

Ferrites are Magnetic Materials that can be used as an Alternative Source of Green Electrical Energy

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Abstract

The solid-state sintering method was used to create the ferrites samples $Mg_{1-x}Li_xFe_2O_4$ for x values of 0.0, 0.1, 0.2, and 0.3. These samples' structural, morphological, magnetic, and electrical properties were the subject of in-depth examination. The power generation of these samples was the subject of a comprehensive investigation, and the role of Li-doping has been discussed. The spinel phase formation in impurity-free samples is confirmed by the XRD pattern. Scanning Electron Microscopy reveals that as $MgFe_2O_4$ is doped with lithium, the average grain size of the samples decreases [1]. $MgFe_2O_4$ has a saturation magnetization of 15.4 emu/g that increases with the lithium content, reaching a maximum of 39.3 emu/g for the $Mg_{0.7}Li_{0.3}Fe_2O_4$ sample. Magnetic recording, microwave magnetic devices, and numerous medical science applications all depend on ferrites. By creating a hydroelectric cell (HEC), ferrites have recently been shown to be an alternative green energy source. On the metal-oxide surface, the processes of water adsorption and dissociation play a significant role in the production of electricity in ferrites. The thermodynamic driving force is what leads to the stable formation of bonds between metal and oxygen or metal and hydroxyl when water is sprayed on a hydroelectric cell. The interaction between these ions and the d orbital of the Fe atom is what causes the surface of ferrite to react with water [2]. Water dissociates into H_3O^+ and OH^- ions as a result of this interaction and migrates toward silver and zinc electrodes, respectively. For a Li = 0.2 doped $MgFe_2O_4$ sample, a typical hydroelectric cell with a diameter of 2 inches produces 17.1 mA of peak current and 949 mV of voltage with a maximum output power of 15.85 mW.

Keywords: Materials science; $MgFe_2O_4$; Ferrites; Magnetic materials

Introduction

Ferrites are a group of magnetic materials that are used in a lot of different applications like microwave devices, computer memory chips, magnetic recording media, making radio frequency coils, transformer cores, rod antennas, and many other areas of telecommunications and electronic engineering. It is because of its appealing properties, such as the square hysteresis loop, high saturation magnetization, and high Curie temperature. A large portion of the delicate ferrites have spinel structure which comprises of the 8 recipe units of $M_2+Fe_{23}+O_4$ [3]. Ordinarily 'M' is a divalent ion of range between 0.80 Å to 1.0 Å, for example, Mn, Mg, Compact disc, Fe, Zn, Cu and so on and Fe_{23} is a trivalent particle. Spinel ferrite has a complex structure made up of a closed-packed cubic array of 32 oxide ions that creates 64 tetrahedral and 32 octahedral sites in one unit cell [containing eight formula units $(M_2+Fe_{23}+O_4)_8$] [4]. There are two kinds of sites in these unit cells. The oxygen ions around one of them occupy the corner of an octahedron, making it an octahedral or B-site. The other is known as the tetrahedral or A site, where M_2+ is at the center of a tetrahedron with oxygen ions occupying the corners. In general, the cation distribution on the A and B sites is shown by: $M_{2+\delta}Fe_{3+1-\delta}A[M_{2+1-\delta}Fe_{3+1+\delta}]BO_2-4$, where $\delta = 1$ for typical spinel structure and $\delta = 0$ for backwards spinel structure. The electric, dielectric, magnetic, and structural properties of spinel ferrites are heavily influenced by the distribution of cations between the tetrahedral and octahedral sites.

Metal-oxide surfaces offer incredible potential for a wide assortment of uses like attractive recording media, water-gas shift response, and photocatalytic parting and so on. A new green electrical energy source has emerged thanks to the dissociation of water and the generation of electric current and voltage by a hydroelectric cell. Water can adsorb on oxide surfaces in a variety of ways [5]. First, for H_2O dissociation, well-ordered ionic single-crystal samples frequently do not react. In oxide polycrystalline samples, the dissociation of

water on the surface may be caused by reaction at defect sites and facet edges, whereas defect sites on single crystals are very few [6]. Water dissociation is influenced by oxygen deficiency surfaces and defect lattice sites. The formation of relatively strong chemisorption bonds on some ionic surfaces is the second distinctive feature of H_2O adsorption. This allows molecular adsorbed H_2O to remain stable even at room temperature. The stability of the water structures that are formed is determined by a delicate balance between water-water hydrogen bonding and water-metal oxide interactions at metal-oxide surfaces. Numerous researchers have demonstrated experimentally that adsorbed water can separate into hydroxyl, atomic oxygen, and atomic hydrogen. Figure provides a schematic representation of the various water dissociation pathways [7].

Experimental

The typical double sintering ceramic method, in which oxides or carbonates were used as precursors, was used to prepare the samples. By wet grinding in distilled water, the specified molar ratios of magnesium oxide (MgO), iron oxide (Fe_2O_3), and lithium carbonate (Li_2CO_3) were mixed and ground in accordance with the stoichiometric composition of $Mg_{1-x}Li_xFe_2O_4$ ($x = 0.0, 0.1, 0.2, 0.3$) [8]. Pre-sintered mixed powders were placed in an ambient atmosphere for five hours at 750 °C. The obtained powders were once more mixed and

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ground before pellets were produced. For each sample, two different kinds of pellets were made: one with a diameter of two inches for the hydroelectric cell and another with a diameter of eight millimeters for electrical characterization. All samples' pellets were sintered at 1050 °C for 5 hours, with a 5 °C/min control over the rate of heating and cooling. Finally, silver coating was applied to the opposite faces of the 8 mm-diameter pellets for the purpose of electrical characterization [9]. For the purpose of hydroelectric characterization, a two-inch-diameter pellet had a zinc plate fixed to one face, and the other face was coated in a comb pattern with silver. The primary portrayal of tests was completed by the X-beam diffraction (XRD Rigaku Miniflex II, step size = 0.02°) procedure utilizing Cu K α radiation (frequency $\lambda = 1.5406 \text{ \AA}$). The JEOL/JSM-6610LV scanning electron microscope was used to examine the microstructure details of the samples. All of the samples were subjected to room temperature magnetic measurements using a vibrating sample magnetometer (VSM, Lake Shore 7304). A digital multi meter (DMM) was used to measure the voltage and current that was produced by each hydroelectric cell. The Alpha-A high-performance Frequency Analyzer from Novocontrol Technologies was used to measure the AC resistivity of the samples [10].

Results and Discussion

Structural analysis

The X-ray powder diffraction pattern of Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ (0 \leq x \leq 0.3) samples is depicted. This is evident from the MgFe $_2$ O $_4$ XRD pattern, where the obtained peak positions are identical to those described in JCPDS file (73-1720), which demonstrates the formation of an inverse spinel phase with a Fd $3m$ space group. The FullProf program was used to analyze the samples' XRD patterns using the Rietveld refinement method. For each sample, the Wyckoff positions for the initial structural parameters (metal 8a, iron 16d, and oxygen atoms 32e) and the structural model (Fd $3m$) have been taken. To compare Bragg's intensities with those calculated from a possible structural model, the method makes use of a least-squares method. The experimental data's fitting quality is evaluated by calculating parameters like "goodness of fit 2" and R factors. Figure depicts the typical Rietveld refinement X-ray pattern for each sample. The cross section boundary esteem increments from 8.3842 Å to 8.3713 Å which shows the consolidation of Li $^+$ particles in the Magnesium ferrite.

Scanning Electron Microscopy (SEM)

The microstructure of ferrite samples has a significant impact on their magnetic and electrical properties. Common SEM pictures of the sintered pellets for the Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ (0 \leq x \leq 0.3) examples are displayed. It very well may be seen that the micrographs of all examples show arbitrarily situated fine translucent construction. The samples of Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ have tightly packed grains. The differences in the growth rates of the various phases in the samples may be the cause of the grain size distribution among the samples, despite the fact that all of the samples are mostly homogeneous in nature [11].

Magnetic properties

All samples' M-H loops were recorded from the VSM all the way up to the maximum field of 2T at room temperature, as depicted. The M-H loop is well saturated in all samples. In Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ ferrites, the saturation magnetization increases slowly as Li concentration rises. It is common knowledge that magnesium ferrite is an inverse spinel, and the cations are distributed as [Mg $_{1-x}$ Li $_x$ Fe $_2$] $_A$ [Mg $_2$ Fe $_2$] $_B$ O $_4$, where x is the degree of inversion, or the proportion of (A) sites occupied by Fe $^{3+}$ cations. The exchange interactions and interactions

between the magnetic moments on the tetrahedral (A-site) and octahedral (B-site) sites are what determine the ferrites' magnetic properties. In spinel ferrite, a B-site ion has six A-site and six B-site ions as its closest neighbors, while an A-site ion has 12 B-site ions as its closest neighbors [12]. Neel's two sublattice model says that the super exchange interaction between A and B is more important than the sublattice interactions between A and B. Figure depicts the alignment of A-site and B-site magnetic moments in accordance with Neel's model. As a result, spinel ferrites have a net magnetization of $M = M_B - M_A$. The MgFe $_2$ O $_4$'s lithium doping may lessen the A-B interaction, which raises the compounds' magnetic moments. According to S. Rahman et al., the simultaneous migration of Fe $^{3+}$ ions from A-sites to B-sites and the replacement of Mg $^{2+}$ ions with Li $^+$ in the A-site may have led to an increase in saturation magnetization when Li is present.

Hydroelectric properties

The adsorption of water molecules, as well as their dissociation and conduction of OH $^-$, H 3 O $^+$ ions in the ferrites medium, are the foundations upon which a hydroelectric cell operates. Figure depicts a schematic representation of the water molecule adsorption and dissociation mechanism on the surface of ferrites. 6. Water molecules immediately separate into hydronium (H 3 O $^+$) and hydroxide (OH $^-$) ions when they come into contact with the ferrite surface.

As can be seen, the total voltage that is generated between the silver and Zn electrodes is $E_{cell} = 0.22 + 0.76 = 0.98 \text{ V}$. This voltage creates an electric field between the electrodes, which helps the ions (H 3 O $^+$, OH $^-$) in the ferrite medium move around more.

On the surface of Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ samples, the attraction between the oxygen lone pair electron of the water molecule and the Fe $^{3+}$ ions at the octahedral site, which form a strong chemisorption bond between them, causes the water molecule to dissociate. Defects in oxygen have also been shown to play a significant role in the dissociation of water molecules [13]. In the lab, hydroelectric cells with a diameter of two inches were made, as shown. In order to examine the hydroelectric properties of Mg $_{1-x}$ Li $_x$ Fe $_2$ O $_4$ cells, we dipped each sample in deionized water for 30 minutes and recorded the open circuit voltage and short circuit current for each sample. We rehashed such perceptions in sets of tests to notice the consistency of results. All of the observations were made in the natural environment and at room temperature. According to Figure, these hydroelectric cells generated an emf of 859–965 mV and a maximum current of 17–2.47 mA. During the initial phase (five to ten minutes), we observed some fluctuation in the open voltage which remained constant for more than 24 hours and became almost constant. However, the current's response does not match the values that R. K. Kotnala et al. We discovered that current rapidly decreases over time [14]. This decline in current could be a consequence of immersion of Fe-locales in octahedral because of contribution in transportation of OH $^-$ and H 3 O $^+$ particles in the ferrite medium. The primary obstacle to large-scale energy production for an extended period of time is the decrease in current in hydroelectric cells. To fix this issue, additional research is required. As depicted in Fig., we discovered that Li doping enhanced the voltage and current (power) response of the ferrite samples. The Mg $_{0.8}$ Li $_{0.2}$ Fe $_2$ O $_4$ sample exhibits maximum current. Monovalent lithium ions take the place of divalent magnesium ions, which cause the compounds' charge imbalance to result in oxygen vacancy. Chemidissociation may rise as a result of this increase in oxygen vacancies caused by lithium doping, which changes the current. However, as we discussed, modifying the current in hydroelectric cells for large-scale power production necessitates additional research [15].

Conclusions

Polycrystalline $Mg_{1-x}Li_xFe_2O_4$ ($0.0 \leq x \leq 0.3$) ferrite tests have been incorporated by strong state strategy. XRD analysis has confirmed the purity of the phase. The grain boundaries are found to diminish with Li replacement which was determined by utilizing Rietveld refinement procedure. SEM images revealed a decrease in grain size with Li substitution in surface morphology. Neel's two sub-lattices Model provides an explanation for an increase in saturation magnetization (M_s) with Li substitution in $Mg_{1-x}Li_xFe_2O_4$ samples. Voltage, current, and power generation in hydroelectric cells have all been thoroughly studied. The sample of $Mg_{0.8}Li_{0.2}Fe_2O_4$ had the most power. The fact that ferrite $Mg_{1-x}Li_xFe_2O_4$ materials are responsible for the dissociation of water molecules into ions is confirmed by the resistivity response with frequency of samples both without water and with water. However, modifying the current in hydroelectric cells for large-scale power production requires additional research. Ferrites therefore: An alternative source of eco-friendly and safe electrical energy might be magnetic materials.

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Conflict of Interest

None

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