International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 05, May-2019

ADVANCES IN NANO-MATERIALS: A REVIEW

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***Abstract*— Nanomaterials have been used for many different things for many years, but they are also found in nature. In ash clouds from volcanoes, sea breeze and in the smoke from a fire, for example nanomaterials are, in other words, not just something made in a laboratory. But nanotechnology has made it possible for humans to create materials that include nanoforms and we do that more and more because they have some advantages that substances in bigger sizes do not have. From the last few years applications of nanomaterials are getting wide and so the advancement in them too. This review illustrates some of the advancements held in nanomaterials under different fields such as bio-medical, material science, energy, electronics, etc.**

***Keywords*— Nanomaterials, Nanotechnology, Nanoparticles, Graphene oxide.**

I. INTRODUCTION

Nanotechnology is a branch of science that is based on the applied principles of physics, electronics, engineering and material science at a molecular or submicron level. The term 'nanotechnology' is derived from a Greek word 'nano' meaning 'dwarf', hence it relates to materials of very small size ranges (0.1–100 nm) [1]. Materials with at least one external dimension that measures 100 nanometres or less or with internal structures measuring 100 nm or less are usually considered as nano-materials. They may be in the form of particles, tubes, rods or fibres. The nano-materials that have the same composition as known materials in bulk form may have different physico-chemical properties than the same materials in bulk form, and may behave differently if they enter the body. They may thus pose different potential hazards. The use of nano-materials in commercial products is rapidly increasing. In 2006, more than 300 commercial products on the market claimed to have enhanced properties due to incorporated nano-materials; this number had more than quadrupled by 2010. Silver is the most common nano-material used in products, followed by carbon-based nano-materials and metal oxides such as TiO_2 [2].

II. LITERATURE BASED ADVANCES IN NANOMATERIALS

Morones et al. [3] analysed the bactericidal effect of silver nanoparticles. They have identified the action of silver nanoparticles against Gram-negative bacteria. This mainly happens in three ways: (1) nanoparticles of range 1–10 nm attach to the surface of the cell membrane and drastically disturb its proper function, like permeability and respiration; (2) they are able to penetrate inside the bacteria and cause further damage by possibly interacting with sulfur- and phosphorus-containing compounds such as DNA; (3) silver ions released by nanoparticles have an additional contribution to the bactericidal effect of the silver nanoparticles.

Li et al. [4] explains the usage of Co_3O_4 nanotubes, nanorods, and nanoparticles as anode materials of lithium-ion batteries. The results show that the Co_3O_4 nanotubes prepared by a porous-alumina-template method display high discharge capacity and superior cycling reversibility. Furthermore, Co_3O_4 nanotubes exhibit excellent sensitivity to hydrogen and alcohol, owing to their hollow, nanostructured character.

Li et al. [5] demonstrated that aqueous graphene dispersions can be readily formed by controlled chemical conversion of GO colloids without the need for either polymeric or surfactant stabilizers. Chemically converted graphene can now be viewed as a special water-soluble conducting macromolecule that can be simply obtained from graphite. Graphene sheets should be superior to normal synthetic conducting polymers in terms of thermal and chemical stability and mechanical strength, and more competitive than carbon nanotubes in terms of production cost.

Si and Samulski [6] exfoliate graphene by using platinum nanoparticles. They propose a Pt-graphene composite with a novel graphene morphology derived from drying aqueous dispersions of platinum nanoparticles adhered to graphene. Face-to-face aggregation of graphene sheets is arrested by 3-4 nm fcc Pt crystallites on the graphene surfaces, and in the resulting jammed Pt-graphene composite, the Pt acts as spacers resulting in mechanically exfoliated, high surface area material.

Bruce et al. [7] demonstrates that the chemistry of nanomaterials is important for future research into rechargeable lithium batteries. The significance of nanomaterials is demonstrated by their incorporation, in the form of nanoparticles, into the latest commercial rechargeable lithium batteries; for example, nano-$LiFePO_4$ cathodes and tin–carbon alloy anodes. To store more energy in the anode, new nanoalloys or displacement reactions, or conversion reactions will be required. It also highlights the important advantages of nanostructured materials, as opposed to simple nanoparticulate materials. For example, the superior properties of TiO_2 nanowires and mesoporous $LiCoO_2$.

Kim et al. [8] report the direct synthesis of large-scale graphene films using chemical vapour deposition on thin nickel layers, and present two different methods of patterning the films and transferring them to arbitrary substrates. The transferred graphene films show very low sheet resistance of ~280Ω per square, with ~80 per cent optical transparency. At low temperatures, the monolayers transferred to silicon dioxide substrates show electron mobility greater than 3,700 cm^2V^{-1} s^{-1} and exhibit the half-integer quantum Hall effect, implying that the quality of graphene grown by chemical vapour deposition is as high as mechanically cleaved graphene. Employing the outstanding mechanical properties of graphene, we also demonstrate the macroscopic use of these highly conducting and transparent electrodes in flexible, stretchable, foldable electronics.

Wang et al. [9] demonstrated the $Ni(OH)_2$/GS composite as an interesting material for electrochemical pseudocapacitors with potentially high energy densities, high power densities, and long cycle life. Single-crystalline $Ni(OH)_2$ hexagonal nanoplates grown on grapheme sheets(GS) showed high specific capacitances and remarkable rate capability, significantly outperforming $Ni(OH)_2$ nanoparticles grown on graphite oxide(GO) and $Ni(OH)_2$ nanoplates simply mixed with GS.

They also showed that the quality of graphene and the morphology and crystallinity of the nanomaterials are important to the high electrochemical performance of these graphene based composite materials for energy storage. For achieving a large operating voltage range and optimize the energy and power densities of real supercapacitors it is highly desirable to couple $Ni(OH)_2$/GS material with a suitable counter electrode material with a comparably high performance.

He et al. [10] demonstrated that GO possesses high fluorescence quenching ability as well as different affinities toward ss- and dsDNA using both theoretical calculations and experimental studies. They designed a new homogeneous sensor for multiplex, sequence-specific DNA detection. GO can be readily synthesized in large quantities, and in contrast to dually labelled molecular beacons, the probe is only labelled with a single dye, which reduces the cost for DNA assays. Even the availability of large planar surfaces of GO makes it possible to detect multiple molecular targets in the same solution. the GO-based DNA detection also improves the sensitivity by at least an order of magnitude as compared to conventional molecular beacons, which reflects the superquenching ability of GO that minimizes the background fluorescence.

Hu et al. [11] concluded graphene-based nanomaterials to be the excellent antibacterial materials with mild cytotoxicity. Fabrication of macroscopic GO (graphene oxide) and rGO (reduced graphene oxide) paper was demonstrated via simple vacuum filtration. Given the superior antibacterial effect of GO nanosheets and the fact that GO nanosheets can be mass-produced and easily processed to make freestanding and flexible paper with low cost.

Xia et al. [12] demonstrated ultrahigh-bandwidth photodetectors using single and few layer graphenes. In these novel photodetectors, the interaction of photons and graphene, the properties of the photogenerated carriers, and the transport of the photocarriers are fundamentally different from those in conventional group IV and III–V materials. These unique properties of graphene enable very high bandwidth (potentially 0.500 GHz) light detection, very wide wavelength detection range, zero dark current operation, good internal quantum efficiency and ease of fabrication.

Splendiani et al. [13] revealed a surprising emergence of photoluminescence in MoS_2 layers. This observation is consistent with the theoretical prediction of indirect to direct bandgap transition in going from multilayer to monolayer MoS_2. Such behaviour, arising from d-orbital related interactions in MoS_2, may also arise in other layered transition metal dichalcogenides.

Klemm et al. [14] have generated a new family of nanocellulos (MFC, NCC & BNC) from nature based materials. It has been shown that the cellulose microfibrils present in wood can be liberated by high-pressure homogenizer procedures. The product, microfibrillated cellulose (MFC), exhibits gel-like characteristics. A second type of nanocellulose, nanocrystalline cellulose (NCC), is generated by the removal of amorphous sections of partially crystalline cellulose by acid hydrolysis. NCC suspensions have liquid-crystalline properties. In contrast to MFC and NCC, which are prepared from already biosynthesized cellulose sources, third nanocellulose variant, bacterial nanocellulose (BNC), is prepared from low-molecular-weight resources, such as sugars, by using acetic acid bacteria of the genus Gluconacetobacter.

Robinson et al. [15] developed nanosized, reduced graphene oxide (nano-rGO) sheets with high near-infrared (NIR) light absorbance and biocompatibility for potential photothermal therapy. The single-layered nano-rGO sheets were ∼20 nm in average lateral dimension, functionalized noncovalently by amphiphilic PEGylated polymer chains to render stability in biological solutions and exhibited 6-fold higher NIR absorption than nonreduced, covalently PEGylated nano-GO. Attaching a targeting peptide bearing the Arg-Gly-Asp (RGD) motif to nano-rGO afforded selective cellular uptake in U87MG cancer cells and highly effective photoablation of cells in vitro.

Bertolazzi et al. [16] show that monolayer MoS_2 is a flexible and strong material with a high Young's modulus, comparable to stainless steel. The measured strength of monolayer MoS_2 is close to the theoretical intrinsic strength of the Mo-S chemical bond, indicating that the monolayer is mostly free of defects and dislocations capable of reducing mechanical strength. As MoS_2 can be readily dispersed in a wide variety of solvents, it could be interesting as a reinforcing element in composites. The presence of sulphur in MoS_2 could furthermore allow easy functionalization and efficient load transfer between MoS_2 and the composite matrix.

Yin et al. [17] have developed a facile preparation strategy for MoS_2– MoO_3 hybrid nanomaterials through heat assisted partial oxidation of MoS_2 nanosheets in air followed by the subsequent thermal-annealing-driven crystallization. The obtained MoS2–MoO_3 material exhibited p-type conductivity. As a proof-of-concept application, an n-SiC/p-MoS_2–MoO_3 heterojunction was applied in LEDs.

Huang et al. [18] has discussed about the graphene-based nanomaterials for flexible and wearable supercapacitors. Freestanding compact graphene-based paper electrodes are mechanically flexible and possess a high electrical conductivity, but they show only a moderate rate capability and power density owing to their limited porous structures. In contrast, 3D porous graphene-based electrodes show good rate capability, while they usually have limited mechanical strength and need some flexible support substrate to endow them with flexibility. Fibre-shaped supercapacitors are very flexible and can be woven into fabrics with excellent wearability and breathability.

III. CONCLUSIONS

Nanomaterials have taken the position of many conventional materials because of its wide applications and advantages. By changing the size of the particles to nanoscales, material's mechanical, physical and even chemical properties also change. Nanomaterials are today widely used in textiles, bio-medical, energy sources such as rechargeable batteries, cosmetics, food preservations, etc. For the properties which cannot be attained by conventional materials, lot of advancement is being taking place in nanomaterials. This review shares some of the advancements achieved in nanomaterials.

REFERENCES

[1] Beg S., Rizwan M., Sheikh A.M., M. Hasnain S., Anwer K. and Kohli K. (2011), "Advancement in carbon nanotubes: basics, biomedical applications and toxicity, *JOURNAL OF PHARMACY AND PHARMACOLOGY*, pp 141–163.
[2] Mcintyre R.A. (2012), "Common nano-materials and their use in real world applications", *Science Progress*, 95(1), pp 1-22.
[3] Morones J.R., Elechiguerra J.L., Camacho A., Holt K., Kouri J.B., Ram´ırez J.T. and Yacaman M.J. (2005), "The bactericidal effect of silver nanoparticles", *NANOTECHNOLOGY*, Volume: 16, Issue: 10, pp 2346-2353.
[4] Li W., Xu L. and Chen J. (2005), "Co_3O_4 Nanomaterials in Lithium- Ion Batteries and Gas Sensors", *ADVANCED FUNCTIONAL MATERIALS*, Volume: 15, Issue: 5, pp 851-857.
[5] Li D., Müller M.B., Gilje S., Kaner R.B., Wallace G.G. (2008)," Processable aqueous dispersions of graphene nanosheets", *NATURE NANOTECHNOLOGY*, Volume: 3, Issue: 2, pp 101-105.
[6] Si Y. and Samulski E.T. (2008), "Exfoliated Graphene Separated by Platinum Nanoparticles", *CHEMISTRY OF MATERIALS*, Volume: 20, Issue: 21, pp 6792-6797.
[7] Bruce P.G., Scrosati B., Tarascon J. (2008), "Nanomaterials for Rechargeable Lithium Batteries", *ANGEWANDTE CHEMIE*, Volume: 47, Issue: 16, pp 2930-2946.
[8] Kim K.S., Zhao Y., Jang H., Lee S.Y., Kim J.M., Kim K.S., Ahn J., Kim P., Choi J. & Hong B.H. (2009)," Large-scale pattern growth of graphene films for stretchable transparent electrodes", *NATURE*, Volume: 457, Issue: 7230, pp 706-710.
[9] Wang H., Casalongue H.S., Liang Y., and Dai H. (2010), "$Ni(OH)_2$ Nanoplates Grown on Graphene as Advanced Electrochemical Pseudocapacitor Materials", *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY* Volume: 132, Issue: 21, pp 7472-7477.
[10] He S., Song B., Zhu D.L.C., Qi W., Wen Y., Wang L., Song S., Fang H. and Fan C. (2010), "A Graphene Nanoprobe for Rapid, Sensitive, and Multicolor Fluorescent DNA Analysis", *ADVANCED FUNCTIONAL MATERIALS*, Volume: 20, Issue: 3, pp 453-459.
[11] Hu W,, Peng C., Luo W., Lv M., X., Li D., Huang Q., Fan C. (2010), "Graphene-Based Antibacterial Paper", *ACS NANO*, Volume: 4, Issue: 7, pp 4317-4323.
[12] Xia F., Mueller T., Lin Y., Valdes-Garcia A. and Avouris P. (2010), "Ultrafast graphene photodetector", *CONFERENCE ON LASERS AND ELECTRO-OPTICS*.
[13] Splendiani A., Sun L., Zhang Y., Li T., Kim J., Chim C., Galli G. and Wang F. (2010), "Emerging Photoluminescence in Monolayer MoS_2", *NANO LETTERS*, Volume: 10, Issue: 4, pp 1271-1275.
[14] Klemm D., Kramer F., Moritz S., Lindstrm T., Ankerfors M., Gray D. and Dorris A. (2011), "Nanocelluloses: A New Family of Nature-Based Materials", *ANGEWANDTE CHEMIE*, Volume: 50, Issue: 24, pp 5438-5466.
[15] Robinson J.T., Tabakman S.M., Liang Y., Wang H., Casalongue H.S., Vinh D. and Dai H. (2011), "Ultrasmall Reduced Graphene Oxide with High Near-Infrared Absorbance for Photothermal Therapy", *JOURNAL OF THE AMERICAN CHEMICAL SOCIETY*, Volume: 133, Issue: 17, pp 6825-6831.
[16] Bertolazzi S., Brivio J. and Kis A. (2011), "Stretching and Breaking of Ultrathin MoS_2", *ACS NANO*, Volume: 5, Issue: 12, pp 9703-9709.

[17] Yin Z., Zhang X., Cai Y., Chen J., Wong J.I., Tay Y., Chai J., Wu J., Zeng Z., Zheng B., Yang H.Y., and Zhang H. (2014)," Preparation of MoS2–MoO3 Hybrid Nanomaterials for Light-Emitting Diodes", *Angewandte Chemie*, Volume126, Issue46.
[18] Huang L., Santiago D., Loyselle P., and Dai L. (2018), "Graphene-Based Nanomaterials for Flexible and Wearable Supercapacitors", *SMALL JOURNAL*, Volume 14, Issue 43.