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Physiochemical, optical and magnetic properties of nickel-magnesium ferrite nanoparticles for various applications

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The current work focuses on the properties of $MgFe_2O_4$, $Ni_{0.5}Mg_{0.5}Fe_2O_4$, and $NiFe_2O_4$ nanoparticles synthesized via the glycothermal reaction method. The product compounds were characterized for structural, morphology, optical, and magnetic properties using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), Transmission electron microscopy (TEM), Scanning electronic microscope (SEM), and Energy dispersive X-ray spectroscopy (EDX). Their magnetic properties were evaluated using Electron paramagnetic resonance (EPR) and Mössbauer spectroscopy (MS) techniques. XRD data for all materials revealed single-phase formation with no impurities detected. Using the Debye-Scherrer equation calculated from the highest peak (311) plane, the crystal sizes for $MgFe_2O_4$, $Ni_{0.5}Mg_{0.5}Fe_2O_4$, and $NiFe_2O_4$ were determined to be 11.4 ± 0.2 nm, 9.1 ± 0.2 nm, and 8.6 ± 0.2 nm, respectively. XRD data was also used to determine the values of the lattice parameters, which were 8.380 nm, 8.350 nm, and 8.330 nm for $MgFe_2O_4$, $Ni_{0.5}Mg_{0.5}Fe_2O_4$, and $NiFe_2O_4$, respectively. The reduction in these values was attributed to smaller ionic radii of Ni^{+2} (0.069 nm) substituting larger ions of Mg^{+2} (0.072 nm). A single spinel structure of the ferrites was also confirmed by FT-IR data where two bands near 400 cm^{-1} and 600 cm^{-1} were observed, which are the features of the single spinel structure. Hence, the XRD and FT-IR results correlated well. TEM images reveal spherical-shaped particles for all materials with average particle size distribution for $MgFe_2O_4$, $Ni_{0.5}Mg_{0.5}Fe_2O_4$, and $NiFe_2O_4$ nanoparticles as 18.62 ± 3.42 nm, 17.46 ± 2.59 nm, and 16.11 ± 2.93 nm, respectively. The morphology of the nanoparticles observed from SEM photograms shows clustering and fewer clustered particles as the substitution of the magnesium ions increases. The elements in each compound were verified using energy-dispersive EDX and confirmed to be true as the desired compounds. No contamination was observed. The optical properties were investigated using UV-visible spectroscopy. The energy values for the band gap derived from the Tauc plot were obtained for $MgFe_2O_4$, $Ni_{0.5}Mg_{0.5}Fe_2O_4$, and $NiFe_2O_4$ nanoparticles were 2.07 eV, 1.92 eV, and 1.88 eV, respectively. The magnetic nature of the prepared samples was established through EPR and MS. The EPR study confirmed the paramagnetic behaviour of the materials. MS results revealed ferrimagnetic and paramagnetic Fe ions in materials. MS spectra were fitted with two sextets (ferrimagnetism) and one doublet (paramagnetism). These results suggest that these materials can be suitable for various applications, such as in medical and electrical.

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