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Structure, Microstructure, Magnetic, Electromagnetic and Dielectric Properties of Nanostructured Mn–Zn Ferrite Synthesized through Glycine-Nitrate Combustion

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1- Introduction

Mn-Zn ferrite is one of the most important magnetic ceramic materials well known for high magnetic saturation and low magnetic loss at high frequencies (8-10 MHz). Mn-Zn ferrite is applicable in inducers core, transformers, antenna rods, electromagnetic interference devices, microwave devices and biomaterials applications such as cancer cure and pharmacy.

Nanosized Mn–Zn ferrites have been produced by many processes such as mechanical alloying Sol-Gel, hydrothermal and combustion synthesis. Recently, the combustion synthesis process has attracted wide attentions due to its ability to produce nanoparticles with high surface area. If glycine and metal nitrate are chosen as fuel and oxidizer respectively, the process is called glycine-nitrate process (GNP). In the present study, the effect of glycine/nitrate (G/N) molar ratio on the structure, microstructure, magnetic, electromagnetic and dielectric properties of $Mn_{0.5}Zn_{0.5}Fe_2O_4$ is examined.

2- Experimental

The metallic nitrates $Fe(NO_3)_3.9H_2O$, $Zn(NO3)_2.6H_2O$ and $Mn(NO_3)_2.4H_2O$ as oxidants and glycine (H_2NCH_2COOH) as reductive were used. The above mentioned metallic nitrates and glycine were solved in 100 cc distilled water for three G/N ratio of 0.39 (30% lower than stoichiometry), 0.56 (stoichiometry) and 0.72 (30% higher than stoichiometry). The solution was put into a large beaker and heated in a common microwave oven to vaporize the excess water and accomplish the reaction with a tiny combustion. The combustion yields voluminous dark ashes accompanied by a large amount of gas. Structure and microstructure were evaluated using X-ray diffraction (XRD, Bruker D8) and scanning electron microscope (SEM, LEO 1455VP). The magnetic properties were measured by a vibrating sample magnetometer (VSM). The electromagnetic and dielectric properties were evaluated at room temperature by an LCR meter (GWINSTEC, LCR-8110G) in the frequency range from 1 KHz to 10 MHz.

3- Results and Discussion

Fig. 1 shows the X-ray diffraction patterns of Mn-Zn ferrites synthesized by GNP at different G/N molar ratios. The formation of the Mn–Zn ferrite can be confirmed clearly due to the appearance of at least (111) (isolated, $2\theta \approx 18^{\circ}$), (220) (isolated, $2\theta \approx 30^{\circ}$) and (311) (isolated, $2\theta \approx 35.4^{\circ}$) reflections in the respective XRD pattern.

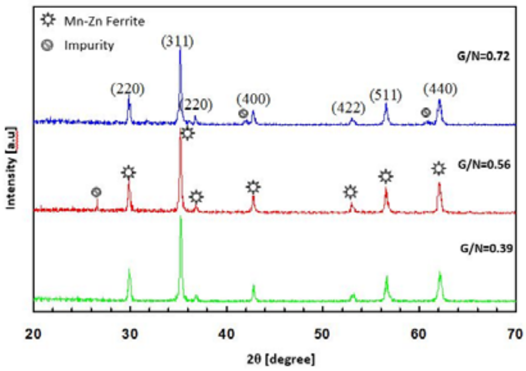

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Fig. 1 X-ray diffraction patterns of the Mn–Zn ferrites synthesized at various G/N ratios

SEM microphotograph of the as-synthesized Mn-Zn ferrite clusters at G/N ratio of 0.72 is illustrated in Fig. 2. As it can be seen, agglomerated clusters show a lot of pores that are associated with the large amount of gases released during the combustion synthesis.

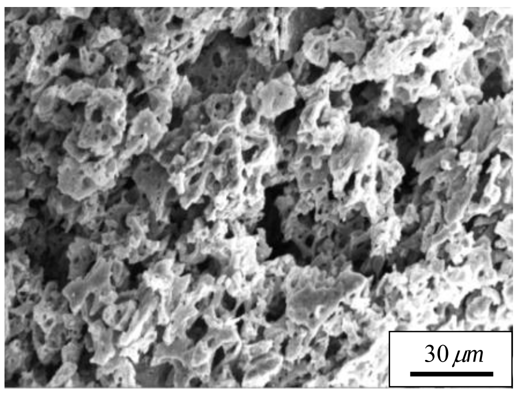

Fig. 2 SEM microphotograph of the Mn–Zn ferrites synthesized at G/N ratio of 0.72

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Fig. 3 shows the magnetization-field (M-H) curves of the as-prepared powders. Referring to this figure, the saturation magnetization is in the range of 60.5-63.3 emu/g, indicating superior magnetic properties of the all synthesized powders.

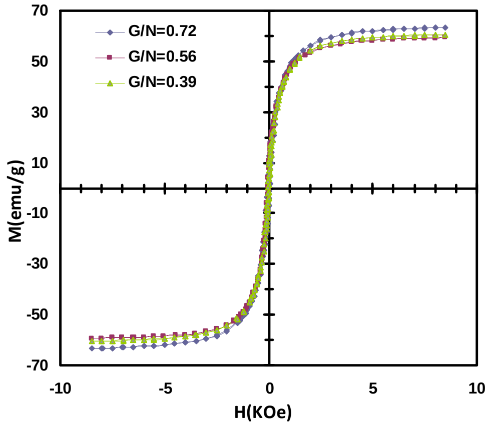

Fig. 3 Hysteresis curves of the as-synthesized Mn–Zn ferrite powders at room temperature

Fig. 4 displays the variation of the real part of permeability with respect to frequency. The lower G/N molar ratio, the higher permeability. On the other hand, just the powder synthesized at lower G/N molar ratio indicates a Mn-Zn ferrite phase without impurity (Fig. 1). Hence, it can be deduced that permeability strongly depends on the impurity.

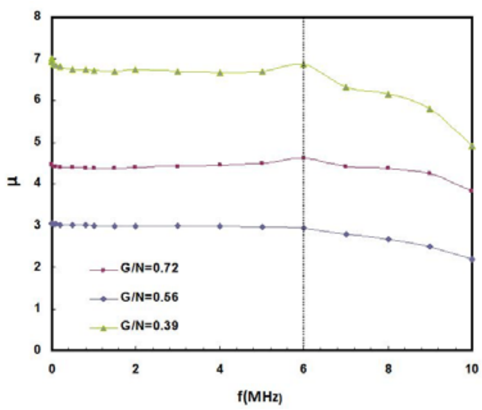

Fig. 4 Variation of permeability as a function of frequency for Mn–Zn ferrite samples

The frequency dependence of the dielectric constant, □', of the all synthesized powders at room temperature is illustrated in Fig. 5. For all samples, dielectric constant shows maximum values at low frequency, then decreases rapidly by increasing frequency and becomes frequency independent at high frequency. This behavior can be interpreted on the basis of the interfacial polarization mechanism. According to this mechanism, dielectric structure of ferrites is made up of well conducting grains separated by the poorly conducting layer of grain boundaries. In the low frequency region, the charge carriers can pass through the grains and reach to the grain boundaries through the electron hopping. Due to high resistance of the grain boundary, the electrons accumulate at the grain boundaries and produce the build-up of layers of charge at interfaces. Such internal charge layers make large contributions to dielectric constant. In contrast, as the frequency of the applied field is increased, before the charge carriers can pile up at the grain boundaries, they reverse their direction of motion. Hence, the probability of electrons reaching the grain boundaries decreases and subsequently polarization and dielectric constant start to decrease.

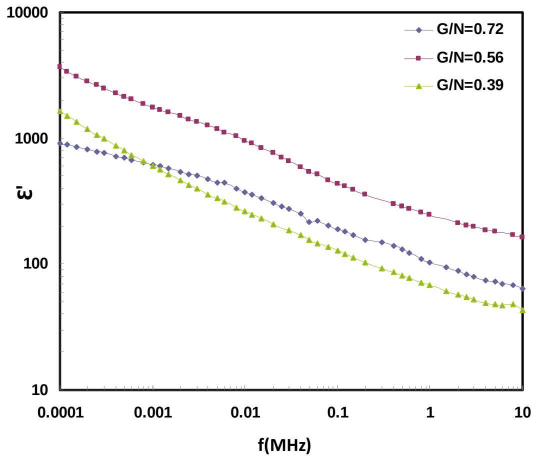

Fig. 5 Dielectric constant as a function of frequency at various G/N ratios

4- Conclusions

In this study, nanocrystalline Mn-Zn ferrite was prepared by an auto-combustion method and the effects of the fuel concentration on the properties was studied. XRD diffraction confirms formation of the nanostructured Mn-Zn ferrite in all cases. Magnetic measurements show that saturation magnetization is in the range 60.5-63.3 emu/g. The powders prepared with the lower G/N ratio show the higher permeability in the all measured frequencies. Dielectric constant decreases with increasing the frequency, indicating the normal behavior of ferrites.