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Hydrophilic Nature of Cobalt Ferrite Thin Film Deposited By Spray Pyrolysis Technique

H. J. Kardile[1], M. K. Babrekar[2], R. R. Chilwar[3], S. R. Nimbore[4], A. A. Pandit[5]
[1]*Arts, Commerce and Science College, Sonai, Nevasa, Ahmednagar, India – 414602*
[2]*Department of Physics, Indraraj College of Arts, Science and Commerce, Sillod, Aurangabad, India (MS)*
[3]*Department of Physics, Yogeshwari Mahavidyalaya, Ambajogai, Beed, India (MS)*
[4]*Department of Physics, Arts, Commerce and Science College, Ashti, Beed, India (MS)*
[5]*Department of Physics, Yeshwantrao Chavan College, Sillod, Aurangabad, India (MS)*
Corresponding author: H. J. Kardile

Abstract: Cobalt ferrite ($CoFe_2O_4$) thin film in nanocrystalline form has been deposited using spray pyrolysis technique. The film was deposited onto preheated glass substrate which subsequently annealed at 500°C for 4 h. The prepared film was characterized by X-ray diffraction technique. XRD analysis reveals the formation of single phase cubic spinel structured film. The crystallite size calculated from Debye-Scherrer's formula show nanocrystalline nature of the film. The lattice constant calculated from XRD data is in good agreement with the reported values. The thickness of the film was measured by surface profiler and found to be 249 nm. The hydrophilic nature of the film was confirmed through surface wettability properties by using contact angle method. The contact angle of the present film is 65.47° which is less than 90° showing the film is hydrophilic in nature.

Keywords: Cobalt ferrite, thin film, XRD, hydrophilic nature.

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I. INTRODUCTION

Spinel ferrite of the formula MFe_2O_4 is a very good candidate for variety of technological application due to their excellent electrical and magnetic properties. They exhibit unique chemical, structural, mechanical and magnetic properties and have a variety of promising technological applications in high-density recording devices, color imaging, ferrofluids, high frequency devices and magnetic refrigerators [1]. Recently, spinel ferrites in thin film form are of great importance for advanced applications because of their excellent chemical stability and other better electrical, optical and magnetic properties. The thin films of spinel ferrites for desired application can be prepared by controlling all the optimizing parameters. For advance applications of thin film ferrite we need high quality, uniform thickness ferrite films deposited at low temperature [2].

Cobalt ferrite is a unique spinel ferrite possessing very high magnetic and electrical properties. It possess inverse spinel structure in which Co^{2+} ions occupy octahedral site while Fe^{3+} ions occupy both tetrahedral and octahedral site. This leads the cobalt ferrite to have excellent magnetic properties such as large magnetic anisotropy and magnetostriction as well as high electrical resistivity. The thin film of cobalt ferrite has been studied by many researchers with a view to understand their electrical and magnetic behaviour [3]. The gas sensing and supercapacitive applications have been studied by few researchers. However, surface wettability properties of the cobalt ferrite thin films is rarely studied and reported in the literature [4-5]. The wettability studies of the film will show whether the film is hydrophilic or hydrophobic in nature. The hydrophilic nature of the film can be used in improved separation in medical diagnostics, improved efficiency in heat transfer devices and heat exchangers, improve surface interaction in filtration devices etc. The hydrophobic film show applications in improved corrosion resistance, improved moisture detection instrumentation, HPLC medical diagnostics improved separation etc [6].

A variety of physical as well as chemical methods has been applied for the deposition of cobalt ferrite thin films such as pulsed laser deposition technique, RF sputtering, Spin coating, chemical vapor deposition, Spray pyrolysis etc [7]. Among all these methods spray pyrolysis is a very good technique for deposition of spinel ferrite thin film. The method is easy, cost effective, requires less experimentation, operates at low temperature and is useful for large surface area deposition as compared to other techniques. In view of the above facts, the aim of the present work is to develop cobalt ferrite thin film by spray pyrolysis technique and investigate the wettability properties of the film.

II. EXPERIMENTAL

Analytical reagent (AR) grade cobalt nitrate (Co $(NO_3)_3.6H_2O$) and ferric nitrate (Fe $(NO_3)_3.9H_2O$) were used as starting material without any further purification. The glass substrate of the size 75 x 25 x 1.45 mm^3 was carefully cleaned by sequential treatment with chromic acid, ethanol, and acetone followed by dipping with deionized water in an ultrasonic bath for 30 min, and the same glass plates was used for the deposition. The deposition of the film was carried out using spray pyrolysis technique by optimizing the parameters like spray rate, nozzle to substrate distance, pressure etc. The details of the experimental procedure for the deposition of thin film using spray pyrolysis technique are already reported in our previous reports.

The crystal structure and phase purity of prepared thin film was studied by using X-ray diffractometer (XRD) (Philips) with Cu-Kα radiation in the 2θ range of 20°- 80° with wavelength (λ = 1.5406 Å). The contact angle was measured with the help of contact angle meter (Ramehart Instruments Co. USA) equipped with CCD camera. The film thickness was estimated using spectroscopy reflectometer of make Stellar Net Inc. USA.

III. RESULTS AND DISCUSSION

3.1 Structural studies

Fig. 1 depicts X-ray diffraction pattern of the cobalt ferrite thin film recorded at room temperature. The XRD pattern shows the reflections (111), (220), (311), (222), (400), (422) (511) and (440) belonging to cubic spinel structure. The anlysis of the XRD pattern reveals the formation of single phase cubic spinel structure of the film. The most intense peak (311) of the XRD pattern was chosen to estimate the crystallite size. The crystallite size was determined using Debye-Scherrer's formula and found to be 21 nm indicating the nanocrystalline nature of the film. The lattice constant calculated from the known values of interplanner spacing (d) and Miller indices found to be of the order of 8.382 Å. The obtained value of lattice constant of the present cobalt ferrite thin film is in good agreement to that reported in the literature [8].

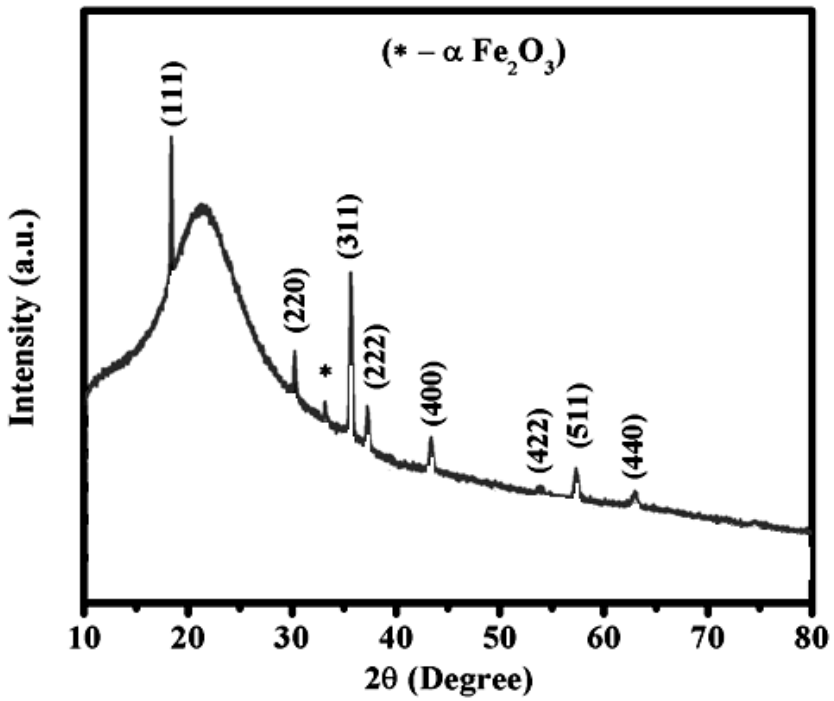

Fig. 1 X-ray diffraction patterns of $CoFe_2O_4$ thin films

3.2 Wettability studies

The unique oleophobic–hydrophilic surfaces are highly desirable in many important applications such as antifogging, detergent free self cleaning, anti-fouling, water-oil separation etc due to their special wetting behavior. For the present cobalt ferrite thin film, the wettability studies were carried out by contact angle meter. Fig. 2 represents photograph of the water droplet on the prepared cobalt ferrite thin film. The contact angle was measured using contact angle meter and it is found to be 65.47° which is less than 90° showing the film is hydrophilic in nature. Thus, the prepared cobalt ferrite thin film on account of its hydrophilic nature can be used for antifogging, detergent free self cleaning, anti-fouling, water-oil separation etc.

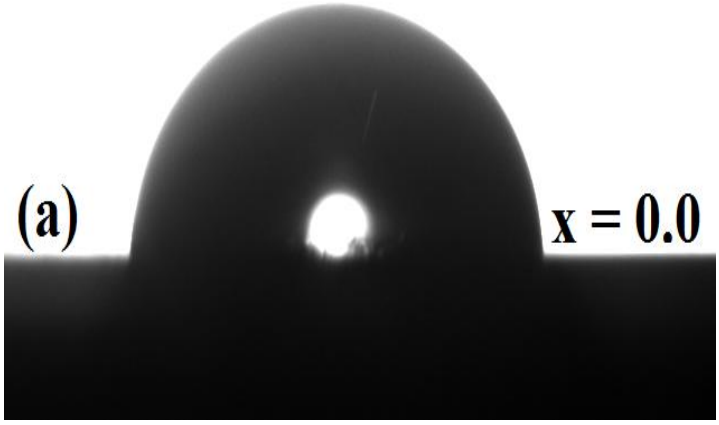

Fig. 2: Contact angle of $CoFe_2O_4$ thin film

IV. CONCLUSIONS

Cobalt ferrite thin film in nanocrystalline form has been successfully deposited on preheated glass plate by spray pyrolysis technique. The obtained film show uniform thickness of the order of 249 nm. X-ray diffraction analysis revealed the formation of single phase cubic spinel structured thin films with crystallite size 17 nm and lattice constant 8.382 Å. The contact angle of the prepared film is below 90° indicating the hydrophilic nature of the film. The prepared thin film can suitably used for different applications like antifogging, detergent free self cleaning, anti-fouling, water-oil separation etc.

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