Spectroscopy, Optical Properties of NiFe2O4 Nanoparticles Prepared by Co-Sputtering Technique in Different Gasses Mixture Ratio

Baha T. Chiad, Ruaa A. Mohammed

Abstract— We report the optical properties of the inverse spinel ferrite NiFe2O4,All the films were deposited on Si (100) substrateby co-sputtering technique, We carried out variable gasses mixture argon to oxygen for transmittance measurements on the thin films to investigate the optical properties. Thicknesses of the films determined by x-ray reflectivity vary from 73nm to 176nm as the varies of gas mixture from 30:70 to 10:90 (Ar:O2) respectively . The films were characterized by Fourier transform infrared (FTIR) , Optical properties were studied by UV-vis reflectance spectra. The value of optical indirectband gap ranging between (1.779-1.785ev) was found to be independent of thickness of the film. The absorption spectra of NiFe2O4nanoparticles for the prepared sample in the spectral uv- visible region 400-700 was obtained.

Index Terms— Nickel Ferrite, Co-Sputtering , FTIR, , UV-vis spectroscopy.

I. INTRODUCTION

Ferrites are a very important group of magnetic materials due to their extensive use in a wide range of applications, such as ferrofluids, radar absorbing coatings, waveguides in the gigahertz region, biomedical and clinical devices, magnetic resonance imaging, oxyfuel technology, gas sensors, for the fabrication of magnetic cores

of read/write heads for high-speed digital tapes or for disc recording [1-5]. NFO is one of the most attracting material of spinel ferrite due to their interesting and important properties such as high electrical resistivity, large expansion coefficient, high saturation magnetization, high permeability and low eddy current loss, etc. In view of these

properties, it is used as one of the best microwave absorber materials. This type of ferrites is also used in various forms such as nanoparticles, nanowires, nanotubes, thin films and so on [6-7]. Several techniques are used for the preparation of ferrite particles, such as citric acid combustion method, sol-gel method, organic gel thermal decomposition method, hydrothermal method, co-precipitation method

[8-9]. Sol-gel is a simple method that has advantages, such as simple preparation route,

with precisely controlled relative stoichiometric ratios, which produces ultrafine and homogeneous powders [9]. Spinel ferrites are a large important class of

materials with the general formula MFe2O4, where M is a divalent cation. Nickel ferrite,
NiFe2O4 (NFO), is an inverse spinel in whichthe tetrahedral sites (A) are occupied by Fe2+and Ni2+ ions [10,11].

There are various growth parameters that affect the microstructure of the film such as substrate temperature during deposition, thermal expansion coefficient and lattice mismatch between the film and substrate, deposition time, distance between the target and substrate,gasses mixture etc. Size and surface effects lead to strong deviations from bulk properties, which additionally depend on the sample thickness and stoichiometry[10], The thin films of these inverse ferrites display relatively

weaker physical properties compare to the bulk counterparts[12,13].
In this study, highly crystalline nanosized nickel ferrite thin film was prepared by spray co-sputtering techniques, (NiFe2O4) nanostructures at low pressures with employment of concentric Ni and Fe targets. The structural characteristics of the prepared nanostructures are studied.

II. EXPERIMENT

The dc plasma sputtering system used in this work contains of a vacuum chamber, two discharge electrodes, vacuum pumps, and cooling and heating facilities.
The chamber could be evacuated down to 10^{-3} mbar by a rotary pump and to 10^{-5} mbar by a diffusion pump. The base vacuum was determined by the purpose of the discharge process. The inter-electrode distance was 4cm, The two targets of highly pure nickel (Ni, 0.9999) and iron (Fe, 0.999) were mounted on the cathode with some geometrical arrangement suitable for the work, as shown in Fig. (1)while the substrate on the anode ,the gasses mixture was controlled by mixture unit before inter to the champers Highly-pure oxygen gas was flowing to the chamber throughout needle valve to represent the reactive gas required to form the compound of nickel ferrite. Thickness measurements on the prepared film samples were performed by the laser interference method, The films thickness was measured and characterized by Fourier-Transform Infrared (FTIR) Spectroscopy .then the spectral measurement for the prepared sample was measured to obtained the value of the optical energy band gap .

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fig.1

samples were ranging in 1.779-1.785eV, respectively as shown in fig (5)

FIG. (2) FTIR SPECTRA FOR NIFE$_2$O$_4$ THIN FILMS PREPARED
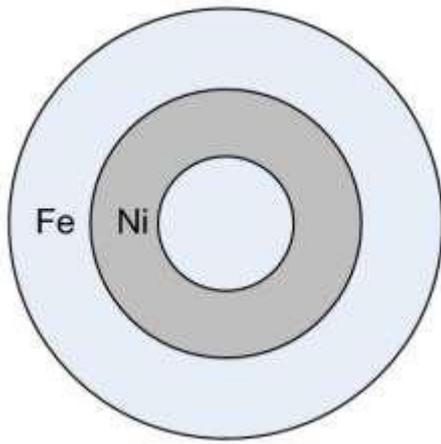
III. RESULT AND DISSECTION :

The film thickness was measured as a function of gas mixture, The minimum thickness was ~73nm for the film sample prepared using Ar:O2 gas mixture of 10:90, while the maximum thickness of ~176nm was measured for the sample prepared using Ar:O2 gas mixture of 30:70 for the same deposition time. This can be attributed to the increase in argon content in the gas mixture, which lead to increase the density of argon atoms – and hence Ar+ ions – generated by the electric discharge ,In the FTIR transmission spectrum of the prepared nanostructured NiFe2O4 thin film in Fig. (2), two distinct peaks are observed around 430 and 590 cm-1. They are attributed to the octahedral metal stretching vibration (Ni-O) and the tetrahedral metalintrinsic stretching vibration (Fe-O), respectively. Other peaks observed in the range 2800-3600 cm-1 are assigned to the stretching modes of the free or adsorbed water. Figure (3) shows the absorption spectra in the spectral region 400-800nm at room temperature. It is clear that the absorbance decreases with decreasing argon content (i.e., increasing oxygen content) in the gas mixture. This behavior is in accordance to the increase in film thickness with decreasing argon content in the gas mixture as the absorption coefficient and hence the absorbance (A) increases with increasing film thickness. These spectra are very important to determine and study the energy band gap of the prepared nanostructures fig (4) show the Absorption spectra of the prepared NiFe2O4 film samples using different ratios of Ar:O2 gas mixtures, A common way to extract the direct (*Egdirect*) and indirect (*Egindirect*) energy band gaps from optical absorption spectra is the Tauc plot, The value of optical energy band gap is calculated by extrapolating straight line portion of (αhv)^2 versus photon energy (hv). The intercept on the horizontal axis gives the value of indirect energy gap one can see that the optical energy band gap decreases with increasing oxygen content in the gas mixture. This may be due to the increase in the film thickness with increasing oxygen content. The increase in film thickness leads to increase the defects in crystal structure which causes an increase in localized states inside the energy gap and then decrease in its value (*Eg*). There is another possible reason for such behavior that may originate from the increase in grain size, as mentioned above, as a red shift was observed from the absorption edge.[14]. The values of indirect energy band gaps (*Egindirect*) of the prepared
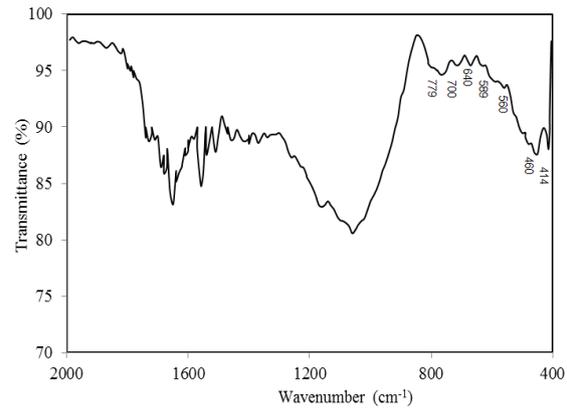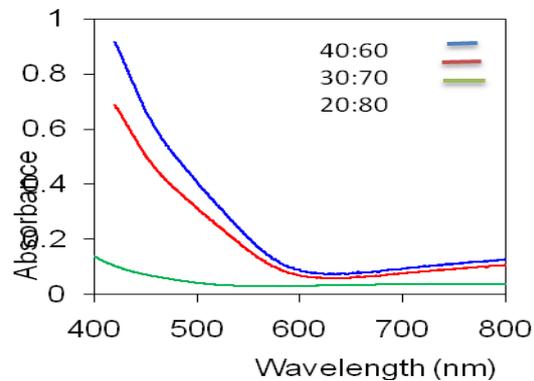
Fig(3)Absorption spectra of the prepared NiFe$_2$O$_4$ film samples using different ratios of Ar:O$_2$ gas mixtures
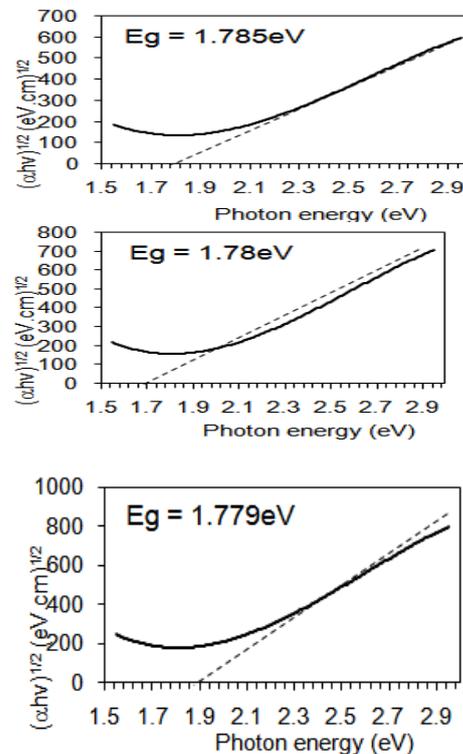

Fig. (4) Determination of indirect optical energy gap (E$_g$) for the NiFe$_2$O$_4$ samples prepared using different mixing ratios Ar and O$_2$ gases

IV. CONCLUSION

According to the obtained results The gas mixing ratio (Ar/O_2) is very important parameter to control and determine the phases of final Nickel Ferrite sample.The gas mixing ratio and inter-electrode distance have reasonable effects on the particle size of the prepared Nickel Ferrite. The average particle size of the sample prepared using gas mixture of 30:70 and inter-electrode distance of 4cm was greater than the sample prepared using gas mixture of 10:90 and the same inter-electrode distance. The value of optical energy band gap OF Nickel Ferrite was decreasing with increasing the oxygen content in the gas mixture, that may originate from the increase in grain size, as mentioned above, as a red shift was observed from the absorption edge.

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