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A study on Gallium substituted cobalt ferrite nanoparticles by coprecipitation route

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Abstract: Magnetic nanoparticles of $CoFe_2O_4$ and $CoFe_{1.4}Ga_{0.6}O_4$ have been synthesized by coprecipitation route. The FTIR spectra of $CoFe_{2-x}Ga_xO_4$ (x: 0.6 and 0.6 at 500°C) ferrite system was carried out in a KBr medium. Particle size as estimated by full width half maximum (FWHM) of the strongest x-ray diffraction (XRD) peak were found in the range of 22- 35 ± 4 nm. SEM images reveal that the sample surface exhibit well defined crystalline nanoparticles of spherical shapes with small agglomeration. Energy dispersive x- ray (EDAX) analysis confirms the presence of Co, Fe, Ga and oxygen compounds in the prepared nanoparticles. TEM was used to characterize the microstructure of the samples and particle size determination, which exhibited the formation of spherical nanoparticles.
Keywords: A study on Gallium substituted cobalt ferrite nanoparticles by coprecipitation route.

1. Introduction:

Ferrites have many technological applications in permanent magnets, magnetic drug delivery, microwave absorbing materials, high density information storage technology, broadband transformers, magnetic resonance and ferrofluid technology [1-3]. Among the spinel ferrites $CoFe_2O_4$ is a hard magnetic material that has excellent chemical stability, high mechanical hardness, high coercivity, moderate saturation magnetization, high corrosion resistivity, high cubic magnet to crystalline anisotropy and high Curie temperature [4]. From the literature survey, Song et al.[5] investigated magnetic properties of a series of Ga-substituted Co ferrites, $CoGa_xFe_{2-x}O_4$ (x:0.0–0.8) and found that the magnitude of magnetostriction decreases monotonically while the magnitude of maximum strain derivative (dk/dH)max increased for a small amount of Ga. No detailed report has been cited in the literature on the Ga substituted Co ferrites nanoparticles.

2. Experimental procedure:

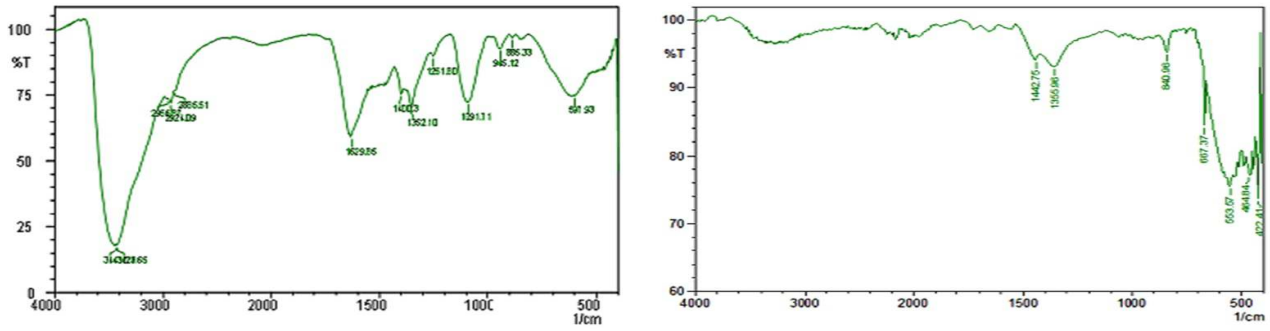
Ferrites nanoparticles of $CoFe_{2-x}Ga_xO_4$ ($0 \leq x \leq 0.8$) were prepared by co precipitation method. The molarity of the coprecipitation agent (NaOH) was 3mol/l. The solution of $CoCl_2.6H_2O$, $FeCl_3$, $Gacl_3$, in their stoichiometry (100 ml of 0.1M $CoCl_2.6H_2O$, 50 ml of 1.4M $FeCl_3$,50 ml of 0.6M $GaCl_3$, in the case of $CoFe_{1.4}Ga_{0.6}O_4$) were mixed in double distilled de–ionized water. The salt solutions were mixed together with continues stirring. The neutralization is carried out with NaOH solution, and the pH is maintained around 12.Few drops of PEG – 400 were added to the precipitate and heated at 80°C using a hot plate with continues stirring for 2 hrs. The precipitate was washed and filtered several times with deionized distilled water. The

precipitate was then dried at 100°C for overnight. The dried sample was fluffy mass in appearance which is grinded for 2 hrs, and the resulting powder was sintered for 5 hrs at 500°C. After sintering the sample was again grinded using the ball milling apparatus and the resulting powder sample was subjected to various characterizations.

3. Result and discussion

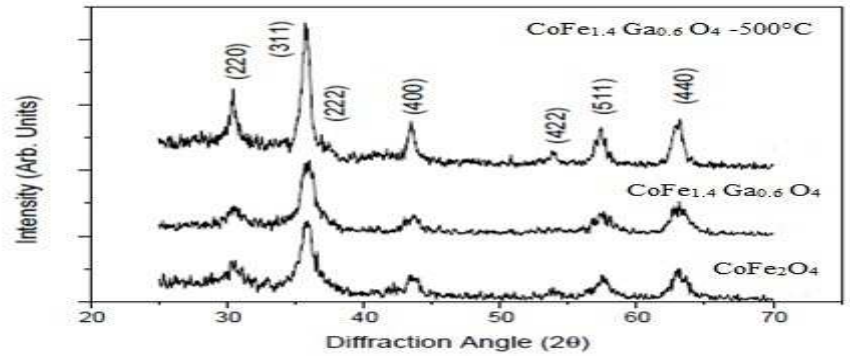
3.1. FTIR Analysis:

The FTIR spectra of $CoFe_{2-x}Ga_xO_4$ (x: 0.6 and 0.6 at 500°C) ferrite system was carried out in a KBr medium and is recorded in the range of 4000 to 400 cm^{-1}. Fig (1) shows the FTIR spectrum of $CoFe_{1.4}Ga_{0.6}O_4$ before and after thermal treatment. The absorbed water is shown by the peaks between 3400 to 3445 cm^{-1}, but after the thermal treatment the water band was removed. The band around 1630 to 1650 cm^{-1} is assigned to O-H stretching and O-H bending mode of vibration respectively [6]. Two absorption band are found below 1000 cm^{-1} which is common in all ferrites. Absorption at the frequency around 450 – 385 cm^{-1} is caused by the stretching of tetrahedral metal ions and oxygen bonding. Absorption at the frequency around 600 – 550 cm^{-1} is caused by oxygen in the direction perpendicular to the axis joining the octahedral ion and oxygen [7]. The CH_3 band is found at 1440 cm^{-1}.



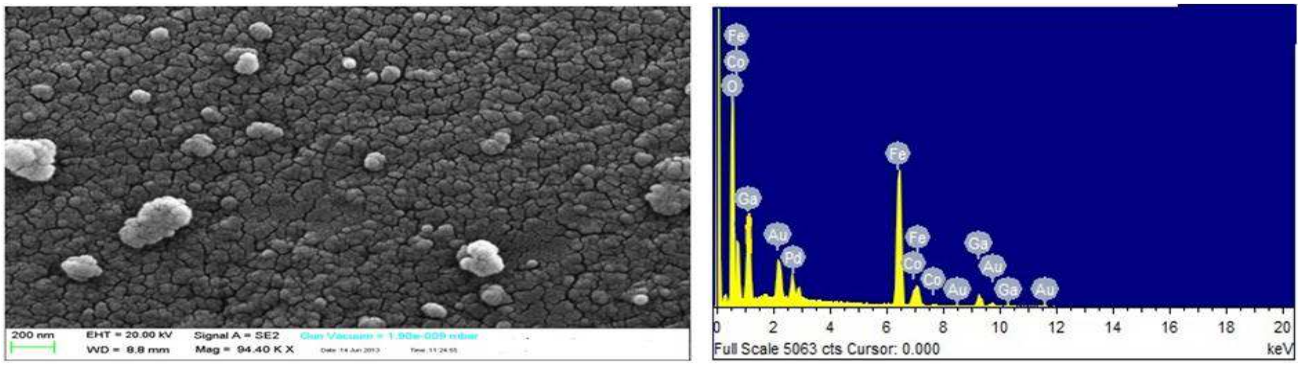
3.2. Xrd structural analysis:

The x-ray diffraction (XRD) pattern for the sample was recorded and confirmed the formation of well defined single phase spinel structure. Fig (2) represents the XRD pattern of $CoFe_2O_4$ and $CoFe_{2-x}Ga_xO_4$ (x: 0.6 and 0.6 at 500 °C). All the samples are in single phase cubic spinel structure. The peaks are well indexed with the standard pattern of JCPDS card number: 22-1086 ($CoFe_2O_4$). The average crystalline size of the powder sample was found to be 35 nm and 29 nm for the Co- ferrite and for the Co ferrite containing 0.6 mol of Gallium.



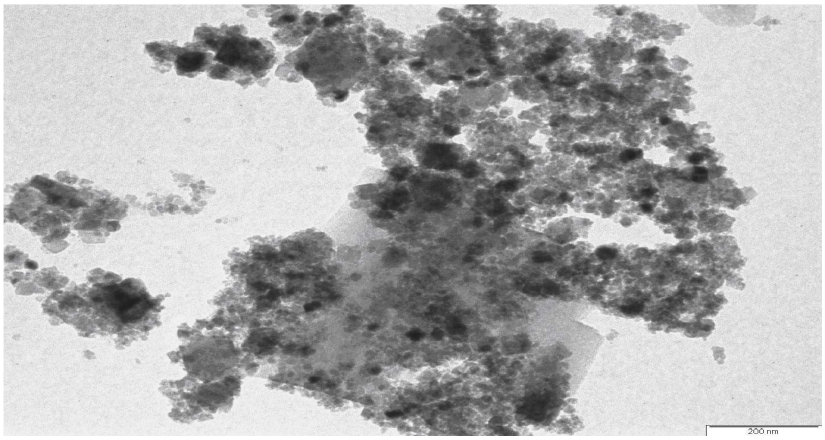
3.3. SEM/EDX:

Figure (3) shows the SEM/EDX image $CoFe_{2-x}Ga_xO_4$ (x: 0.6) nanoparticles. From the SEM image, the particles are of spherical in shape with soft agglomeration in it. The crystalline size is around 24 nm which is nearer to the size obtained in XRD analysis. The EDS spectrum reveals the presence of Co, Fe, Ga, Au, Pd and O elements in the sample. The Au, Pd peaks are due to thin coating of gold on the sample surface to make the sample conducting. These data reveals that there is no contamination of elements in the prepared $CoFe_{2-x}Ga_xO_4$.



3.4. TEM:

From the TEM image, fig (5) of $CoFe_{2-x}Ga_xO_4$ (x: 0.6), it is seen that the nanoparticles having different grain size and separated from each other. Mostly agglomerated particles are seen in the TEM images, but some particles in a spherical shape are also seen that are well separated in the sample.



4. Conclusion:

$CoFe_{2-x}Ga_xO_4$ are prepared by co-precipitation method and annealed at 500°C. The FT-IR spectra show absorption bands around 600 cm^{-1} and 400 cm^{-1} which are attributed to the stretching vibrations of tetrahedral complexes and octahedral complexes respectively. The XRD spectra reveal the average crystallite size to be in the range of 29-35nm.The morphology and the particle size was determined using FESEM and TEM.

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