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Investigation of Physical Properties for Nanostructured Magnetic Materials Treated by Irradiation

A Thesis Submitted in Partial Fulfillment of the Requirement
for Ph.D. Degree in Physics

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Abstract

Nanoparticle ferrite with the chemical formula $\text{Mg}_{1-x}\text{Zn}_x\text{Fe}_2\text{O}_4$ (where $x=0.0, 0.1, 0.2, 0.3, 0.4$ and 0.6) have been prepared by the sol-gel technique. The composition and purity of ferrite are hardly affected their properties. Therefore, the elemental concentration of these samples was measured by the X-ray fluorescence and thermal neutron activation analysis techniques to check the real composition of the prepared samples. The results of both methods were compared with each other and with the molecular ratios of the as-prepared samples. No existing elemental impurity was detected.

The samples were characterized by X-ray diffraction (XRD) and Infrared analysis (IR). Single-phase structure of these ferrites was confirmed using (XRD). All samples showed two absorption bands in the IR spectra, ν_t and ν_o , in the absorption range 550 and 400 cm^{-1} , respectively. Transmission Electron Microscope (TEM) showed that the particle size of the samples lies in the range of $(5.7\text{--}10.6\text{ nm})$. The hysteresis studies revealed superparamagnetic behavior at room temperature for all samples. The dead layer thickness (t) was calculated and its effect on the magnetization and magnetic losses was discussed. The Specific Absorption Rate (SAR) in an alternating magnetic field operating at a frequency 198 kHz for these ferrites has been studied. It was found that the sample with $x = 0.2$ has the highest value of SAR although it does not has the highest value of saturation magnetization.

Sample with the chemical formula $\text{Mg}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ i.e. $x = 0.2$ was annealed at temperatures of $400, 600$ and $800\text{ }^\circ\text{C}$ for 4 hours. No extra lines were observed in the XRD spectra for all annealed samples. The sample $\text{Mg}_{0.8}\text{Zn}_{0.2}\text{Fe}_2\text{O}_4$ ferrites showed superparamagnetic phase as that the as-prepared and annealed samples at 400 and at $600\text{ }^\circ\text{C}$, respectively. On the other hand, the annealed sample at $800\text{ }^\circ\text{C}$ showed hysteresis behavior with

Abstract

$H_c = 7.89$ mT and $M_r = 5.86$ emu/g. On annealing, up to 600 °C, SAR values decreased and above it, the SAR values increased. Moreover, the sample with $x = 0.2$ has been doped by Gd^{3+} according to the chemical formula $Mg_{0.8}Zn_{0.2}Fe_{2-y}Gd_yO_4$ (where $y = 0.025, 0.05, 0.075$, and 0.1) and these samples were also prepared by sol-gel technique. XRD for all investigated samples confirmed single spinel phase structure. TEM analysis showed that the particle size of the samples lies in the range of (12–32 nm). $Mg_{0.8}Zn_{0.2}Fe_{2-y}Gd_yO_4$ ferrite nanoparticles displayed superparamagnetic phase. The saturation magnetizations for the doped samples with Gd^{3+} ions are lower than that of undoped one and decreased with the Gd^{3+} contents. The SAR values also decreased after doping.

$Mg_{1-x}Zn_xFe_2O_4$ and $Mg_{0.8}Zn_{0.2}Fe_{2-y}Gd_yO_4$ samples have been irradiated in the thermal neutrons channel of the Second Egyptian Research Reactor for short and long time $t_{irr}=10$ min and $t_{irr}=1$ h and doses 6.0×10^{13} and 3.6×10^{14} n/cm², respectively. The used neutron flux was 10^{11} n/cm²/sec. After short-time irradiation: a deformation and oxidization in XRD spectra have appeared. Moreover, there is an increasing in the saturation magnetization after irradiation for the investigated samples. The SAR values decreased after irradiation for all samples in spite of increasing the M_s .

β^- emitting radioisotopes have been produced by thermal neutron capture reaction in the nuclear reactor. These radionuclides may be useful to kill cancer cells via crossfire effect and could be employed besides the local hyperthermia of the magnetic materials.

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