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EVOLUTION OF MAGNETIC AND OPTICAL PROPERTIES IN SPINEL FERRITE $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ THIN FILM

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Introduction

Co_3O_4 is normal and antiferromagnetic below 40 K. The Co^{3+} occupied in the octahedral sites have zero magnetic moment due to low spin state of the ion. It has been found the Co^{2+} with high spin configuration are in charged of the antiferromagnetic property. It has been investigated the evolution of structural, magnetic, and optical properties as Fe is added to Co_3O_4 .

Experimental

$\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ samples were prepared as thin films on Si(100) substrates with thickness of about 1 μm by a sol-gel method employing spin-coating process. The precursor solution for fabricating Co_3O_4 films was prepared by dissolving $\text{Co}(\text{CH}_3\text{CO}_2)_2 \cdot 4\text{H}_2\text{O}$ powder in 2-methoxyethanol at 70 °C. For Fe doping, $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ was dissolved together with $\text{Co}(\text{CH}_3\text{CO}_2)_2 \cdot 4\text{H}_2\text{O}$. The variation of structural properties with Fe composition in the $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films was investigated by X-ray diffraction (XRD). The magnetic and optical properties have been explored by vibrating-sample magnetometer (VSM), Mössbauer spectroscopy (MS), X-ray photoelectron spectroscopy (XPS), and spectroscopic ellipsometry (SE).

Results and Discussion

Figure 1 exhibits XRD spectra for the present $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films. It is seen that the same spinel structure as Co_3O_4 is maintained up to $x = 0.55$ with gradual increase of the cubic lattice constant with x , which is in accordance with Vegard's law. However, the XRD investigation indicates the coexistence of two phases between $x = 0.76$ and 0.93 as clearly seen in Fig. 2 where the evolution of the (311) peak with x is exhibited. The result of magnetic property measurements by VSM on the $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films is exhibited in Fig. 3. Paramagnetic behavior was observed below $x = 0.55$. Optical properties of the $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films were measured by SE in the 1.5 – 4eV photon-energy range. As shown in Fig. 4, the imaginary part of the dielectric function of $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ evolves as the Fe composition changes. As the Fe composition increases, the 2.8-eV absorption, due to p-d charge-transfer (CT) transition between O and octahedral Co^{3+} ion, is reduced in intensity. [1] The 1.65-eV structure, due to d-d CT transition between octahedral Co^{3+} and tetrahedral Co^{2+} ions also suffers reduction in strength as x increases. These results indicate that the Fe^{3+} ions substitute octahedral Co^{3+} sites mostly for low Fe compositions. Measurements by XPS and MS revealed that Fe have Fe^{2+} as well as Fe^{3+} ionic valence at high Fe compositions.

Ferrimagnetic behavior is due to the replacement of Co^{2+} and Co^{3+} by Fe^{2+} and Fe^{3+} respectively, inducing the unbalanced magnetic moments in tetrahedral and octahedral sites.

Reference

[1] K. J. Kim, Y. R. Park, D. H. Hyun, S. H. Lee, J. Appl. Phys. 96, 1975 (2004).

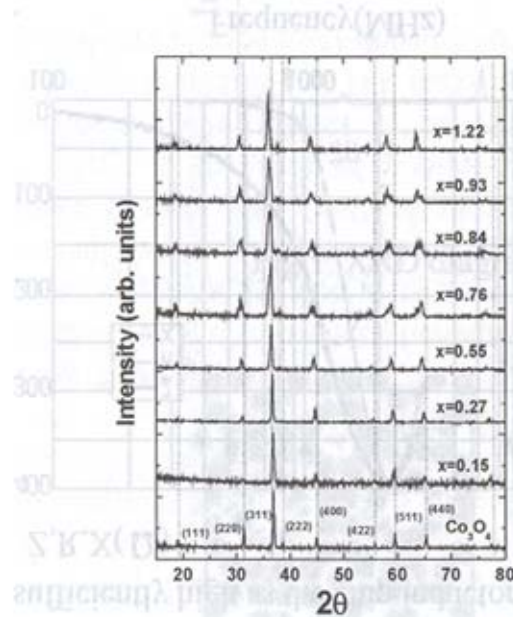


Fig. 1. Result of XRD measurements on $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films.

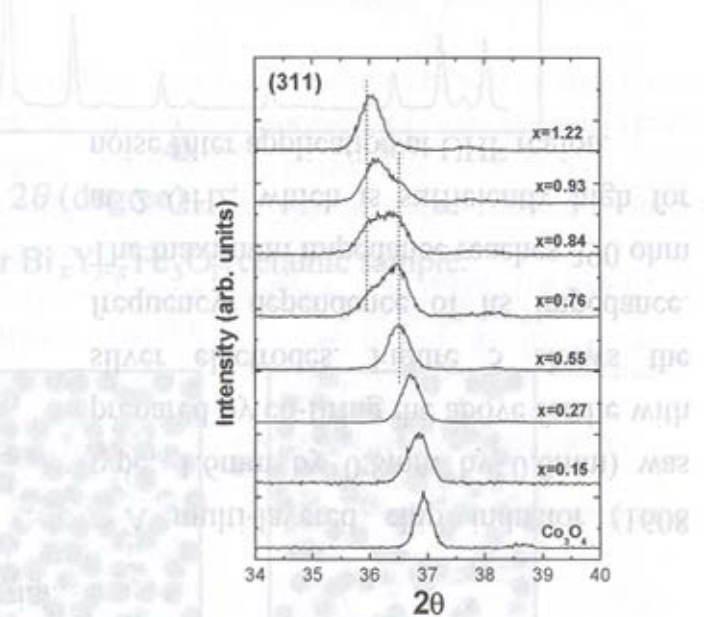


Fig. 2. Evolution of XRD (311) peak of $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films.

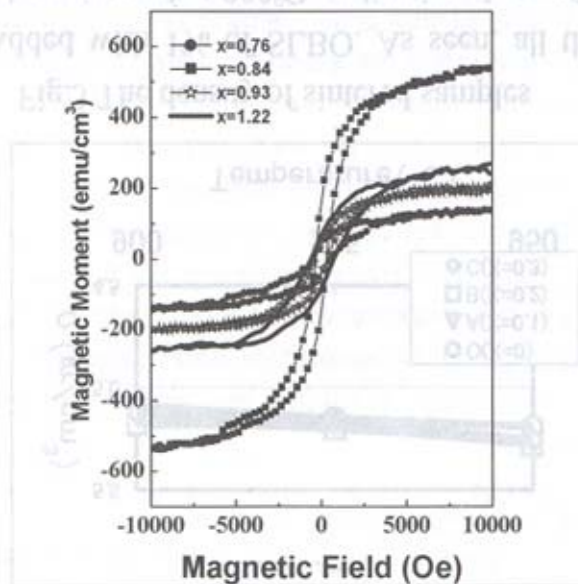


Fig. 3. Result of VSM measurements on $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films at room temperature.

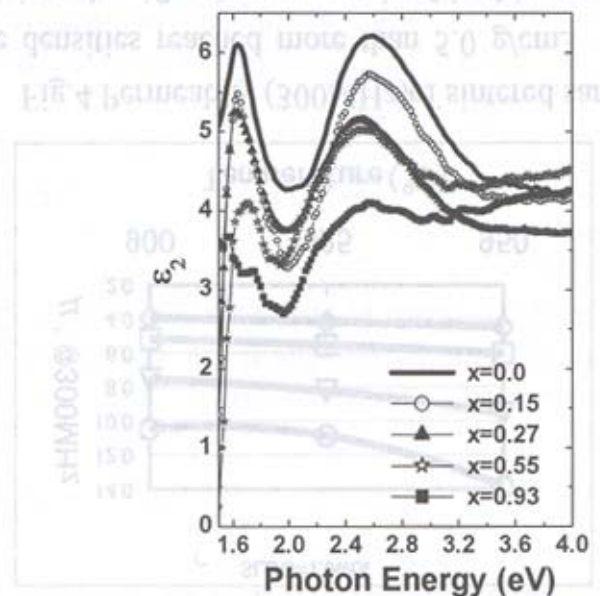


Fig. 4. Imaginary parts of dielectric functions of $\text{Fe}_x\text{Co}_{3-x}\text{O}_4$ films measured by SE.