Effect of Gamma Irradiation on Structural and Magnetic Properties of Bi Substituted Cobalt Ferrite Nanoparticles

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Magnetic materials with spinel structure have been interesting due to their wide range of applications for large spin polarization and high magnetic critical temperatures; well above the room temperature. Ferrimagnetic and electrical properties of the spinel ferrites are strongly influenced by the distribution of cations along with Fe^{3+}-Fe^{2+} between the tetrahedral and octahedral sites. Cobalt ferrite, an inverse spinel at bulk and partial inversion in nano order has been important for discussion. The interplay of cations for site occupation tunes the electric and magnetic properties of the cobalt ferrite. In the present study attempts have been made to observe magnetic properties of both gamma irradiated (1 KGy) and unirradiated cobalt ferrite by substituting Bi^{2+} in place of Fe. Bi^{3+} substituted spinel cobalt ferrite nanoparticles was prepared by auto combustion method. Phase formation and surface morphology was confirmed by the XRD and FESEM respectively. The particle size was estimated to be in nano range from study of FESEM image. Particle size and hoping length were increased with the substitution of Bi^{3+} due to the large size of bismuth compared to the iron. The magnetic properties of Bi substituted cobalt ferrite nanoparticles analyzed before and after gamma irradiation. Before gamma radiation saturation magnetization and remnant magnetization increased with Bi substitution while coercivity is decreased. In case of irradiated samples there is irregular variation of magnetic properties with bismuth substitution. In this case saturation magnetization and remnant magnetization has increased from parent to 5 % substitution after that it is decreased. Coercivity showed higher value in 10 % substitution and remaining samples showed lower than the parent cobalt ferrite.

Keywords: Functional materials, Spinel, Magnetization, Nanoparticles

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Plan of presentation

Introduction to Cobalt Ferrites

- **Structure, Magnetic properties**
- **change due to doping with Bi**
- **change to gamma irradiation**

Experimental (characterization) Technique

Results and Discussion

Conclusions

Introduction

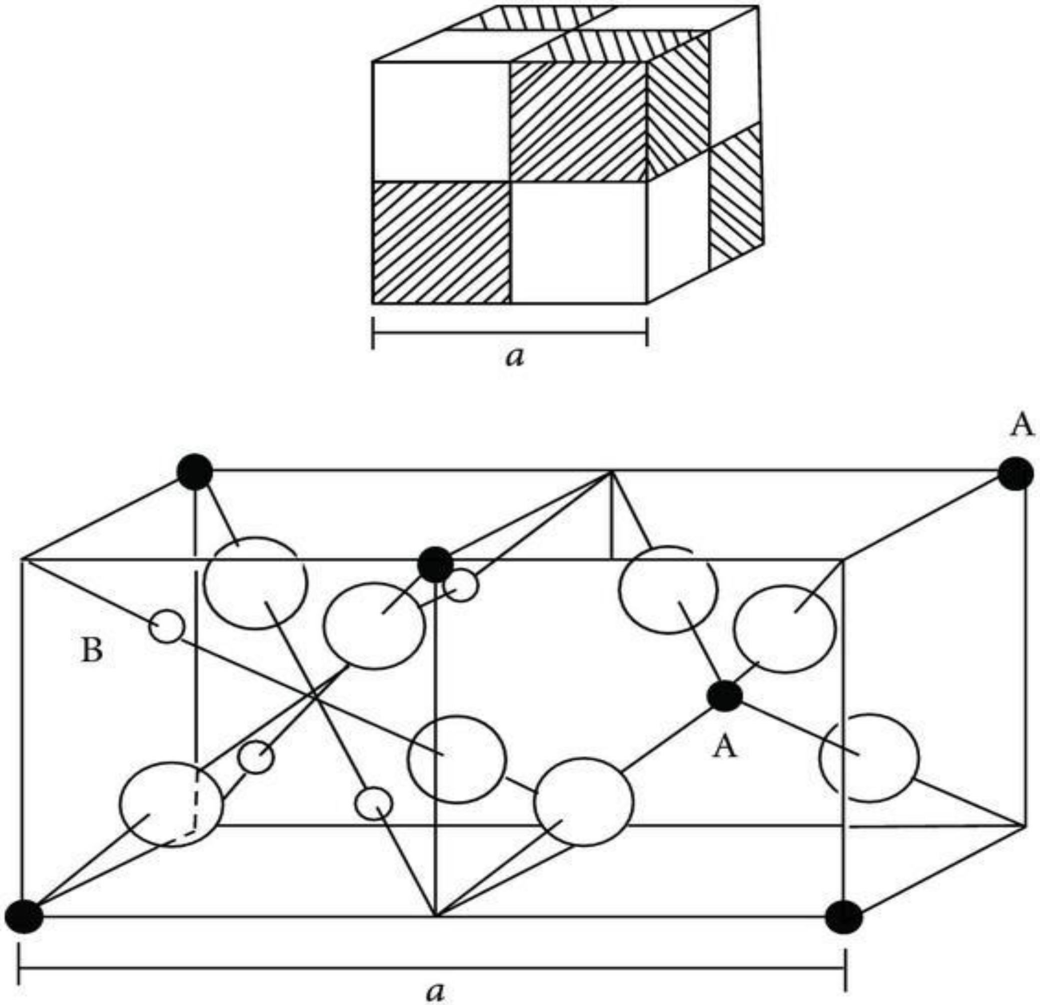
$CoFe_2O_4$ (CFO) is a hard magnet among soft spinel magnets which is also characterized with large magneto-crystalline anisotropy and magneto-striction, chemical stability, unique nonlinear spin-wave properties and high resistivity along with low eddy current loss

- **hard magnetic material**
- **high coercivity**
- **moderate magnetization**
- **large magnetic anisotropy**
- **large magnetostrictive coefficient**

Cobalt ferrite, an inverse spinel at bulk and partial inversion in nano order

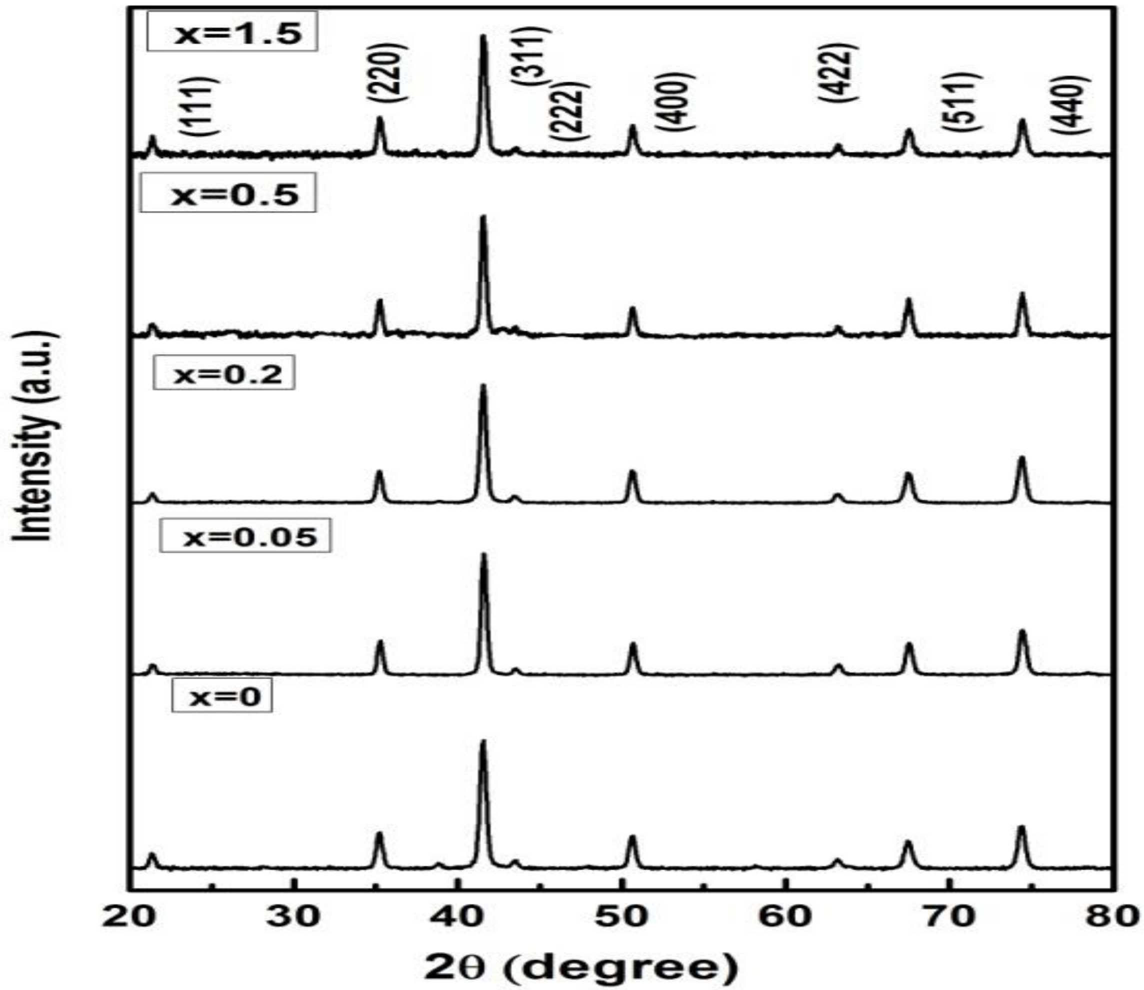
Cation distribution is given by $(Fe^{3+}{}_{\delta}M^{2+}{}_{1-\delta})_A\ [Fe^{3+}{}_{2-\delta}M^{2+}{}_{\delta}]_B\ O_4$, where δ is the degree of inversion.

For the normal spinel, $\delta = 0$ whereas for the inverse spinel system, $\delta = 1$ and its value lies between 0 and 1 depending upon the synthesis techniques, calcination and sintering temperature

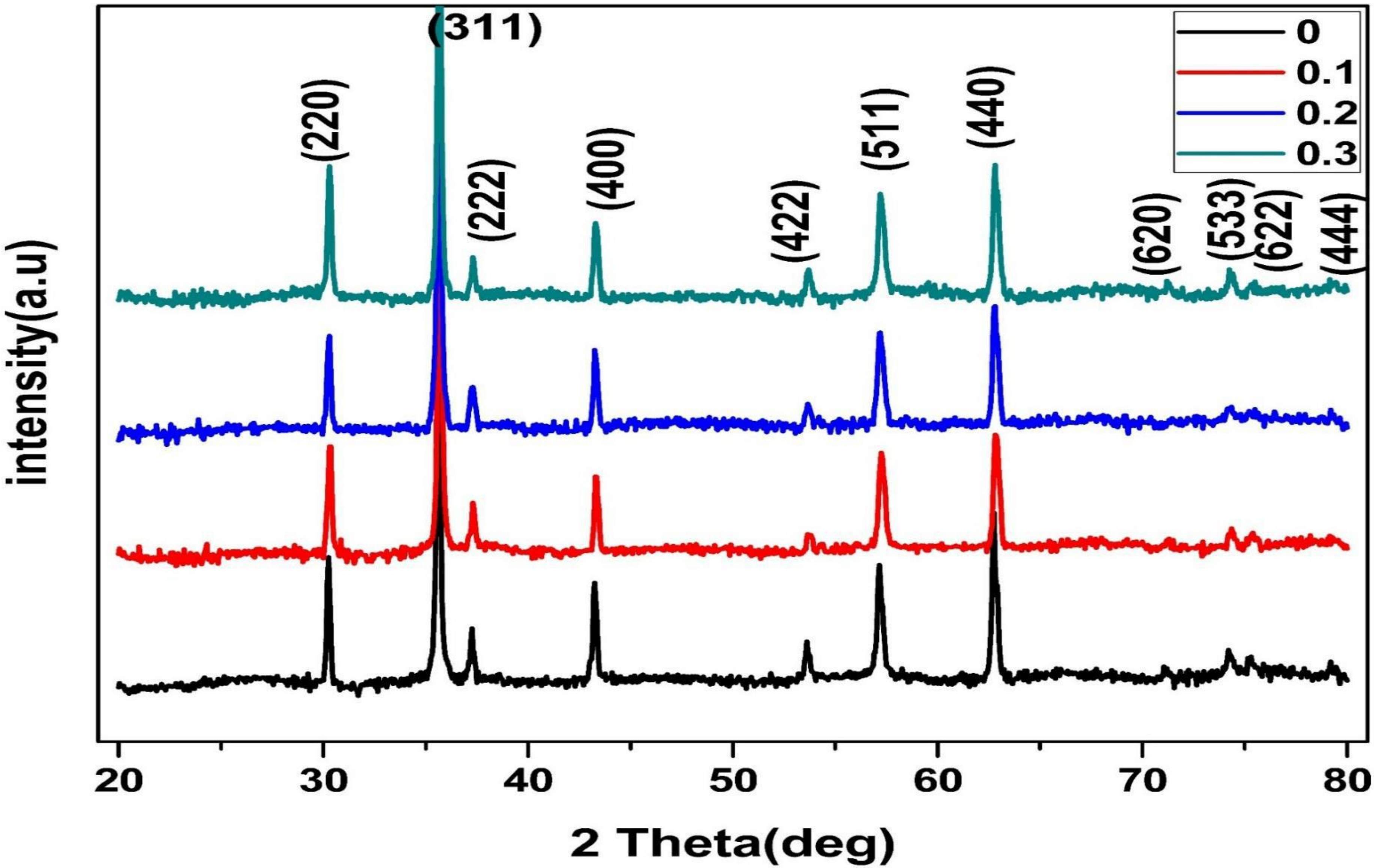


The magnetic and electric properties of spinel systems are mostly governed by three types of interactions among cations located at tetrahedral (A) and octahedral (B) sites. These are symbolized as A-A, B-B and A-B interactions. Among these interactions A-B interaction is the strongest over the rest A-A and B-B interactions and which is antiparallel in nature

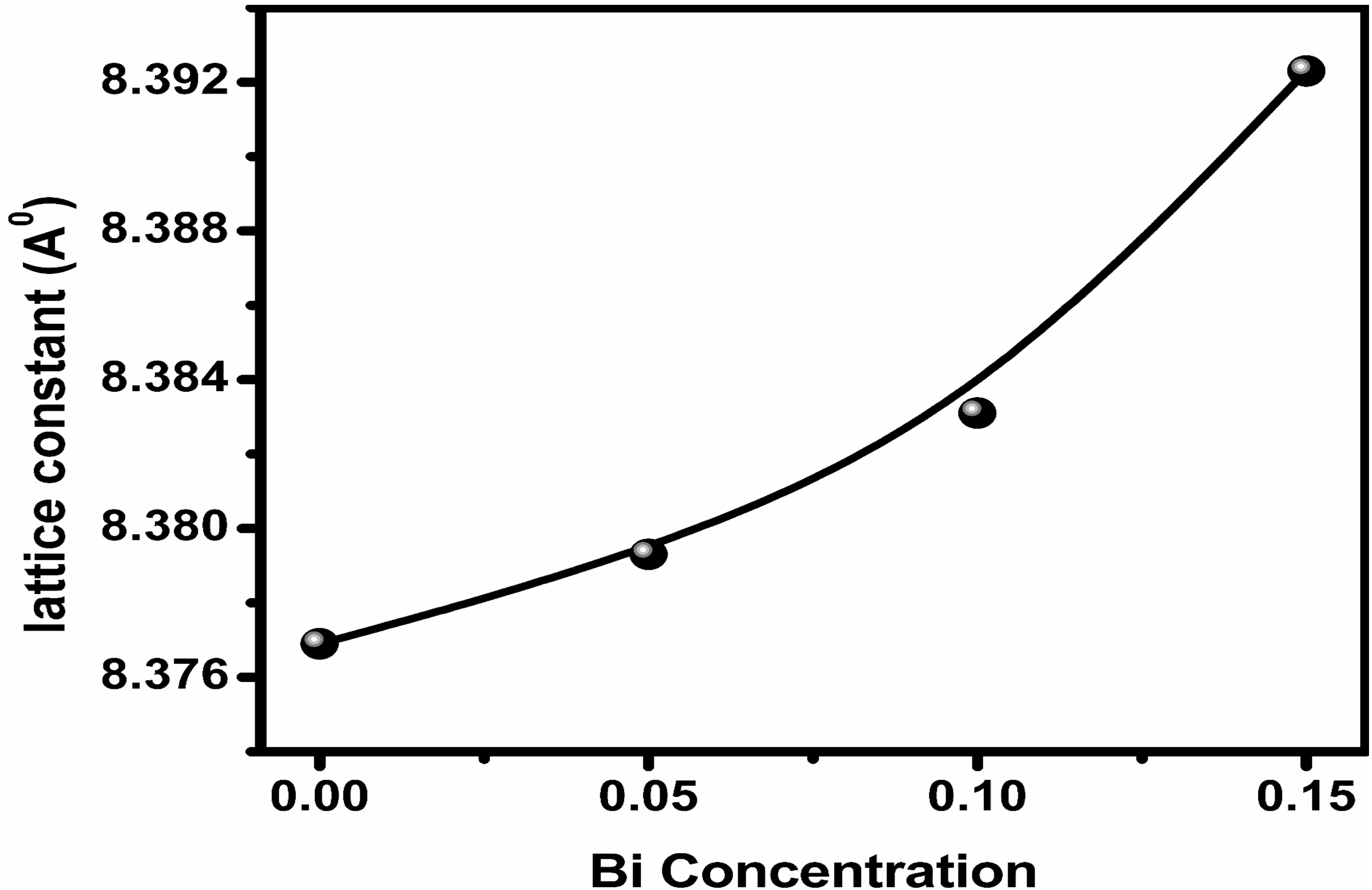
The spinel structure. The unit cell divided in to octants; tetrahedral cations A and octahedral cations B and O atoms are shown in two octants



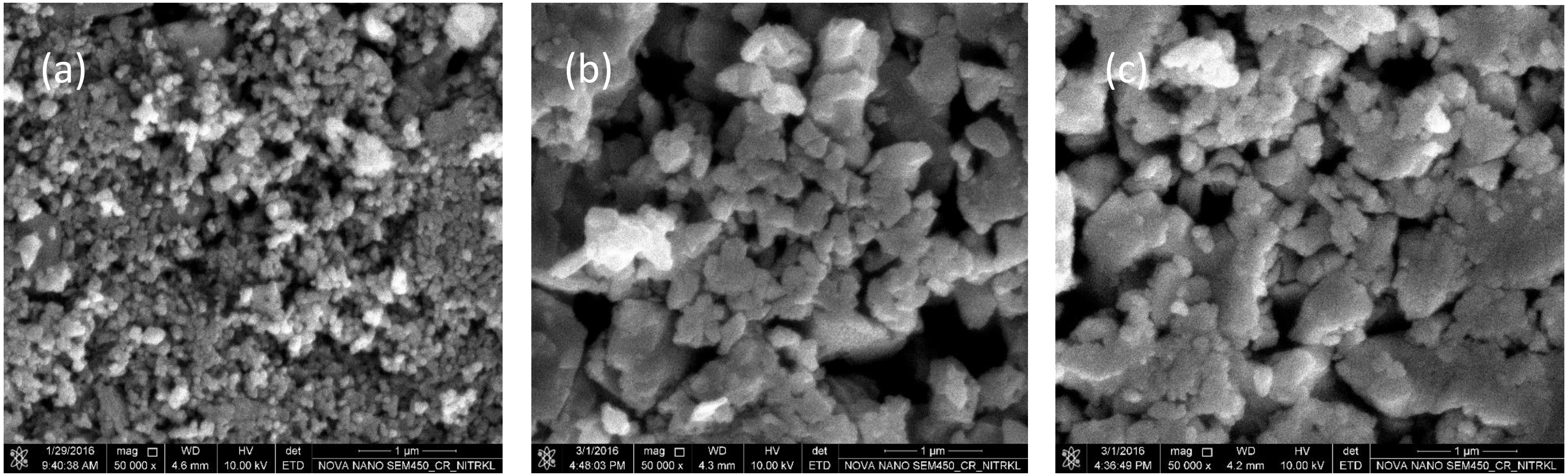
From the XRD pattern it is identified for x = 0.00, 0.05, 0. 2, 0.5, 1.5 shows peaks consistent with cubic spinal phase. From the most intense peak of the reflection (311), we have estimated the average particle size of the nanoparticle using Debye– Scherrer equation.

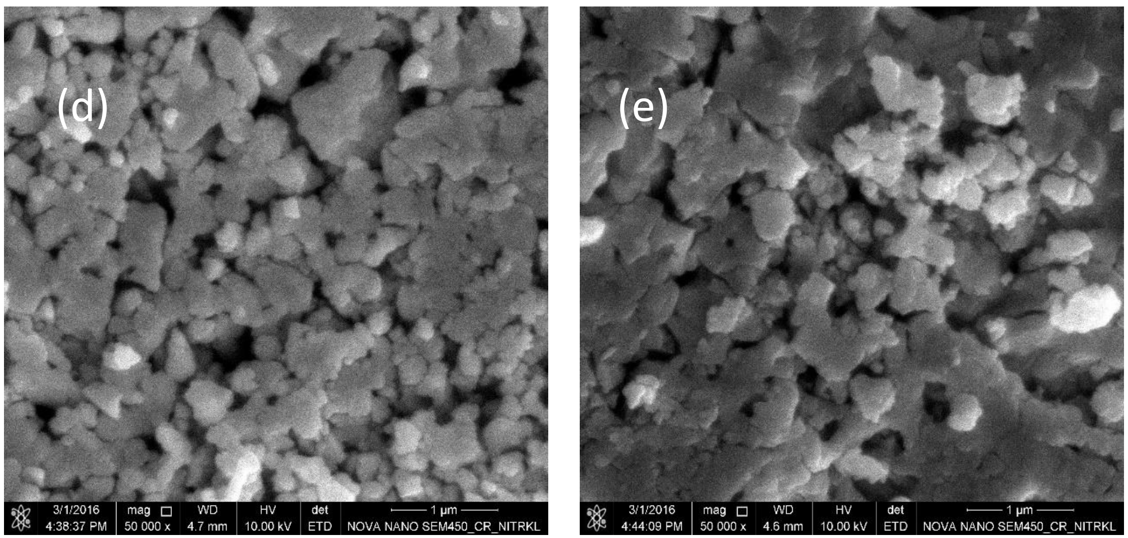


XRD pattern of the CoFe2-xBixO4



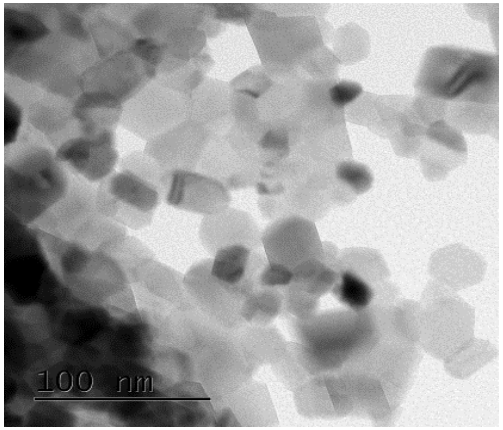
Variation of lattice constant of the $CoFe_{2-x}BixO_4$

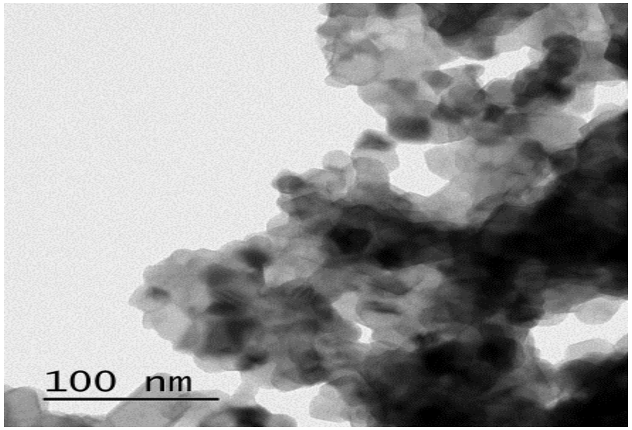




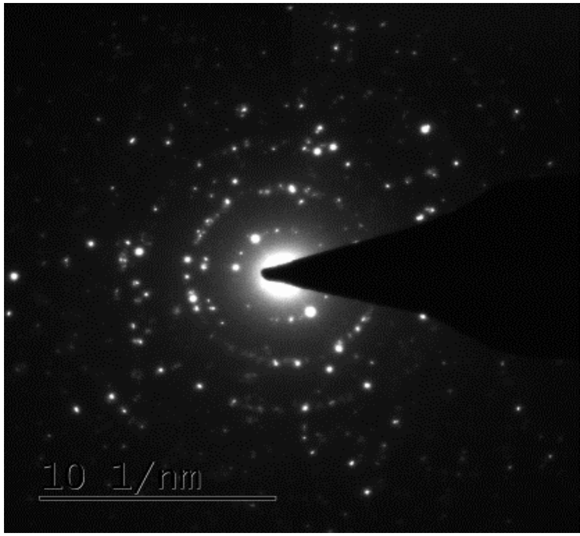
FESEM image of $CoBixFe_{2-x}O_4$ (where x = 0.00, 0.05, 0. 1, 0.50, 1.50) nano ferrite particles.

It is clear from the FESEM images that the particles have an almost homogeneous distribution and some particles are in agglomerated form. A apparent growth in the particle size is observed which is due to Bi substitution (40 nm – 240 nm).

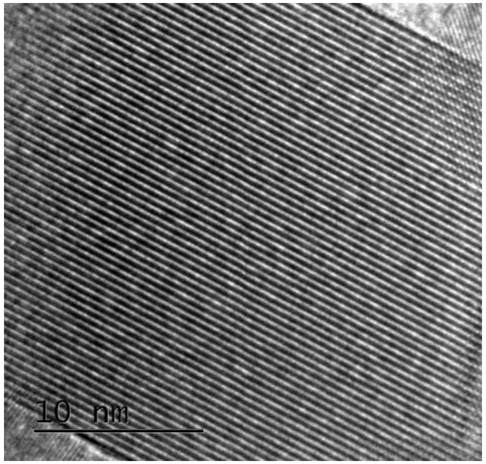


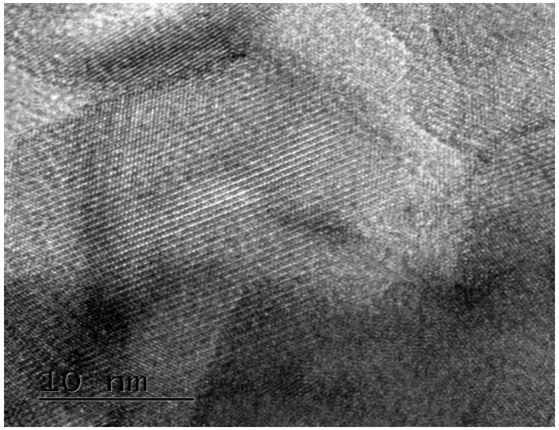


TEM image of $CoFe_2O_4$ nanocrystals and x= 0.5 Bi dopd synthesized at 600 °C



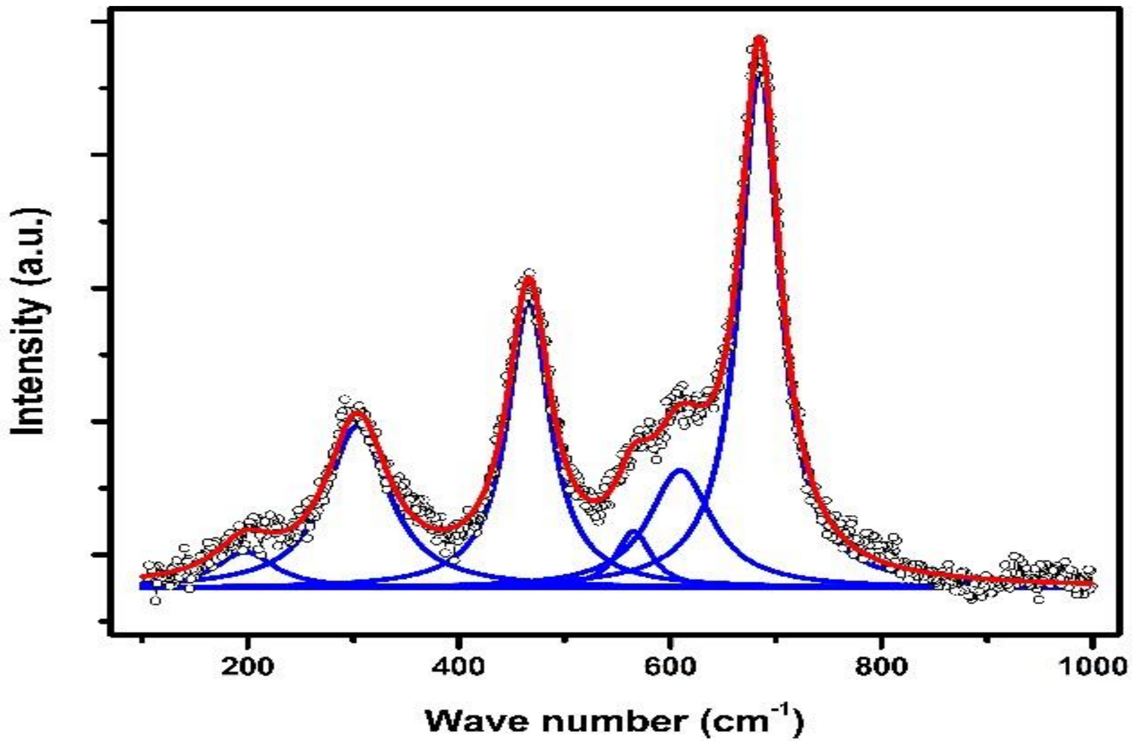
Selected area electron diffraction
(SAED) of the specimen showing diffuse rings from $CoFe_2O_4$ reflections.





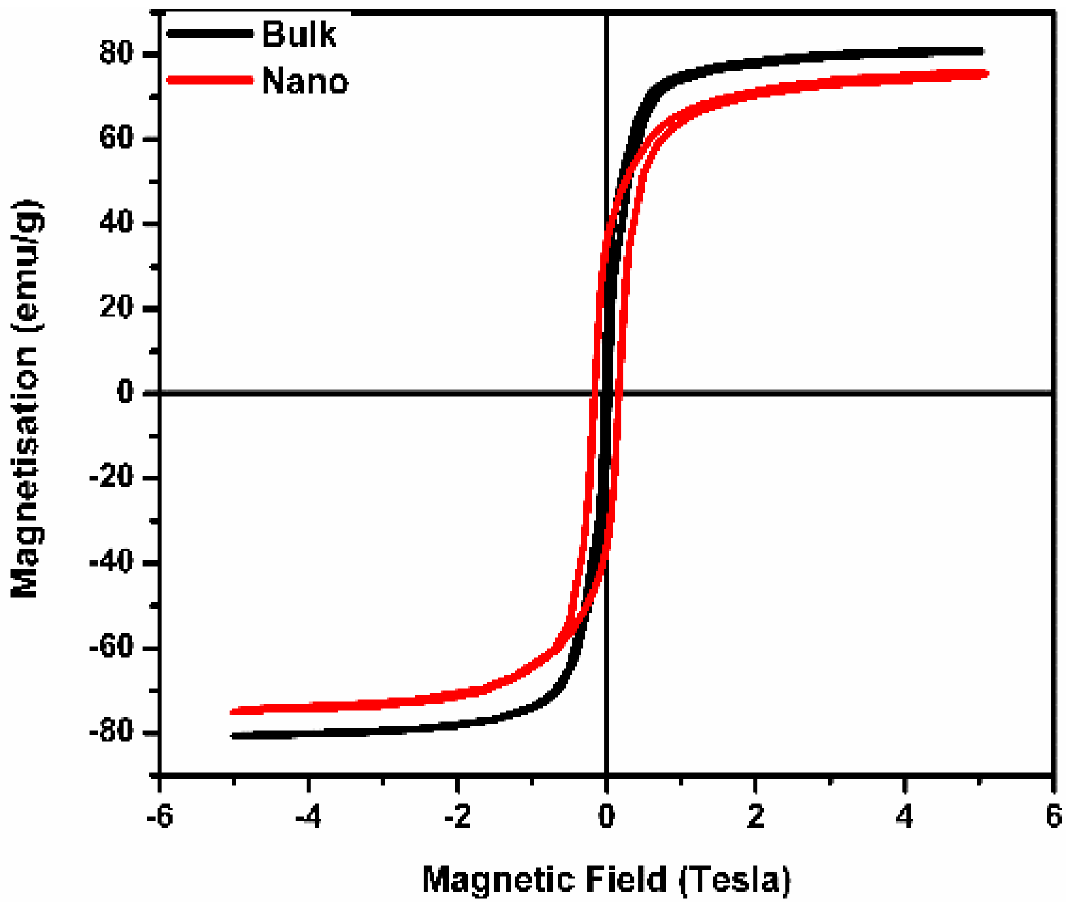
HRTEM lattice image of $CoFe_2O_4$ and x= 0.5 Bi dopd synthesized at 600 °C nanocrystallite

- **The lattice parameter value obtained in all cases is 8.378 Å, which is in good agreement with the value obtained from XRD pattern.**

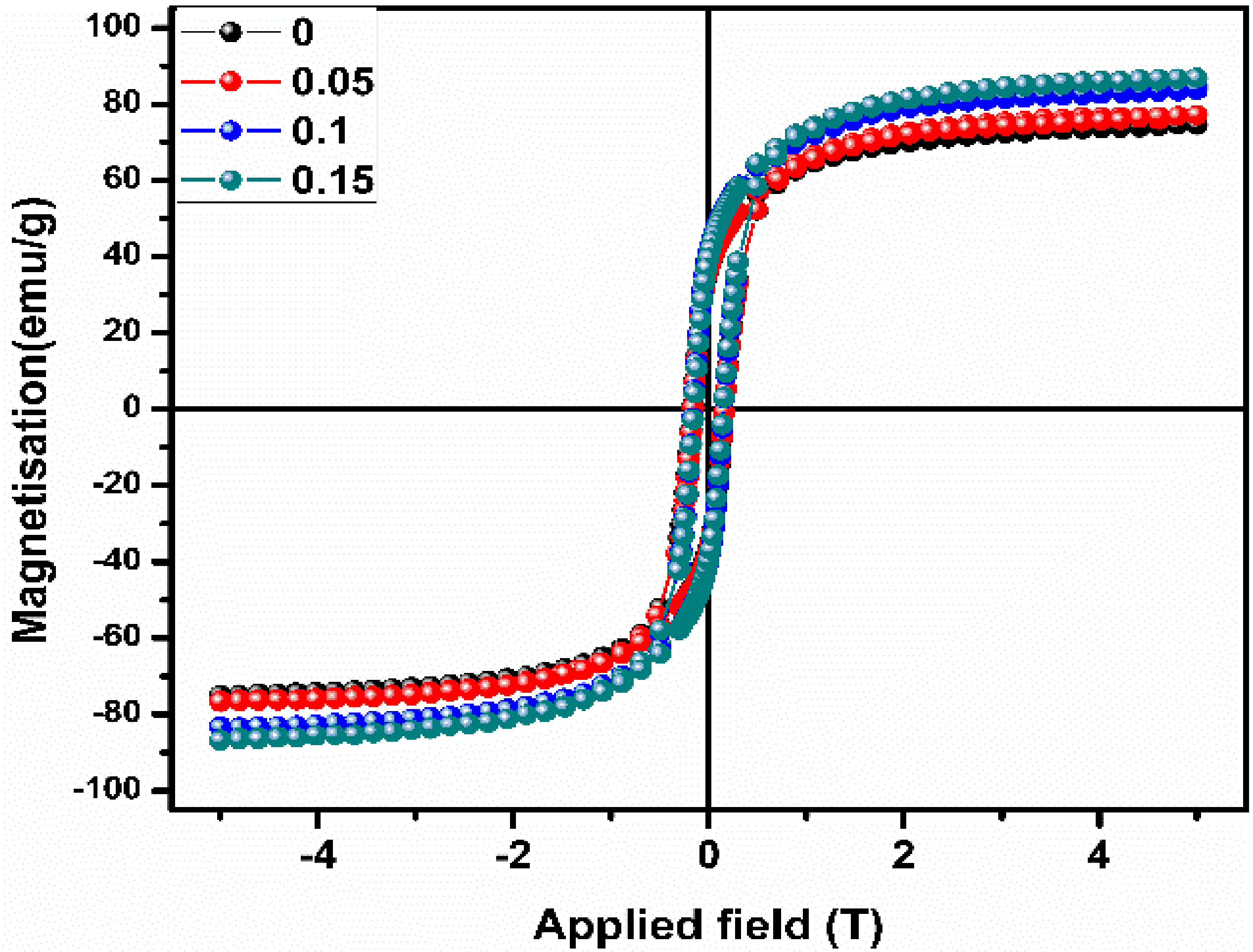


Raman spectra of cobalt ferrite nanoparticles

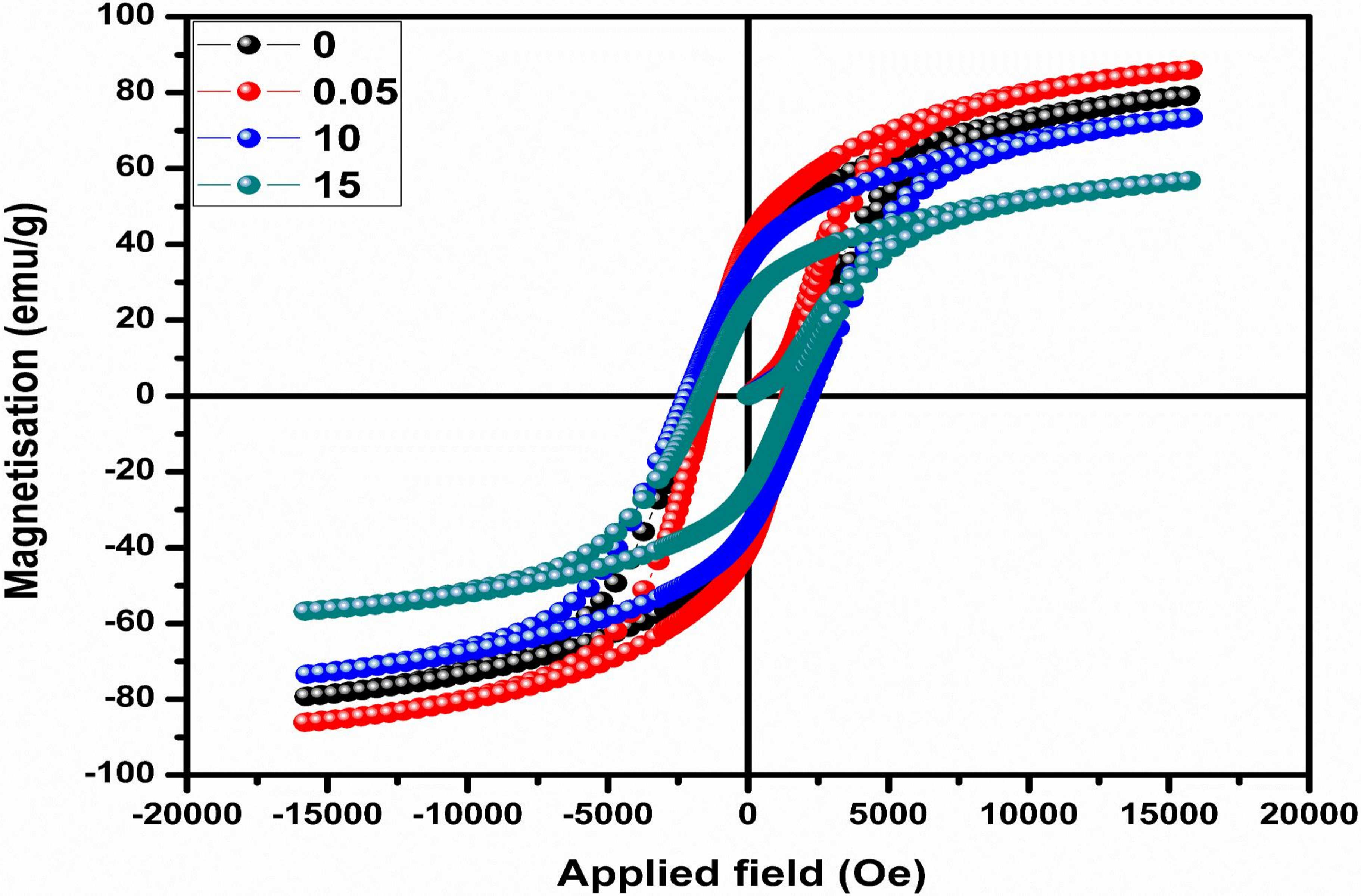
In ferrites the modes below the 600cm^{-1} belongs to octahedral vibrations (BO_6 group) and above it belongs to tetrahedral vibrations (AO_6 group) of the oxygen atoms. The most intense Raman peak in octahedral modes is 466 cm^{-1} and for tetrahedral site is 684 in cobalt ferrite.



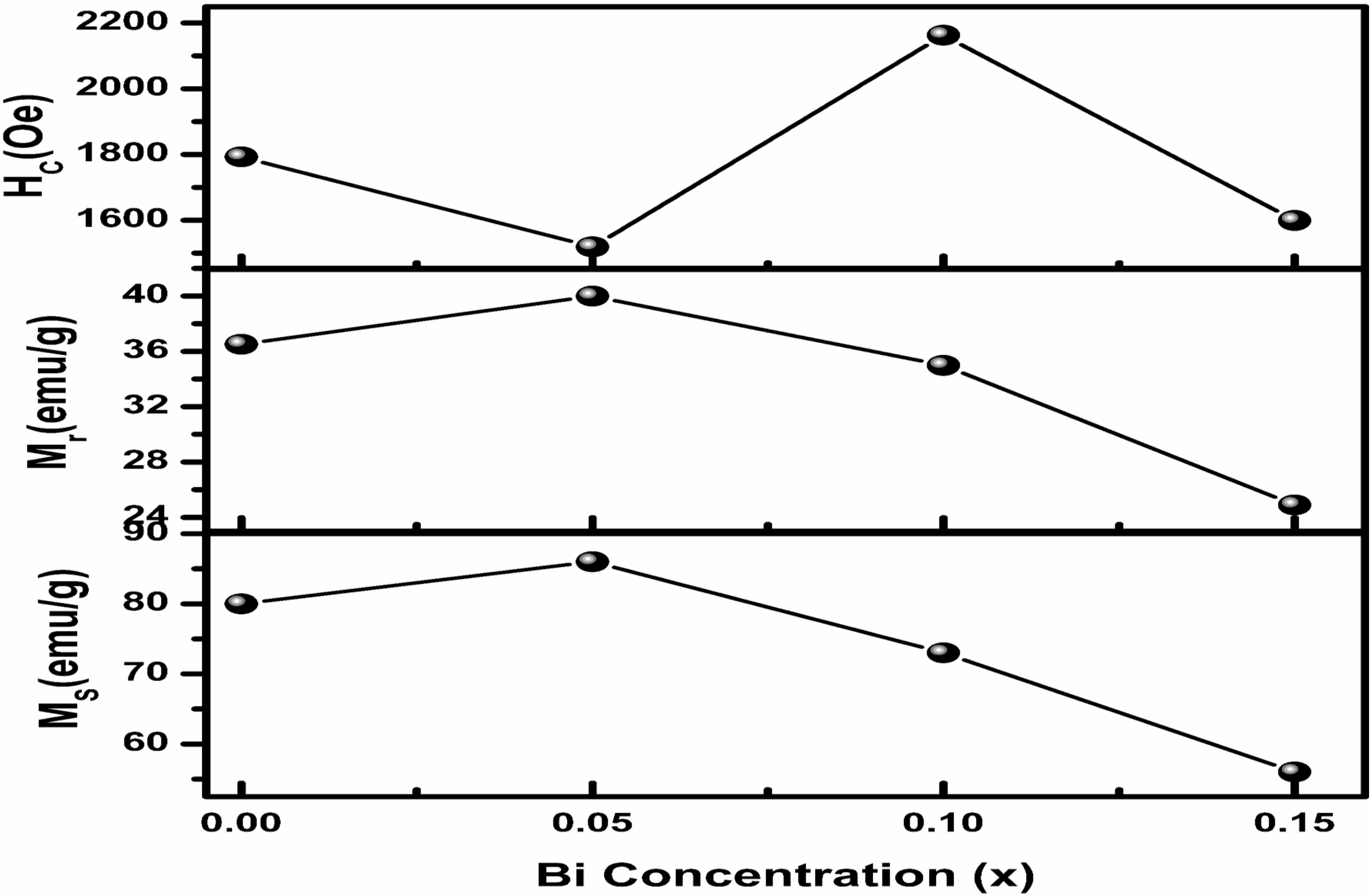
Room temperature M-H loops of the bulk and nano cobalt ferrite.



Room temperature M-H loops of Bi^{3+} substituted cobalt ferrite nanoparticles



Room temperature M-H loops of gamma irradiated Bi^{3+} substituted cobalt ferrite nanoparticles



Variation magnetic parameter for gamma irradiated Bi^{3+} substituted cobalt ferrite nanoparticles

Conclusion

Bi doped cobalt ferrite nano form shows particle growth (FESEM, TEM)

It was observed from the room temperature M-H loop that nanoparticles showed lower saturation magnetization value and higher coercivity as compared to the bulk cobalt ferrite.

Controlled particle growth has brought interesting features in electrical and magnetic properties in the Bi modified systems.

In addition, there was enhancement in saturation magnetization and reduction in coercivity in bismuth substituted cobalt ferrite nanoparticles.

Before gamma radiation saturation magnetization and remnant magnetization increased with Bi substitution while coercivity decreased. In case of irradiated samples there is irregular variation of magnetic properties with bismuth substitution


Thank You