



Preparation and Analysis of Physical Properties of Graphene Oxide with a Change of Treatment in the Modified Hummer Method

Endah Puspita¹, Marzuki Naibaho², Luh Ayu Melinia¹, Ramlan^{1,*}, Masno Ginting²

¹Department of Physics, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Palembang 30128, Indonesia

²Center for Advanced Materials Research (PRMM), National Research and Innovation Agency (BRIN), South Tangerang 15314, Indonesia

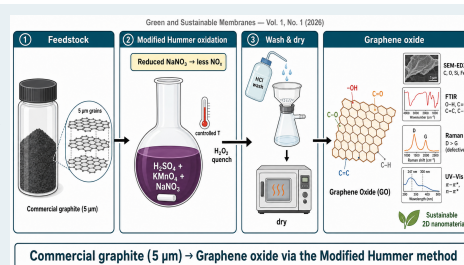
✉ Corresponding author: ramlan@unsri.ac.id

ARTICLE HISTORY: Received: March 1, 2026 | Revised: April 8, 2026 | Accepted: April 29, 2026

ABSTRACT

Graphene oxide (GO) is a versatile 2D carbon nanomaterial that underpins a growing class of sustainable functional technologies, from water purification and gas separation membranes to energy storage devices and photocatalysts for environmental remediation. Realising these promises at scale requires GO building blocks that are reproducible, defect-controlled, and produced by synthesis routes with reduced environmental burden. The Modified Hummer method addresses the safety and emissions limitations of the original Hummer procedure — primarily by minimising sodium nitrate usage and lowering the formation of toxic NO_x gases — but the resulting GO's structural and chemical quality still depends on graphite feedstock and processing conditions. Here, the physical properties of GO synthesised from 5-micron commercial graphite using the Modified Hummer method have been analysed. The SEM-EDX results show that GO has thick surface layers due to the bonding of functional groups to the GO surface, and the elements contained in GO consist of C, O, Mg, Al, Si, S, Cl, K, and Fe. The emergence of S and Cl is attributed to the presence of H₂SO₄ used in the synthesis and HCl used during the GO washing process. Based on the FTIR results, GO produces spectra showing several functional groups, namely O–H, C=O, C=C, C–H and C–O, formed from graphite oxidised using KMnO₄, NaNO₃ and H₂O₂. Based on Raman results, GO has a higher D-peak intensity than G-peak intensity, indicating that GO has a high level of crystal lattice defects (amorphous). Based on the UV-Vis results, GO has absorption bands at 247 nm and 300 nm, indicating the presence of $\pi-\pi^*$ transitions from aromatic C=C and $n-\pi^*$ from C=O bonds. Together, these features — high oxygen content, abundant hydrophilic surface functionalities, and a defect-rich aromatic lattice — make the synthesised GO a suitable building block for fabricating low-energy, water-compatible composite membranes for selective separations and pollutant uptake, supporting the broader transition toward greener membrane technologies.

Keywords: graphene oxide; graphite; Modified Hummer; KMnO



1. Introduction

Graphene oxide (GO) is a 2D carbon (graphene) nanomaterial that has been known for more than 150 years [1], [2]. GO is commonly known as a chemical compound of carbon (non-stoichiometric), hydrogen and oxygen in a variable ratio that is highly dependent on the manufacturing process [3]. GO has a hexagonal carbon structure similar to graphene with contents such as alkoxy hydroxyl groups (C–O–C), (–OH), carbonyl (C=O), carboxylic acid (–COOH) and other functional groups [4].

The interlayer spacing in GO widens in the presence of oxygen-containing groups [5]. The functional groups present in GO make it hydrophilic, promoting maximum exfoliation and high homogeneous dispersion of GO in a polar polymer matrix and significantly increasing GO interfacial bonds [6]. The highly oxidized form of GO is an electrical insulator with a band gap of approximately 2.2 eV [7].

GO is an attractive material for development because of its low cost, easy access, and broad ability to convert to graphene [8]. GO has physical properties such as a large specific surface area, good mechanical flexibility, high thermal stability and good electrical conductivity [9]. The physical properties of GO can make it a highly sought-after material

in various fields of application such as electronics, energy, biomedicine, and environmental applications [10]. Examples include desalination [11], drug delivery systems [12], oil-water separation [13,14], catalysis [15], solar cells [16] and energy storage [17].

In the manufacture of GO, a classic chemical oxidation method is carried out by Brodie, Staudenmaier, and Hummer [18]. These processes, especially the Hummer and modified Hummer methods, use graphite as a raw material in an oxidation reaction with a strong oxidant; the graphite is then exfoliated (sonicated) to produce GO [19]. The Hummer method has been used as a well-known method for making GO which was developed by Hummers and Offeman in 1958. This is because this method has advantages such as shorter processing time, improved safety, and lower toxicity compared to previously used methods [20]. Twenty years later, the Hummer method was modified to minimize the formation of toxic gases originating from NaNO₃, such as NO₂ and N₂O₄, by removing NaNO₃ [21]. However, in the manufacture of GO there are often difficulties and failures in the GO synthesis process using the Modified Hummer method, namely, the incomplete oxidation of graphite. Therefore, this study carries out GO synthesis with modifications

to the Modified Hummer method.

2. Materials and Methods

GO was prepared using commercial graphite measuring 5 microns using the Modified Hummer method. An illustration of the process of making GO can be seen in Figure 1.

A total of 115 ml of concentrated H_2SO_4 was cooled in an ice bath ($T = 0 - 5^\circ\text{C}$) for 5 minutes. 2.5 g of NaNO_3 was dissolved in H_2SO_4 solvent, 5 grams of graphite were slowly added, and the mixture was stirred using a stirring rod for 30 minutes ($T = 0 - 5^\circ\text{C}$). Then 15 grams of KMnO_4 were slowly added over 2 hours ($T = 0 - 5^\circ\text{C}$). The mixture was stirred again for 2 hours, during which the colour of the solution changed to blackish green. The mixture was removed from the ice bath, the hot plate temperature was set to 45°C , and the solution was stirred using a magnetic stirrer for 1 hour. After that, 230 ml of distilled water was slowly added dropwise into the solution, and the temperature was maintained at 45°C until the solution turned into a thick muddy brown, and stirring was continued for 30 minutes. Then 600 ml of distilled water (90°C) was added to the solution, followed by 50 ml of 30% H_2O_2 added dropwise, after which the solution turned yellow. The solution was allowed to settle and was left overnight. The precipitate was collected and washed using HCl, ethanol, and distilled water with a centrifuge ($v = 3500$ rpm) until the pH was close to neutral. The GO precipitate that had been washed was then dried at 80°C for 24 hours, and the dried GO formed a thin sheet. The GO thin sheets were blended to obtain GO powder flakes, which were ready for characterization. The same characterization was also carried out on commercial graphite powder to compare its properties with GO. The characterizations used in this study were Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX; PhenomProX Desktop), Raman spectroscopy (Raman; iHR320 HORIBA) and Ultraviolet and Visible Spectrophotometry (UV-Vis; Shimadzu 1800). In addition, the formation of graphite into GO can be seen in Figure 2.

3. Results and Discussion

3.1 Scanning Electron Microscope - Energy Dispersive X-Ray (SEM-EDX)

The morphology of graphite and GO is shown in Figure 3.

Figure 3 shows the morphology of the graphite and GO samples at a magnification of 500 times. Figure 3a shows the surface of the graphite material in rough and irregular flakes, while Figure 3b shows the surface of GO, which appears to have layers that make the consistency thicker. In addition, the thickness of the GO surface may be attributed to the presence of oxygen functional groups bound to the GO plane. This clearly indicates that the graphite material has been exfoliated during the oxidation process [22]. Furthermore, the elements contained in the sample can be identified through the EDX spectrum measured at a voltage of 20 kV in Figure 4. The results of the EDX spectrum show the percentage of each component contained in the sample. Figure 4a shows the elements in the graphite sample, where carbon (C) and oxygen (O) have weight percentages of 84.03% and 14.83%, respectively. The high value of the weight percentage of element C indicates that C is the main constituent of the graphite structure, which consists of carbon-carbon bonds. However, besides the presence of element C in graphite, there are other elements such as Mg, Al, Si, K and Fe with percentage values

of 0.06%, 0.29%, 0.56%, 0.05%, and 0.18%, respectively. The appearance of these elements indicates that the graphite used is impure; the Al, Si, and K signals may also arise from stray peaks in the Si detector, which captures X-rays to produce a spectrum [23].

Meanwhile, Figure 4b shows elements in the GO sample. The highest element percentages are found in C and O, with values of 53.09% and 42.13%, respectively. The C content decreased, while the O content increased. This is because graphite is oxidized by potent oxidizing agents such as KMnO_4 , NaNO_3 and H_2O_2 , increasing the oxygen content. In addition, other elements, namely S and Cl, have percentage values of 1.60% and 0.18%, respectively. The S element is likely due to the addition of H_2SO_4 during the synthesis process, while the Cl element likely originates from the HCl washing process, with residual content remaining in GO.

3.2 Fourier Transform Infrared Spectroscopy (FTIR)

Based on the FTIR results, the functional groups in graphite and GO samples have been shown in Figure 5. Figure 5 shows the infrared spectra of graphite and GO, with peaks indicating various functional groups, in the range of $500\text{--}4000\text{ cm}^{-1}$. In addition, Table 2 lists the chemical functional groups identified in graphite and GO. The graphite sample displays a broad peak at 3220.25 cm^{-1} corresponding to O-H (hydroxyl) stretching vibrations. The breadth of the O-H peak indicates the presence of strong hydrogen bonds, such as adsorbed water [24]. In addition, the width of the O-H spectra shows that this graphite contains heavy atoms, where the more comprehensive the spectral peaks, the heavier the atoms and the narrower the spectral peaks, the lighter the atoms. In addition, graphite also shows spectral peaks at the wavenumbers 1718.16 cm^{-1} , 1620.67 cm^{-1} , 1393.36 cm^{-1} and 1038.87 cm^{-1} , with each showing functional groups in the form of C=O (carbonyl), C=C (aromatic), C-H (alkane) and C-O (epoxide).

The GO sample displays spectra similar to those of graphite. The spectra share many common features because the elements present in the two samples are nearly identical, although GO contains additional S and Cl impurities that are not detected by FTIR. Some GO peaks appear at lower wavenumbers than in graphite, such as O-H groups at the wavenumber 3193.50 cm^{-1} . The O-H group in GO has a broader peak than graphite, and this is attributed to the higher water content originating from the distilled water used in the GO washing process. After that, at the wavenumber 1718.48 cm^{-1} there is a stretching vibration of the C=O group located in the GO layer. At the wavenumber 1617.61 cm^{-1} a peak appears due to the C=C stretching vibration of the unoxidized carbon structure. The C=C bond is a carbon-carbon double bond, indicating skeletal vibrations of graphite that has not been exfoliated [25]. At 1382.39 cm^{-1} there is a sharp peak with moderate transmittance corresponding to C-H bending vibrations of the alkane functional group in aliphatic hydrocarbons [26], whereas at 1035.42 cm^{-1} there is a C-O stretching vibration associated with the graphite structure [27]. The C-O bond originates from alcohol functional groups, which appear in the range of $900\text{--}1300\text{ cm}^{-1}$. The presence of the C-O bond suggests that GO still contains alcohol groups originating from the ethanol used in the washing process.

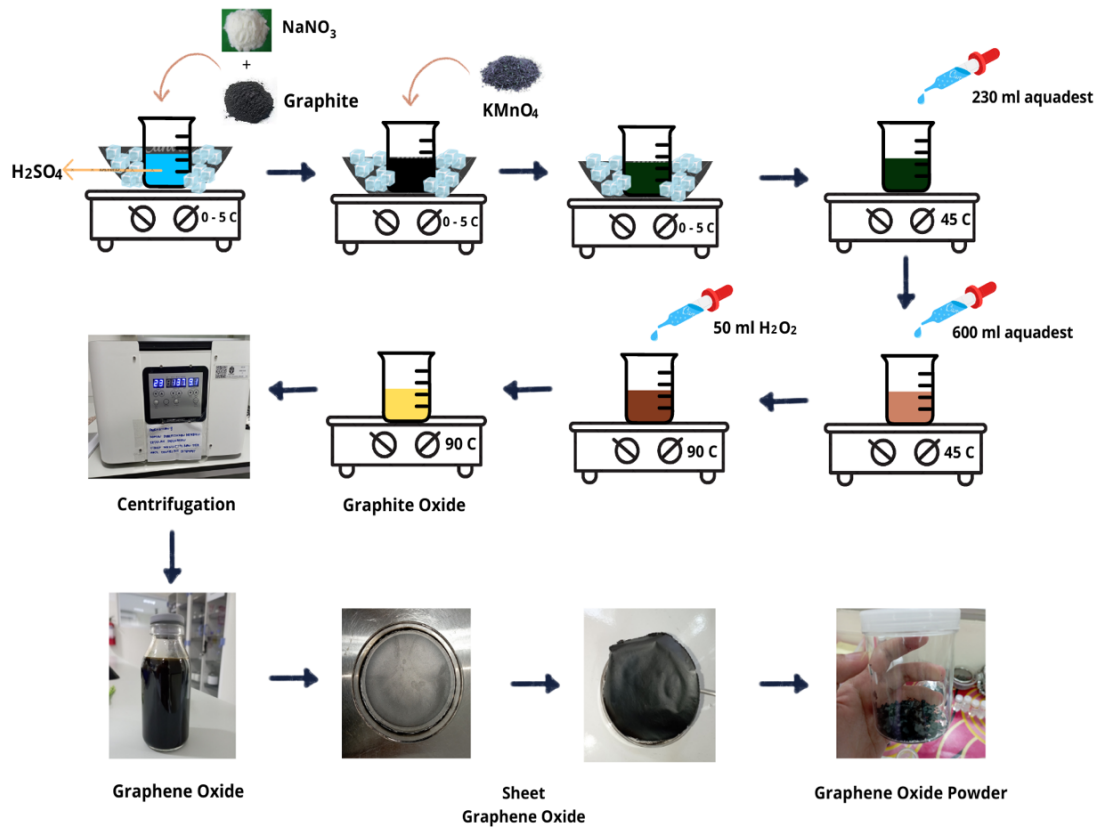


Figure 1. Process of making graphene oxide via the Modified Hummer method

Table 1. Comparison of elements in graphite and GO samples.

Sample	Composition (%wt)		Mg	Al	Si	S	Cl	K	Fe
	C	O							
Graphite	84.03	14.83	0.06	0.29	0.56	-	-	0.05	0.18
GO	53.09	42.13	0.08	0.88	1.66	1.60	0.18	0.23	0.16

Table 2. FTIR spectra on graphite and GO.

Sample	Functional Group (cm^{-1})				
	H stretching vibrations (hydroxyl)	C=O stretching vibration (carbonyl)	C=C stretching vibration (aromatic)	H bending vibration (alkene)	C-O stretching vibration (epoxide)
Graphite	3220.25	1718.16	1620.27	1393.36	1038.87
GO	3193.50	1718.48	1617.61	1382.39	1035.42

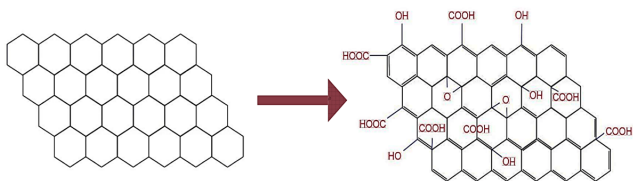


Figure 2. The chemical structure of graphene oxide (GO)

3.3 Raman Spectroscopy

The Raman spectra of graphite and graphene oxide samples are shown in Figure 6. Figure 6 shows the Raman spectra of the graphite and GO samples. These spectra are characterized by the presence of peaks in the disorder band (D), graphite band (G) and overtone band (2D). The D band can be interpreted as a longitudinal optical (LO) phonon in which a peak induced by lattice disorder is associated with disturbances in the hexagonal symmetrical graphite lattice, such as structural defect sites, edge defects and dangling bonds. The G band is an intense tangential mode that appears with a stretching movement or a scattering in the first-order E_{2g} phonon in the sp^2 C-C bond plane [28,29]. In contrast, the 2D band is a second-order continuation of the D band, appearing at wavenumbers from 2500 to 3200 cm^{-1} [30].

The graphite sample has a D band at a wavenumber of

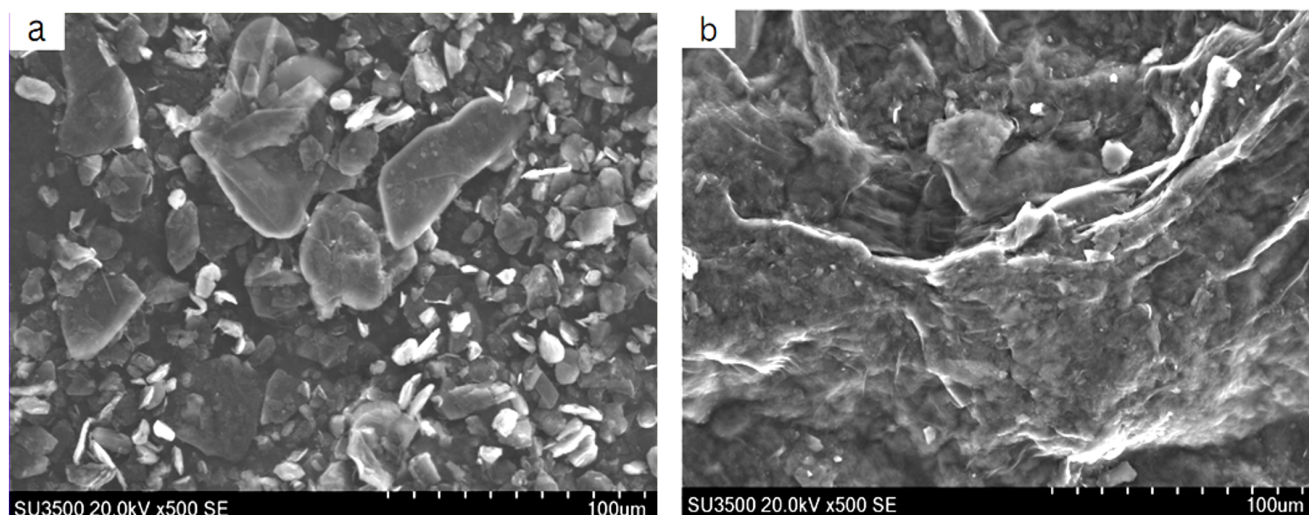


Figure 3. SEM images of (a) Graphite and (b) GO at 500x magnification

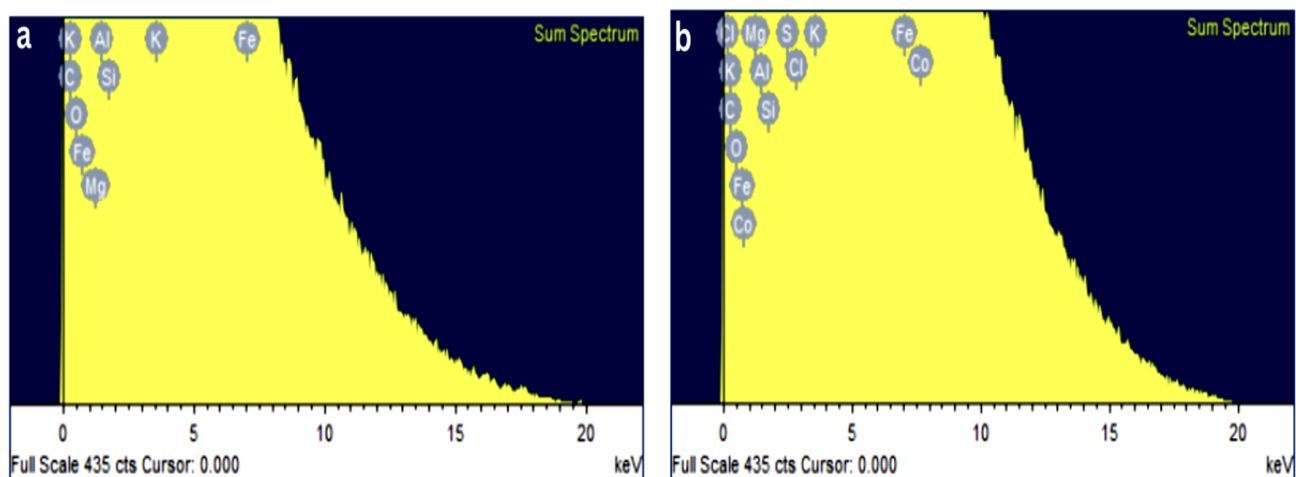


Figure 4. EDX spectra on (a) Graphite and (b) GO

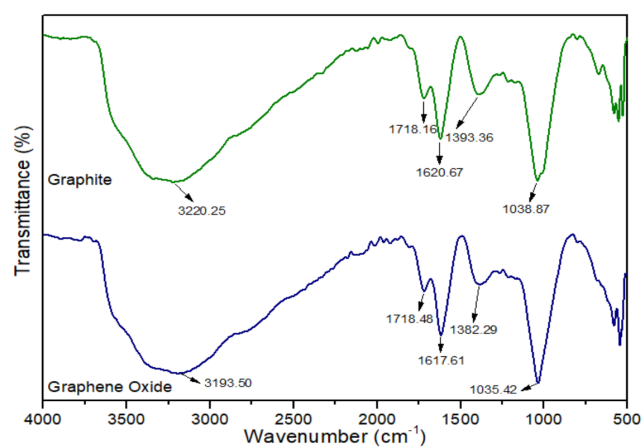


Figure 5. FTIR spectra on (a) Graphite and (b) GO

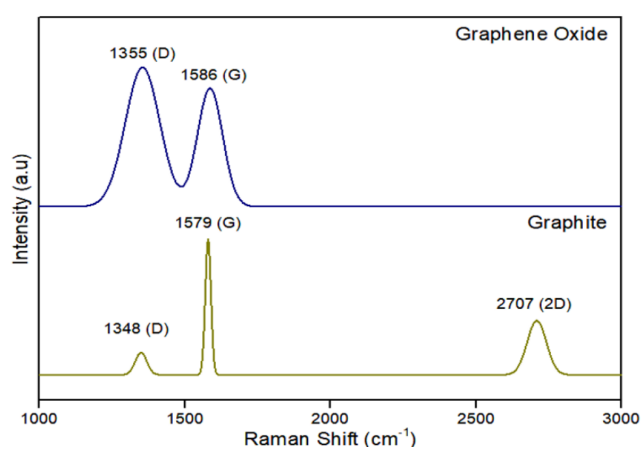


Figure 6. Raman spectra on graphite and GO

1348 cm^{-1} . The intensity of the D band reflects the defect level in the graphite lattice; a higher D-band intensity indicates more defects. The D band on graphite shows a relatively low intensity, indicating a low level of crystal defects. In addition, there is a G band at a wavenumber of 1579 cm^{-1} , which shows the vibration of sp^2 -bonded carbon atoms in a two-dimensional hexagonal lattice in the carbon layer. The intensity of the G band is higher than that of the D band, indicating that graphite has a well-ordered crystal lattice [31]. At the wavenumber 2707 cm^{-1} there is a 2D band which shows the intrinsic properties of graphite and the occurrence of a second-order process from a zone-boundary LO phonon. The Raman spectra of GO indicate the successful oxidation of graphite. The GO sample displays a D-band peak with a wavenumber of 1355 cm^{-1} , showing a blue shift of the D-band peak from 1348 to 1355 cm^{-1} after the graphite undergoes oxidation. Additionally, a G band appears at the wavenumber 1586 cm^{-1} . The D band intensity is higher and the G band intensity is lower, indicating defects in the GO lattice structure. The increased D-band intensity may be attributed to the incorporation of certain functional groups in the carbon backbone [32].

3.4 Ultraviolet and Visible Spectrophotometry (UV-Vis)

The UV-Vis spectra of graphite and GO samples are shown in Figure 7. Figure 7 depicts the UV-Vis spectra of graphite and GO samples, characterizing the wavelengths and molecular transitions of these carbon-derived materials. The graphite sample shows absorption bands in the 250–300 nm wavelength range. The appearance of graphite absorption bands generally indicates an excitation of π -plasmon or plasmon peaks of π - π^* C=C bonds in the sp^2 hybrid region of the graphite structure [32,33]. In the GO sample, an absorption band at 247 nm is seen, which is associated with the π - π^* transition from C=C aromatic, while the absorption band at 300 nm, related to the $\text{n}-\pi^*$ transition, indicates the successful oxidation of graphite to GO [34–37]. In addition, the peak intensity ratio in the absorption band also shows the degree of oxidation; the higher the peak intensity, the higher the degree of oxidation [31].

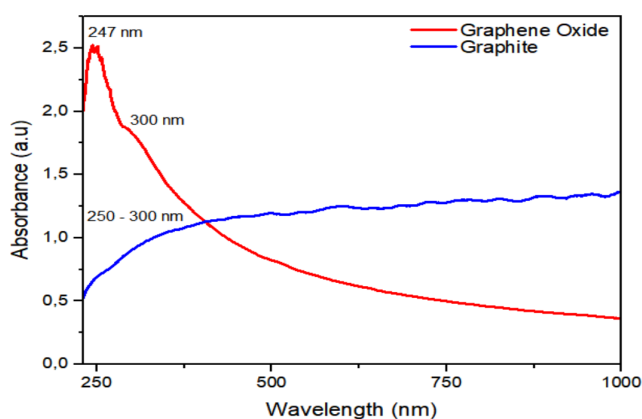


Figure 7. UV-Vis spectra on graphite and GO

4. Conclusions

An analysis of the physical properties of GO made from 5-micron graphite using the Modified Hummer method has been completed. Based on the SEM data, the synthesized

GO exhibited a layered morphology indicating that the functional groups had been bound to the surface of the GO plane, and the most abundant elements in GO were C and O, with weight percentages of 53.09% and 42.13%, respectively. The high oxygen content is caused by strong oxidizing agents such as KMnO_4 , NaNO_3 and H_2O_2 . Based on FTIR data, an O-H functional group appears at the wavenumber 3193.50 cm^{-1} , indicating the presence of hydrogen and oxygen. The broad O-H peak suggests a high water content in GO. In addition, the Raman data show that GO has a high level of crystal defects, as indicated by the high D-peak intensity compared to the G peak, while the UV-Vis data show that GO has absorption bands at wavelengths of 247 nm and 300 nm, indicating the presence of π - π^* transitions from C=C aromatic and $\text{n}-\pi^*$ from C=O bonds.

ACKNOWLEDGEMENTS

The authors are grateful for research funding assistance or scholarships issued by BRIN and the physics department at Sriwijaya University for the opportunity that has been given to conduct research at the Center for Advanced Materials (PRMM)-BRIN.

REFERENCES

- [1] Rhazouani A, Gamrani H, El Achaby M, Aziz K, Gebrati L, Uddin MS, AZIZ F. Synthesis and Toxicity of Graphene Oxide Nanoparticles: A Literature Review of. *BioMed Research International*. 2021;2021(1). doi:10.1155/2021/5518999.
- [2] Singh R, Ullah S, Rao N, Singh M, Patra I, Darko DA, Is-sac CPJ, Esmaeilzadeh-Salestani K, Kanaoujiya R, Vijayan V. Synthesis of Three-Dimensional Reduced-Graphene Oxide from Graphene Oxide. *Journal of Nanomaterials*. 2022;2022(1). doi:10.1155/2022/8731429.
- [3] Sun L. Structure and synthesis of graphene oxide. *Chinese Journal of Chemical Engineering*. 2019;27(10):2251-2260. doi:10.1016/j.cjche.2019.05.003.
- [4] Smith AT, LaChance AM, Zeng S, Liu B, Sun L. Synthesis, properties, and applications of graphene oxide/reduced graphene oxide and their nanocomposites. *Nano Materials Science*. 2019;1(1):31-47. doi:10.1016/j.nanoms.2019.02.004.
- [5] Muniyalakshmi M, Sethuraman K, Silambarasan D. Synthesis and characterization of graphene oxide nanosheets. *Materials Today: Proceedings*. 2020;21:408-410. doi:10.1016/j.matpr.2019.06.375.
- [6] Xu L, Teng J, Li L, Huang HD, Xu JZ, Li Y, Ren PG, Zhong GJ, Li ZM. Hydrophobic Graphene Oxide as a Promising Barrier of Water Vapor for Regenerated Cellulose Nanocomposite Films. *ACS Omega*. 2019;4(1):509-517. doi:10.1021/acsomega.8b02866.
- [7] Jiříčková A, Jankovský O, Sofer Z, Sedmidubský D. Synthesis and Applications of Graphene Oxide. *Materials*. 2022;15(3):920. doi:10.3390/ma15030920.
- [8] Arthi G PB, BD L. A Simple Approach to Stepwise Synthesis of Graphene Oxide Nanomaterial. *Journal of Nanomedicine & Nanotechnology*. 2015;06(01). doi:10.4172/2157-7439.1000253.
- [9] Surekha G, Krishnaiah KV, Ravi N, Padma Suvarna R. FTIR, Raman and XRD analysis of graphene oxide films prepared by modified Hummers method. *Journal of Physics: Conference Series*. 2020;1495(1):012012. doi:10.1088/1742-6596/1495/1/012012.
- [10] Ranjan P, Agrawal S, Sinha A, Rao TR, Balakrishnan J, Thakur AD. A Low-Cost Non-explosive Synthesis of Graphene Oxide for Scalable Applications. *Scientific Reports*. 2018;8(1). doi:10.1038/s41598-018-30613-4.
- [11] Abraham J, Vasu KS, Williams CD, Gopinadhan K, Su Y, Cherian CT, Dix J, Prestat E, Haigh SJ, Grigorieva IV, Carbone P, Geim AK, Nair RR. Tunable sieving of ions using graphene oxide membranes. *Nature Nanotechnology*. 2017;12(6):546-550. doi:10.1038/nnano.2017.21.

- [12] Xu Y, Wang Y, Wang T, Zhang L, Xu M, Jia H. Demulsification of Heavy Oil-in-Water Emulsion by a Novel Janus Graphene Oxide Nanosheet: Experiments and Molecular Dynamic Simulations. *Molecules*. 2022;27(7):2191. doi:10.3390/molecules27072191.
- [13] Li B, Tang W, Zhou Y, Sun D, Li B, Ge Y. Bioinspired copper-graphene oxide hybrid membrane prepared via electrochemical-driven strategy: design, mechanism, and oil-water separation. *Separation and Purification Technology*. 2023;319:124037. doi:10.1016/j.seppur.2023.124037.
- [14] Wang J, Tian S, Liu X, Wang X, Huang Y, Fu Y, Xu Q. Molecular Dynamics Simulation of the Oil–Water Interface Behavior of Modified Graphene Oxide and Its Effect on Interfacial Phenomena. *Energies*. 2022;15(12):4443. doi:10.3390/en15124443.
- [15] Jeong WL, Park SH, Jho YD, Joo SK, Lee DS. The Role of the Graphene Oxide (GO) and Reduced Graphene Oxide (RGO) Intermediate Layer in CZTSSe Thin-Film Solar Cells. *Materials*. 2022;15(10):3419. doi:10.3390/ma15103419.
- [16] Vasiliev VP, Manzhos RA, Kochergin VK, Krivenko AG, Kabachkov EN, Kulikov AV, Shulga YM, Gutsev GL. A Facile Synthesis of Noble-Metal-Free Catalyst Based on Nitrogen Doped Graphene Oxide for Oxygen Reduction Reaction. *Materials*. 2022;15(3):821. doi:10.3390/ma15030821.
- [17] Zhao J, Zhang J, Yin H, Zhao Y, Xu G, Yuan J, Mo X, Tang J, Wang F. Ultra-Fine Ruthenium Oxide Quantum Dots/Reduced Graphene Oxide Composite as Electrodes for High-Performance Supercapacitors. *Nanomaterials*. 2022;12(7):1210. doi:10.3390/nano12071210.
- [18] Méndez-Lozano N, Pérez-Reynoso F, González-Gutiérrez C. Eco-Friendly Approach for Graphene Oxide Synthesis by Modified Hummers Method. *Materials*. 2022;15(20):7228. doi:10.3390/ma15207228.
- [19] Chen X, Qu Z, Liu Z, Ren G. Mechanism of Oxidization of Graphite to Graphene Oxide by the Hummers Method. *ACS Omega*. 2022;7(27):23503–23510. doi:10.1021/acsomega.2c01963.
- [20] Hummers WS, Offeman RE. Preparation of Graphitic Oxide. *Journal of the American Chemical Society*. 1958;80(6):1339–1339. doi:10.1021/ja01539a017.
- [21] Liu X, Shi L, Jiang W, Zhang J, Huang L. Taking full advantage of KMnO₄ in simplified Hummers method: A green and one pot process for the fabrication of alpha MnO₂ nanorods on graphene oxide. *Chemical Engineering Science*. 2018;192:414–421. doi:10.1016/j.ces.2018.07.044.
- [22] Rochman RA, Wahyuningsih S, Ramelan AH, Hanif QA. Preparation of nitrogen and sulphur Co-doped reduced graphene oxide (rGO-NS) using N and S heteroatom of thiourea. *IOP Conference Series: Materials Science and Engineering*. 2019;509:012119. doi:10.1088/1757-899x/509/1/012119.
- [23] Siburian R, Sihotang H, Lumban Raja S, Supeno M, Simanjuntak C. New Route to Synthesize of Graphene Nano Sheets. *Oriental Journal of Chemistry*. 2018;34(1):182–187. doi:10.13005/ojc/340120.
- [24] Mouhat F, Coudert FX, Bocquet ML. Structure and chemistry of graphene oxide in liquid water from first principles. *Nature Communications*. 2020;11(1). doi:10.1038/s41467-020-15381-y.
- [25] Bera M, Chandravati, Gupta P, Maji PK. Facile One-Pot Synthesis of Graphene Oxide by Sonication Assisted Mechanochemical Approach and Its Surface Chemistry. *Journal of Nanoscience and Nanotechnology*. 2018;18(2):902–912. doi:10.1166/jnn.2018.14306.
- [26] Hartwig JF, Larsen MA. Undirected, Homogeneous C–H Bond Functionalization: Challenges and Opportunities. *ACS Central Science*. 2016;2(5):281–292. doi:10.1021/acscentsci.6b00032.
- [27] An SS, Yun KS, Zhong L. Graphene oxide-modified ZnO particles: synthesis, characterization, and antibacterial properties. *International Journal of Nanomedicine*. 2015;79. doi:10.2147/ijn.s88319.
- [28] Carolina Sparavigna A. Graphene, Graphene Oxide and Carbon Nanotubes in Raman Spectroscopy. *International Journal of Sciences*. 2024;13(07):1–26. doi:10.18483/ijsci.2773.
- [29] Tan LL, Ong WJ, Chai SP, Mohamed AR. Reduced graphene oxide-TiO₂ nanocomposite as a promising visible-light-active photocatalyst for the conversion of carbon dioxide. *Nanoscale Research Letters*. 2013;8(1). doi:10.1186/1556-276x-8-465.
- [30] Chipara DM, Panaitescu DM, Lozano K, Gabor RA, Nicolae CA, Chipara M. Raman spectroscopy and molecular bases of elasticity: SEBS-graphite composites. *Polymer*. 2019;176:74–88. doi:10.1016/j.polymer.2019.05.019.
- [31] Olumurewa KO, Olofinjana B, Fasakin O, Eleruja MA, Ajayi EOB. Characterization of High Yield Graphene Oxide Synthesized by Simplified Hummers Method. *Graphene*. 2017;06(04):85–98. doi:10.4236/graphene.2017.64007.
- [32] Ramya AV, Manoj B, Mohan AN. Extraction and Characterization of Wrinkled Graphene Nanolayers from Commercial Graphite. *Asian Journal of Chemistry*. 2016;28(5):1031–1034. doi:10.14236/ajchem.2016.19577.
- [33] Pimpang P, Wongrerkdee S, Chooapun S. Charge transfer improvement of ZnO-based dye-sensitized solar cells modified with graphite nanosheets and bilayer photoelectrode structures. *Ferroelectrics*. 2019;552(1):1–9. doi:10.1080/00150193.2019.1653077.
- [34] Rokmana AW, Asriani A, Suhendar H, Triyana K, Kusumaatmaja A, Santoso I. The Optical Properties of Thin Film Reduced Graphene Oxide/Poly (3,4 Ethylenedioxythiophene):Poly (Styrene Sulfonate)(PEDOT:PSS) Fabricated by Spin Coating. *Journal of Physics: Conference Series*. 2018;1011:012007. doi:10.1088/1742-6596/1011/1/012007.
- [35] Rabchinskii MK, Shnitov VV, Dideikin AT, Aleksenskii AE, Vul' SP, Baidakova MV, Pronin II, Kirilenko DA, Brunkov PN, Weise J, Molodtsov SL. Nanoscale Perforation of Graphene Oxide during Photoreduction Process in the Argon Atmosphere. *The Journal of Physical Chemistry C*. 2016;120(49):28261–28269. doi:10.1021/acs.jpcc.6b08758.
- [36] Sunderrajan S, Miranda LR, Pennathur G. Improved stability and catalytic activity of graphene oxide/chitosan hybrid beads loaded with porcine liver esterase. *Preparative Biochemistry & Biotechnology*. 2018;48(4):343–351. doi:10.1080/10826068.2018.1446153.
- [37] Rommozzi E, Zannotti M, Giovannetti R, D'Amato CA, Ferraro S, Minicucci M, Gunnella R, Di Cicco A. Reduced Graphene Oxide/TiO₂ Nanocomposite: From Synthesis to Characterization for Efficient Visible Light Photocatalytic Applications. *Catalysts*. 2018;8(12):598. doi:10.3390/catal8120598.