Preparation and Characterization of Amorphous Carbon Nanotube-MoS2 Nanohybrid

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***Abstract*: Recently amorphous carbon nanotube have become alternative to the crystalline carbon nanotube due to their easy synthesis procedure. Numerous properties of amorphous CNT can be varied through hybridizing it with several nanomaterial. MoS2 nanosheets has good optoelectronic and physical property, which makes it suitable as an additive with other material. In this work, amorphous CNT – MoS2 nanohybrid were synthesized by using hydrothermal method. Amorphous carbon nanotube has been prepared separately through a low temperature synthesis process. Nanohybrids were characterized by using X-ray diffraction, field emission scanning electron microscope, high resolution transmission electron microscope, energy-dispersive X-ray spectroscopy. Band gap of as prepared hybrids were also calculated.**

***Keywords*: amorphous carbon nanotube, MoS2, nanohybrids.**

1. Introduction

In recent days, nanostructure material plays a vital role in the field of nanoscience and nanotechnology. Electronic devices are shrinking day by day as devices are becoming nanometer size. Though silicon is most useful material for semiconductor device fabrication for some good features. Researchers are doing extensive studies for developing other zero, one and two dimensional material, so that they can be useful in modern device fabrication. Among all the nanostructure material, carbon nanotube [1] is most interesting two dimensional material due to its amazing optical, electronic and mechanical properties [2]-[4] which makes them suitable for microelectronics device fabrication. Depending on its crystalline property, it can be classified into two types such as crystalline carbon nanotube [5] and amorphous carbon nanotube [6]. So far, several methods like arc discharge [7], laser ablation [8], chemical vapour deposition[9] have been discovered for preparation of crystalline carbon nanotube. However, these methods are very complicated and require high temperature like above 800^0C. On the other hand, amorphous carbon nanotube can be synthesized by simple chemical process and it almost require very less temperature such as 225^0C. Furthermore, defects and dangling bond in amorphous CNT makes them suitable to react with environment easily and can formed in different nanostructure hybrids. On the other hand, among metal chalcogenides [10], MoS2 is very important material due to its fascinating electronic and physical property [11]-[22]. Bulk MoS2 is an indirect band gap material with band gap of 1.2 eV whereas MoS2 nanosheets is a direct band gap material with band gap of 1.8 eV. Owing to its fascinating properties, it is widely used in energy storage [23], solar cells [24], wearable devices [25], catalysis [26], double-layer capacitors [27], lubricants [28], photo emitting devices [29], hydrogen storage [30]. MoS2 is used to enhance the piezoelectricity of polymer based Nano generator [31-41]. For synthesis of MoS2 Nano sheets, several methods like liquid exfoliation [42], wet chemical reaction [43], hydrothermal process [44], chemical vapour deposition[45] etc. have been discovered. Here in this paper, amorphous carbon nanotube – MoS2 nanohybrid synthesis procedure and its characterisation has been done.

2. Material and Methods

Ferrocene ($(C_5H_5)_2Fe$, Merck), ammonium chloride (NH4Cl) and hydrochloric acid (HCl) are the main material used in this process. For synthesis of amorphous CNT, first ferrocene and ammonium chloride were taken in 1:2 weight ratio. Then weighted material placed in a mortar and grinded very well. After that, the mixture were placed in a quartz beaker and kept it in an oven with 225^0C for 30 minutes. Then the black product was washed with DI-water and dilute HCL repeteadly for removing the impurity present in amorphous CNT. Then final product was kept in an oven with 60^0C for 24 hrs.

For synthesis of amorphous CNT-MoS2 nanohybrid, 2 mmol of sodium molybdate dihydrate were dissolved together in 50 ml deionized (DI) water for 2 min. Then, 10 mmol of L-cysteine was added to the solution followed by sonication for 30 minutes. Afterthat, 10 M HCl was added to the solution drop by drop until the pH value of the solution was become less than 1. This solutions were stirred for 30 minutes for making a homogeneous solutions. Then the solutions were transferred into a teflon lined stainless steel autoclave and 0.5 g of as prepared amorphous CNT were poured into it. Solutions contained autoclave were kept in a hot air oven at 200^0C for

Table 1
Compositional analysis of amorphous CNT – MoS2 hybrid sample from EDX study

Element Line	Net Counts	Net Counts Error	Int. Cps/nA	Int. Error	Weight %	Weight % Error	Atom %	Atom % Error	Formula
C K	1025	+/- 96	---	---	25.88	+/- 0.81	48.00	+/- 4.50	C
O K	1910	+/- 183	---	---	21.53	+/- 0.69	29.97	+/- 2.87	O
S K	11560	+/- 1308	---	---	21.23	+/- 0.80	14.75	+/- 1.67	S
S L	0	+/- 51	---	---	---	---	---	---	
Mo L	12889	+/- 1914	---	---	31.36	+/- 1.55	7.28	+/- 1.08	Mo
Mo M	142	+/- 60	---	---	---	---	---	---	
Total					100.00		100.00		

25hrs. Finally, the heated solutions were kept in room temperature for a definite time and washed with di-water and ethanol repeatedly. Finally, the product was dried at 60^0C for 16 hrs.

3. Characterization and results

Amorphous CNT – MoS2 nanohybrids has been characterized by field emission scanning electron microscope (JEOL 6340F FEG-SEM), high resolution transmission electron microscope (JEOL-JEM 2100), X-ray diffraction (XRD, Bruker), energy-dispersive X-ray spectroscopy.

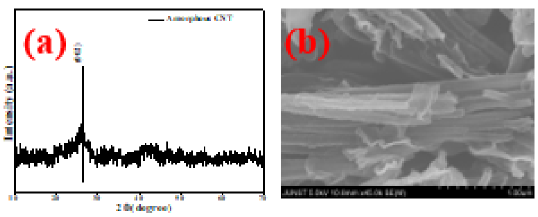

Fig. 1. (a) XRD and (b) FE-SEM image of amorphous carbon nanotube

Figure 1(a) shows the FE-SEM image of amorphous carbon nanotube sample. From there it can be observed the formation of carbon nanotube. Figure 1(b) shows the XRD pattern taken using Cu Kα radiation (wavelength λ = 0.15418 nm) with normal θ-2θ scanning in the range between 10 - 70 ° of as synthesized amorphous carbon nanotube. Sample shows one peak centering around 2θ ≈ 26.5 ° which is the for the (002) plane of 2 dimensional graphitic phase of carbon. However, the peaks is not prominent which means it has poor crystallinity.

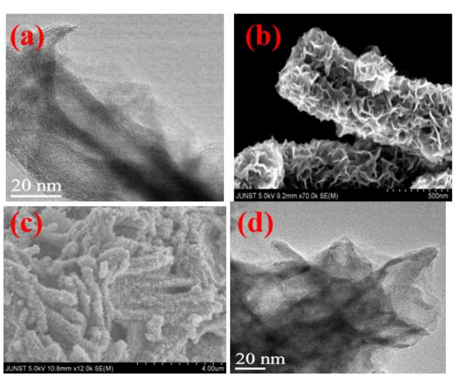

Fig. 2. (a and b) FE-SEM and (c and d) HRTEM images of amorphous CNT – MoS2 nanohybrid

From FE-SEM and HRTEM images, it is clearly observed the formation of MoS2 nanosheets decorated amorphous carbon nanotube. Compositional analysis of as prepared nanohybrids were done by EDAX analysis. From there, it is observed that atom ratio between Mo and S is about 1:2.026, which is very close to the stoichiometric MoS2. Apart from Mo and S, there are also present carbon element which is corresponds to amorphous carbon nanotube.

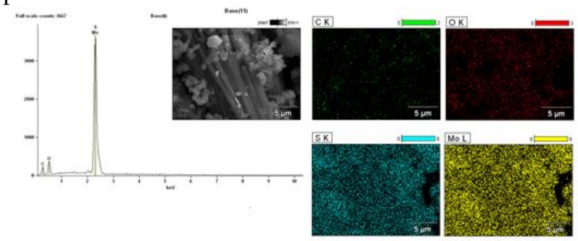

Fig. 3. EDX spectra of ACNT – MoS2 hybrid sample with corresponding elemental mapping

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. Here, XRD pattern of amorphous CNT-MoS2 nanohybrid have been taken using Cu Kα radiation (wavelength λ = 0.15418 nm) with normal θ-2θ scanning in the range between 10 - 80°. There is present two hump at in the XRD pattern of ACNT-MoS2 sample at 2θ = 33^0 and 56.63^0 which is corresponds to the (100) and (110) plane of MoS2. On the other side, band gap is a major factor for determining optoelectronic properties of any nanomaterial. Specially the electrical conductivity can be figure out from band gap study. Here band gap of as synthesized sample has been determined by using tauc plot and its estimated value is 2.6 eV.

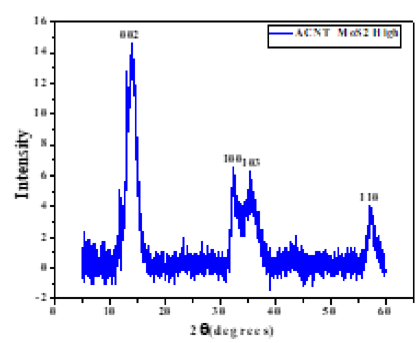

Fig. 4. XRD pattern amorphous CNT – MoS2 nanohybrid

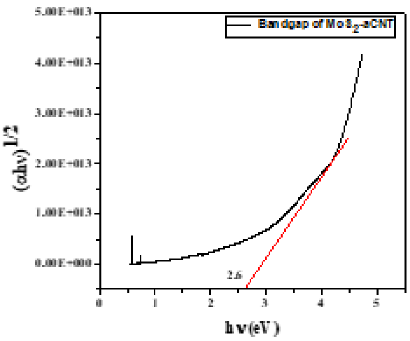

Fig. 5. Band gap plot of amorphous CNT – MoS2 nanohybrid

4. Conclusion

Synthesis procedure of amorphous carbon nanotube are quiet easy and it can be used as a replacement of crystalline carbon nanotube in several application by growing it with some other nanomaterial. Amorphous-CNTs have been successfully synthesized via a relatively simple technique. The detection of hydroxyl groups implies that the walls of the nanotubes are amorphous, with the introduction of numerous defects. Here amorphous CNT- MoS2 nanohybrids has been synthesized by using hydrothermal process. These composite may be useful for removing toxic dye from water and supercapacitor application.

References

[1] S. Iijima, Helical microtubules of graphitic carbon. Nature 354 (1991) 56–58.
[2] E. Flahaut, A. Peigney, C. Laurent, C. Marliere, F. Chastel, A. Rousset, Carbon nanotube– metal–oxide nanocomposites: microstructure, electrical conductivity and mechanical properties, Acta Mater. 48 (14) (2000) 3803–3812.
[3] D. Silambarasan, V.J. Surya, V. Vasu, K. Iyakutti, Single walled carbon nanotube– metal oxide nanocomposites for reversible and reproducible storage of hydrogen, ACS Appl. Mater. Interfaces 5 (21) (2013) 11419–11426.
[4] M. G. Willinger, G. Neri, A. Bonavita, G. Micali, E. Rauwel, T. Herntrich, N. Pinna, "The controlled deposition of metal oxides onto carbon nanotubes by atomic layer deposition: examples and a case study on the application of V2O4 coated nanotubes in gas sensing," Phys. Chem. Chem. Phys. 11 (19) (2009) 3615–3622.
[5] Wei-WenLiu, Siang-PiaoChai, Abdul Rahman Mohamed, U. Hashim. Synthesis and characterization of graphene and carbon nanotubes: A review on the past and recent developments. Journal of Industrial and Engineering Chemistry. Volume 20, Issue 4, 25 July 2014, Pages 1171-1185.
[6] Kim Han Tan, Roslina Ahmad, Bey Fen Leo, Ming Chian Yew, Bee Chin Ang, Mohd Rafie Johan. Physico-chemical studies of amorphous carbon nanotubes synthesized at low temperature. Materials Research Bulletin 47 (2012) 1849–1854.
[7] M. I. Mohammad, Ahmed A. Moosa, J. H. Potgieter and Mustafa K. Ismael. Carbon Nanotubes Synthesis via Arc Discharge with a Yttria Catalyst. Hindawi ISRN Nanomaterials, volume 2013 (2013).
[8] Justyna Chrzanowska, Jacek Hoffman, Artur Małolepszy, Marta Mazurkiewicz, Tomasz A. Kowalewski, Zygmunt Szymanski, Leszek Stobinski. Synthesis of carbon nanotubes by the laser ablation method: Effect of laser wavelength. Volume 252, Issue 8, August 2015, pp. 1860–1867.
[9] Sayangdev Naha, Ishwar K. Puri, "A model for catalytic growth of carbon nanotubes". Journal of Physics D: Applied Physics. 41 (6), 2008.
[10] Wonbong Choi. Nitin Choudhary. Gang Hee Han. Juhong Park. Deji Akinwande. Young HeeLee. Recent development of two-dimensional transition metal dichalcogenides and their applications. Materialstoday. Volume 20, Issue 3, April 2017, pp. 116-130.
[11] Q. H. Wang, K. Kalantar-Zadeh, A. Kis, J. N. Coleman, M.S. Strano. Electronics and optoelectronics of two-dimensional transition metal dichalcogenides. Nat. Nanotechnol. 2012, 7, 699–712.
[12] F. H. L. Koppens, T. Mueller, P. Avouris, A.C. Ferrari, M. S. Vitiello, M. Polini. Photodetectors based on graphene, other two-dimensional materials and hybrid systems. Nat. Nanotechnol. 2014, 9, 780–793.
[13] A. Castellanos-Gomez, N. Agraït, G. Rubio-Bollinger. Optical identification of atomically thin dichalcogenide crystals. Appl. Phys. Lett. 2010, 96, 213116.
[14] H. Li, G. Lu, Z. Yin, Q. He, H. Li, Q. Zhang, H. Zhang. Optical Identification of Single- and Few-Layer MoS2 Sheets. Small 2012, 8, 682–686.
[15] M. Buscema, G. A. Steele, H. S. J. van der Zant, A. Castellanos-Gomez. The effect of the substrate on the Raman and photoluminescence emission of single-layer MoS2. Nano Res. 2014, 7, 561–571.
[16] K. Liu, J. Feng, A. Kis, & A. Radenovic. Atomically thin molybdenum disulfide nanopores with high sensitivity for DNA translocation. ACS Nano 8, 2504-2511.
[17] J. Brivio, D. T. Alexander, & A. Kis. Ripples and layers in ultrathin MoS2 membranes. Nano Lett 11, 5148-5153.
[18] S. V. Prabhakar Vattikuti, C. Byon. Synthesis and characterization of molybdenum disulfide nanoflowers and nanosheets: Nanotribology. Hindawi Publishing Corporation, Journal of Nanomaterials. 2015.
[19] M. A. Lukowski, A. S. Daniel, F. Meng, A. Forticaux, L. Li, S. Jin. Enhanced hydrogen evolution catalysis from chemically exfoliated metallic MoS2 nanosheets. Journal of American Chemical Society. 2013, 135(28), 10274–10277.
[20] Y. Tian, J. Zhao, W. Fu, Y. Liu, Y. Zhu, Z. Wang. A facile route to synthesis of MoS2 nanorods. Materials Letters. 2005,59, 3452–3455.
[21] Hari Sarkar, Binoy Bera, Sudakshina Kundu. Sleep Mode Transistor Sizing Effect of MTCMOS Inverter Circuit on Performance in Deep Submicron Technology. Global Journal of Trends in Engineering (GJTE) Vol. 2, no. 4, 2015.
[22] Binoy Bera, Madhumita Das Sarkar. Piezoelectric Effect, Piezotronics and Piezophototronics: A Review. Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-11, 2016.
[23] Binoy Bera. Silicon Wafer Cleaning: A Fundamental and Critical Step in Semiconductor Fabrication Process. International Journal of Applied Nanotechnology. 2019; 5 (1): 8–13p.
[24] Binoy Bera. Synthesis, Properties and Applications of Amorphous Carbon Nanotube and MoS2 Nanosheets: A Review. Nano Trends: A Journal of Nanotechnology and Its Applications. 2019; 21(1): 36–52p.
[25] Binoy Bera. Hydroxyapatite, Synthesis of numerous CdS quantum dot composite material: A Review. International Journal of Nanomaterials and Nanostructure. 2019; 5 (1) 1–11p.
[26] Binoy Bera. Porous Silicon and its Nanoparticles: A Theoretical Study. International Journal of Applied Nanotechnology.2019; 5 (1): 14–18p.
[27] Binoy Bera. Synthesis and Applications of ACNT-MoS2 Nanocomposite. A Review. International Journal of Nanomaterials and Nanostructure. 2019; 5 (1) 31–38p.
[28] Diana Berman, Ali Erdemir, Anirudha V. Sumant. Graphene: a new emerging lubricant. Materials Today, Volume 17, Issue 1, January–February 2014, pp. 31-42.
[29] Mehmet Copuroglu, Pinar Aydogan, Emre O. Polat, Coskun Kocabas, and Sefik Süzer. Gate-Tunable Photoemission from Graphene Transistors. Nano Lett., 2014, 14 (5), pp 2837–2842. DOI: 10.1021/nl500842y.
[30] Hamid Ghorbani Shiraz, Omid Tavakoli. Investigation of graphene-based systems for hydrogen storage. Renewable and Sustainable Energy Reviews, Volume 74, July 2017, Pages 104-109.
[31] B. Bera. Literature Review on Electrospinning Process (A Fascinating Fiber Fabrication Technique). Imperial Journal of Interdisciplinary Research (IJIR). Vol. 2, Issue 8, 2016.
[32] B. Bera, Madhumita Das Sarkar. Piezoelectricity in PVDF and PVDF Based Piezoelectric Nanogenerator: A Concept. IOSR Journal of Applied Physics (IOSR-JAP). Volume 9, Issue 3 Ver. I, PP 95-99.
[33] Binoy Bera, Dipankar Mandal, Madhumita Das Sarkar. Sensor Made of PVDF/graphene Electrospinning Fiber and Comparison between Electrospinning PVDF Fiber and PVDF/graphene Fiber Imperial Journal of Interdisciplinary Research (IJIR). Vol. 2, Issue 5, 2016.

[34] Binoy Bera, Madhumita Das Sarkar. Gold Nanoparticle Doped PVDF Nanofiber Preparation of Concurrently Harvesting Light and Mechanical Energy. IOSR Journal of Applied Physics (IOSR-JAP). Volume 9, Issue 3 Ver. III (May - June 2017), pp. 05-12.
[35] Binoy Bera, Madhumita Das Sarkar. PVDF based Piezoelectric Nanogenerator as a new kind of device for generating power from renewable resources. IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE). Volume 4, Issue 2 (Mar. - Apr. 2017), pp. 01-05.
[36] Binoy Bera. preparation of polymer nanofiber and its application. Asian journal of physical and chemical sciences. volume 2, issue 4, 1-4, 2017. article no. AJOPACS. 35651.
[37] BinoyBera. literature Review on Triboelectric Nanogenerator. Imperial Journal of Interdisciplinary Research, 2(10):1263-1271 January 2016.
[38] Binoy Bera. preparation of MoS2 nanosheets and PVDF nanofiber. Asian journal of physical and chemical sciences. volume 2, issue 4, 1-9, 2017.article no. AJOPACS. 35176.
[39] Binoy Bera. Nanoporous Silicon Prepared by Vapour Phase Strain Etch and Sacrificial Technique. IJCA Proceedings on International Conference on Microelectronic Circuit and System MICRO 2015(1):42-45, December 2015.
[40] BinoyBera, Dipankar Mandal, Madhumita Das Sarkar. Porous Silicon and its Nanoparticle as Biomaterial: A Review. Imperial Journal of Interdisciplinary Research (IJIR). Vol. 2, Issue11, 2016.
[41] Binoy Bera. A Review on Polymer, Graphene and Carbon Nanotube: Properties, Synthesis and Applications. Imperial Journal of Interdisciplinary Research (IJIR). Vol. 3, Issue 10, 2017.
[42] Jonathan N. Coleman, Mustafa Lotya, Arlene O'Neill, Shane D. Bergin, Paul J. King, Umar Khan, Karen Young, Alexandre Gaucher, Sukanta De (2011-02-04). Two-Dimensional Nanosheets Produced by Liquid Exfoliation of Layered Materials. Science. 331 (6017): 568–571.
[43] X.H. Zhang, C. Wang, M.Q. Xue, B.C. Lin, X. Ye, W.N. Lei, "Hydrothermal synthesis and characterization of ultrathin MoS2 nanosheets," Chalcogenide Letters Vol. 13, No. 1, January 2016, pp. 27 – 34.
[44] Qinglin Zhang, Zhanwei Xu, Hejun Li, Liyan Wu,Gaoxiang Cao & Kezhi Li. Synthesis of MoS2 Nanosheets by Solid-State Reaction in CVD Furnace. Integrated Ferroelectrics. Volume 128, Issue 1, 2011.
[45] Claudia Altavilla, Maria Sarno, and Paolo Ciambelli. A Novel Wet Chemistry Approach for the Synthesis of Hybrid 2D Free-Floating Single or Multilayer Nanosheets of MS2@oleylamine (M=Mo, W). Chem. Mater. 2011, 23, 3879–3885.