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SYNTHESIS AND CHARACTERIZATION OF BORON NITRIDE-GRAPHENE OXIDE (BN-GO) HYBRID COMPOSITES FOR ENERGY APPLICATIONS

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ABSTRACT

One of the primary challenges lies in the development of sustainable and environmentally friendly energy storage devices to address escalating energy demands. To fulfill this need, there is a growing interest in exploring novel materials that possess these desired characteristics. Over recent decades, two-dimensional (2D) materials have garnered significant attention from researchers due to their remarkable properties. Graphene, an allotrope of carbon, is a two-dimensional material consisting of a single layer of carbon atoms arranged in a hexagonal lattice. Additionally, graphene oxide (GO), a derivative of graphene, is formed by oxidizing graphene. Graphene oxide retains some of the properties of graphene but also gains additional features such as dispersibility in water and enhanced chemical reactivity due to the presence of functional groups. Boron nitride (BN) emerges as a promising 2D material offering unique attributes such as high thermal and chemical stability, substantial surface area, wide bandgap, and excellent mechanical and thermal properties. This present work deals with the synthesis and characterization of Boron nitride-graphene oxide (BN-GO) composite materials for energy applications. The synergistic effects arising from the integration of graphene oxide and boron nitride result in enhanced mechanical strength, thermal conductivity, and chemical stability.The versatile nature of BN-GO composites allows for their incorporation into polymers, facilitating their integration into flexible and lightweight energy systems. X-ray powder diffraction (XRD) and UV-visible analysis (UV-Vis) are utilized for the characterization of the resultant samples. BN-GO composites are regarded as promising candidates for the development of advanced composites with enhanced electrical and chemical properties for energy-related applications.

Keywords: - Composites, Hexagonal Boron nitride, Graphene oxide, Energy applications

INTRODUCTION

In the pursuit of innovative materials for energy applications, Boron nitride (BN) and graphene oxide (GO) have emerged as promising materials for a wide range of energy applications due to their unique properties and versatile functionalities. Boron nitride, a structural analog of graphene, possesses excellent thermal conductivity, high electrical insulation, and chemical inertness, making it highly desirable for thermal management and electrical insulation in various energy systems[1]. On the other hand, graphene oxide, derived from graphene through oxidation, exhibits exceptional mechanical strength, large surface area, and tunable chemical properties, rendering it suitable for energy storage and conversion devices such as supercapacitors and batteries[2]. Despite their individual advantages, both boron nitride and graphene oxide have certain limitations that hinder their practical applications. For instance, boron nitride typically exhibits poor dispersion in polymer matrices, limiting its effectiveness as a reinforcement phase in composite materials. Similarly, graphene oxide often suffers from reduced electrical conductivity and mechanical strength compared to pristine graphene, thereby compromising its performance in energy-related applications. To overcome these challenges, researchers have explored the fabrication of hybrid composites combining boron nitride and graphene oxide. By synergistically combining the unique properties of these two materials, such hybrid composites aim to overcome the limitations of individual components and achieve enhanced performance for energy applications. Strategies such as surface functionalization, chemical modification, and controlled synthesis have been employed to improve the dispersion, compatibility, and interfacial interactions between boron nitride and graphene oxide within the composite matrix[3]. The successful fabrication and characterization of boron nitride-graphene oxide (BN-GO) hybrid composites hold significant promise for advancing various energy technologies. These hybrid materials not only offer improved thermal and electrical properties but also enable the development of lightweight, durable, and efficient energy devices. With ongoing research, and efforts focused on optimizing synthesis methods, enhancing material properties, and exploring new application avenues, the future of BN-GO hybrid composites in energy applications appears highly promising. This present work focuses on the experimental techniques and methods employed for the production of exfoliated boron nitride sheets from bulk boron nitride, along with details on the synthesis process of the sample. Additionally, it also emphasis on the preparation of hybrid composites of exfoliated boron nitride and graphene oxide(BN/GO). Furthermore, XRD analysis and UV-visible analysis were carried out to characterize the prepared sample. BN/GO composites can be incorporated with polymers and could be successfully utilized for future energy applications.

MATERIALS AND METHODS

All materials used were procured from Sigma

Aldrich, USA, (AR Grade), including Boron Nitride (with a molecular weight of 24.82g/mol), Graphene Oxide, Deionized water, and DMF (Dimethyl Formamide).

Boron nitride undergoes the process of liquid phase exfoliation technique to form boron nitride nanosheets. 3 gm of Boron Nitride powder was dissolved in 200 ml of DMF (N, N-dimethylformamide) and subjected to continuous stirring for approximately 30 minutes using a magnetic stirrer to ensure uniform dispersion. Subsequently, the dispersion underwent ultrasonication using a probe sonicator for around 1 hour to achieve exfoliation into nanosheets. The resulting supernatant solution was then subjected to agitation at 3000 revolutions per minute (rpm) to remove any remaining unexfoliated particles. Following filtration, the particles were washed with deionized water and subsequently dried in a hot air oven at 80°C for approximately 24 hours and were subjected to simple functionalization using a suitable modifier.

Synthesis of BN/GO hybrid composites

The dried substance, BN, was ground into powder and now 50ml of deionized water was added and stirred for 15 minutes. Then 0.2gm of Graphene Oxide (GO) was added in different weight ratios (Table 1) and stirred for 1 hour. Both the mixtures are then sonicated for 30 minutes. Then they are again stirred for 1 hour and centrifuged. Finally, they are dried for 24 hours in a hot air oven at 100ºC.

Sl.No	Ratio	Boron Nitride (gm)	Graphene Oxide (gm)	Sample Code
1	1:1	0.2	0.2	BNGO1
2	1:2	0.4	0.2	BNGO2

Table 1: Represents the weight ratio of BN/GO composites

RESULTS AND DISCUSSION

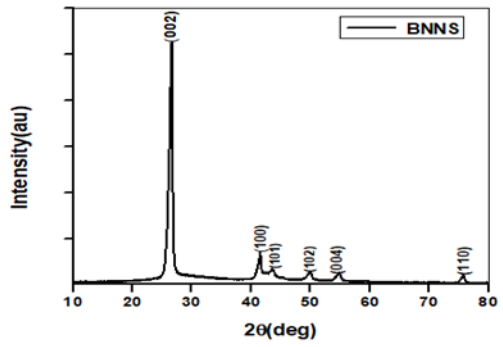
All samples underwent X-ray diffraction (XRD) characterization with an X-PERT-PRO X-ray Diffractometer equipped with CuKα radiation (λ=1.5218A^0). UV-visible spectroscopic studies were conducted using a UV-DRS-Spectrophotometer, specifically the Thermofisher Evaluation 220 instrument.

XRD Analysis

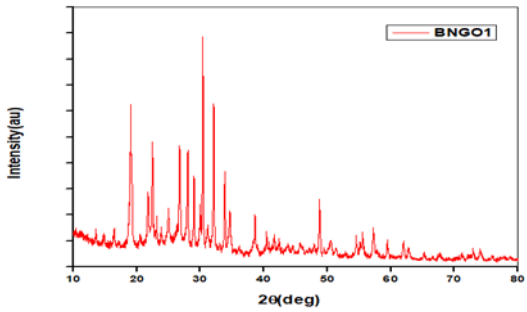
X-ray diffraction analysis of powdered samples is conducted to assess their crystal purity and structure. The characteristic peak observed at 26.62° in Figure 1(a) corresponds to the (002) hkl plane of exfoliated BNNS, aligning well with JCPDS Card No. 34-0421 [4]. Graphene oxide shows minor peaks persist at 2θ = 20.1°, 23.9°, and 26.4°, suggesting that graphene oxide remains incompletely linked with oxygen atoms[5]. Additionally, less pronounced peaks are detected at 41.59° and 54.94°. Boron nitride-graphene

oxide(BN-GO) composites are thus synthesized. Figure 1(b) displays the X-ray diffraction pattern of Boron nitride-graphene oxide, revealing characteristic peaks for BNGO1 at 19.06°, 22.59°, 26.67°, 30.51°, 32.20°, 34.04°, 34.75°, 38.92°, 48.78°, 55.86°, 62.06°, and 73.06°. New peaks emerge with higher intensity, confirming the BN and GO integration. In Figure 1(c), BNGO2 exhibits peaks at 16.03°, 22.42°, 26.96°, 30.03°, 32.03°, 34.48°, 38.84°,40.54°, 42.39°, 48.89°, 357.39°, and 61.89° respectively. The peaks in BNGO1 and BNGO2 become narrower and more intense, indicating higher crystallinity. Comparing BN-GO composites (BNGO1 & BNGO2) with exfoliated BNNS reveals increased peak intensity due to BNNS layer stacking, suggesting thicker BNNS layers. This indicates that newer peaks indicate the incorporation of graphene oxide with BNNs resulting in the formation of a composite.

(a)



(b)



(c)

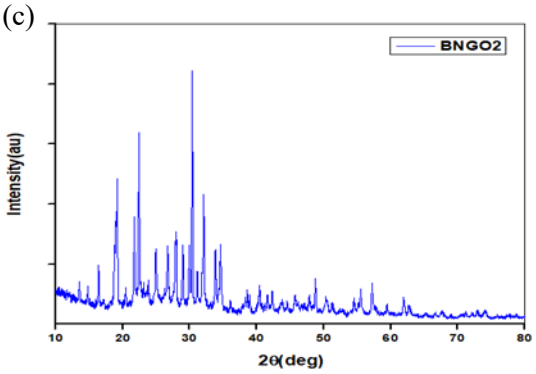


Fig 1: XRD patterns of (a) BNNS, (b) BNGO1, and (c)BNGO2

UV-Visible Analysis

The UV spectrum reveals distinct absorption peaks in both the UV and visible regions for BNGO1, and BNGO2, as depicted in Fig 2. In Figure 2(a), the UV-visible spectrum of BNNS shows a prominent absorption peak at 215nm in the UV region, which corresponds to the π-π* transitions of the aromatic BN structures[6]. The position and intensity of this peak could also explain the electronic structure of the composite formed. In the UV–visible spectrum, graphene oxide exhibited an absorption peak at 226 nm[7]. The relationship between energy and wavelength is described by the equation Energy(eV) = $1240/\lambda_{onset}$ (nm), where λ_{onset} is the wavelength at which different emission and transitions occur prominently in the material's spectrum. BNGO1 shows an absorption peak at 200.14nm with the λ_{onset} value equal to 277nm and is attributed to the unique electronic transitions occurring within the composite material(Figure 2(a)). This phenomenon likely arises from the combined properties of boron nitride and graphene oxide, leading to specific absorption characteristics

in the UV spectrum. In Figure 2(b), BNGO2 exhibits an absorption peak at 202nm. The combination of boron nitride and graphene oxide might create a new electronic structure with different energy levels compared to the individual components. The Energy(eV) for BNGO1 and BNGO2 from UV analysis is 4.47eV and 4.1eV respectively.

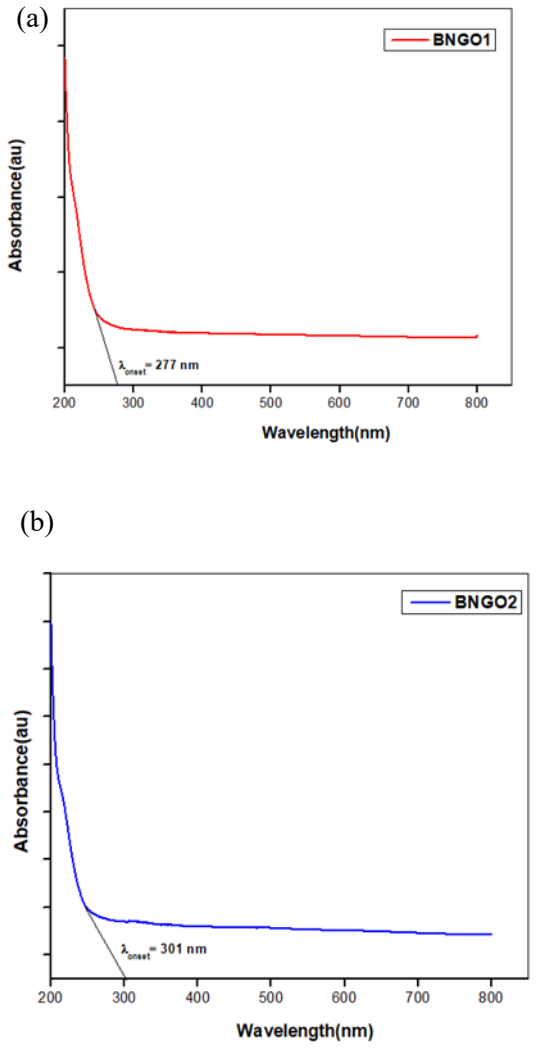


Figure 2: UV-visible analysis of (a)BNGO1 and (b) BNGO2.

CONCLUSION

The present work focuses on the preparation of a Boron nitride-graphene oxide(BN-GO) hybrid composite. This involves the preparation and exfoliation of boron nitride, graphene oxide is synthesized using the modified Hummers method and Boron nitride-graphene oxide composites are fabricated using ultrasonication. Different ratios of BN-GO (1:1 and 1:2) are prepared, thus resulting in BNGO1 and BNGO2 respectively. XRD analysis revealed the formation of exfoliated Boron nitride, the newer peaks in BNGO1 and BNGO2 signify the successful incorporation and formation of BN-GO composites. An increase in the peak intensity in BNGO1 and BNGO2 ensured that the crystalline nature of BNNS was retained after the formation of BN-GO composites. An elevated peak intensity suggests an augmentation in the thickness of BN-GO composite layers. In UV analysis, corresponding bandgap values of BNGO1 and BNGO2 are represented as 4.47eV and 4.1eV respectively. The incorporation of graphene oxide into the boron nitride matrix introduces defects, edges, and functional groups, which can induce localized states within the bandgap. These defects and interfaces can create additional energy levels within the bandgap, reducing its effective width. As a result, the bandgap of the composite material becomes narrower compared to pristine boron nitride whose bandgap is about 6.08eV. This newly developed material represents a novel composite with potential practical applications. Boron nitride-graphene oxide composites offer versatility and could be integrated with polymers to create composite materials, expanding their utility in various energy-related fields. This innovative approach enhances the material's potential for real-

world applications, particularly in areas where energy-related solutions are sought.

CONFLICTS OF INTEREST

No conflicts of interest to declare

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