CORPUS PUBLISHERS

Journal of Mineral and Material Science (JMMS)

ISSN: 2833-3616

Volume 5 Issue 2, 2024

Article Information

Received date : April 07, 2024

Published date: April 29, 2024

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DOI: 10.54026/JMMS/1086

Key Words

Magnetite Nanoparticles; Polypropylene; Electron Spectroscopy

Short Report

Electron Spin Resonance Study of Magnetite Nanoparticles in iPP Matrix

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Abstract

Magnetite nanoparticles based polymer nanocomposites were prepared by blending in solution. The shape of the samples was formed by hot pressing technique. The morphology of the nanocomposites was investigated by transmission electron microscopy and energy dispersive spectroscopy techniques. iPP+Fe_3O_4 nanocomposites' electron spin resonance spectrum was also investigated. As concentration increased, so did the EPR signal's intensity. Due to variations in the magnetic interaction's strength, the linewidth and g-value also altered with concentration.

Introduction

Currently, there is great interest in various thermoplastics and elastomers, which are widely used in industry. One of the fundamental tasks of this direction is the strengthening of elastomers with dispersed fillers [1]. Metal-based fillers improve thermal and electrical conductivity, magnetic susceptibility, heat capacity, and other properties of polymer materials [2]. The properties of nano-objects can differ significantly from the properties of bulk materials of the same chemical composition [3]. If bulk crystal defects are variations of the structure from the ideal crystal order, for nano-objects defects can become a factor that requires serious consideration for a correct understanding of the physicochemical properties of the materials under study [4]. The heterogeneity and multicomponent nature of many systems with reduced dimensions impose specific requirements for the use of the Electron-Spin Resonance (ESR) method. The ESR spectrum can be utilized to identify resonantly active ions in paramagnetic materials and ascertain the symmetry of the surrounding environment [5].

In present work iron oxide nanoparticles and isotactic polypropylene (iPP) based nanocomposites were prepared by blending in solution. The shape of the samples was formed by hot pressing technique [6]. TEM-STEM, JEOL JEM2100 plus microscope was used for morphology study and mapping of samples (Figure 1). The concentration-dependent change of the electron spin state of Fe_3O_4 nanocrystals in the iPP+Fe_3O_4-based polymer nanocomposite was measured using the ESR method. The ESR spectra of polymer nanocomposites based on iPP+Fe_3O_4 are given in Figure 2. The Ultra-High Frequency (UHF) band of 9155MHz was the subject of measurements. The tests were conducted in the region of 1mW for the UHF, 4 minutes for signal recording, and 0.03 seconds for characterizing the inertia of the spectrum recording. The EPR signals were almost without noise. It is known that nanoparticles' magnetic, structural, and dimensional characteristics all affect the form of their resonant absorption signal. As can be seen from the Figure 2, a single and strong ESR signal was observed for iPP+Fe_3O_4-based nanocomposites. Table 1 demonstrated the values of the g-factor, the width of the absorption bands, the intensity of the absorption bands and the area of the absorption region depending on the amount of Fe_3O_4 nanoparticles in the polymer matrix. The value of the g-factor was calculated by the following equation:

$$g = \frac{h\nu}{\beta H}$$

The value of the g-factor and peak intensity increases with the increase in the amount of Fe_3O_4 nanoparticles in the polymer matrix.

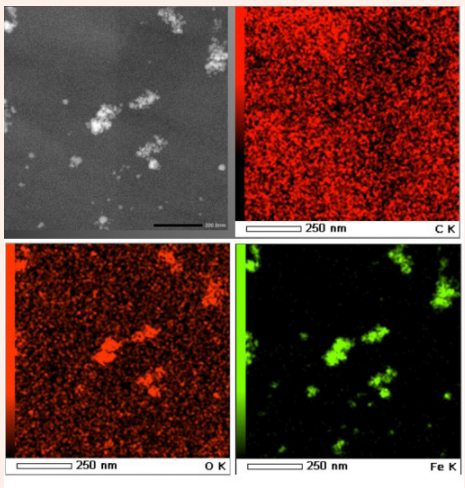

Figure 1: TEM mapping of on iPP+Fe_3O_4 nanocomposite.

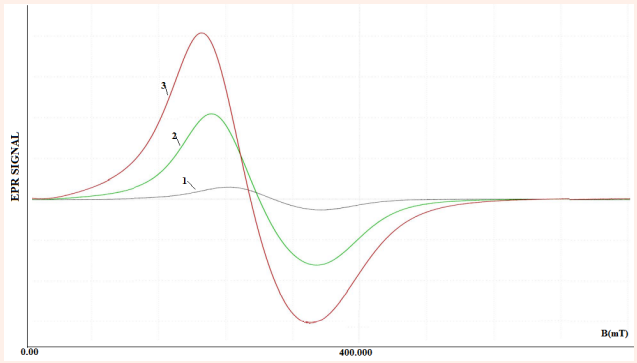

Figure 2: EPR spectra of samples: 1)iPP+3%Fe_3O_4, 2)iPP+5%Fe_3O_4, 3)iPP+7%Fe_3O_4.

Table 1: Results obtained from EPR studies.

Sample	g-factor	Band Width (mT)	Intensity	Area
iPP+3%Fe_3O_4	2.19	113.30	938.00	5.78
iPP+5%Fe_3O_4	2.33	126.10	6115.00	45.33
iPP+7%Fe_3O_4	2.43	129.10	11696.00	100.00

The shape and intensity of the ESR signal can provide information about the interaction between magnetic centers, ultrafine structures, defects in the material structure [7]. Such broad-band absorption lines are characteristic of magnetic particles and are related to the inhomogeneity of the material. The electron-spin state of Fe_3O_4 nanoparticles is related to crystal lattice defects, spin density of unpaired electrons, and also magnetic exchange forces. As the amount of Fe_3O_4 nanoparticles in the polymer matrix increases, the spin density of unpaired electrons changes, which results in a change in the magnetic moment of Fe_3O_4 nanoparticles.

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