International Journal of Chemical Sciences

Research | Vol 15 Iss 4

Synthesis, Applications and Future Perspectives of the Small Art Nanosciences Risen as a Technology

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Received: August 14, 2017; **Accepted:** August 17, 2017; **Published:** August 24, 2017

Abstract

Nanotechnology and sciences is nurturing research to an extent unimaginable. The term stated as a fashion is now a criteria deciding the world's economy in terms of research and development. Applications of this field are seen in every arena such as medicine, engineering, biotechnology etc. The studied bloomed in Japan and is now taking its roots all over the developing nations. In this article, we have collectively researched literature which focusses primarily on the processes employed in synthesizing the nanoparticles giving birth to the entire nanostructure. We are also looking into the survey carried based on the applications and the research unexplored.

Keywords:* *Feedback controlled lithography; Copper phthalocyanine; STM imaging; Nitrogen doped carbon nanotubes; PLLA nanofibers; BCL-2; TNF-α; Viral nanoparticles; Titanium dioxide; Kinetics of crystallization; 3-DNA structure

Introduction

Nanotechnology is a potential field comprising of innumerable applications. These applications are immense in materials, electronics and medicine [1]. Rapid advances in nanotechnology are increasingly influencing routes in which the economy can conceive human ability to look into matter at the atomic and molecular levels. These implications present unimaginable potentials in discovery and innovation. The amalgamation of nanoscience with fields such as biotechnology, information technology, cognitive science and engineering ensures a promise for the development at innumerable levels [2]. One of the most advance applications of molecular nanotechnology is the incorporation of electronic properties with silicon technology. In this technique, each molecule binds appropriately at specific locations on the surfaces of silicon. The templates of the silicon bonds combining with the surfaces are prepared by feedback controlled lithography (FCL). Through this approach, successful Norbornadiene (NBE), C60 and copper phthalocyanine (CuPc) molecular arrays have been made and studied by spectroscopy and STM imaging [3]. Nanoscience systems in retrospect are smaller, and highly efficient. Economic impact of the influence of nanosciences in water treatment is now booming in food security and mankind. Government and intergovernment organizations are needed to measure the potentials of Nanotechnology as a solution to various global water issues to engage primarily in fiscal, social and economic initiatives for which Nanotechnology has come up with water treatment solutions for the improvement of drinking water in developing countries. Environmental pollution and globalization is causing pollution in water bodies to a larger extent for which nano based treatment solutions are the need of the hour. This would require the conversion of the malignant hazardous pollutants into the benign variants which can be solved by using the principles of nano based filters which are typical electro catalytic systems. These possess a pore size lesser than 0.1 µm having high filtration properties which suits the need for water purification. These ideologies would require less capital to install systems with minimum installation charges in less developed countries [4]. Carbon nanotubes are now being used to amplify the performance on fuel cells for oxygen reduction. This is mastered using nanocomposites of graphene based electro catalysts which was the major concern for fuel cells. In this approach, optimization of nitrogen doped carbon nanotubes (CNT) are investigated by galvanostatic measurements in glucose half cells. The catalytic efficacy of the nanostructure is evaluated using 2D simulations. Incorporation of this approach applying oxygen reduction using CNTs demonstrates better performance than the native constituent components [5]. Engineering of nanomaterials to suit various issues requires accurate dose metrics in invigilation of *in vitro* screening to assess potent health risks. This would require scientists to employ standardized methodologies to generate stable nano suspensions forming the structure followed by characterization of the same structure with valid data supporting the experiment. For this, the properties contributing to the modelling of the exact nanostructure is immensely important. These attributes of the structures are further influenced by several factors again which have to be optimized [6]. Nanoparticle composite nanofibers are now being explored for long term adjustments of tumor apoptosis. In this approach, doxorubicin-loaded mesoporous silica nanoparticle is employed. This acts as a drug delivery system using silica which releases the anti-tumor drugs in two different stages-which are drug release in an early stage and sustained release in a later stage. Currently, a novel scaffold is designed to stimulate efficient drug release by loading with doxorubicin (DOX) and conjugated DOX with mesoporous silica using electrospun PLLA nanofibers. This technique has significantly inhibited the growth of tumors by inducing apoptosis. Alongside inhibiting tumors composite nanofibers resulted in the decreased expression of BCL-2 and TNF-α with the up-regulation of Bax, Fas and the activation of caspase-3 levels. BCL-2 and TNF-α are known to induce cancer cells and this process of combining nanofibers results in decreased levels of these tumor factors thereby preventing tumors [7]. Nanostructured materials are highly developed in terms of synthesis, characterization. As the surface area of the nanomolecules is comparatively large when compared to the other molecules, they possess a fairly large surface reaction rates enabling them to have absolute specificity. The minute size of these particles is proven to have enhanced catalytic and sensitive properties [8]. Sometimes, the increased surface area poses several challenges to the nanoparticles utilized to synthesize nanometallic fuels, as these sizes increase the viscosity of the polymers binding to the surface so as to prevent high mass fuels to be formulated. In such cases, when the fuels are subjected to combustion, the surface undergoes heavy loss resulting in the decrease of the area which is needed for the rest of the reaction. To overcome tis, electrospray can be utilized to form a gel within a droplet by the process of evaporation coupled with enhanced aggregation of aluminum metal particles and a suitable oxidizer with an appropriate binder. By employing all the energy released during combustion was much lesser. Coating the desired nanomaterial with aluminum also increases the fuels ignition temperature more than 1000 K [9]. The science of nanomaterials is indeed the most fascinating fields for technical upliftment across the globe. The study holding all the features facilitating increased economy and research is worth all the efforts. The activities in this field are related to their minute size which controls the material properties [10]. However as said earlier the size can be act as a limitation during combustion. To overcome this, a chemical reaction can be allowed which would reduce the size by a process of cracking. This was clearly seen in the work carried out by Dutta et al. There are several approaches utilized to synthesize nanomaterials the most exploited one is, synthesis using titanium dioxide [11]. Recently protein cages act as attractive hosts to engineer a desired nanomaterial. In this process, the protein cage is engineered to provide a suitable scaffold. The selected nanomaterial is synthesized based on an electrostatic ad spatial registry between the organic and inorganic phases to facilitate nucleation of the material as a result synthesizing the whole structure. Cowpea chlorotic mottle virus (CCMV) was engineered to create an analogue of the iron storage protein called ferritin, which holds nano iron oxide amidst the protein cage. The engineered cage creates electrostatic surfaces. These mark the specific reactions synthesizing the desired material [12].

Techniques Explored in the Synthesis of Nanomaterials

Biosynthesis of nanostructures using helical plant viral nanoparticles

In this process, bottom-up approach is used extensively where the nanomolecules are assembled with components of viral nanoparticles (VNP) and virus-like nanoparticles (VLPs) resulting in the production of nano biomaterials (TABLE 1). VNPs and the VLPs are nano scaffolds having large surface area which enables the formation of supramolecular structures. The viral protein cage is further subjected modifications which makes it efficient drug delivery systems, therapeutics and catalysts [13].

TABLE 1. **Classical sizes of nanomolecules using *fusarium* host species.**

S. No	Fusarium species	Concentration	Average size
1	*F. solani*	39+/-1.4	1.02×10^{10}
2	*F. culmorum*	38+/-1.5	0.32×10^{10}
3	*F. scripi*	43+/-1.9	0.78×10^{10}
4	*F. oxysporum*	24+/-1.5	0.42×10^{10}

Synthesis using selenium powder

Nanomaterials in this case are synthesized using metallic selenium alloys. The method is most suitable for the production of quaternary nanostructures. In the first step, a dispersion of selenium powder followed by subjecting to a metal cation. The nanomaterials will start incorporating the metal cation and selenium. The reaction is subjected to different temperatures to maintain stability. The method furthermore, requires selecting an array of concentrations which determines the dimensions of the nanomaterials to be achieved. The chain length of such nanostructures can be increased by the addition of ligands. The reaction terminates with a quenching reaction after the formation of the nanoparticles [14].

Synthesis using anodic aluminum oxide

This is the most fabricated and a low-cost process. This technique employs templates of anodic aluminum oxide in the porous form thereby allowing the regulation of the structure and dimensions of the desired nanostructure. Al_2O_3 in the porous form can be prepared by the anodization of aluminum in suitable electrolytes [15-17]. Anodization results in the formation of an Al_2O_3 substrate which is not yet suited for electrodeposition into the pores as the presence of a non-conductive oxide barrier still exists. For electrodeposition to happen, the barrier pore layer has to be removed. The thickness of the aluminum coating depends on the electric potential which is applied [18]. Large pulse applied results in the detachment of the membrane. Hence regular pulses at short durations are required to establish a uniform coating on to which the suitable nanomaterial can be formed [19]. Nanoscience is also emerging to be a boom in the field of medicine and physiology in the recent times. The new approaches hold innumerable applications in the field of research, diagnoses and therapy. This innovation comes with many challenges primarily being introduction of nanomaterial into the human body as it comes with toxicity issues and cross reactivity [20]. In nanomedicine, targeted drug delivery is a plethora of thinking as it brings in a lot of research. Most studied example would be the potential application of IFN-α nanoparticles as a tool to deliver drugs required to treat cardiovascular diseases. Another striking example would be the designed nano oil droplets used to bring about the encapsulation of the solid nanoparticles targeting the internal pathways thereby enhancing drug delivery process (FIG. 1).

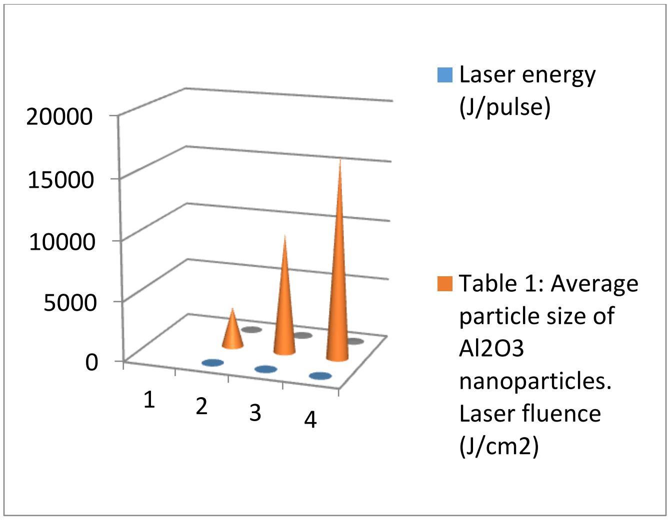

FIG. 1. **Average Al_2O_3 nanoparticles required during synthesis.**

Nucleation of nanoplatelets in hydrothermal synthesis

This process is complicated yet explored in the research arena. The principle involved here is wet chemical synthesis by hydrothermal method. Through this method successful $Bi_{2-x}Sb_xTe_3$ (x=0-2) nanoplatelets have been synthesized. The nanoplatelets formed can be visualized using X-ray diffraction. A two-stage nucleation is required to slowly require building the nanostructure. The reaction temperature affects the kinetics of crystallization and mechanisms during the actual synthesis of $Bi_{2-x}Sb_xTe_3$ nanoplatelets [18].

Results, Discussion and Conclusion

Atomic force microscopy is one of the applications being explored to the highest when the plasma surfaces of the nanostructures are to be studied. AFM is used intensively to study the nanostructures at the sub-nanometer scale to illustrate and investigate the bottlenecks which are present when the structure is fabricated. The application works best when the nanostructure is built on substrates such as polyethylene oxide (PEO), fluorocarbons (CFX) etc. The technique clearly depicts the surface topography and the root mean squares which predict the surface roughness of the fabricated structures. By observing the AFM images of the structures, it becomes possible to bring about a comparative study of the nanofillers which are embedded in a polymeric matrix [19]. Magnetic nanoparticles like PEGylated chitosan are the best drug delivery systems for breast cancer. Docetaxel is used as a model drug immensely to carry out research on tumor regression. Nano substances hold fascinating applications for the detection of pathogens and biomarkers. In this case, the most studied area would be the applications of biosensors for the detection of analytic components within the solutions.

Work produced by Shakur and colleagues, illustrates how dosage depend activation results in accordance with the concentration of the nanoparticles acting as a drug [21]. In DNA nanotechnology, Watson-Crick arranged the molecules into structures in the range of 10 nm to 100 nm. This size of these particles resulted in the formation of free electrons having a sugar phosphate background. This procedure has helped immensely in the urge to create a 3-DNA structure in the DNA itself. DNA nanocrystals are synthesized when they are treated at 90°C to 4°C transition temperature, in the presence of $MgCl_2$. Recently applications of DNA nanotechnology are combined with proteins and cellulose which are crosslinked with streptavidin biotin and used successfully in nanochips. On the whole, nanotechnology is a blessing for science as it just proves as to how small things make a bigger difference.

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