Assembling And Structural Identification of Graphene and Brophene Silver Oxide-Based Nano Composites for Environment Protection and Photo Catalysis and Treatment of Lethal Material

Muhammad Asif
M.Phil. Chemistry Ripah International University Islamabad, Pakistan.
Email: asif19176@gmail.com

Sahrish Arshad
M.Phil. Chemistry, University of Agriculture Faisalabad, Pakistan.
Email: sehrishsen22@gmail.com

Amna Sehar
Ph.D. Chemistry Scholar, Department of Chemistry at Government College University Faisalabad, Pakistan.
Email: amnasehar537@gmail.com

Ghulam Ali
MSc Chemistry, Govt Collage University Faisalabad, Pakistan.
Email: alig03454@gmail.com

Received on: 22-04-2024 Accepted on: 22-05-2024

Abstract

The best carbon two-dimensional materials are graphene oxide and borophene oxide, which have special optical, electrical, mechanical, and fundamental thermal characteristics and may be combined to make composite materials under various favourable conditions. We produced the graphene and borophene nano composite for this work using a few unique oxides based on silver. The fundamentally optimal methods the manufacture of graphene from carbon ore graphite powder was chosen to use the Hummer technique. It was ascorbic acid that converted this graphene into its reduced form. The characteristics of graphene and brophene increase as they are reduced to their reduced graphene state, leading to a planar distance increase. The nanocomposite of graphene and borophene was being created using the Turkevich type technique. Confirmation of the distinct functional group in the product was detected using Fourier transform infrared spectroscopy. The authenticity of these compounds is further supported by their XRD spectra. Comparable methods reveal that the Raman spectra's D and G band values are lower than their true values. Based on oxide composite based on silver, the results demonstrated a degradation of the methylene blue dye of up to 74.34%. Thus, it was determined that the substance being assembled would be used for the breakdown and degradation of another deadly contaminant found in industrial wastewater.

Keywords: graphene, brophene silver, oxide-based Nano composites, environment protection, photo catalysis, lethal material

Introduction

Modern civilization faced many environmental and energy safety concern due to large number of industries set up in the whole world. Most factories are set up in the urban areas which cause serious effect both on the health of human and animal. Every vehicle transportation is increasing which uses different types of fossil foul which have severe effect on the environment. Petroleum based fossil fuel are very dangerous and have negative effect on the environment and the mankind. Now a days scientist and researcher are trying to develop new sources of energy which are not only renewable but also environmentally friendly. Development is going on the production of such resources which are renewable and also waste free.

The greatest alternative in this respect employing metal is semiconducting based on silver-halides resources generated from various metal oxides and metallic nano composites with polymer, metal, and different ranges of ceramic matrix. Different polymers, such as polyamide, or ceramic matrix with additional reinforcement options can all be used to organize these various nano-silver composite materials. The superiority of graphene and brophene silver-based nano composite materials has been seen in numerous research theses. A two-dimensional carbon material called borophene and graphene reagents have demonstrated sp2 hybridization. This sp2 hybridization is what gave it a honeycomb structure. As a result, it possesses qualities including a large surface area, strong mechanical and thermal stability, and high thermal conductivity.The unique characteristics of graphene and borophene structures allow for the remarkable applications of reduced graphene and borophene in research domains such as biosensing, cell catalysis (also referred to as photo-catalysis and cell working), water treatment H20 purification, and excellent energy storage capacitor-based applications. While ion moving thermal conductivity is up to 103 Wm1 K1, charge mobility movement of ions in graphene and brophene is almost identical and is in the range of 105 cm2 V1s1.

Graphene and borophene have surface areas of over 2000 m2 g1, which is more than carbon nanotubes (1250 m2 g1) and significantly more than graphite (10 m2 g1). The unique structural characteristics of graphene and borophene make them suitable for the assembly of nanocomposites made of silver-based oxide halides. Geometrical polarization-based optical and electronic applications can be used with graphene and borophene-based materials. Graphene has an optical transparency range of close to 97.7%.

Since graphene is hydrophobic rather than hydrophilic in nature, it cannot be dissolved in a variety of hydrophilic solvents. In order to solve this issue, graphene and borophene are converted into graphene oxide and borophene oxide, respectively. These oxides, which were previously graphene or borophene, are produced by the carbon compound graphite powder when a powerful, different oxidizing agent is used. As a result, the unique properties of graphene oxides, which consist of oxides based on silver, make them unsuitable for use as energy sources and in electronic-based applications.

By reducing graphene oxide and borophene using a variety of electrical, thermal, potochemical, or chemical methods, one can create reduced graphene oxide and reduced borophene sliver-based oxide. By using graphene and borophene treatment to reduce the aforementioned compound, silver-based nanocomposites with various metals and metal oxides can be created. Metal nanoparticles are also utilised to make composite materials, in a manner similar to that of borophene and its reduced counterpart, as well as graphene oxides and reduced graphene oxides.

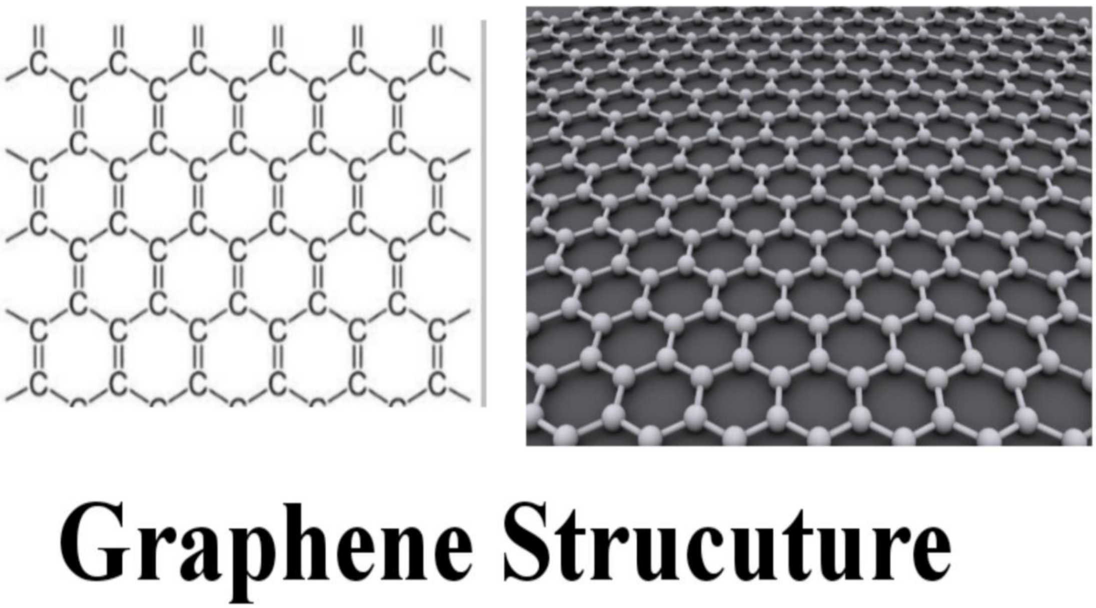
Graphene nanoparticles may absorb and emit light in the visible and ultraviolet range between 200 and 400 nm because of their unique bandgap. They are used in photovoltaic cells and photo-catalysis for the deadly protection of the aquatic environment because of this bandgap. When reduced graphene oxide, borophene oxide, and borophene oxide are used as photo catalysts in the composite, the energy difference of these semiconducting nanomaterials is improved to the greatest extent.

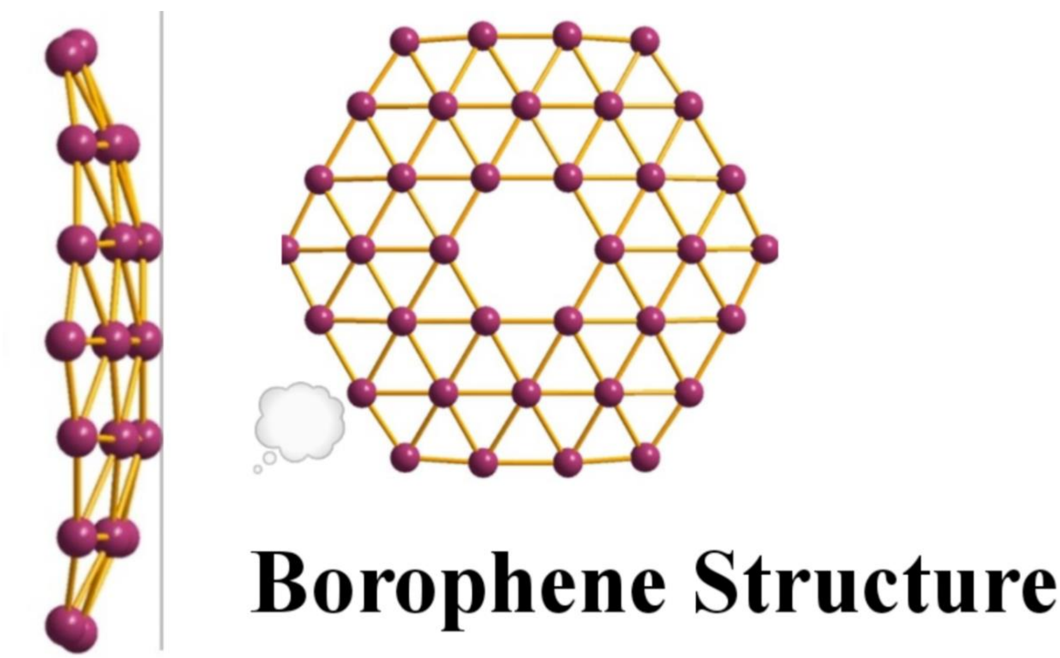
Researchers have clearly shown that materials like graphene oxides or borophene oxides are also the best option for energy-based applications like fuel cells, solar cells that are sensitive to azo dyes, super capacitor storage materials, and some rechargeable lithium-ion oxide batteries. Super energy capacitors, fuel cells, dye-sensitive solar cells, oxide batteries, and other devices that use graphene and brophene-based materials operate at their maximum potential in terms of charge carrier transfer, energy density, energy charge storing capacity, and other relevant parameters.

Specific optical characteristics and electrical conductivity are seen in materials based on graphene and borophene. One well-known phenomena is quantum confinement. The quantum phenomena rendered the materials based on graphene and borophene oxides ideal for photovoltaic cells and photocatalysis. The generation of electron holes is shown by the use of graphene-based materials in dye-sensitized solar cells, which accounts for the materials' remarkable efficiency. The detection, identification, and absorption of numerous non-ideal gases are among the many additional valid uses for materials based on graphene and borophene oxides. As a result, detectors in electrochemical series are used to understand how strong and weak electrolytes behave.

Creating reduced graphene and borophene oxide composites using silver halides and graphene and borophene silver-based oxides was the goal of this work. Advanced spectroscopic techniques were being used to characterize and identify this synthesized material. Some of these fundamental methods, such as UV-visible.

The primary objectives The aim of this research was to construct graphene and borophene oxides based on silver, as well as various composites of reduced graphene and borophene oxides using silver halides. These synthetic materials were being discovered and characterised using sophisticated spectroscopic methods, some of which were fundamental techniques including Raman spectroscopy, XRD, FTIR, UV-visible, and SEM.


Graphene Strucuture


Borophene Structure

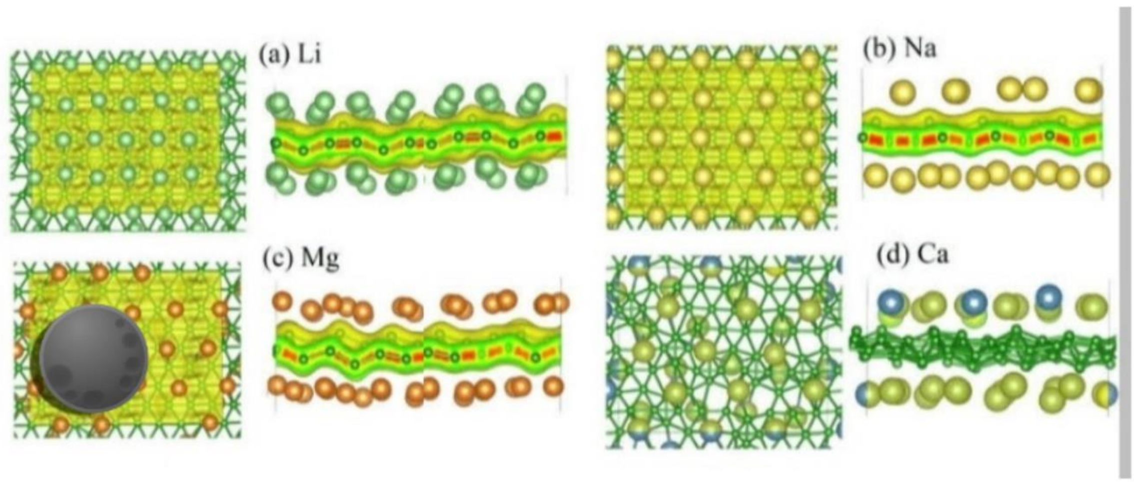
2.Materials and methods

2.1Preparation of Nano composites

Many studies on Nano composites have been reported in the literature Incorporating silver nanoparticles into a water-soluble matrix Polyvinyl alcohol, acrylic acid and polyvinylpyrrolidone can be easily removed. Nano composite is thermodynamically favorable as they pass through polymer functional groups. There are few reports on the introduction of silver Nano composite into hydrophobic polymers. Researcher also revealed the introduction of silver halides into polystyrene by using pre-fabricated NPs. The introduction of silicate NPs into PMMA via suspension polymerization was also carried out. Similar to the introduction of basic some silver into polyethylene, improved by thermal properties were reported. Fluoride matrix material These syntheses where successful reasons is the interactions between some functional groups. Groups with surface state charges on Nano composites. Incorporation of nanoparticles into polymers with ester functionality is more difficult the reasons is that because the ester groups interact so weakly with NPs with through dipolar interactions. So, introduction of capping agents is required to form Nano composites. Acrylic compound is Widely used in aerospace/construction applications where mechanically stable properties are important. that was Used in medicine due to bio comparability. For all above type these reasons, PMMA was chosen as a polymer matrix. Always use PMMA (Mw = 751 kDa, TG = 104-105 °C). Acrylic particles were then added to the THF/PMMA mixture and stirred for a further hour in order to suspend them. When the entire mixture was thoroughly mixed, the mixture was cast in methanol, PMMA was deposited immediately, and the suspended Ag NPs were trapped in its lattice. The compound is then dried, ground to a fine powder and pressed into thin films ready for characterization and analysis. A range of Nano composites was investigated, with silver contents ranging from 2% to 36% by weight (0.2% to 3.6% silver by volume.

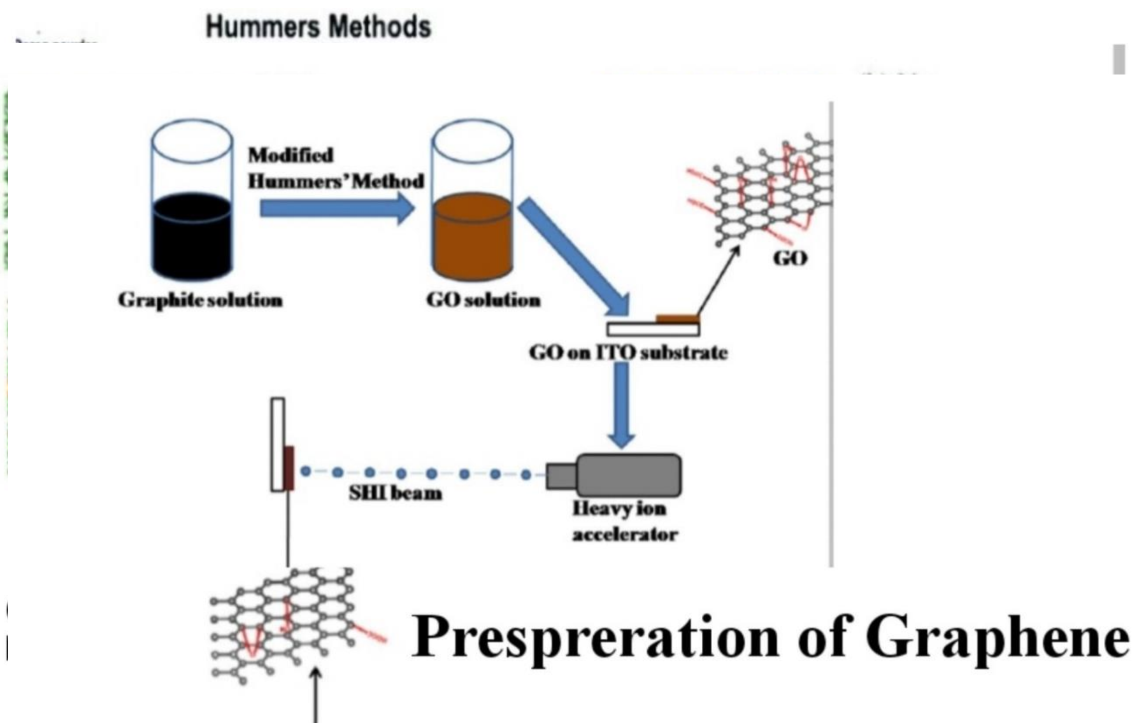
2.2 Preparation of graphene oxide and borophene oxide

Graphite powder was used to make the oxides of graphene and borophene. Graphite powder is acquiring Sigma Aldrich's business. The greatest example of the modified Hummer's technique for creating graphene nano composite nano-sheets is given in the picture. A 9:1 mixture of 275 mL sulfuric acid (H_2SO_4) and 35 mL phosphoric acid was combined, then the mixture was placed in the freezer for an hour to chill. Subsequently, 2.255 grammes of graphite powder were added gradually while the mixture was continuously stirred. Potassium permanganate ($KMnO_4$), 13.221 g, was gradually added to the mixture. Using a magnetic stirrer, this kind of combination was agitated for 12.5 hours, or until the solution became an intense shade of green. After adding 40 mL of hydrogen peroxide (H_2O_2) dropwise and stirring for 12 minutes, the surplus $KMnO_4$ was removed from the magnet. After the exothermic process, everything cooled down. After adding 350 mL of water to the graphene solution, the mixture was centrifuged for 25 minutes at 5000 rpm. at create the GO sheets, the leftover material from the centrifuge was first cleaned with ethanol and then dried in an oven set at 85 to 90 degrees Celsius for 25 hours. Ascorbic acid was used to transform the generated GO into another kind of reduced graphene. At 60 °C, 0.4 g of GO nanosheet was mixed with DIW using a magnetic stirrer. The mixture was further agitated when 5.6 g of ascorbic acid was added [23]. After dispersing 100 milligrammes of GO nano sheets in 40 millilitres of water, the reaction mixture was sonicated for an hour to create a homogenous suspension.Next, 25.6 mL of $AgNO_3$ (10 mM) was added in the mixture. For thirty minutes, the commentary that followed was put on hold. After that, put the reaction vessel in a bath at constant temperature and continuously stir while adding 124 mL of a 10 mM sodium citrate solution dropwise into the reaction mixture. After that, the mixture is cooked for two hours. These mixtures were then washed twice with water and alcohol, respectively. The resulting product was frozen in a dry freezer for later use.



Sample of Borophene film

Structure diagram of Borophene



2.3 Assembling of Nano composite membrane

The permeation parameter and rejection parameter are both influenced by the thickness of the assembled membrane. When constructing or fabricating a membrane, an optimistic approach is used if the thickness of the membrane is high, since this implies that the pollutant rejection is high and the permeability is low. A 5.5 mL composite solution of reduced graphene and borophene silver nanoparticles and graphene silver oxide nanoparticles should be diluted separately with 50–60 mL of water. The composite-based nano membrane was assembled utilising the filtration AS technique, allowing the fluid to flow through the membrane effortlessly at a pressure of 0.7 bar. These solutions were diluted by filtering them over a 1.1 µm cellulose acetate membrane. Before being used, the manufactured assembly layer or membrane must be well dried overnight.The particular filtration test is used to verify the layer's effectiveness. For this reason, we use an indication known as methylene blue. A UV–visible spectrophotometer was used to examine the assembly process.

2.4 Characterization techniques

Graphene can be characterized by many techniques including some are these
. atomic force microscopy
. transmission electron microscopy
. Raman spectroscopy.

. UV–visible spectroscopy
. SEM analysis
. Fourier transforms infrared spectroscopy

The number of graphene membrane layers may be ascertained using atomic force spectroscopy, and graphene oxide sheet structure and shape can be identified using transmission electron microscopy (TEM) pictures. The ultramarine the graphene oxide's visible spectrum revealed an absorption peak at a wavelength of around 225-226 nm. Following ascorbic acid reduction, the abdunant peak of reduced graphene oxide was measured at 225 nm. Graphene, borene, and their oxides have very anisotropic mechanical and electronic character parameter qualities. This means that their distinctive metallic band structure is shown in a path where a large band gap is present in a zigzag pattern.X-ray diffraction methods may be used to visulize and characterise the crystal structure of borophene graphene material. We use the X-ray method in this manner. These X-rays must be diffracted from the crystal structure material when they are incident upon or laid down on it. When examining the diffraction of x-rays with identical wavelengths, a particular lattice is studied. The x-rays with short wavelengths that are used When an X-ray beam is incidentally applied to an atom, it might result in an elastic or inelastic collision. The collision connection is represented in Equation (1).

$2d \sin \theta = n\lambda$

where n is the order of diffraction, θ is the diffraction angle, λ is the wavelength of the incoming X rays, and d is the distance.X-ray diffraction (XRD) is primarily used to compute or determine the internal component or structure of crystallites and their modes of occurrence. It is also used to calculate the size of the crystallites by using Scherer's relation, as indicated in Equation (2).

$dhkl = k\lambda \quad dhkl = K\lambda/B\cos \theta$

The structural and chemical makeup of nano composite material is studied using this technology.material is exposed to light, and when that light travels through the material, it may be absorbed or released from the nanocomposite portion of the material. The Raman effect, which is now being studied, is caused by inelastic scattering and results in a longer shift in frequency, which is expressed in cm^{-1}. Eq. (3) provides a mathematical demonstration of them.

$\Delta V = (1/\lambda 0 + 1/ \lambda 1)$

where λ1 is the wavelength of light from Raman scattered rays, and λo is the incoming laser light wavelength. The units of measurement for laser light and Raman wavelengths are nanometers. Many crystal features, including grain size, phase formation, and crystal structure, are often discussed using Raman spectroscopic methods.

The morphology of the constructed Nano composite thin film is ascertained using SEM examination. The electron beam that is created while the SEM operates comes from an electron cannon that blasts electrons into the material. By using magnetic lenses, an electron beam is shown. The electron beam is scanned using scanning coils to look for signals. SEM is used to ascertain material composition, topography, morphology, and crystallographic details. The sample's parameters are characterised using the EDX approach. With this method, every component in a sample generates a distinct spectrum.

One characterization method for its identification is visible and ultraviolet spectroscopy.

various materials' photocatalytic and photocatalytic characteristics. In organic compounds, it is used to choose between conjugation and unsaturation. In light of the photocatalytic characteristics of Calculating the membrane's efficiency. Spectrophotometers with a range of 195–1100 nm and a scanning speed of 1–3810 nm/min are used in UV–vis and spectroscopy. The foundation of visible and ultraviolet spectroscopy is the Beer-Lambert equation. Spectroscopy may be used to determine optical characteristics such as luminescence, reflectance, and absorption. The energy difference, refractive index, optical conductivity, and a few other fundamental optical characteristics of semiconducting materials may all be found via ultraviolet visible spectroscopy.

An improved analytical approach utilised to analyse the functional groups in the processed samples is Fourier transform infrared spectroscopy. Plotted infrared spectra at a wavenumber (cm−1) and transmittance percentage. A mathematical technique or instrument for processing time field spectrum in the frequency range area domain spectrum is the Fourier transform. In chemistry, FTIR spectroscopy is often used to identify functional groups in molecules.

2.5 Catalytic activity of Material

The catalytic process The catalytic activity was assessed by passing a solution of methylene blue dye through Membranes composed of reduced graphene oxide, borophene oxide, and nano reduced oxide of silver combine to produce nano composites.Catalytic removal MB was carried out on the samples at intervals of 30 minutes and 35–125 minutes. Grab a spectrophotometer at 660 nm and utilise it. Estimate the percentage of dye removal using the relationship shown in the equation. (when A and A0 are denotes the value of absorbance at zero and time "t"). In this equation

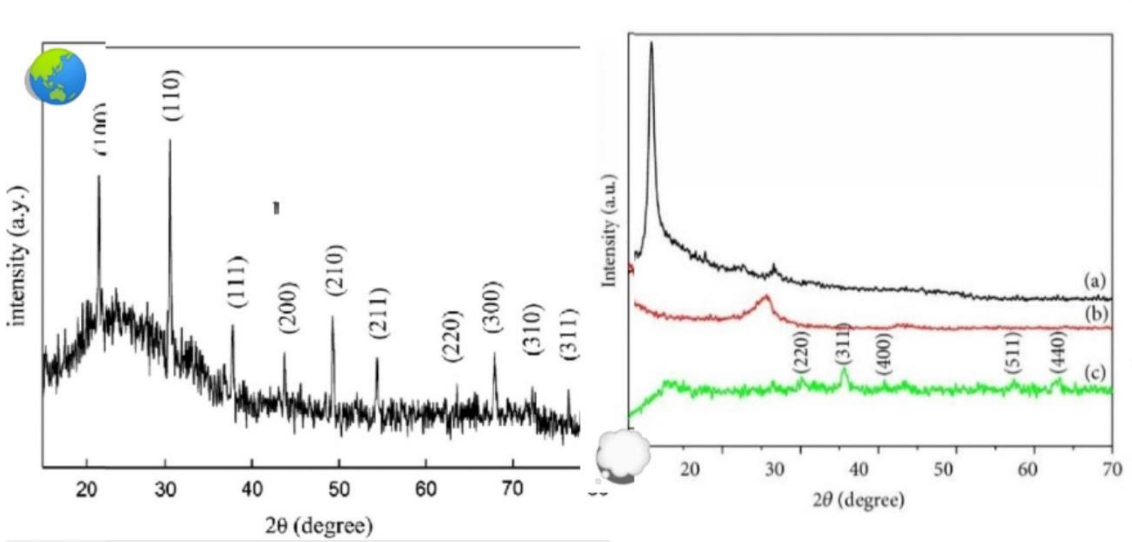
Decay (%) = 1 - at/A0

Results And Discussion

Graphite powder was chemically exchanged to yield graphene and borophene oxides. These oxides are converted to ascorbic acid in reduced form. Turkevich approach, one of the most significant techniques, developed a nano composite of silver with graphene and borophene oxides.

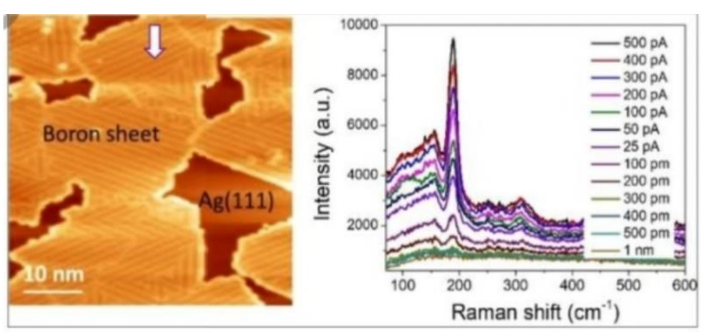
Structure analysis

The structural characteristics of the graphene and borophene sliver-based compound are examined using the X-ray diffraction method.To verify the reduction of graphene oxide and other borophene oxides into reduced form, however, the XRD analysis is used to determine the oxidation state of graphite powder into graphene and borophene oxide. The XRD characterisation was being performed on powder material. Figure 1 displays the XRD spectra. The graph indicates that the peak of graphene oxide is located at 10.4°. This peak indicates the oxidation of the precursor material, graphite powder. Graphite has a similar peak at 25°. This observation shows that the angle shifts from 25° to 10.4° when graphite oxidises to graphene oxide. This angle shifting demonstrates that the d-spacing changed from 3.35 °C to 8.49 °C as well. An additional peak at an angle of 22.62° can be seen in the XRD spectra of rGO, which is the result of the graphitization of the plane. The graphene oxide value decreases,



XRD ANALYSIS of Graphene And Borophene

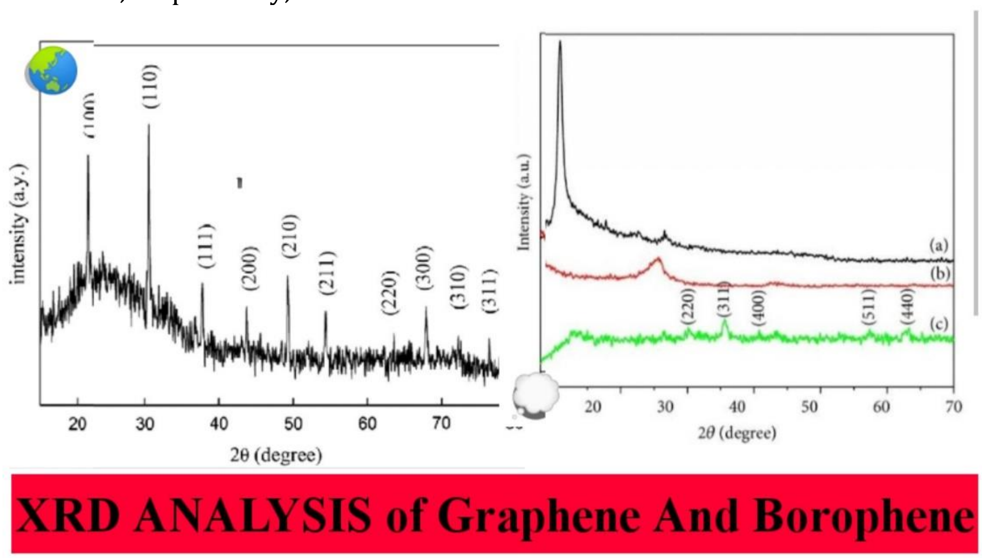
causing the d-spacing in rGO to decrease from 8.49 Å to 3.92 Å. Figure 2's XRD spectra reveal the crystallinity of graphite. The large hump-shaped peak in the graphene borophene silver-based oxides represents the amorphous structure OR lattice. When the XRD spectra of the graphene oxide silver nano composite are examined, the lattice planes identified as (111.5), (200), and the approximate, (220), cause the XRD peaks to shift at angles of 38.2°, 44.4°, and 64.6°. XRD spectra of graphene and borophene in their reduced forms the nano composite displays maxima at 38.2, 44.4, and 64.6 degrees. The lattice planes for (111), (200), and (220) are shown by these peaks. The face-centered cubic structure of the compound based on silver is confirmed by all these lattice planes, which explains why the XRD characteristic peaks of reduced form graphene oxide and graphene borophene both exhibit the presence of silver. When compared to other composites, the XRD spectra of the silver nano composite show a broad-shaped peak.



RAMAN TECHNIQUES ANALYSIS

Raman spectroscopic analysis

When examining the degree of oxidation and reduction in compounds related to graphite, such as graphene and borophene oxides, Raman spectroscopy is used. This research experience project uses an argon laser with a wavelength of 514-515 nm. The concepts of oxidation and reduction are examined using the D and G bands as a framework. The nano composite of graphene and borophene's Raman spectra. The graph indicates that the D and G bands have two distinct maxima located at 1358.32 cm−1 and 1595.30 cm−1. Likewise, the reduced form's D and G band values are less than those of the graphene oxides. The rGO's D and G bands are, respectively, 1353.21 cm−1 and 1587.46 cm−1.FIG. 1



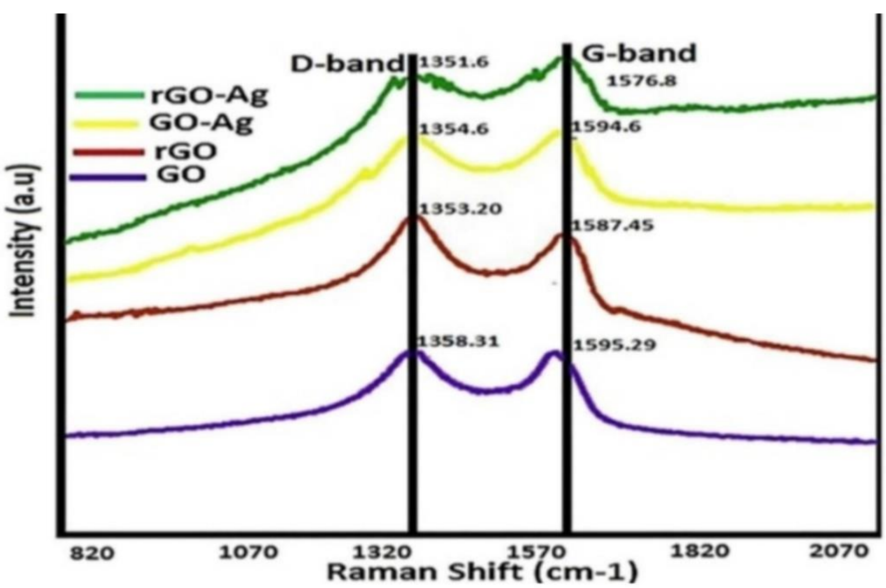
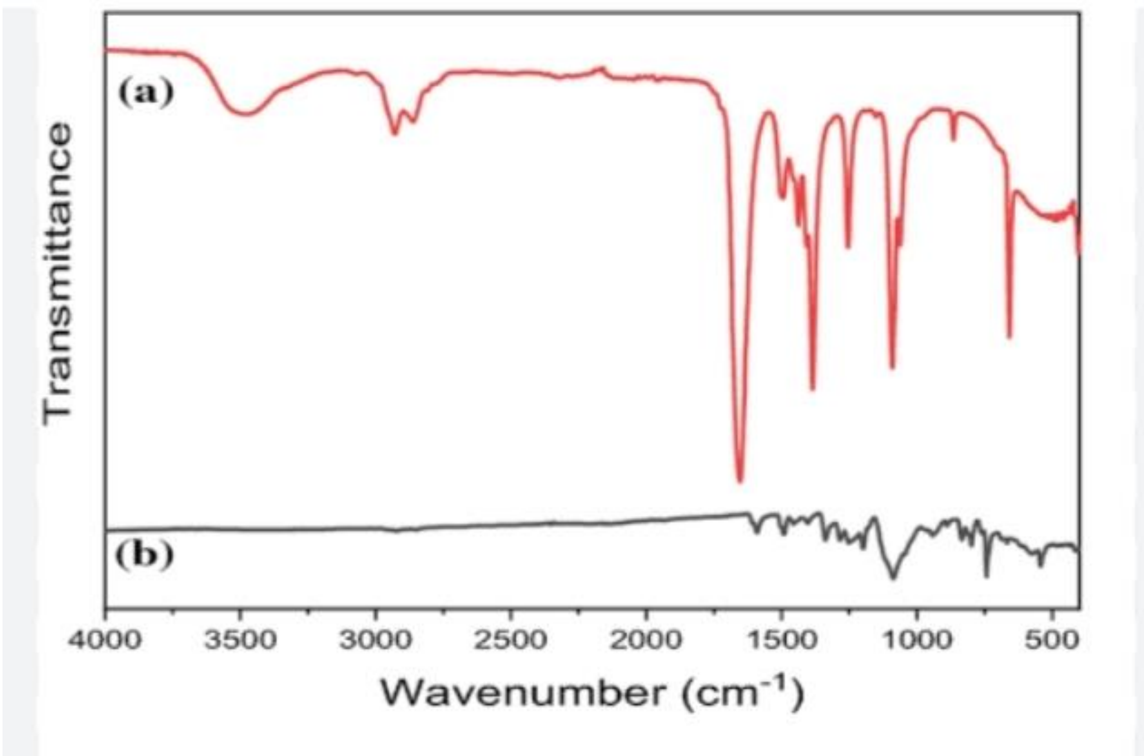


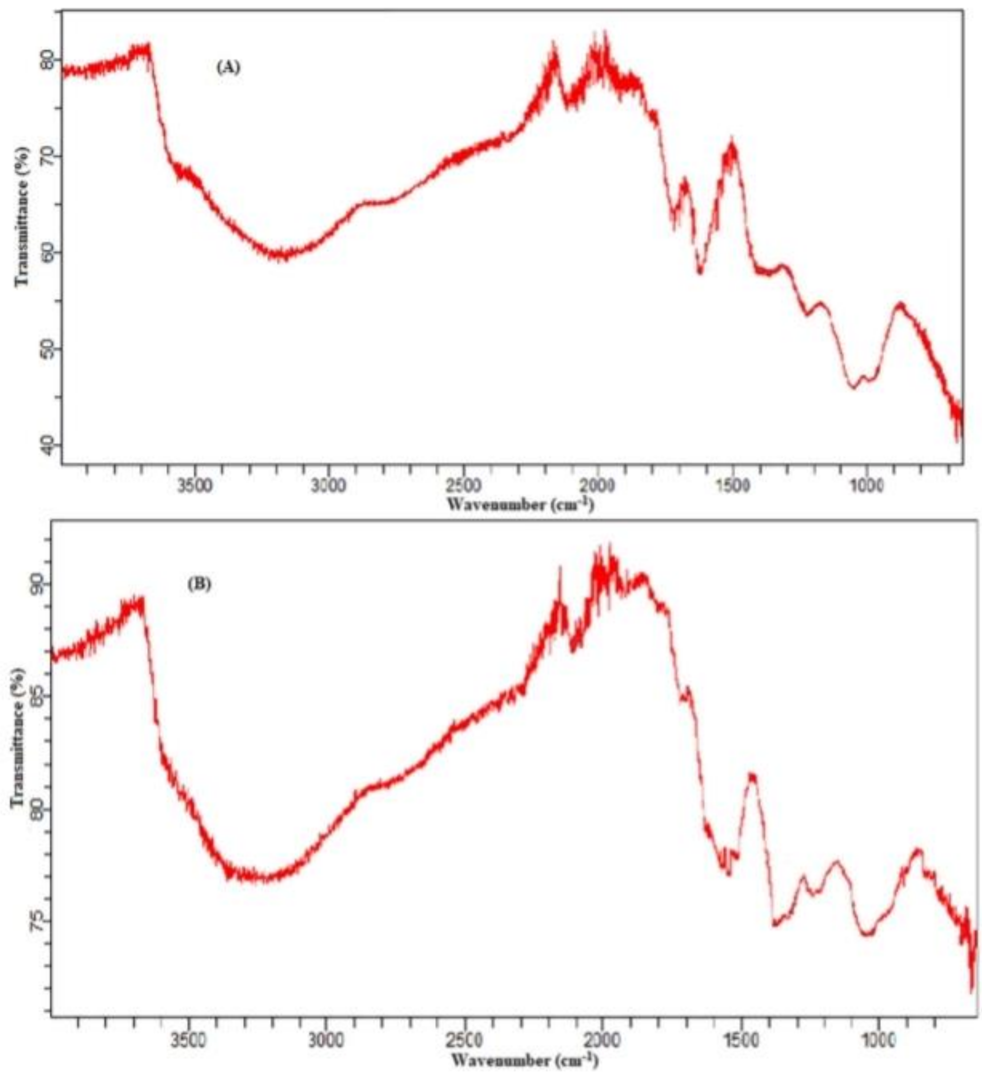
Fig 2 Shown the analysis

Fourier transform infrared spectroscopy analysis

The functional groups found in graphene oxide, borophene oxide, and reduced form nano nanocomposite silver-based oxides were verified by FTIR analysis. The graph displays the distinctive wide stretching peak of OH within the 3500–3450 cm−1 range. Comparably, C–O peak is between 2353 and 1710 cm−1, C–O peak is close to 1710 cm−1, and C–C lies between 1600 and 1600 cm−1. Similar peaks are also seen for several functional groups depending on oxygen. The characteristic broad stretching peak of OH is seen in the FTIR spectra of the graphene and borophene silver oxides nano composite in the range of 3500–3400 cm−1. Additional peaks related to Ag are also produced in this region, including C–O 1300 cm−1 and C=C 1600 cm−1, so the discussion of the characteristic broad stretching peak of OH is lessened as a result of the OH group's reduction. This peak is located between 3500 and 3400 cm-1.

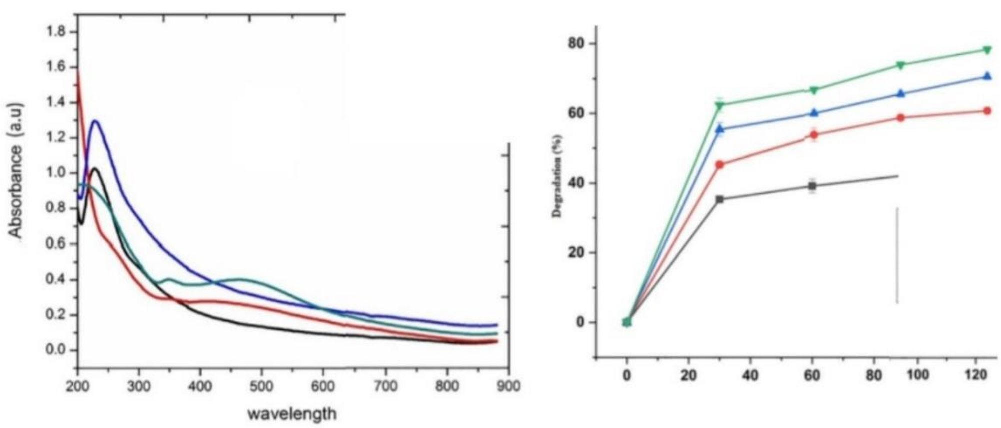


, C–O peak



How remove dye(efficiency)

The membrane made of graphene, reduced graphene, borophene, and borophene oxides—both of which are used in silver-based nanocomposites—was subjected to methylene blue solution. The prominent peaks at 660–665 nm was produced during their UV–visible spectroscopy research. The intensity of the peaks that have decreased the natural characteristics of the material, from graphene and borophene oxides to reduced form and ultimately their composites, is reflected in these peaks. These peaks demonstrate the materials' photocatalytic activity and potential for pollutant breakdown.By monitoring the catalysis at intervals of 35 minutes, the duration required for the catalytic breakdown of MB was optimised. The highest deterioration was seen at 125 minutes (47.56 percent for oxides, 60.56 percent for reduced form GO, and 71.14%). Using a decreased graphene Ag based composite material, the maximum quantity of MB dye was destroyed at 125 minutes. This implies that the developed composite material may be used to cause colour deterioration. The goal of Ursino et al. purification is the development of a water Nano composite membrane. Conventional polymeric membranes are unsuitable for treating wastewater due to a number of issues, including fouling. Silver NP Nano composite with graphene borophene oxides is used for water filtration and fouling resistance. They serve as a water filler to boost the filter's efficiency. The use of metal composites such as graphene and borophene may increase both photocatalytic activity and filtering efficiency. In order to investigate the effects of silver nanoparticle size on filtering effectiveness and capability, Yang et al. developed three different kinds of silver graphene composite nanomembrane. Further analysis of the generated material was conducted using TEM and UV-vis spectroscopy. Pathology This study endeavour looked at the catalytic activity of several chemicals, and the findings were quite positive.The catalytic performance of the graphene oxides, borophene oxides, and their reduced oxides composite showed promising efficacy for the removal of dye, which may be employed to remove colours from textile effluents. The level of environmental pollution has dramatically grown as a result of human activities. Composite materials are one type of advanced materials that can be used to tackle this challenge.



Conclusion

Owing to the unique properties of graphene and its composites, they find several uses in the domains of technology, medicine, and research. The solution approach is used to make composites of reduced form oxides, graphene, and borophene, as well as their oxides. A composite is created by this procedure.FTIR, Raman, UV-visible spectroscopy, SEM, EDX, XRD, and FTIR were employed to characterise the method. Raman spectra show that the reduced forms of graphene and borophene silver nano composites have D and G peaks of

1351.5 cm-1 and 1576.7 cm-1, respectively. Peaks for the oxygen-based functional group are discernible in the FTIR spectra of the synthesised nanocomposites. After 120 minutes, the MB dye's maximum degradation of 79.35 percent was reached.

References.

1. Abbas M., Hussain T., Iqbal J., Rehman A. U., Zaman M. A., Jilani K., Masood N., Al-Mijalli S. H., Iqbal M.,Nazir A. Synthesis of silver nanoparticle from Allium sativum as an eco-benign agent for biological applications. Pol. J. Environ. Stud. 2022, 31, 533–538.
2. Ajeesha T., Ashwini A., George M., Manikandan A., Mary J. A., Slimani Y., Almessiere M., Baykal A.Nickel substituted MgFe2O4 nanoparticles via co-precipitation method for photocatalytic applications. Phys. B: Condens. Matter 2021, 606, 412660.
3. Al Banna L. S., Salem N. M., Jaleel G. A., Awwad A. M. Green synthesis of sulphurs nanoparticles using Rosmarinus officinal is leaves extract and nematicidal activity against Meloidogyne javanica. Chem.Int. 2020, 6, 137–143.
4. Alahmari F., Rehman S., Almessiere M., Khan F. A., Slimani Y., Baykal A. Synthesis of Ni0.5Co0.5-xCdxFe1.78Nd0.02O4 (x ≤ 0.25) nanofibers by using electrospinning technique induce anti cancer and anti-bacterial activities. J. Biomol. Struct. Dyn. 2021, 39, 3186–3193.
5. Alam S. N., Sharma N., Kumar L. Synthesis of graphene oxide (GO) by modified hummers method and its thermal reduction to obtain reduced graphene oxide (rGO). Graphene 2017, 6, 1–18.
6. AL-Dharob M. H., Mouhamad R. S., Al Khafaji K. A., Al-Abodi E. E. Antibacterial efficacy of cotton nanofiber soaked in Ag, ZnO and TiO2 nanoparticles. Chem. Int. 2022, 8, 58–67.
7. Ali F. A. A., Alam J., Shukla A. K., Alhoshan M., Ansari M. A., Al-Masry W. A., Rehman S., Alam M. Evaluation of antibacterial and antifouling properties of silver-loaded GO polysulfone nanocomposite membrane against Escherichia coli, Staphylococcus aureus, and BSA protein. React. Funct. Polym. 2019, 140, 136–147.
8. Ali F., Hamza M., Iqbal M., Basha B., Alwadai N., Nazir A. State-of-art of silver and gold nanoparticles synthesis routes, characterization and applications: a review. Z. Phys. Chem. 2022, 236, 291–326.
9. Aljameel S. S., Almessiere M. A., Khan F. A., Taskhandi N., Slimani Y., Al-Saleh N. S., Manikandan A.,Alishaimi E. A., Baykal A. Synthesis, characterization, anti-cancer analysis of Sr0.5Ba0.5DyxSmxFe8−2xO19 (0.00≤ x≤ 1.0) microsphere nano composites. Nanomaterials 2021, 11, 700.
10. Amer M. W., Awwad A. M. Green synthesis of copper nanoparticles by Citrus limon fruits extract, characterization and antibacterial activity. Chem. Int. 2021, 7, 1–8.
11. and Fe doped LaNiO3 and their photocatalyst efficacy for methyl green oxidation under visible light
12. Awwad A. M., Amer M. W. Biosynthesis of copper oxide nanoparticles using Ailanthus altissima leaf extract and antibacterial activity. Chem. Int. 2020, 6, 210–217.
13. Awwad A. M., Amer M. W., Salem N. M., Abdeen A. O. Green synthesis of zinc oxide nanoparticles (ZnO-NPs) using Ailanthus altissima fruit extracts and antibacterial activity. Chem. Int. 2020, 6,
14. Awwad A. M., Salem N. M., Aqarbeh M. M., Abdulaziz F. M. Green synthesis, characterization of silver sulphide nanoparticles and antibacterial activity evaluation. Chem. Int. 2020, 6, 42–48.
15. Bhatti H. N., Hayat J., Iqbal M., Noreen S., Nawaz S. Biocomposite application for the phosphate ions removal in aqueous medium. J. Mater. Res. Technol. 2018, 7, 300–307.
16. Bhatti H. N., Safa Y., Yakout S. M., Shair O. H., Iqbal M., Nazir A. Efficient removal of dyes using carboxymethyl cellulose/alginate/polyvinyl alcohol/rice husk composite: adsorption/desorption, kinetics and recycling studies. Int. J. Biol. Macromol. 2020, 150, 861–870.
17. Chigondo M., Chigondo F., Nyamunda B. Synthesis of hydrous CeO2 polypyrrole nanocomposite as a rapid and efficient adsorbent for defluoridation of drinking water. Environ. Nanotechnol.

Monit.Manag. 2021, 16, 100462.
18. Choker A. A., Achugwo C. N. Distribution, source identification and eco-toxicological risks of PAHs in sediments of Aba River at Ogbor-Hill region, Nigeria. Chem. Int. 2022, 8, 47–57.
19. Dimiev A. M., Tour J. M. Mechanism of graphene oxide formation. ACS Nano 2014, 8, 3060–3068.
20. Elsherif K. M., El-Dali A., Alkarewi A. A., Mabrok A. Adsorption of crystal violet dye onto olive leaves powder: equilibrium and kinetic studies. Chem. Int. 2021, 7, 79–89.
21. George M., Ajeesha T., Manikandan A., Anantharaman A., Jansi R., Kumar E. R., Slimani Y., Almessiere M., Baykal A. Evaluation of Cu–MgFe2O4 spinel nanoparticles for photocatalytic and antimicrobial activates. J. Phys. Chem. Solid. 2021, 153, 110010.
22. Gunasekaran S., Thanrasu K., Manikandan A., Durka M., Dinesh A., Anand S., Shankar S., Slimani Y.,Almessiere M. A., Baykal A. Structural, fabrication and enhanced electromagnetic wave absorption properties of reduced graphene oxide (rGO)/zirconium substituted cobalt ferrite (Co0·5Zr0·5Fe2O4) Nano composites. Phys. B: Condens. Matter 2021, 605, 412784.
23. Hsiao M.-C., Ma C.-C. M., Chiang J.-C., Ho K.-K., Chou T.-Y., Xie X., Tsai C.-H., Chang L.-H., Hsieh C.-K.Thermally conductive and electrically insulating epoxy nanocomposites with thermally reduced graphene oxide–silica hybrid nanosheets. Nanoscale 2013, 5, 5863–5871.
24. Idika D., Ndukwe N., Ogukwe C. Appraisal of bed height and flow rate effect on the removal of dyes on Pine biomass. Chem. Int. 2022, 8, 42–46.
25. Iqbal S., Bibi I., Majid F., Kamal S., Iqbal M., Alfryyan N. Graphene oxide (GO) nanocomposite with Gd
26. Jalal G., Abbas N., Deeba F., Butt T., Jilal S., Sarfraz S. Efficient removal of dyes in textile effluents using aluminum-based coagulants. Chem. Int. 2021, 7, 197–207.
27. Kausar A., Zohra S. T., Ijaz S., Iqbal M., Iqbal J., Bibi I., Nouren S., El Messaoudi N., Nazir A. Cellulose-based materials and their adsorptive removal efficiency for dyes: a review. Int. J. Biol. Macromol. 2023,224, 1337–1355.
28. Khawaja H., Zahir E., Asghar M. A., Asghar M. A. Graphene oxide, chitosan and silver nanocomposite as a highly effective antibacterial agent against pathogenic strains. Colloids Surf. A 2018, 555, 246–255.
29. Kumar A., Yasin G., Vashistha V. K., Das D. K., Rehman M. U., Iqbal R., Mo Z., Nguyen T. A., Slimani Y.,Nazir M. T., Zhao W. Enhancing oxygen reduction reaction performance via CNTs/graphene supported iron protoporphyrin IX: a hybrid Nano architecture electrocatalyst. Diamond Relat. Mater.2021, 113, 108272.
30. Menazea A. A., Ezzat H. A., Omara W., Basyouni O. H., Ibrahim S. A., Mohamed A. A., Tewfik W.,Ibrahim M. A. Chitosan/graphene oxide composite as an effective removal of Ni, Cu, As, Cd and Pbfrom wastewater. Compute. Theor. Chem. 2020, 1189, 112980.
31. Naeem H., Ajmal M., Qureshi R. B., Muntha S. T., Farooq M., Siddiq M. Facile synthesis of graphene oxide–silver nanocomposite for decontamination of water from multiple pollutants by adsorption, catalysis and antibacterial activity. J. Environ. Manag. 2019, 230, 199–211.
32. Naseer A., Iqbal M., Ali S., Nazir A., Abbas M., Ahmad N. Green synthesis of silver nanoparticles using Allium cepa extract and their antimicrobial activity evaluation. Chem. Int. 2022, 8, 89–94.
33. Naseer F., Zahir E., Danish E. Y., Gull M., Noman S., Soomro M. T. Superior antibacterial activity of reduced graphene oxide upon decoration with iron oxide nanorods. J. Environ. Chem. Eng. 2020, 8,104424.
34. Nazir A., Raza M., Abbas M., Abbas S., Ali A., Ali Z., Younas U., Al-Mijalli S. H., Iqbal M. Microwave assisted green synthesis of ZnO nanoparticles using Rumex dentatus leaf extract: photocatalytic and antibacterial potential evaluation. Z. Phys. Chem. 2022, 236, 1203–1217.
35. Neolaka Y. A. B., Lawa Y., Naat J. N., Riwu A. A. P., Iqbal M., Darmokoesoemo H., Kusuma H. S. The adsorption of Cr(VI) from water samples using graphene oxide-magnetic (GO-Fe3O4) synthesized from natural cellulose-based graphite (kusambi wood or Schleichera oleos a): study of kinetics,

isotherms and thermodynamics. J. Mater. Res. Technol. 2020, 9, 6544–6556.
36. Noreen S., Ismail S., Ibrahim S. M., Kusuma H. S., Nazir A., Yaseen M., Khan M. I., Iqbal M. ZnO, CuO and Fe2O3 green synthesis for the adsorptive removal of direct golden yellow dye adsorption: kinetics,equilibrium and thermodynamics studies. Z. Phys. Chem. 2021, 235, 1055–1075.
37. Pei S., Cheng H.-M. The reduction of graphene oxide. Carbon 2012, 50, 3210–3228.
38. Pei S., Zhao J., Du J., Ren W., Cheng H.-M. Direct reduction of graphene oxide films into highly conductive and flexible graphene films by hydrohalic acids. Carbon 2010, 48, 4466–4474.
39. Pusty M., Rana A. K., Kumar Y., Sathe V., Sen S., Shirage P. Synthesis of partially reduced graphene oxide/silver nanocomposite and its inhibitive action on pathogenic fungi grown under ambient conditions. ChemistrySelect 2016, 1, 4235–4245.
40. Salem N. M., Awwad A. M. Green synthesis and characterization of ZnO nanoparticles using Solanum rantonnetii leaves aqueous extract and antifungal activity evaluation. Chem. Int. 2022, 8, 12–17.
41. Sharif S., Zaman Q. u., Hassan F., Javaid S., Arif K., Mansha M. Z., Ehsan N., Nazir S., Gul R., Iqbal M.,Nazir A. Coagulation of metallic pollutants from wastewater using a variety of coagulants based on metal binding interaction studies. Z. Phys. Chem. 2021, 235, 467–481.
42. Tan S., Wu X., Xing Y., Lilak S., Wu M., Zhao J. X. Enhanced synergetic antibacterial activity by a reduce graphene oxide/Ag nanocomposite through the photothermal effect. Colloids Surf. B 2020, 185, 110616.
43. Tang J., Chen Q., Xu L., Zhang S., Feng L., Cheng L., Xu H., Liu Z., Peng R. Graphene oxide–silver nanocomposite as a highly effective antibacterial agent with species-specific mechanisms. ACS Appl. Mater. Interfaces 2013, 5, 3867–3874.
44. Thebo K. H., Qian X., Zhang Q., Chen L., Cheng H.-M., Ren W. Highly stable graphene-oxide-based membranes with superior permeability. Nat. Commons. 2018, 9, 1–8.
45. Ukpaka C. P., Ugiri A. C. Biodegradation kinetics of petroleum hydrocarbon in soil environment using Mangnifera indica seed biomass: a mathematical approach. Chem. Int. 2022, 8, 77–88.
46. Ullah S., Campéon B. D. L., Ibraheem S., Yasin G., Pathak R., Nishina Y., Anh Nguyen T., Slimani Y.,Yuan Q. Enabling the fast lithium storage of large-scalable γ-Fe2O3/Carbon nan architecture anode material with an ultralong cycle life. J. Ind. Eng. Chem. 2021, 101, 379–386.
47. Ursino C., Castro-Muñoz R., Drioli E., Gzara L., Albeirutty M. H., Figoli A. Progress of nanocomposite membranes for water treatment. Membranes 2018, 8, 18.
48. Vi T. T. T., Rajesh Kumar S., Rout B., Liu C.-H., Wong C.-B., Chang C.-W., Chen C.-H., Chen D. W., Lue S. J. The preparation of graphene oxide-silver nanocomposites: the effect of silver loads on Gram-positive and Gram-negative antibacterial activities. Nanomaterials 2018, 8, 163.
49. Whang T.-J., Huang H.-Y., Hsieh M.-T., Chen J.-J. Laser-induced silver nanoparticles on titanium oxide for photocatalytic degradation of methylene blue. Int. J. Mol. Sci. 2009, 10, 4707–4718.
50. Yang K., Huang L.-J., Wang Y.-X., Du Y.-C., Zhang Z.-J., Wang Y., Kipper M. J., Belfiore L. A., Tang J.-G. Graphene oxide Nano filtration membranes containing silver nanoparticles: tuning separation efficiency via nanoparticle size. Nanomaterials 2020, 10, 454.
51. Zaman Q. u., Anwar S., Mehmood F., Nawaz R., Masood N., Nazir A., Iqbal M., Nazir S., Sultan K.Experimental modeling, optimization and comparison of coagulants for removal of metallic pollutants from wastewater. Z. Phys. Chem. 2021, 235, 1041–1053.