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Effect of Spin Coating Parameters on Optical and I–V Characteristics of Fe_2O_3 Thin Films

Niranjan S. Samudre[1], Bharat G. Thakare[1], Navnath M. Yajgar[1], Amol R. Naikda[1], Bhushan B. Chaudhari[1], Sudam D. Chavhan[1*], R. R. Ahire[1], Sachin J. Nandre[2*],

1 Department of Physics, S. G. Patil Art's, Science and Commerce College, Sakri (Maharashtra)

2 Department of Physics, U. P. College, Dahivel (Maharashtra)

**Email: - sachinjnandre@gmail.com ,sudam1578@gmail.com*

Abstract

Iron oxide (Fe_2O_3) thin films were successfully prepared on glass substrates using a simple and cost-effective spin coating technique to study the influence of spin speed on their optical and electrical properties. A 0.5 M ferric chloride ($FeCl_3$) precursor solution was used for deposition, and films were coated at 2500 rpm and 3000 rpm for 60 s. The deposited films were annealed at 600 °C for 5 h to obtain the crystalline hematite (α- Fe_2O_3) phase with improved structural stability. Optical properties were analysed using UV–Visible spectroscopy, which revealed strong absorption in the visible region along with good transparency at longer wavelengths. The optical band gap, estimated from Tauc plots, was found to range between 1.84 and 1.90 eV, indicating that spin speed influences film thickness and microstructural uniformity. Electrical characterization was carried out through current–voltage (I–V) measurements in the voltage range of 0–14 V at room temperature. The films exhibited semiconducting behaviour with nearly ohmic conduction at lower voltages. The film deposited at 3000 rpm showed higher current and lower resistance compared to the 2500 rpm film, suggesting enhanced crystallinity and improved charge carrier mobility. These findings confirm the significant role of spin coating parameters in tailoring Fe_2O_3 thin films for optoelectronic and energy-related applications.

Keywords: - Fe2O3 thin films, Spin coating, Optical band gap, I–V characteristics, Hematite, Optoelectronic applications, Photovoltaics.

1. Introduction

Iron oxide (Fe_2O_3) thin films have emerged as promising materials for optoelectronic and energy applications due to their earth abundance, non-toxicity, and suitable bandgap (~2–2.2 eV) for solar energy conversion (1,2). Among deposition techniques, spin coating is widely recognized as a cost-effective and versatile method for producing uniform thin films with controlled thickness and morphology (3,4). The performance of Fe_2O_3thin films is strongly influenced by spin coating parameters such as spin speed, precursor concentration, solvent composition, and annealing temperature, which govern film thickness, crystallinity, and surface roughness (5–7). These structural modifications directly affect optical properties including

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absorption edge, bandgap energy, and refractive index (8,9), as well as electrical transport behaviour such as leakage current and resistive switching (10–12). Recent studies have demonstrated that tuning spin speed and annealing conditions can significantly enhance charge carrier mobility and optical transparency, thereby improving device performance in photoelectrochemical cells and sensors (13,14). Furthermore, solvent composition and precursor concentration have been shown to alter defect states and bandgap values, enabling bandgap engineering for tailored optoelectronic applications (7,15). Surface morphology control through optimized spin parameters also plays a critical role in determining I-V characteristics and stability of Fe_2O_3thin films (16,17). Consequently, understanding the correlation between spin coating parameters and the resulting optical and electrical properties is essential for advancing Fe_2O_3-based devices in photovoltaics, gas sensing, and resistive switching technologies (18–20).

2. Materials and Methods

2.1 Materials

Ferric chloride ($FeCl_3$, extra pure 97%) was used as the precursor material. Analytical grade ammonia solution was employed to adjust the pH-03 of the precursor solution. Double distilled (DD) water was used as the solvent medium to ensure purity and minimize contamination during film preparation.

2.2 Preparation of Precursor Solution

A 0.5 M solution of ferric chloride was prepared by dissolving 0.675g of $FeCl_3$ in 5 mL of double distilled water. Ammonia was added dropwise under continuous stirring until a homogeneous solution was obtained. The solution was filtered to remove any undissolved particulates and stored in airtight containers prior to deposition.

2.3 Substrate Cleaning

Glass substrates were ultrasonically cleaned sequentially in acetone, ethanol, and double distilled water for 10 minutes each, followed by drying in ambient air. This cleaning procedure ensured removal of organic and inorganic contaminants, thereby improving film adhesion and uniformity.

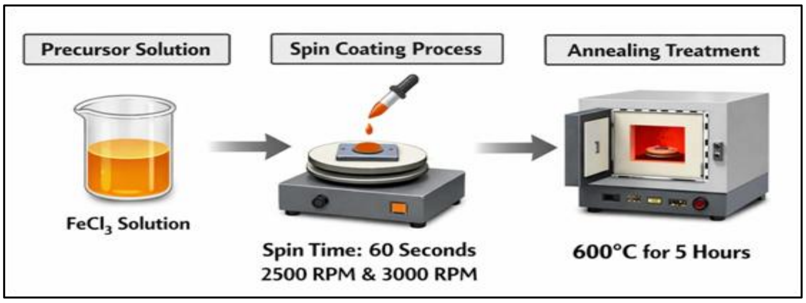

Figure 1 Formation of Fe_2O_3 Thin Films by Spin Coating Method

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2.4 Spin Coating Deposition

The prepared precursor solution was dispensed onto the centre of the substrate mounted on the spin coater chuck. Spin coating was performed at two different speeds: 2500 rpm and 3000 rpm, each for a duration of 60 seconds. During spinning, centrifugal force spread the solution uniformly across the substrate, while solvent evaporation occurred simultaneously, forming a thin liquid film.

2.5 Annealing Treatment

After deposition, the coated substrates were dried at 100 °C for 10 minutes to remove residual solvent. Subsequently, the films were annealed at 600 °C for 5 hours in a muffle furnace to induce crystallization of the hematite (α- Fe_2O_3) phase. Annealing at this temperature was chosen to enhance crystallinity, grain growth, and stability, which are critical for optical and electrical studies.

3. Results and Discussion

3.1 Optical Properties

Fe_2O_3 thin films were successfully deposited on glass substrates using the spin coating technique, with constant spin speed, varied between 2500–3000 rpm. UV–Vis. spectroscopy revealed strong absorption in the visible region, accompanied by good transparency at longer wavelengths. The optical band gap, determined using Tauc's relation, was found to range between 1.84–1.90 eV. This variation is attributed to differences in film thickness and microstructural uniformity induced by changes in spin speed. These findings highlight the critical role of deposition parameters in tailoring the optical response of Fe_2O_3 thin films.

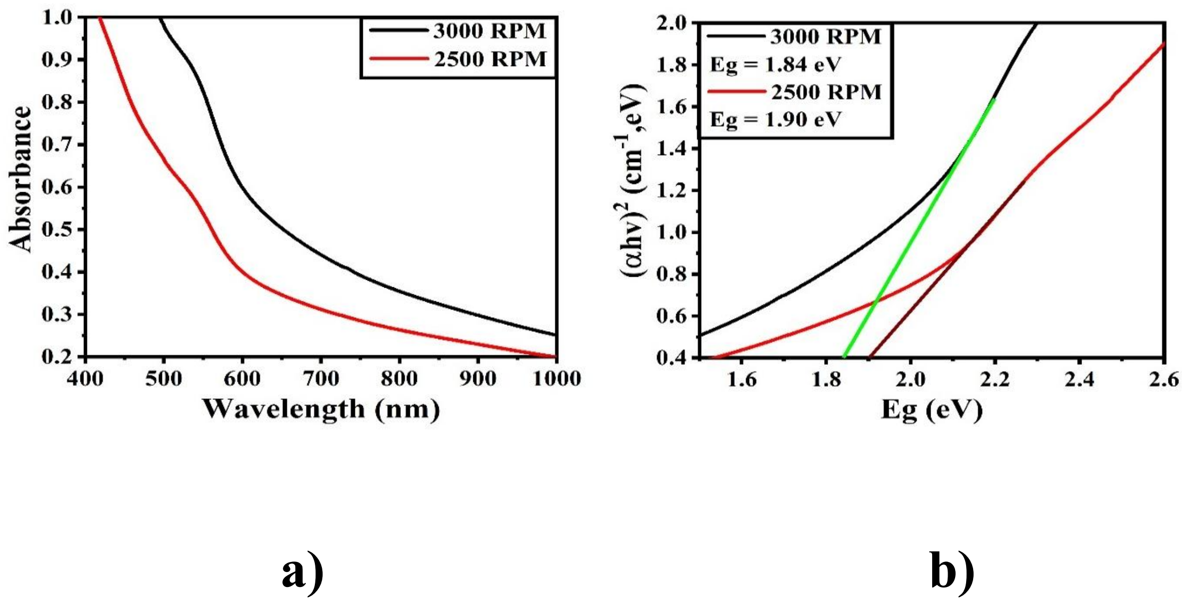

Figure 2 a) UV-Visible absorption spectra of Fe_2O_3 thin films, b) Tauc plot Vs photon energy (hν) of Fe_2O_3.

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3.2 Electrical Properties

The current–voltage (I–V) characteristics of Fe_2O_3 thin films deposited by the spin coating method at 2500 RPM and 3000 RPM with a constant spin time of 60 second were investigated to evaluate their electrical conductivity behaviour. The measurements were carried out in the voltage range of 0–14 V at room temperature.

Both films exhibit a continuous increase in current with increasing applied voltage, confirming the semiconducting nature of the Fe_2O_3 thin films. The nearly linear trend at lower voltages indicates ohmic conduction behaviour, suggesting good electrical contact between the electrodes and the film surface. However, a comparatively higher current response is observed in the film deposited at 3000 RPM.

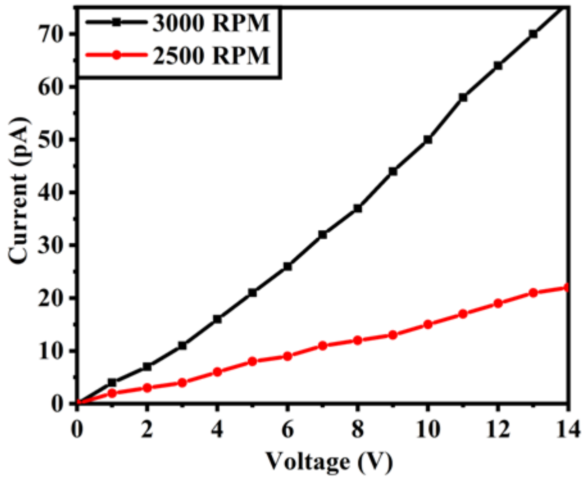

Figure 3 Current–voltage (I–V) characteristics of Fe_2O_3 thin films.

At 14 V, the 3000 RPM film shows significantly higher current than the 2500 RPM film, indicating lower electrical resistance and enhanced charge carrier transport. The improvement in conductivity with increasing spin speed can be attributed to better film uniformity, reduced grain boundary scattering, and improved crystallinity. Higher spin speed generally produces thinner and more homogeneous films, which facilitate efficient carrier mobility and reduce trap-assisted recombination.

3.3 Application Suitability

The spin-coated Fe_2O_3 thin films exhibit an optical band gap in the range of 1.84–1.90 eV with strong absorption in the visible region, making them suitable for solar energy harvesting and optoelectronic applications. The tuneable band gap and transparency at longer wavelengths support their potential use as absorber or window layers in thin-film solar cells and photoelectrochemical devices. The observed semiconducting behaviour with nearly ohmic conduction confirms efficient charge transport characteristics. The higher conductivity obtained

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at 3000 RPM suggests improved crystallinity and reduced grain boundary scattering, enhancing carrier mobility. These properties make the films promising candidates for photovoltaic devices, photodetectors, gas sensors, electrochromic systems, and photocatalytic applications.

4. Conclusion

Fe_2O_3 thin films were successfully deposited on glass substrates using the spin coating technique at 2500 and 3000 RPM with a constant spin time of 60 s. Optical studies revealed strong visible light absorption with a band gap ranging from 1.84–1.90 eV, indicating suitability for solar and optoelectronic applications. Electrical measurements confirmed semiconducting behaviour with improved conductivity at higher spin speed due to enhanced film uniformity and crystallinity. The study demonstrates that spin coating parameters significantly influence the optical and electrical properties of Fe_2O_3 thin films. Therefore, controlled variation of deposition conditions provides an effective route to tailor material properties for renewable energy devices and electronic applications.

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