



Synthesize and Characterization of a Novel Nano Graphene Oxide Sulfolene derive

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Abstract

Carbon-based nanoparticles, particularly graphite nanoformulations have seized plenty of fancies currently, groundbreaking development is being made with these formulations and the potentials are limitless. Graphene Oxide has a huge molecular structure, carries many functional groups together with hydroxyl, carboxylic, carbonyl and epoxide companies which are best for esterification and amidation reactions. on this observe Nano graphene oxide synthesized using changed Hummer approach and novel graphene oxide sulfolene derive. The synthesized nanocomposites characterised the usage of diverse devices consisting of X-ray diffraction (XRD), Fourier transforms infrared spectroscopy (ft-IR), Proton atomic attractive reverberation (H1-NMR), territory emanation filtering electron magnifying instrument. The crystallite size for the newly synthesized compound (GOSO) from diffraction styles of X-ray turned into calculated the usage of equations: (Debye – Scherer) equation and Williamson – corridor equation and as compared between them.

Keywords: Nano graphene Oxide, graphene oxide sulfolene derive, Crystallite size, XRD

1. Introduction

Graphene oxide (pass), sub-atomic detailing (C140H42O20), sub-atomic weight (2043.8 g/mol) is a tantamount structure of graphite layer, besides the airplane of carbon – debris in graphene oxide is firmly decorated by using utilizing oxygen-containing companies [1], Graphene oxide answer is just accessible, and can be "drop strong" onto a matrix framing a graphene oxide sheet [2]. go has earn full-size consideration because of its one-of-a-kind attributes; because of the exact homes of graphene, it very well might be managed as an ideal material for different projects in the fields of physical science, science, fabric mechanical skill and designing, and science [3]. It has honeycomb carbon math, two-dimensional (second); The second erectile structure allows it to be used in various natural areas, gem mixed with one-molecule thickness, along the edge of splendid electrical, optical, warm, and mechanical homes, enormous floor district. This staggering component is yield from its synthetic structures made out of sp³ carbon spaces contiguous sp² carbon area and numerous exogenous valuable organizations which incorporate epoxy (connecting oxygen iotas), hydroxyl In the base plane, the carboxyl and carbonyl moieties encompass the edge of the nanoparticle [4, 5]. The graphene drift of relatives comprises of individuals that incorporate lessening graphene oxide (rGO) and graphene oxide (pass), graphene sheets and layered graphene's including not many multilayer and

multilayer graphene (MLG), go has a wide zone of projects comprising of; film period of separating wastewater, radiochemical squander, gases, substantial metals and CO₂ in ecological security. Terminals for strength stockpiling frameworks supercapacitors and lithium batteries [6-16]. the utilization of move composites with nanoparticles of metals and diverse functionalization as a viable regular substance impetus for various responses which incorporates amalgamation of biofuel. Synthetically altered move the utilization of as a medication administration for disease treatment [17, 18]. Metals that incorporate nanomaterials can be utilized in controlling exceptional assortments of contamination, for example, antibacterial vendors, anticancer cure, and utilized inside the broad field of bundles because of their capacity to do them because of an enormous number of the helpful partnerships of their substance frameworks [19, 20]. Nanomaterials (NMs) have gotten significance in innovative headways because of their substantial, synthetic and natural properties. NMs are sorted depending on their size, creation, structure, and beginning spot [21]. The graphene has increased a few interests especially inside the nanomedicine and biomedical field which incorporate medication delivering utility, the pass gives unprecedented stacking potential and usefulness pondering the stacking proportion can move as much as 200% which make it a suitable help for bounty biomolecules [22, 23]. Almutairi et al [24] arranged the Nanocomposites

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of Co-doped graphene oxide (cross) and are employed for the photocatalytic movement for water parting as a result of its uncommon solvency, and tunable bandgap [25]. Graphene oxide (cross) an oxidized type of graphene, has increased additional interest since it is easy to functionalize, equipped for the mark with a fluorescent test and similar with greatest biomolecules, these specific places of the move make it a promising nanomaterial for bio-application [26-28]. Carbon-based absolutely nanomaterials comprehensive of graphene and its subordinates have incredible centrality in biomedical applications. these days, hardly any scientists are zeroing in on misusing graphene-based nanohybrids for electrochemical biosensing [29]. In the most recent years, (cross) nanosheets have attracted exceptional interest different fields along with supercapacitors, batteries, and photocatalysis [30, 31]. Graphite is a semiconductor without the force of legislation, due to the small fraction of the valence band of graphite delayed to the conduction band, wherein realities snared a reason for the utilization of the real places of graphite [32-34]. as an approach to flip graphene bundles into certainty, one needs to create the material. The current examination zeroed in on another compound amalgamation strategy for building up a novel nanomaterial composite; (GOSO) graphene oxide sulfolene subordinate, affirmed with Fourier change infrared spectroscopy FT-IR, Proton atomic attractive reverberation H1-NMR, X-beam diffraction XRD and field emanation checking electron magnifying lens FESEM instruments. The crystallite size for the recently blended compound (GOSO) Debye – Scherer and Williamson – Lobby conditions.

2. Experimental

Chemical and Equipment

Graphite, hydrogen peroxide, potassium permanganate, sodium nitrate, Sulfolene from fluka, harming hydrochloric, sulfur consumption, THF, DMF from BDH.

Synthesis of Graphene oxide (GO)

The graphene oxide was set up from graphite powder by the changed Hummer strategy [35, 36]. Two-gram of graphite was added to 50 ml cool concentrated sulphuric corrosive (H_2SO_4) and blended in an ice bath for 15 minutes. At that point one gram of sodium nitrate $NaNO_3$ (11.7 mmol.) and 6 gram of potassium permanganate ($KMnO_4$) (37.9 mmol.) was conveyed to the appropriate response and blended in an ice shower for two hrs. The ice-tub eliminated furthermore, the temperature of the blend changed into kept at $35^\circ C$ in a water bath, for a half-hour. From that point forward, the blend got pale (profound pink-earthy colored tone). Deionized water 50 ml had been added, it raised-up to $90^\circ C - 98^\circ C$. The total got weakened through the expansion of 250 ml of warmth

deionized water and hydrogen peroxide 30% (~30 mL) brought until the appropriate response developed to become to clear yellow. The response thing was centrifuged and washed with deionized water and 5% HCl, course of action again and again. sometime, the item got dried at $40^\circ C$ for 24 hrs. [37,38], this progression as demonstrated in figure 1.

Graphene oxide with sulfolene

In a dried beaker 250 mL, weight 0.2 g of grapheme oxide (0.097 mmol.) that prepared in step 2.1 and mixed with 100 ml of Dimethylformamide DMF, this mixture sonicated for 1hr. in room temperature to form a homogenous solution, 7.2 g of 3-sulfolene (59.9 mmol.) was added into combination with refluxing for 1 hr. at $80^\circ C$. After the response became completed, the item washed with ethanol a few times to kill the entirety of the unreacted 3-sulfolene, the strong item changed into at last dried [39], this step as proven in figure 2.

3. Result and Discussion

FTIR assessment changed into used to see the intentional associations blessing inside the (move) and (GOSO), observe 3a and 3b recommends the ft-IR range of (move) and (GOSO) powders separately, the (go) range shows the top at 3386.39 cm^{-1} considering O-H widening vibration, 1724.36 cm^{-1} become weighty C=O extending band, and top at 16.228 cm^{-1} , 1378.85 cm^{-1} can be credited to C=C connecting of fragrant ring, C-Kindhearted bowing independently, the brand name top at $1029.\text{eight}\text{ cm}^{-1}$ by goodness of C-O epoxy establishment [35]. notice 3b proposes (GOSO) range the top at 3419.17 cm^{-1} for Beneficent affiliations widening, 1643.05 cm^{-1} considering C=O ester extending vibration, the top at 1569. 77 is credited to C=C fragrant ring, the apexes 1350.69, 1150. 53 cm^{-1} offered out to the uneven and symmetric of S=O bonds, in like manner 1127.19, 1024.02 and 953.627 cm^{-1} considering C-O, epoxy, S-O bowing separately [44].

H^1 -NMR spectra of graphene oxide (GO) show the brand name tops at Figure 4 at (8.08) ppm is committed to the proton of -COOH parties, (7.50) ppm is singlet named to the protons of - Goodness phenolic social events, the singlet that shows up at (7) ppm is administered to the phenyl parties. Every one of them is weak and expansive due to the de-making sure about of the electron thickness that yielded by the hydrogen holding between the (GO) layers of graphene oxide which prompts decrease the substance move of the protons. The singlet, Figure 5 (2.5) ppm is has a spot with the dissolvable (c).

The top at (3.75) ppm is singlet assigned to the –CH groups that additionally S get-together to influence substance move [45]. Figure 4, Figure 5 (GOSO), the tops at (2.32, 2.75) ppm are allowed to the dissolvable, Figure 4 (8.17) ppm because of H-iotas of carboxyl get-togethers of (GO), Figure 5 (6.09) ppm multiplet are an immediate consequence of H-particles of phenyl gathering [46].

X-Ray Diffraction (XRD) of graphene oxide as showed up in Figure 6, massive interlayer dividing indistinguishable from 8.06 Å at the position ($2\theta = 10.97^\circ$) dissipating of the top at 26° considering oxidized after the compound oxidation and stripping [35].

In Figure 7 the (XRD) of (GOSO) shows different summits show up ($2\theta = 10.97$) at d-confining 8.06 Å (0.806) nm display to (GO). Precisely when the functionalization of the 3-sulfolene with (GO), the interlayer detaching was besides advanced by these trades. Thus, appearing differently in relation to the development of the interlayer of the (GO) sheets from 0.806 nm to join six pinnacles $2\theta = 34.02, 38.80, 48.86, 49.51, 54.73$ and 55.35 need to d-dissipating 2.63° (0.263) nm, 2.63° (0.263) nm, 1.86° (0.186) nm, 1.83° (0.183) nm, 1.67° (0.167) nm, and 1.65° (0.165) nm only [39].

Crystallite size

The diffraction styles of X-beam for the recently blended compound crystallite length had been determined with regards to (Debye-Scherrer) condition [47].

$$D = (k \lambda) / (\beta \times \cos^2 \theta) \dots \dots \dots (1)$$

where; D: the crystallite size, λ : X-beam frequency (nm), β : 1/2-width at half greatest (HWHM), alright:

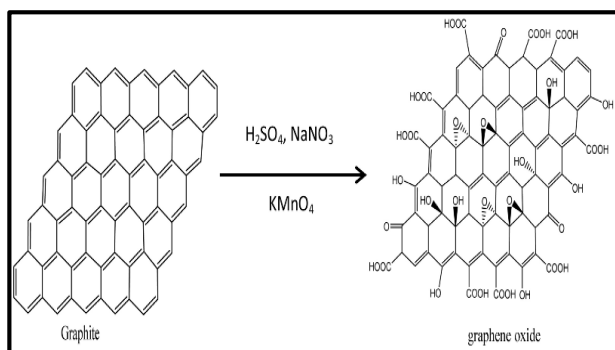


Figure 1: preparation of grapheme oxide

is s related, hape viewpoint, regularly taken as 0.nine. θ is the x-beam point. in sync with the condition (1), the determined crystallite length of (go) is (sixteen) nm anyway for the elective compound (GOSO) (34.96) nm.

The other equation used to calculate the crystallite size called (Williamson – Hall) (W-H) condition [48]:

$$\beta \times \cos^2 \theta = [(k \lambda) / (D)] + [4 \epsilon \times \sin \theta] \dots \dots (2)$$

Where ϵ the microstrain of particles, the chose crystallite size from reasonable between ($\sin^2 \theta$) on the x-axis, ($\beta \times \cos^2 \theta$) on the y-focus point, D is directed by block ($K \lambda / D$). Table 1 shows the evaluations of the crystallite size directed by utilizing (Williamson – Entry) condition microstrain to the GOSO (- 0.00239).

The negative appraisals of microstrain for GOSO show to retinal weight. Obviously, the association between's the (Debye – Scherer) and (Williamson – Path) conditions uncovers that the commonplace Crystallite size that constrained by utilizing (Debye – Scherer) condition was higher than the (Williamson – Passage) this is can be ascribed to the pinnacle's width relative with the crystallite size and inside tendency that one which is little when utilizing powder [17].

The grain size and surface morphology were seen by the field flood isolating electron microscopy (FESEM) strategy. FESEM pictures as demonstrated as follows. Figure 9 uncovers that for GO FESEM picture was extremely sharp edges and level surface, the dull hazy situations comprise of a few layers of sheets additionally crimped and wrinkled zones. Figure image 10 shows the appears ripples and kinked for (GOSO) in their surface which represent multilayers [18].

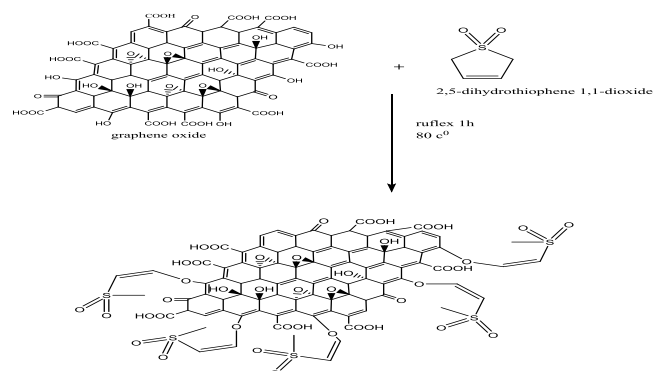


Figure 2: Preparation of Graphene oxide sulfonene

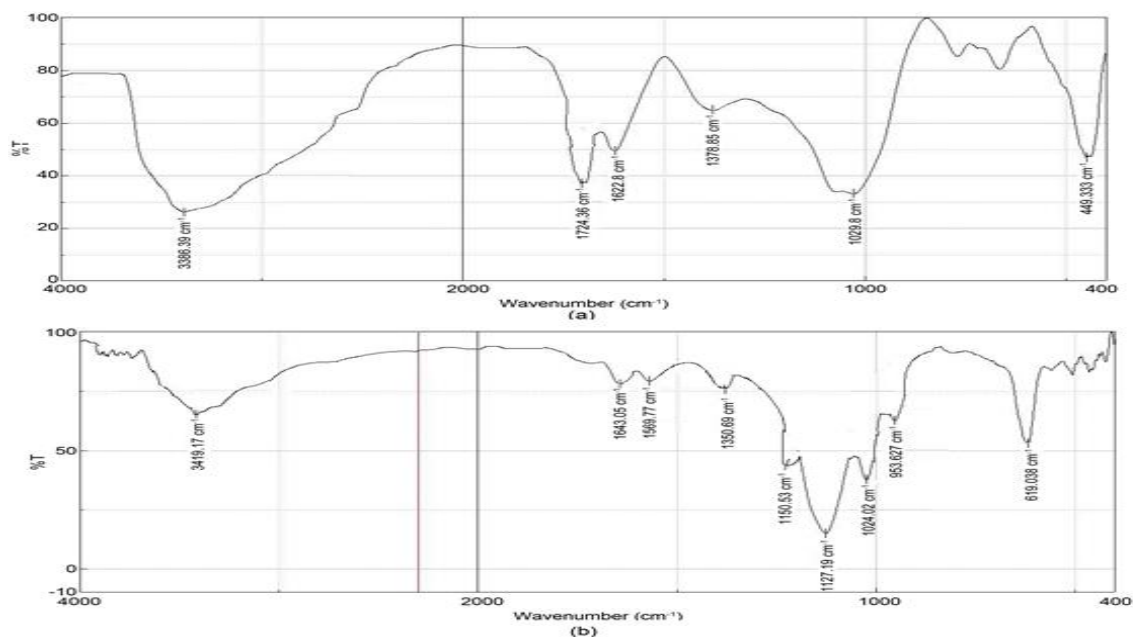
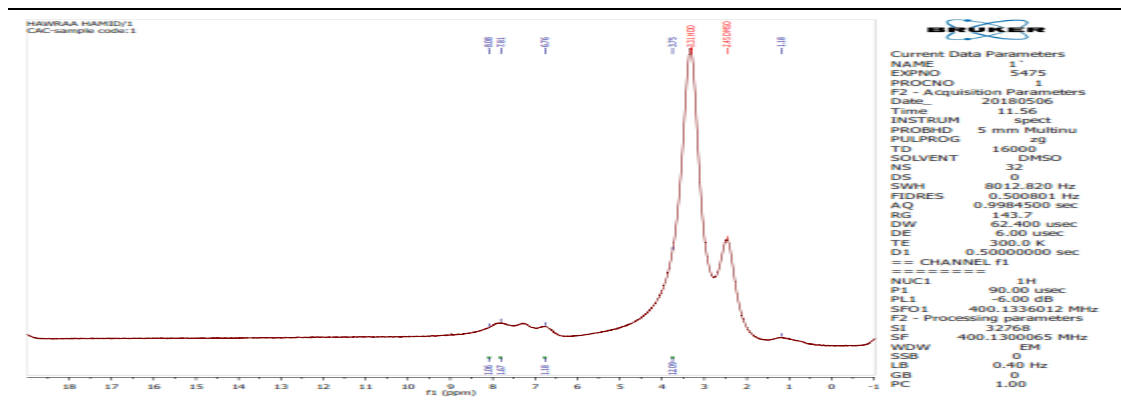
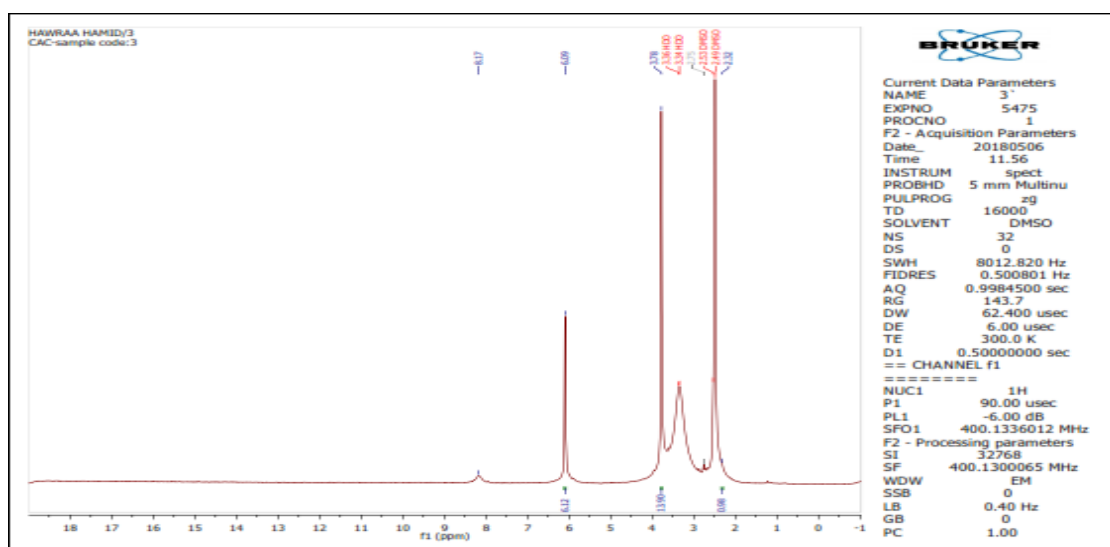


Figure 3: (a) FT-IR for Graphene oxide and (b) Graphene oxide sulfone

Figure 4: ¹H- NMR for Graphene oxideFigure 5: ¹H- NMR for Graphene oxide sulfone

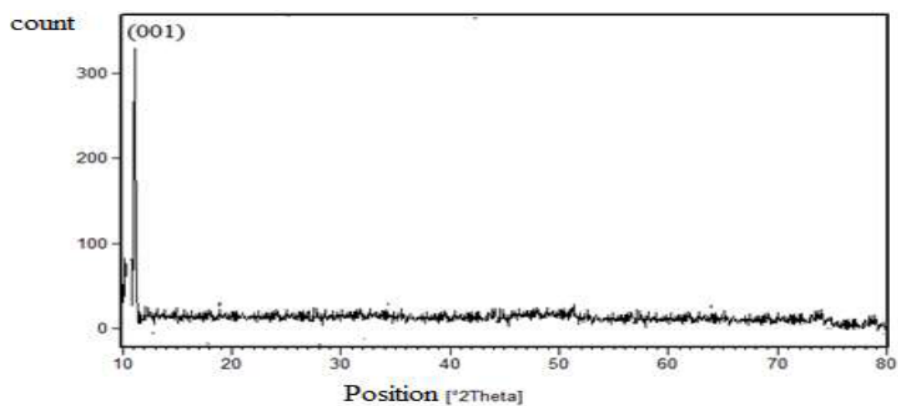


Figure 6: XRD-Diffraction for Graphene oxide

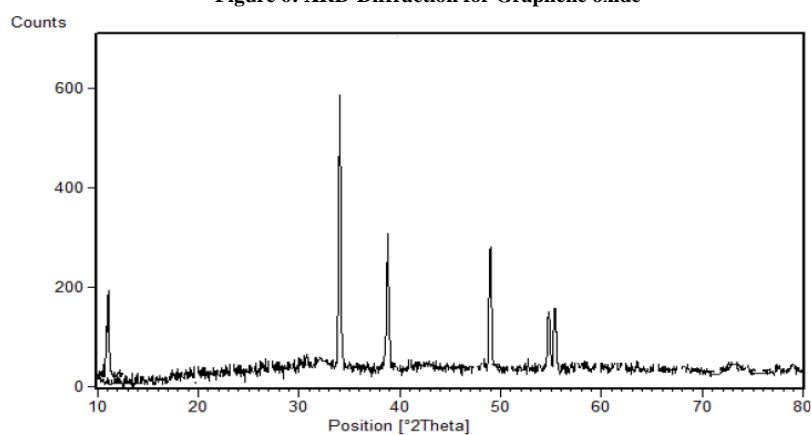


Figure 7: XRD-Diffraction for Graphene oxide sulfone

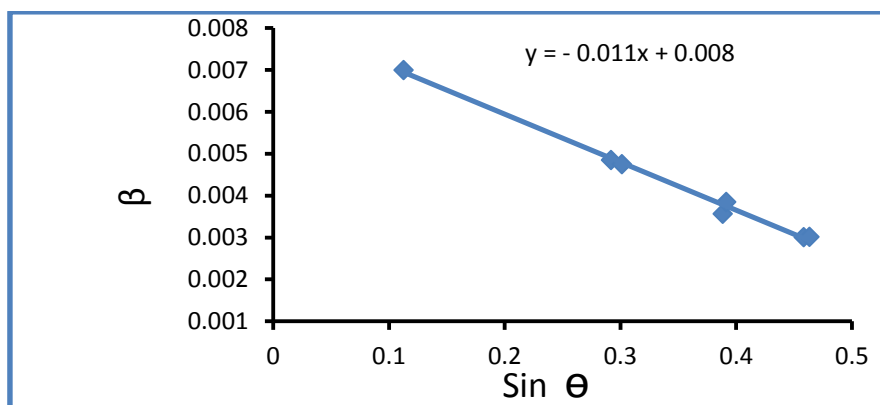


Figure 8: The estimation of crystallite size by (Williamson-Corridor) condition for GOSO

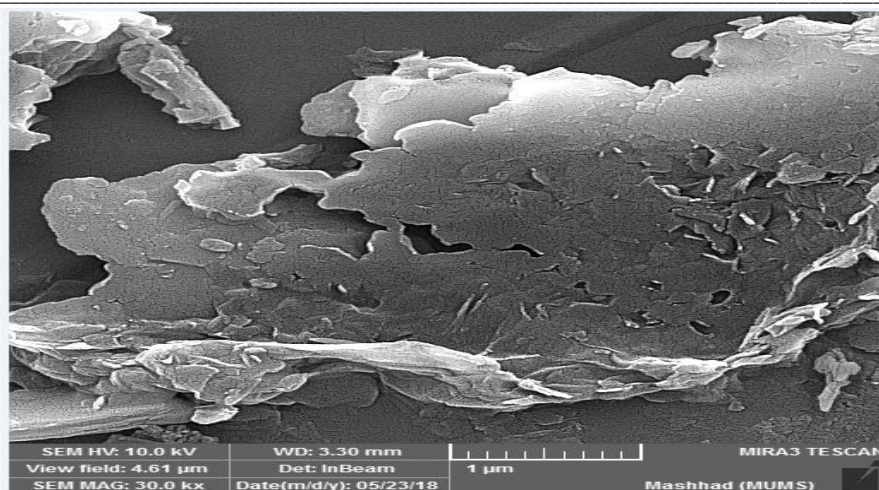


Figure 9: FESEM for Graphene oxide

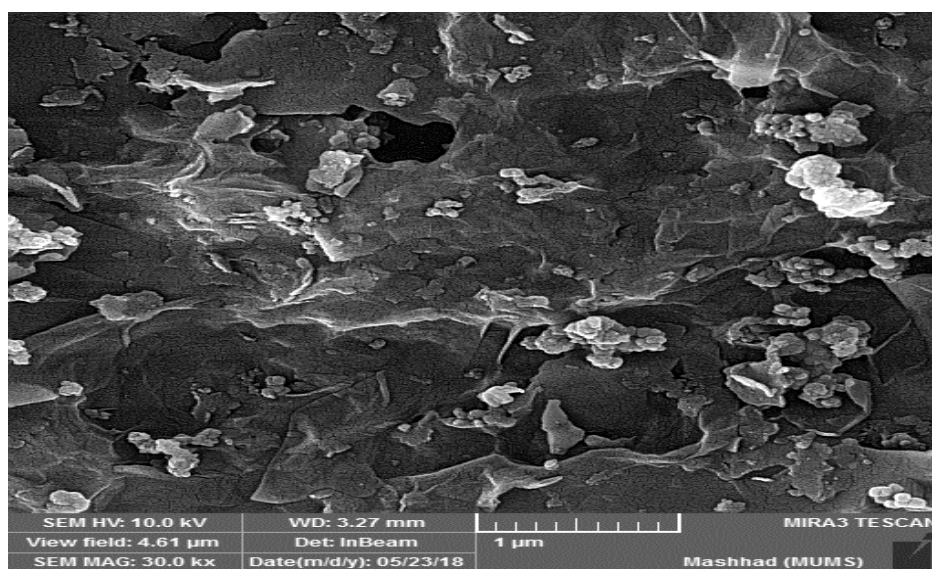


Figure 10: FESEM for Graphene oxide sulfonate

Table 1: The calculated crystallite sizes of the GOSO by using (Debye-Scherer) equation.

Compound	2θ(deg)	FWHM (rad)	D (nm)	D _{ave} .(nm)
GOSO	10.97	0.0087	16.00	34.96
	34.02	0.002901	49.95	
	38.8	0.002901	50.64	
	48.86	0.003624	41.97	
	49.51	0.00435	35.06	
	54.73	0.003624	43.02	
	55.35	0.003624	43.14	

4. Conclusion

Graphene oxide (GO) and the novel graphene oxide sulfonate (GOSO) was effectively incorporated through a changed Hummer's strategy. The presence of oxygen-containing utilitarian gatherings and trademark tops in FT-IR and XRD examination further decided the fruitful combination of GO and GOSO sheets which gave more occasions to likely utilization of GO and GOSO in various fields. This information will give a reference to the additional investigation of the idea of graphene oxide and graphene oxide sulfonate. The deshielding of the electron thickness by hydrogen holding between the layers of (GO) that prompts diminish the substance move of the proton so it shows up at the low side, while the pinnacle of (- Goodness) bunch in (GOSO) vanished due to the holding contact with 3-sulfonate which give an incredible proof to this effective compound functionalization, additionally the top at 8.17 quality to the carboxylic gathering (- COOH) of (GO) to a similar site.

The examples of XRD determined crystallite size by utilizing (Debye-Scherrer) and (William-child Corridor) conditions, thought about between (Debye-Scherrer) and (Williamson-Lobby) conditions, the normal of crystallite size utilizing (Debye-Scherrer) condition was higher than (Williamson-Corridor) condition which credited to the width tops to particles size and interior feeling which was little when the powder has utilized, additionally (GO) and (GOSO) portray by FESEM noticed dim ill-defined situations comprise of a few layers of sheets and light ill-defined situations speak to not many layers.

5. Conflicts of interest

"There are no conflicts to declare".

6. Formatting of funding sources

Self

7. Acknowledgments

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8. References

- [1] Paulchamy, B., Arthi, G. and Vignesh, B.D., 2015. A simple approach to the stepwise synthesis of graphene oxide nanomaterial. *J Nanomed Nanotechnol*, 6(1), p.1.
- [2] Randolph, Peter, Joshua Mendez, and Scott Stagg.,2018 "The Past, Present, and Future of Sample Preparation for CryoEM."
- [3] Kamel, S., El-Sakhawy, M., Anis, B. and Tohamy, H.A.S., 2019. Graphene: Structure, Synthesis, and Characterization; a brief review. *Egyptian Journal of Chemistry*, 63(Special Issue (Part 2)), 9-10.
- [4] Dreyer, D.R., Park, S., Bielawski, C.W. and Ruoff, R.S., 2010. The chemistry of graphene oxide. *Chemical society reviews*, 39(1), pp.228-240.
- [5] Rostamizadeh, S., Hemmasi, A. and Zekri, N., 2017. Magnetic amine-functionalized graphene oxide as a novel and recyclable bifunctional nanocatalyst for solvent-free synthesis of pyrano [3, 2-c] pyridine derivatives. *Nanochemistry Research*, 2(1), pp.29-41.
- [6] Yu, C., Shi, L., Yao, Z., Li, D. and Majumdar, A., 2005. Thermal conductance and thermopower of an individual single-wall carbon nanotube. *Nano Letters*, 5(9), pp.1842-1846.
- [7] Berber, S., Kwon, Y.K. and Tománek, D., 2000. Unusually high thermal conductivity of carbon nanotubes. *Physical review letters*, 84(20), p.4613.
- [8] Guo, Z., Zhang, D. and Gong, X.G., 2009. Thermal conductivity of graphene nanoribbons. *Applied physics letters*, 95(16), p.163103.
- [9] Ni, Z., Wang, Y., Yu, T. and Shen, Z., 2008. Raman spectroscopy and imaging of graphene. *Nano Research*, 1(4), pp.273-291.
- [10] Malard, L.M., Pimenta, M.A.A., Dresselhaus, G. and Dresselhaus, M.S., 2009. Raman spectroscopy in graphene. *Physics reports*, 473(5-6), pp.51-87.
- [11] Ferrari, A.C., Meyer, J.C., Scardaci, V., Casiraghi, C., Lazzeri, M., Mauri, F., Piscanec, S., Jiang, D., Novoselov, K.S., Roth, S. and Geim, A.K., 2006. Raman spectrum of graphene and graphene layers. *Physical review letters*, 97(18), p.187401.
- [12] Röhrl, J., Hundhausen, M., Emtsev, K.V., Seyller, T., Graupner, R. and Ley, L., 2008. Raman spectra of epitaxial graphene on SiC (0001). *Applied Physics Letters*, 92(20), p.201918.
- [13] Ni, Z.H., Chen, W., Fan, X.F., Kuo, J.L., Yu, T., Wee, A.T.S. and Shen, Z.X., 2008. Raman spectroscopy of epitaxial graphene on a SiC substrate. *Physical Review B*, 77(11), p.115416.
- [14] Compton, O.C. and Nguyen, S.T., 2010. Graphene oxide, highly reduced graphene oxide, and graphene: versatile building blocks for carbon-based materials. *small*, 6(6), pp.711-723.
- [15] Acik, M., Mattevi, C., Gong, C., Lee, G., Cho, K., Chhowalla, M. and Chabal, Y.J., 2010. The role of intercalated water in multilayered graphene oxide. *ACS Nano*, 4(10), pp.5861-5868.
- [16] Sanchez, V.C., Jachak, A., Hurt, R.H. and Kane, A.B., 2012. Biological interactions of graphene-family nanomaterials: an interdisciplinary review. *Chemical research in toxicology*, 25(1), pp.15-34.
- [17] Al-Saadi, T.M. and Jihad, M.A., 2016. Preparation of Graphene Flakes and Studying Its

- Structural Properties. *Iraqi Journal of Science*, 57, pp.145-153.
- [18] Shahriar, L. and Athawale, A.A., 2014. Graphene oxide synthesized by using modified hummers approach. *Int. J. Renew. Energy Environ. Eng*, 2(01), pp.58-63.
- [19] Aldujaili, N. H. and Banoon, S. R., 2020. Antibacterial Characterization of Titanium Nanoparticles Nanosynthesized by *Streptococcus Thermophilus*. *Periódico Tchê Química*. 17(34):311-320.
- [20] Priyadarsini, S., Mohanty, S., Mukherjee, S., Basu, S. and Mishra, M., 2018. Graphene and graphene oxide as nanomaterials for medicine and biology application. *Journal of Nanostructure in Chemistry*, 8(2), pp.123-137.
- [21] Jeevanandam, J., Barhoum, A., Chan, Y.S., Dufresne, A. and Danquah, M.K., 2018. Review on nanoparticles and nanostructured materials: history, sources, toxicity and regulations. *Beilstein journal of nanotechnology*, 9(1), pp.1050-1074.
- [22] Gurunathan, S. and Kim, J.H., 2016. Synthesis, toxicity, biocompatibility, and biomedical applications of graphene and graphene-related materials. *International journal of nanomedicine*, 11, p.1927.
- [23] Yin, P.T., Shah, S., Chhowalla, M. and Lee, K.B., 2015. Design, synthesis, and characterization of graphene–nanoparticle hybrid materials for bioapplications. *Chemical Reviews*, 115(7), pp.2483-2531.
- [24] Almutairi, M.M., Ebraheim, E.E., Mahmoud, M.S., Atrees, M.S., Ali, M.E. and Khawassek, Y.M., 2019. The nanocomposite of TiO₂@ Ni-or Co-doped Graphene Oxide for Efficient Photocatalytic Water Splitting. *Egyptian Journal of Chemistry*, 62(9), pp.1649-1658.
- [25] Jiang, X., Nisar, J., Pathak, B., Zhao, J. and Ahuja, R., 2013. Graphene oxide as a chemically tunable 2-D material for visible-light photocatalyst applications. *Journal of catalysis*, 299, pp.204-209.
- [26] Pham, T.A., Choi, B.C., Lim, K.T. and Jeong, Y.T., 2011. A simple approach for immobilization of gold nanoparticles on graphene oxide sheets by covalent bonding. *Applied Surface Science*, 257(8), pp.3350-3357.
- [27] Liu, Y., Liu, C.Y. and Liu, Y., 2011. Investigation on fluorescence quenching of dyes by graphite oxide and graphene. *Applied Surface Science*, 257(13), pp.5513-5518.
- [28] Liu, Y., Yu, D., Zeng, C., Miao, Z. and Dai, L., 2010. Biocompatible graphene oxide-based glucose biosensors. *Langmuir*, 26(9), pp.6158-6160.
- [29] Dasgupta, A., Sarkar, J., Ghosh, M., Bhattacharya, A., Mukherjee, A., Chattopadhyay, D. and Acharya, K., 2017. Green conversion of graphene oxide to graphene nanosheets and its biosafety study. *PloS one*, 12(2).
- [30] Fan, H., Liu, H., Hu, X., Lv, G., Zheng, Y., He, F., Ma, D., Liu, Q., Lu, Y. and Shen, W., 2019. Fe 2 P@ mesoporous carbon nanosheets synthesized via an organic template method as a cathode electrocatalyst for Zn–air batteries. *Journal of Materials Chemistry A*, 7(18), pp.11321-11330.
- [31] Chen, M.L., Meng, Z.D., Zhu, L., Choi, J.G., Park, C.Y., Lee, S.C., Hong, D.S., Lee, J.G., Jang, W.K. and Oh, W.C., 2011. Dispersion stability of metal (oxide)-graphene nanofluids with electrical and thermal properties. *Science of Advanced Materials*, 3(6), pp.887-892.
- [32] Van Bommel, A.J., Crombeen, J.E. and Van Tooren, A., 1975. LEED and Auger electron observations of the SiC (0001) surface. *Surface Science*, 48(2), pp.463-472.
- [33] Forbeaux, I., Themlin, J.M. and Debever, J.M., 1998. Heteroepitaxial graphite on 6 H– SiC (0001): Interface formation through conduction-band electronic structure. *Physical Review B*, 58(24), p.16396.
- [34] Oshima, C., Itoh, A., Rokuta, E., Tanaka, T., Yamashita, K. and Sakurai, T., 2000. A heteroepitaxial-double-atomic-layer system of monolayer graphene/monolayer h-BN on Ni (111). *Solid State Communications*, 116(1), pp.37-40.
- [35] Hawraa H. Radey, Hadi Z. Al-Sawaad, Moayed N. Khalaf, Synthesis and Characterization of Novel Nano Derivatives of Graphene Oxide, *Graphene*, 7, (2018), 17-29.
- [36] Hawraa H. Radey, Moayed N. Khalaf, Hadi Z. Al-Sawaad, Novel Corrosion Inhibitors for Carbon Steel Alloy in Acidic Medium of 1N HCl Synthesized from Graphene Oxide, *Open Journal of Organic Polymer Materials*, 8, (2018), 53-79.
- [37] Shahriary, L. and Athawale, A.A., 2014. Graphene oxide synthesized by using modified hummers approach. *Int. J. Renew. Energy Environ. Eng*, 2(01), pp.58-63.
- [38] Chammingkwan, P., Matsushita, K., Taniike, T. and Terano, M., 2016. Enhancement in mechanical and electrical properties of polypropylene using graphene oxide grafted with end-functionalized polypropylene. *Materials*, 9(4), p.240.
- [39] Li, W., Yue, Y.Z., Wang, M.Y., Li, Q. and Ren, R., 2016. Using maleic anhydride functionalized graphene oxide for improving the interfacial properties of carbon fiber/BMI composites. *Express Polymer Letters*, 10(11).

- [40] Huang, Y., Hu, Y., Chen, L., Yang, T., Huang, H., Shi, R., Lu, P. and Zhong, C., 2018. Selective biosorption of thorium (IV) from aqueous solutions by ginkgo leaf. *PLoS one*, 13(3).
- [41] Al-Hilfi J.A., Kahdim Z.J., Fandi T.S., and Ahmed L.M. 2020. Structural Study of Complexes from Hexafluoroacetylacetone, Pyrazole, And Its Pyrazole Derivative with Some Metals BY FT-IR, and ¹H-NMR. *PERIÓDICO TCHÊ QUÍMICA*, 17(34), pp. 567-456.
- [42] Dwivedi, C., Pandey, I., Pandey, H., Ramteke, P.W., Pandey, A.C., Mishra, S.B. and Patil, S., 2017. Electrospun Nanofibrous Scaffold as a Potential Carrier of Antimicrobial Therapeutics for Diabetic Wound Healing and Tissue Regeneration. In *Nano-and Microscale Drug Delivery Systems* (pp. 147-164). Elsevier.
- [43] Semnani, D., 2017 "Geometrical characterization of electrospun nanofibers." In *Electrospun Nanofibers*, pp. 151-180. Woodhead Publishing.
- [44] Al Juhaiman, L.A., 2016. Polyvinyl pyrrolidone as a corrosion inhibitor for carbon steel in HCl. *International Journal of Electrochemical Science*, 11(3), pp.2247-2262.
- [45] Chammingkwan, P., Matsushita, K., Taniike, T. and Terano, M., 2016. Enhancement in mechanical and electrical properties of polypropylene using graphene oxide grafted with end-functionalized polypropylene. *Materials*, 9(4), p.240.
- [46] Aldosari, M.A., Othman, A.A. and Alsharaeh, E.H., 2013. Synthesis and characterization of the in situ bulk polymerization of PMMA containing graphene sheets using microwave irradiation. *Molecules*, 18(3), pp.3152-3167.
- [47] Monshi, A., Foroughi, M.R. and Monshi, M.R., 2012. Modified Scherrer equation to estimate more accurately nano-crystallite size using XRD. *World journal of nano science and engineering*, 2(3), pp.154-160.
- [48] Theivasanthi, T. and Alagar, M., 2011. Nano sized copper particles by electrolytic synthesis and characterizations. *Int. J. Phys. Sci*, 6(15), pp.3662-3671.