Synthesis, Characterization and Magnetic Study of $Ni_{0.7}Zn_{0.3}Fe_2O_4$: Comparison of the Nano with the Bulk

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Abstract

The structural and the magnetic study of the 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$ synthesized by combustion method using malic acid as the fuel was studied. The XRD and IR studies revealed the formation of the single phase spinel oxide. The resistivity studies of the oxide showed that the 'sintered' oxide have lower resistivity as compared to 'as prepared' oxide. The Curie temperature, saturation magnetization and the blocking temperature of the 'sintered' oxide is found to be higher as compared to the 'as prepared' oxide.

Introduction

Nanoparticles of spinel ferrites have attracted a great interest for a long time in addressing the fundamental relationship between magnetic properties and their crystal chemistry and structure. Since nanoparticles have often novel properties that are different from their bulk properties due to their small size, they are becoming a core component of advanced materials that have wide practical applications with noble optical, electrical, magnetic and catalytic properties [1]. Nickel zinc ferrite is the soft magnetic ferrite and it has a widespread applications. It is used in various components for application at high frequency range due to their high electrical resistivity, chemical stability and good electromagnetic properties [2, 3]. In this study, we are comparing the properties of the nano with the bulk.

Experimental: Synthesis

Synthesis of $Ni_{0.7}Zn_{0.3}Fe_2O_4$ was done using combustion method. The respective metal nitrates were taken and heated till it melts. To this molten solution was then added the fuel (malic acid). This mixture was then heated in a preheated furnace at 400^0C for 10min. The oxide which was formed was then heated at 500^0C for 5hrs to remove any unburned organic species and then ground for 2hrs. This oxide formed is called as the 'as prepared' $Ni_{0.7}Zn_{0.3}Fe_2O_4$ (NZFA). This oxide was then presintered at 800^0C for 5hrs and then sintered at 1000^0C for 10hrs. This is 'sintered' oxide (NZFS). The characterization and studies of both 'as prepared' and 'sintered' oxide was done in order to find out the difference in the different properties that occur when there is a change in particle size.

Result and Discussion: XRD studies

The XRD patterns shown in Fig.1 confirmed the formation of single phase cubic spinel ferrite. From the XRD pattern it was found that the 'sintered' oxide has sharp peaks as compared to the peaks of 'as prepared' oxide which are relatively broader and has average crystallite size of 29 nm.

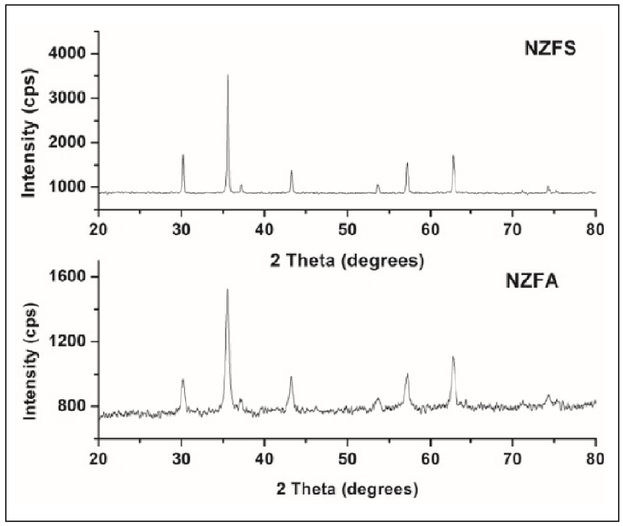

Fig. 1: XRD patterns of 'as prepared' (NZFA) and 'sintered' (NZFS) $Ni_{0.7}Zn_{0.3}Fe_2O_4$

IR Studies

The IR spectra of 'as prepared' and 'sintered' oxide confirm the formation of the spinel oxide with two bands at around $400cm^{-1}$ and $600cm^{-1}$. These two bands are attributed to the intrinsic stretching vibrations of the metal at octahedral and tetrahedral site, respectively.

DC Electrical resistivity

Fig. 2 shows the plot of resistivity v/s temperature of the 'as prepared' and 'sintered' oxide. It can be seen from Fig. 2 that, the resistivity goes on decreasing as temperature increases. This behaviour indicates

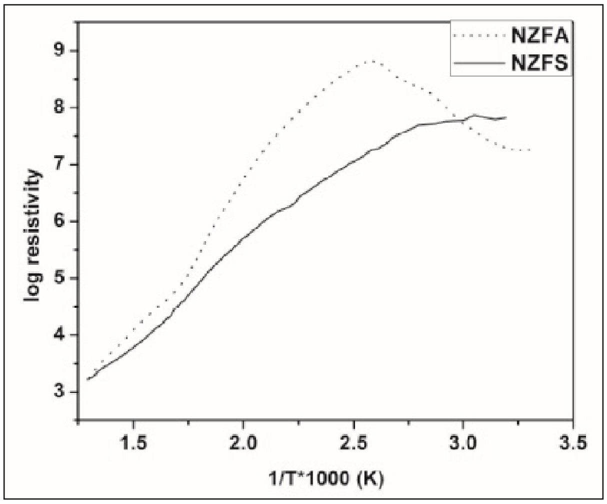

Fig.2: The plot of resistivity v/s temperature of 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$

that both 'sintered' and 'as prepared' oxide shows semiconducting nature. The resistivity of 'sintered' oxide is found to be lower as compared to the 'as prepared' oxide. This lower resistivity of the 'sintered' oxide can be explained as described by B. P. Rao et al [4]. As the 'sintered' oxide has low porosity it will cause individual grains to come close and also the increased average grain diameter of the ' sintered' oxide will reduce the grain boundary dimensions; this both will increase the cross sectional area of the conductor thus leading to the decrease in resistivity in the 'sintered' oxide.

AC susceptibility studies

Fig.3 showed the plot of normalised ac susceptibility v/s temperature. It can be observed from the nature of the plot of Fig.2 that the 'as prepared' oxide shows

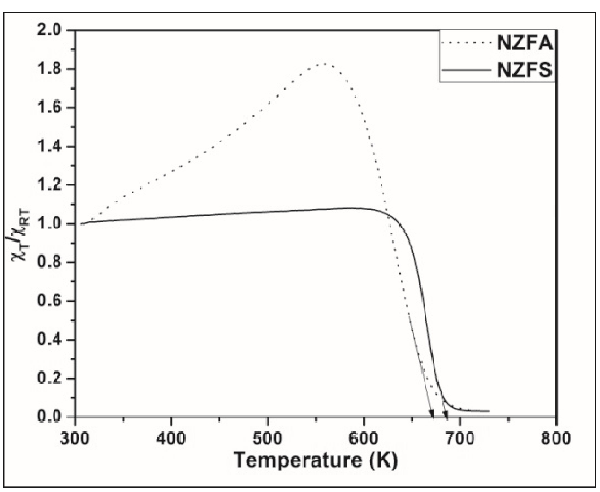

Fig.3: The normalised ac susceptibility v/s temperature of 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$

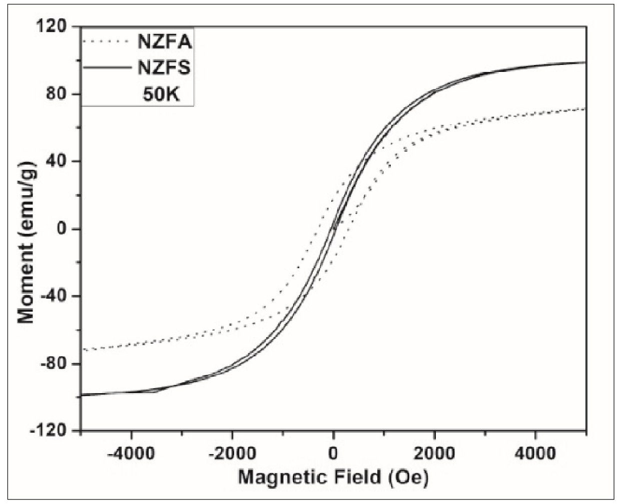

Fig.4: The plot of magnetization v/s field carried out at 50K of 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$

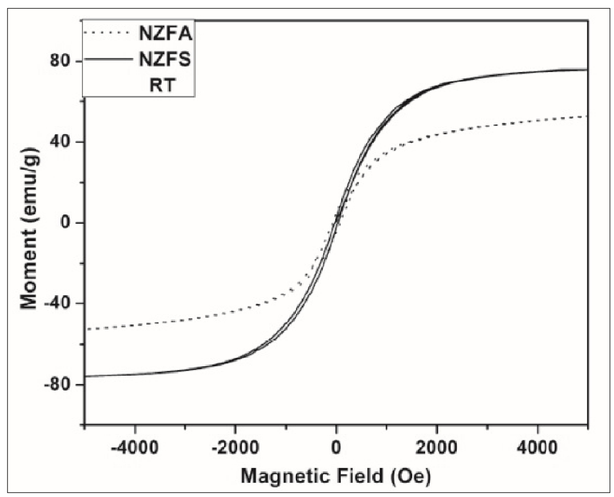

Fig.5: The plot of magnetization v/s field carried out at RT of 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$

single domain while the 'sintered' oxide shows multidomain nature of the particles with Curie temperature of 688K for 'sintered' sample while for ' as prepared' sample it is lower i.e. 672K.

VSM studies

Fig.4 and Fig.5 showed the plot of magnetization v/s magnetic field of the oxide at 50K and RT, respectively. It can be seen from Fig 4 and 5 that the saturation magnetization value of 'sintered' oxide is more as compared to the 'as prepared' oxide. The lower value of Ms in NZFA can be attributed to the non saturation effects because of the random distribution of the small particles with enhanced values of magneto crystalline anisotropy [5]. The oxide showed higher magnetization value at 50K as compared to RT this

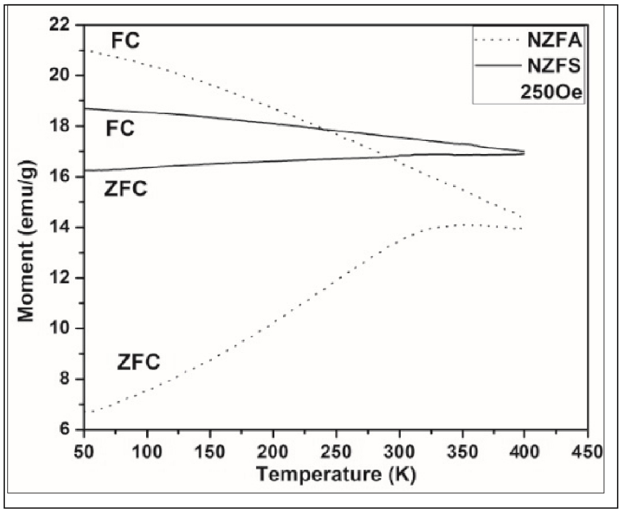

Fig.6: The ZFC –FC curves of 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$ at 250Oe

is because of the lower thermal fluctuations at lower temperature.

Fig.6 showed the ZFC-FC curve of the 'sintered' and 'as prepared' oxide at a constant applied field of 250Oe.

It can be seen from Fig.5 that incase of ZFC curve as the temperature increases the magnetization goes on increasing reaches a maximum and then again starts decreasing. The point at which the, magnetization is maximum is called as the blocking temperature. The blocking temperature is clearly observed in 'as prepared' oxide while in 'sintered' oxide it is higher than 400K. The broad maximum at the blocking temperature is a sign of wide distribution of particle size.

Conclusion

We were able to synthesize successfully the single phase cubic, spinel 'as prepared' and 'sintered' $Ni_{0.7}Zn_{0.3}Fe_2O_4$. The 'as prepared' samples have low density and crystallite size. They showed single domain particle with lower Curie temperature as compared to 'sintered' samples with multidomain particles. Both the oxide showed semiconducting nature with 'sintered' samples showing lower resistivity than 'as prepared' samples. The magnetization studies revealed that the oxides showed soft magnetism with 'sintered' samples having higher saturation magnetization and blocking temperature.

References

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