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The stability in different solvents of rGO/magnetite obtained via ionizing radiation

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1. Introduction

Graphene oxide is a single layer of sp^2 hybridized carbon atoms, containing various oxygen-functional groups on the surface [1]. This nanomaterial exhibits excellent physicochemical properties such as mechanical stability, electrical mobility, and thermal conductivity. Due to its oxygen-functional groups, it has high dispersibility in various solvents, providing high versatility for various applications. Solubility can be improved through the formation of a steric barrier when dispersed in water, leading to a reduction in electrostatic interactions between particles and an increased potential for surface functionalization [2]. Several metals have been incorporated into graphene-based nanocomposites. The synthesis of graphene oxide/magnetite nanocomposites has been explored due to enhanced magnetic, catalytic, and biocompatible properties [3]. This study aims to evaluate the stability of magnetic graphene oxide nanocomposites obtained through electron beam irradiation. The nanomaterials were irradiated using an industrial electron accelerator at different doses (20, 40, and 80 kGy). Characterization methods included UV/VIS spectrophotometry to measure the amount of ultraviolet radiation absorbed by the samples and zeta potential (ζ) for nanoparticle dispersion stability analysis. In the UV/VIS analyses, a standard absorption peak at around 230 nm was observed, confirming the presence of C=C bonds. Zeta potential evaluation at pH 4, 7, and 9 demonstrated effective dispersion stability in the sample irradiated at 80 kGy.

2. Methodology

2.1 Graphene Oxide (GO) Synthesis

Graphene oxide (GO) was obtained using the modified Hummers method.

2.2 Synthesis of Magnetite/Graphene Oxide Nanocomposite via Electron Beam

Initially, 48mg of graphene oxide was dispersed in deionized water, and after exfoliation, the medium was alkalized and adjusted to pH=11 with a 30% ammonia solution under agitation. Later, a solution containing 80mg of $FeSO_4.7H_2O$ was slowly added to the mixture. Subsequently, the samples were irradiated at doses of 20, 40, and 80 kGy, at a dose rate of 10.01 kGy/s, using an industrial electron accelerator (Dynamotron Inc., 37.5 kW, E=1.5 MeV, 25 mA). The process concluded with washing the samples and allowing them to dry.

2.3 UV-VIS Spectrophotometry Characterization

The equipment used was the Amersham Biosciences Ultrospec 2100 pro, located at Ipen, in the Biotechnology Center. Samples were tested in the range of 200nm to 800nm, at a concentration of 1mg/mL, and deionized water from the Milli-Q system was used as the blank solution.

2.4. Zeta Potential

Data were obtained using an Anton Paar Lifesizer 500 zeta potential measurement device. The zeta potential values necessary for indicating suspension stability are above +30mV or below -30mV [5].

2.5. Stability Study

The stability study was conducted following the OECD Council protocol [6] with modifications. The test involved changing the environmental conditions, such as pH, which plays a fundamental role in the behavior of nanomaterials, affecting their adsorption. Dispersion stability was determined by measuring absorbance at 230 nm at 0h and 6h.

3. Results and Discussion

3.1 Absorbance Analysis at Different Electron Beam Irradiation Doses

UV-VIS spectrophotometry was performed to examine the reduction behavior of GO, as shown in Figure 1. In the GO, MGO 40 kGy, and MGO 80 kGy samples, the formation of absorbance peaks, or plasmonic bands, characteristic at a wavelength around 230 nm was observed. This indicates an increase in C=C bonds, thereby restoring π-π interactions and hydrophobic characteristics. In the MGO 20 kGy sample, there was a shift in the absorption peak to 237 nm, indicating a slight reduction in MGO.

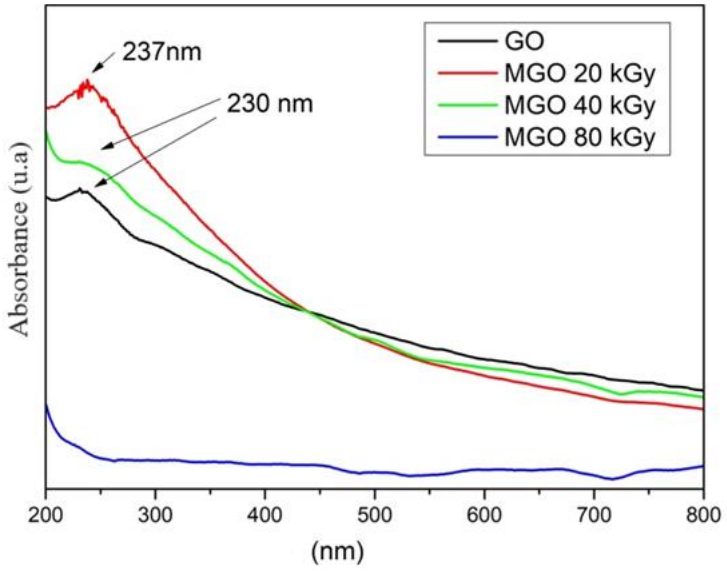

Figure 1: UV-VIS Spectrophotometry of GO, MGO 20 kGy, MGO 40 kGy, and MGO 80 kGy Samples.

3.2. Analysis of the pH Effect on Dispersion

It was observed that the zeta potential at pH 7 exhibited the highest values of negative charge, indicating greater stability for the samples [7], with -32.5mV for MGO 20kGy and -31.7mV for MGO 80kGy. However, at pH 9, values of -26.5mV for MGO 20kGy and -27.8mV for MGO 80kGy, suggested that in this alkaline environment, the samples lose their intermolecular repulsion force, leading to the initiation of aggregation. At pH 4, the negative charge values showed a more drastic variation, with -14.9mV for MGO 20kGy and -17.7mV for MGO 80kGy, indicating that the samples in a more acidic medium have lower stability, as predicted in previous studies.

4. Conclusions

In the initial state, all samples appeared dispersed, but after 6 hours, it became evident that the MGO 20kGy sample exhibited greater stability. Electrostatic repulsion of particles was observed due to the high negative charge values obtained, highlighting that samples at pH 7 demonstrated a stable a behavior in dispersion, as assessed by the zeta potential. It can be concluded that the MGO 20kGy and MGO 80kGy samples maintained good dispersibility and stability. However, as the alkalinity or acidity of the medium increases, the material tends to agglomerate.

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