS) or ferric oxide (Fe_3O_4) through disulfide binders that cleave in a decreasing setting. In cancer cells, the release of encapsulated fluorescein isothiocyanate (FITC) from magnetic nanoparticle-capped MCM-41 due to the existence of large amounts of intracellular DHLA was observed Important advancements in the field of nano-oncology have also been made by enhancing the effectiveness of conventional chemotherapy drugs for a plethora of aggressive human cancers [58,59]. These developments were made by targeting many functional molecules at the tumour site, including nanoparticles, antibodies and cytotoxic agents. In this context, a number of studies have shown that nanomaterials can be used on their own or supplied with therapeutic molecules to modulate important biological processes, such as autophagy, metabolism or oxidative stress, exerting anticancer activity[60]. Therefore, nano-oncology is a very attractive application of nanoscience and enables, in addition to a substantial reduction in systemic toxicity associated with existing chemotherapy therapies, the enhancement of tumour response rates.

IX. CONCLUSION

A. For a diverse array of biological applications, nanoparticles provide a highly desirable medium.
B. For individual and multimodal applications, including biomolecular recognition, therapeutic delivery, biosensing, and bioimaging, the surface and core properties of these systems can be engineered.
C. For a wide variety of uses, nanoparticles have already been used both in vitro and in vivo.
D. However to fully realize their potential, a range of open problems, including acute and long-term health effects of nanomaterials, as well as scalable, reproducible production methods and accurate metrics for the characterization of these materials, need to be addressed.

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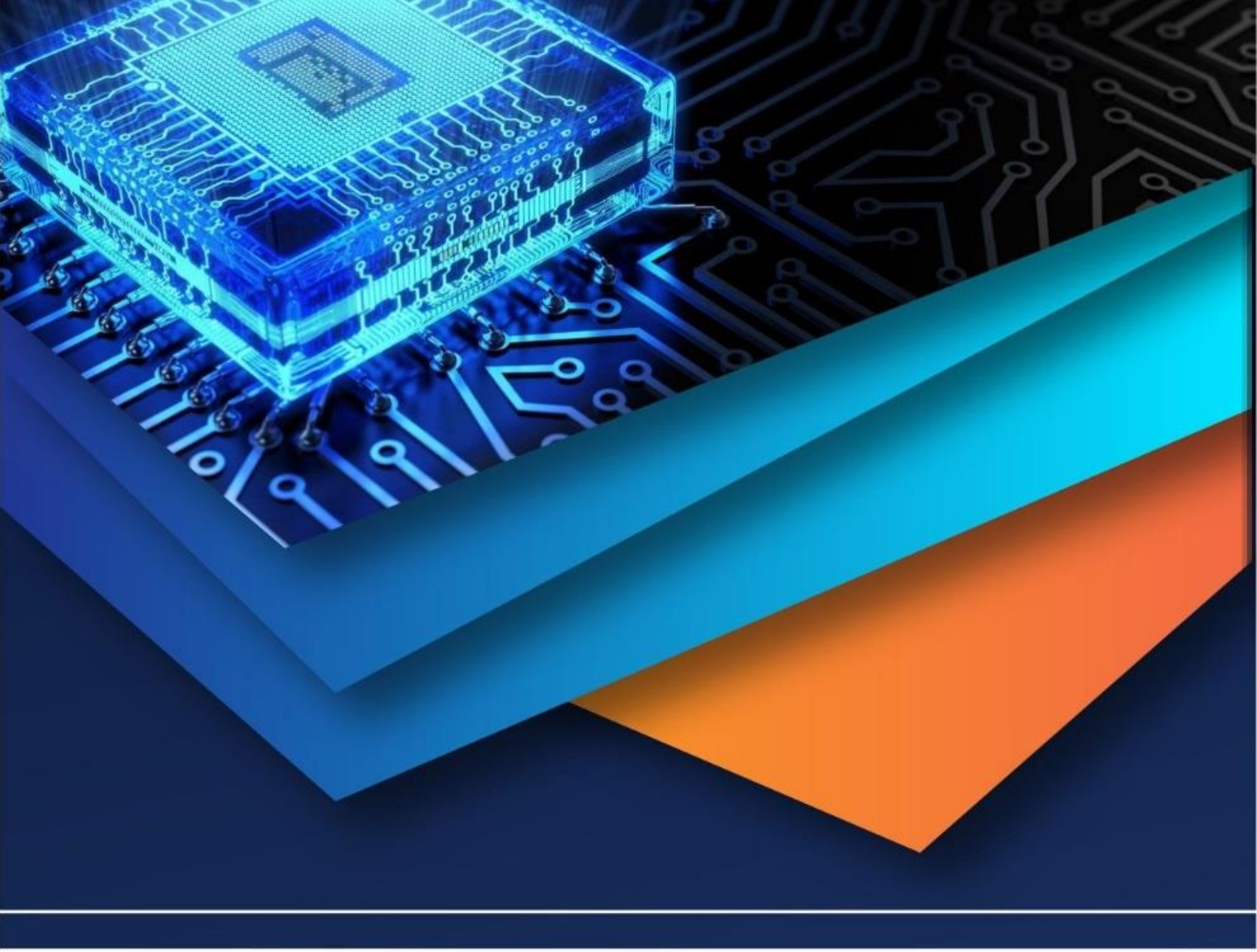

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