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Structural and Magnetic Properties of AL^{3+} Doped NI-ZN Nano Ferrites

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Abstract: Nickel-Zinc Aluminium doped nano ferrites having the composition of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$ have been synthesized by auto combustion method and were characterized by XRD technique, SEM images, FTIR curves and VSM technique. The developed powders were sintered at various temperatures at 350^{0}C, 450^{0}C and 550^{0}C for 5hours and the effect of sintering temperature on structural properties was carried out. The sintering process increased the crystallinity of the sintered material. The powder XRD pattern confirms the single-phase spinel structure for the synthesized sample powders. SEM study shows the uniform particle distribution. The FTIR spectrum shows strong absorption peaks which are typical for cubic spinel crystal structure. The VSM studies reveal that all samples are showed the hysteresis structure.

Keywords: Ni-Zn-Al Nano ferrites, auto combustion technique, XRD, SEM, FTIR, magnetic properties.

I. INTRODUCTION

Ferrites having the general formula $M^{2+}OFe_2O_3$, where M^{2+} represents divalent metal ion and they are magnetic materials with a cubic spinel structure. Ferrites are extensively used in radio electronics, automatic control components and computing engineering and various technical, engineering applications [1,2].In ferrites the substitution of the trivalent and pentavalent ions gives rise to many applications in various areas like magnetic storage, transformer cores, magnetic cards, magnetic recording, permanent magnets, computer peripherals, electronic devices, microwave devices and catalysts [3].The size reduction in the nano scale specifies interesting magnetic properties like pin canting, surface effects, enhanced anisotropy and super paramagnetism. Ni-Zn ferrites are having the mixed spinel structure. The compositional difference in ferrites effects modification of ferrite properties in the re-distribution of ions over the tetrahedral and octahedral sites [4]. Present study explains about the XRD, FTIR, SEM and magnetic properties of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$nano ferrites which were syntheses by auto combustion technique which were sintered at 350 ^{0}C, 450 ^{0}C and 550 ^{0}C for 5hours.

II. EXPERIMENTAL

The aluminium doped nano ferrites with a general formula of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$were produced by auto combustion technique by using metal nitrates of analytical grade (AR) with 99% of purity. The starting materials were zinc nitrate hexahydrate–Zn $(NO_3)_2.6H_2O$(AR), nickel nitrate–Ni $(NO_3)_2.6H_2O$(AR), aluminium nitrate nonahydrate–Al $(NO_3)_3.9H_2O$(GR), Ferric Nitrate–Fe $(NO_3)_3.9H_2O$(GR) & citric acid monohydrade–$C_6H_8O_7.H_2O$(GR). Stoichiometric ratio was taken to compute the required chemicals using electronic weighing balance for an accuracy of 10^{-4} gram. The weighted each chemical was grinded around 45 minutes in agate mortar to get a fine powder and then add citric acid 3:1 ratio to nitrate mixture and grinded for half an hour more. Further 10 ml Methanol/Methyl alcohol is added to the above complex mixture and is grinded for another 15 minutes. Now the entire mixture is transferred into a china dish and kept in the furnace whose temperature can raise uniformly 8 ^{O}C per minute. The entire mixture catches fire and under goes the auto combustion process when the furnace reached around 250 ^{O}C to 270 ^{O}C temperatures. Finally, we get brown color ash sample which is continuously calcinated further 36 hours at a constant temperature 500 ^{O}C. Then the calcinated powder sample taken out from the furnace and again further grinded in agate mortar for another 15 minutes. Finally, the entire powder divided in to three parts and each part of sample was sintered at different temperatures at 350 ^{0}C, 450 ^{0}C and 550 ^{0}C for 5hours respectively.

III. RESULTS AND DISCUSSION

3.1. XRD analysis

The ferrite nano particles of general formula of $Ni_{0.5}\,Zn_{0.5}\,Al_{0.5}\,Fe_{1.5}\,O_4$were calcinated at 350 ^{0}C, 450 ^{0}C and 550 ^{0}C for 5hourswhich were under gone by powder XRD method. Fig.1 shows the X-ray diffraction patterns of all prepared ferrite nano particles and confirm the single phase spinel and nano crystalline structure[5].

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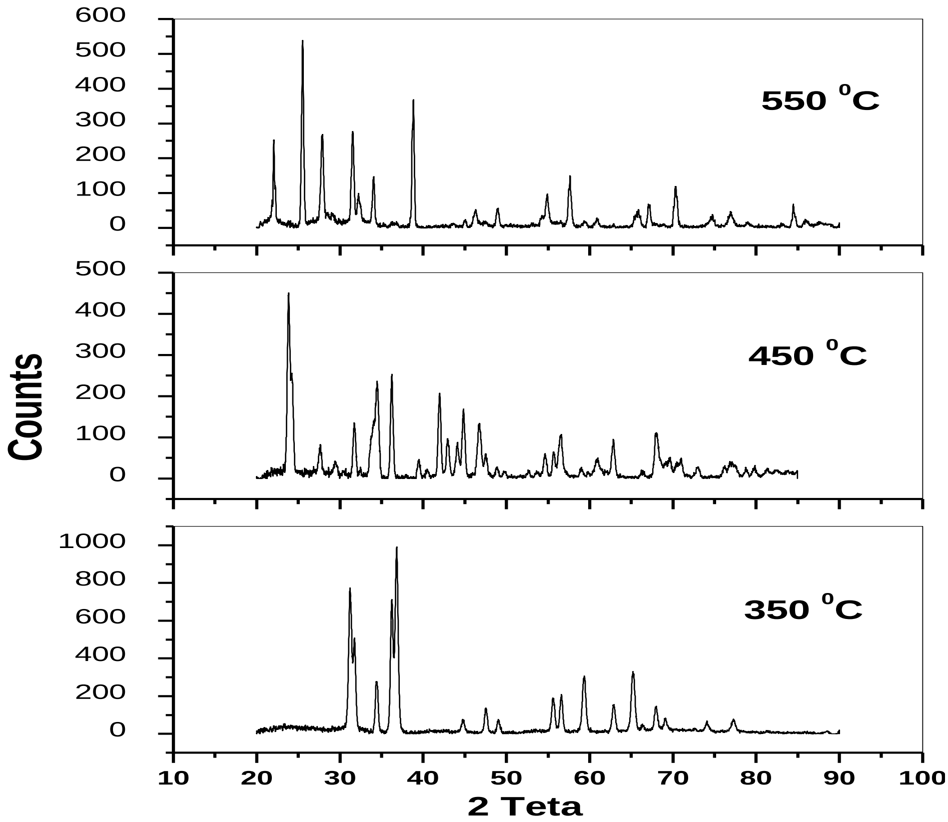

Fig.1. X-ray diffraction pattern of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$ ferrite nano particles

3.2. FTIR Study

Figure 2 shows the Fourier transform infrared spectra of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$ ferrite nano particles calcined at 350 ^{0}C, 450 ^{0}C and 550 ^{0}Cshow the strong absorption bands with two characteristic peaks [6].In ferrites the metal ions are situated at two sub-lattices named tetrahedral (A) site and octahedral (B) site. The high frequency tetrahedral (ν_1) band was observed in the range of 615–641 cm-1 and low frequency octahedralband (ν_2) was observed in the range of 417–434 cm-1.These bands confirm the spinel structure of the prepared ferrite nano particles [7,8].

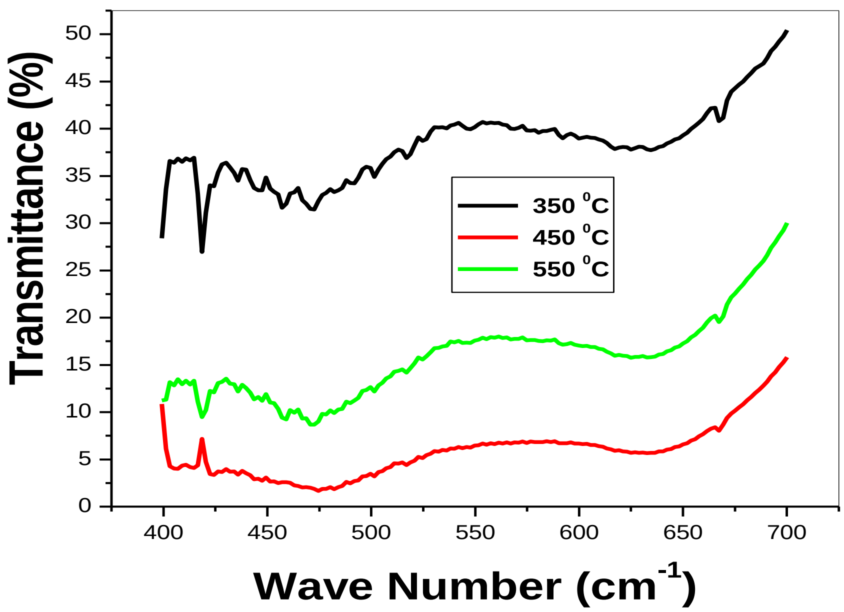

Fig.2 FTIR pattern of $Ni_{0.5}Zn_{0.5}Al_{0.5}Fe_{1.5}O_4$ ferrite nano particles

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3.3. SEM Analysis

Scanning electron morphologies of $Ni_{0.5}$ $Zn_{0.5}$ $Al_{0.5}$ $Fe_{1.5}$ O_4 ferrite nano particles calcinated at 350 ^{0}C, 450 ^{0}C and 550 ^{0}Cwere shown in Fig. 3. From Fig. 3 it is clear that powder particles are in nano-size range and have spherical shaped agglomerates [9,10].

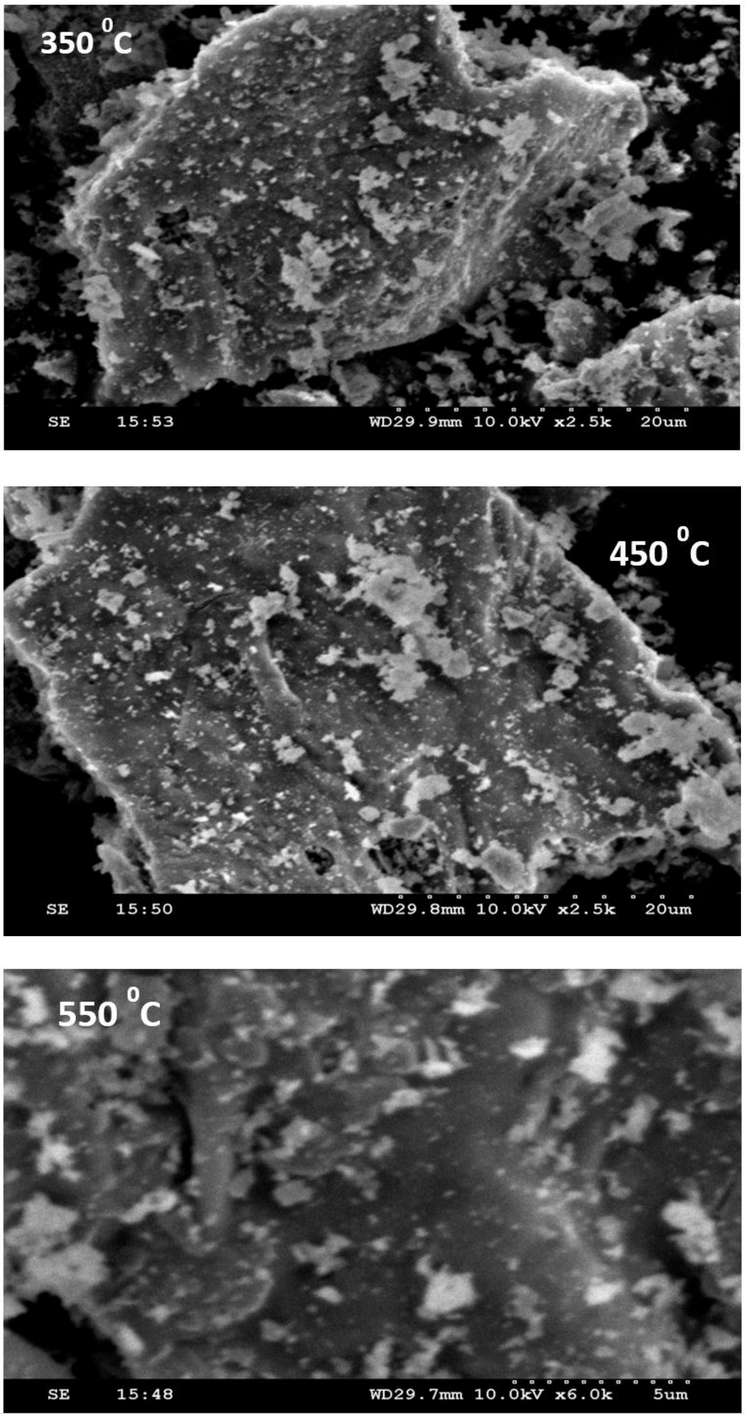

Fig.3. SEM images of $Ni_{0.5}$ $Zn_{0.5}$ $Al_{0.5}$ $Fe_{1.5}$ O_4 ferrite nano particles

3.4. Magnetic properties

The magnetic properties of nano ferrite particles were affected by various parameters such as anisotropy, crystallite size, density, composition and super exchange interactions between tetra and octahedral sites [11,12]. Magnetic hysteresis loops of$Ni_{0.5}$ $Zn_{0.5}$ $Al_{0.5}$ $Fe_{1.5}$ O_4nano ferrite samples calcined at 350 ^{0}C, 450 ^{0}C and 550 ^{0}Cwere obtained at room temperature by vibrating sample magnetometer and are shown in Fig. 4. The magnetic properties like saturation

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magnetization, retentivity, coercivity and magnetic moments were estimated from hysteresis curves. From Fig. 4 it is clear that all prepared ferrite powders show the soft and ferri-magnetic behavior. It is also noticed fromFig.4 is as the sintering temperature increases for all samples the saturation magnetization (M_s) value is decreased [13].

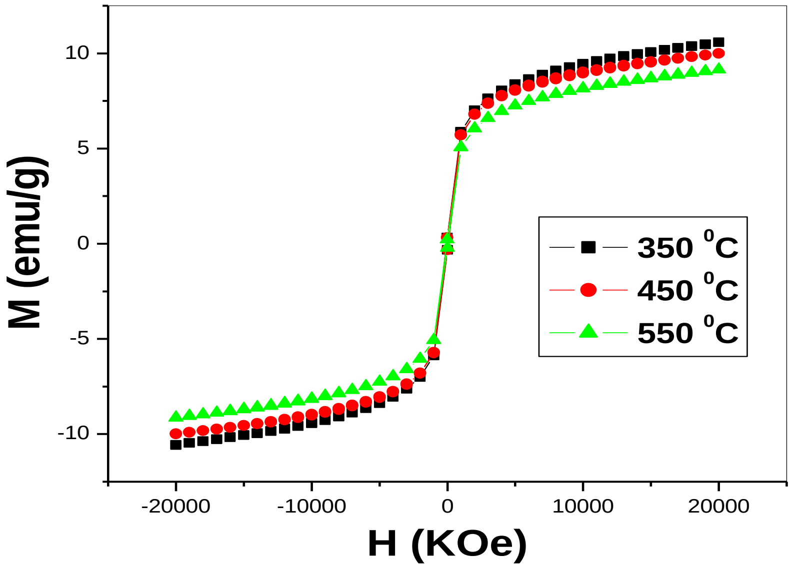

Fig.4. Hysteresis loops of $Ni_{0.5}$ $Zn_{0.5}$ $Al_{0.5}$ $Fe_{1.5}$ O_4 ferrite nano particles

IV. CONCLUSION

$Ni_{0.5}$ $Zn_{0.5}$ $Al_{0.5}$ $Fe_{1.5}$ O_4 ferrite nano particles were synthesized by auto combustion technique. The presence of a single phase spinel cubic structure was verified by XRD analysis. From FTIR spectrum two fundamental bands ν_1 and ν_2 around 641–417 cm-1 were observed, that are the common features of all ferrite materials. SEM studies confirmed the nano-crystalline nature with agglomerated particles. Magnetic hysteresis loops were obtained at room temperature by vibrating sample magnetometer. Magnetic properties were changed with sintered temperature. It was observed that, as the sintering temperature increases for all prepared samples the saturation magnetization (M_s) value is decreased. The lower saturation magnetization may be applicable in the broad range of frequency applications and magnetic recording.

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