Fabrication and Characterization of 2D Nanoparticles

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I. Introduction

The use of carbon nanotubes in engineering has seen a rapid spike in the past decade. With the advancements in our understanding of the quantum world, we have been able to utilize the properties of matter at nanoscale for our requirements. Nano materials show enhanced properties as compared to their bulk counterparts. They have higher tensile strength with reduced probability of defects and show increased flexibility. They also exhibit increased electrical conductivity due to the better ordering and ballistic transport. Their increased perfection also enhances chemical stability. Through their higher surface area to volume ratio, they show better catalytic efficiency. Due to these superior properties, nano materials are heavily replacing other engineering materials in various industries. A Two-Dimensional nanomaterial refers to materials that have 2 dimensions in the nanoscale. In recent years, 2D nanomaterials such as graphene, hexagonal boron nitride (hBN), and metal dichalcogenides (MX2) have attracted a lot of attention due to their satisfactory properties and widespread uses in the electronics, optoelectronics, catalysts, energy storage facilities, sensors, solar cells, lithium batteries, composites, etc. They have improved properties and detection limits which are very important when sensitivity and measuring quanta are involved. Graphene is one of the most widely used example of a 2D nanomaterial. Due to the importance of these nanomaterials in today's world., their characterization and fabrication processes are of great importance. There have been various astonishing developments in the field of fabrication and characterization of 2D nanomaterials that are of great interests for us as students of engineering. Therefore, our group has decided to review research papers about the new advancements and developments in the study of nanomaterials. By reviewing the related research papers, we aim to expand our knowledge about the important characterization and fabrication processes of these 2D nanomaterials.

II. Techniques Involved

A. **Fabrication and characterization of few-layer Graphene** [1]

At 1100℃, the surface of the film mainly consists of a large number of nanosheets with width and length of up to 200 nm and 1 μm. Raising the temperature to 1200℃ leads to thinner nanosheets with width up to 250 nm and length 1.5 μm. At 1300 ℃ , high-quality transparent few-layer graphene with the thickness less than 8 nm, width up to 350 nm, and length more than 3 μm were successfully obtained. The error for the thickness measurements is around 10%. The thickness indicates that the obtained graphene sheet is few-layer graphene, which consists of several single atomic layers. The experimental data show that increase of substrate temperature from 1100 to 1300℃ using this approach produces thinner few-layer graphene on transition metals. It is expected that keep increasing the substrate temperature probably would result in the monolayer graphene.

B. **Fabrication and characterization of polyamide thin film nanocomposite (TFN) nanofiltration membrane impregnated with TiO2 nanoparticles** [2]

A novel thin-film nanocomposite (TFN) nanofiltration membrane has been developed via interfacial incorporation of aminosilanized TiO2 nanoparticles. Polyether sulfone (PES) barrier coating on a porous α-Al2O3 ceramic hollow fiber membrane was employed as the substrate layer. TiO2 nanoparticles were incorporated in pure and functionalized forms into trimesoyl chloride (TMC) organic phase and m-phenylenediamine (m-PDA) aqueous phase, respectively. The surface functionalization of TiO2 nanoparticle was confirmed by XRD, FTIR and UV-vis reflectance spectral analysis. Surface properties of the fabricated composite membranes were investigated using SEM, EDX, AFM and contact angle goniometry. Heat resistibility of polyamide layers were examined using thermo-gravimetric analysis (TGA). Membranes intrinsic properties such as: the permeability, selectivity and pore size determination were also elucidated. The silane coupling agent containing amino-functional groups reinforced TiO2 nano fillers for the good dispersion inside the polyamide skin layer by reducing their surface energy. At ultra-low concentration (0.005 wt.%), the functionalized TiO2 nanoparticles improved the salt rejection to 54% as well as water flux to 12.3 l/m^{2}h. By incorporating a higher concentration of TiO2 nanoparticles, water flux was increased up to 2-fold compared with the pure polyamide membrane with negligible rejection loss. These results demonstrated competency of using functionalized inorganic nanoparticles to increase the product flux and the separation efficiency.

C. **Fabrication of 2D ordered structure of self-assembled block copolymer containing gold nanoparticles** [3]

Ordered 2D nano material structures provide a wide range of applications ranging from optoelectronic and biomedical purposes. In this study, a bottom–up method to fabricate an ordered nanodot structure with entirely wet chemical procedures is proposed by using an amphiphilic block copolymer self-assembled into well-defined two/three-dimensional structures with gold nanoparticles evenly distributed in the hydrophilic domain of the copolymer. The novel properties of materials at nano scale establish them as ideal building blocks of modern technology. This paper reviews the fabrication of these materials. More specifically this paper we discuss the fabrication of an ordered nanodot structure with entirely wet-chemical procedures using an amphiphilic block copolymer self-assembled into well-defined 2D structures with gold nanoparticles evenly distributed in the hydrophilic domain of the copolymer. The results of the study show that the size of gold nanoparticles and the spacing between them can be adjusted by the molecular weight of the block copolymer and the relative amount of gold ion added in the micellar solution. The measurements also conclude that PS–PVP/Au thick film gives a characteristic surface plasmon resonance absorption. These observations show that these nanomaterials have a huge potential application in the optoelectronic and biomedical fields.

D. **Characterization and 2D Self-Assembly of CdSe Quantum Dots at the Air-Water Interface** [4]

Nano structures based on quantum dots are used for building various photonic, electronic, and magnetic devices. Techniques of manufacturing such nanostructures are of a great interest in research due to their wide range of uses and growing popularity. In the following paper, the characterizations and manipulation of the self-assembly of CdSe (Cadmium Selenide) quantum dots at a water-air interface are studied to better understand their properties which will help us in determining important characteristics such as limiting nanoparticle area, easy manipulation of the films, and interparticle distance control. The factors studied include particle size, nature of surfactant, surface pressure, and mixed monolayer systems. Quantum dots of four different sizes were prepared, and TEM micrographs determined average diameters of 23, 41, 75, and 103 Å with standard deviations of 5 (22%), 6 (15%), 18 (24%), and 18 (18%), respectively. Langmuir films were used to find the molar absorptivity of CdSe quantum dots and to analyse the capacity for manipulating the 2D organization of the QDs. Surface modification, particle size, surface pressure, and mixed monolayer systems were found to have significant influences on the self-assembly of the quantum dots at the air-water interface. Controlling the nanoparticle organization and transferring the nanostructured films to our desired substrate helps us two better apply QDs in optoelectronic and magnetic devices along with those that are used for chemical and biosensing. Property of QDs aggregating overtime helps us to use Langmuir films to monitor time related stability of QDs.

III. APPLICATIONS

A. **Two-Dimensional Materials-Synthesis, Characterization and Potential Applications** [5]

Nowadays, many technologies search for the highest efficiency, mainly and more than ever before, on the cooling and anti-wear challenges within machines, devices and components. Several efforts have been made trying to homogeneously disperse nanostructures (oxides, metals, ceramics, CNTs, 2D-nanosheets and others) within conventional fluids to improve their properties, such as thermal transport, viscosity, lubrication, electrical behavior, among others. Nano fillers size has positive effect on conventional fluids performance, that is compared to larger dispersed solid particles making flow through small channels much more easier, also since diverse parameters are critical for devices performance, such as morphology and stability of dispersed nano structures within conventional fluids, fluids composition, viscosity, fast sedimentation, channels clogging, wear or erosion, among others, which are often very serious for systems consisting of small channels. Furthermore, properties improvement is also dependent of various factors, such as filler fraction, temperature, chemical, and interfacial properties on the nanostructure-fluid interfaces. Some nano fluids are currently expensive, partly due to the difficulty in manufacturing. Hence, mass production of nanostructures could further decrease the cost, also low filler fraction is necessary to make nano fluids more affordable before they will see widespread applications.

B. **Bioinspired 2D Nanomaterials for Sustainable Applications** [6]

By integrating 2D nanomaterials with the bio inspired strategies, innovative materials

and technologies have been proposed and realized. In this

research news, recent progress that mainly achieved over the

past decade in bio inspired materials and technologies based on 2D nanomaterials for targeted sustainable energy and environmental technologies, such as energy conversion and storages, environmental remediation, etc., is reviewed and discussed. Among the various natural photonic structures, one class consists of periodically stacked 2D multilayers, also known as Bragg Stacks, have been found in many natural organisms, such as plants, insects, and marine benthos. To meet the increasing requirements on materials for high-performance energy devices, nanomaterials with precisely tailored structures and interfaces inspired from natural species have been created. Bio inspired nanomaterials have demonstrated some extraordinary properties, which are promising for enhancing the overall performance of energy conversion or storage devices. Bioinspired surfaces with super wettability have been intensively explored in past decades by investigating the superwetting phenomenon in nature and this has stimulated the applications of super wettability in liquid-proof textiles, oil–water separations, super/antiadhesion surfaces, etc.

C. **Holey 2D Nanomaterials for Electrochemical Energy Storage** [7]

Construction of efficient and economically viable electrical storage devices is a very important need in the modern world with our heavy dependence on electricity in our day to day life. Recent advancements in nanotechnology has provided means to manufacture such storage devices. The mentioned paper reviews the recent studies of the use of porous 2D nano materials for the purpose of electrochemical energy storage that discuss topics ranging from general methodologies for rational design and controlled synthesis, to their promising applications in various electrochemical energy storage devices. Porous 2D nano materials offer unique chemical and physical properties with useful structural characteristics while posing certain limitations for storage purposes. A careful review of these studies shows that it is highly promising to achieve high energy and power densities simultaneously from rationally designed porous 2D nanomaterials-based composites. The paper also states that facile, versatile, and largescale synthetic methodologies to produce electrochemical storage devices using holey 2D nanomaterials are good research topics. Progress in these will greatly benefit us to achieve advances in technology. The paper concludes by stating that porous 2D nanomaterial is a promising material platform to understand the underlying mechanisms of various energy-related applications by many advanced characterization tools.

D. **Conductive nanofinishes for textiles** [8]

Nanofinishes refers to the process of controlling static charge on a non-conducting textile to transfer the generated charge to the ground. This is generally known as antistatic finishing and has gained more attraction after the introduction of synthetic fibers to provide a level of conductivity for the dissipation of the static charges. During the 19th century, many research studies dealt with the introduction and development of antistatic finishes, which are mainly ionic surfactants such as salts of phosphate esters and quaternary amines, organic salts, glycols, and polyethylene glycols.

Producing metal fibers from stainless steel, aluminum, copper, or nickel is one of the simple approaches for making conductive fibers, however suffering from heavy weight and low flexibility. Wrapping a metallic ribbon or foil such as copper, silver, or gold around a high strength fiber in a helix shape is another method to surpass the inflexibility of metal fibers through the helix arrangement. However, the conductivity is not continuous in these fibers due to the fragile nature of the metal foil. Another approach is adding conductive particles such as silver or carbon nanotubes (CNTs) to produce conductive textiles benefiting from low cost.

IV. CONCLUSION

Upon carefully reviewing all the recent technological advances of the last few decades one can evidently conclude that nanotechnology holds the key to most of the future developments and innovations. All the research papers reviewed above discuss the progress made in the characterization and fabrication od two-dimensional nano materials. The first paper discusses the manufacturing process and all the useful characteristics of few layer graphene, an important nano material whose mass production is necessary for effective use of its abilities. The second paper discusses bioinspired nano materials. The paper discusses efficient methods to combine nature with science for sustainable energy and environmental technologies. The next paper talks about Fabrication and characterization of polyamide thin film nanocomposite (TFN) nanofiltration membrane impregnated with TiO2 nanoparticles. The paper proves the competency of using functionalized inorganic nanoparticles to increase the product flux and the separation efficiency. Our next paper is about Fabrication of 2D ordered structure of self-assembled block copolymers containing gold nanoparticles followed by a paper discussing the characterization and fabrication of CdSe quantum dots by self-assembly on an air-water interface. Next, we review a paper that discusses all the recent progress in the research of porous 2D nano materials for the purpose of electrochemical energy storage. The following paper discusses the potential applications and characterization of modern 2D nano materials. Our last paper discusses the use of nanotechnology in the textile industry and talks about the practical purposes of nano materials in the mentioned context. Going through these papers one can get an idea of the importance of nano materials in this modern era o technology. By harnessing the unique property of objects at nano scale and by better understanding their characteristics and synthesis we can open paths to advancements that were before classified as fiction.

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