Extraction of Optical Constants from Transmittance Spectrum of Cobalt Oxide Films

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Abstract

In this study, we present the production and analysis of cobalt oxide thin films utilizing the cost-effective chemical spray pyrolysis (NSP) technique, which were coated on a glass slide substrate. The optical characteristics of the films were analyzed using UV–visible spectroscopy. The UV-vis examination revealed that all thin layers demonstrated excellent optical transmission, exhibiting the highest transmission of over 79% in the visible band. The produced films exhibited Eg values ranging from 2.9 eV. Furthermore, the optical properties, including the refractive index and extinction coefficient, of all films were measured.

Keywords: Cu_4O_3, Thin films, chemical spray pyrolysis (CSP), Optical constants.

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Introduction

Cobalt oxide thin films have been the subject of various studies and applications. Research has shown that the voltage control of magnetism via electric-field-driven ion migration in cobalt oxide thin films can lead to dynamic electric-field-induced magnetic effects, making them promising for use in magnetic memories, spintronic systems, and artificial neural networks [1]. Additionally, cobalt-doped zinc oxide thin films have been investigated for their high Curie temperature, with the potential for ferromagnetic properties in a wide temperature range [2]. Furthermore, cobalt oxide thin films have been studied for their electrochromic properties, as well as their potential use in electrochemical capacitors [3-5]. Cobalt oxide thin films have shown potential for various applications, such as in solar absorbers, photo-catalysis, photovoltaics, magnetic memories, spintronic systems, artificial neural networks, smart windows devices, and supercapacitors. Several synthesis methods have been employed to produce cobalt oxide thin films, including ion-beam sputtering, inorganic polycondensation, and spray pyrolysis [6-11]. These methods have been used to control the film's structure, morphology, and properties This work cobalt oxide thin films were synthesized using chemical spray pyrolysis (CSP) process. The optical constants parameters were estimated in this work.

2. Experimental details

2.1. Synthesis of thin films

The procedure of chemical spray pyrolysis (CSP) is used to create thin coatings of cobalt oxide. The compound utilized as the Co source was cobalt chloride dehydrate ($CoCl_2.2H_2O$). The first solution was made by dissolving 20 ml of de-ionized water (H_2O) and 10 ml of methanol (CH_3OH). The molar content of nickel nitrate was 0.1M. The solution mixtures were vigorously agitated using a magnetic stirrer for a duration of 30 minutes, resulting in the creation of a transparent green and uniform solution. Subsequently, the solution was applied onto a glass substrate that had been heated to a temperature of 400°C. The distance between the spray nozzle and the substrate was set at a constant value of 40 cm. Prior to the deposition process, the glass substrates underwent a cleaning procedure including acetone, followed by rinsing with de-ionized water and subsequent air drying. Following deposition, the films were permitted to gradually cool at ambient temperature.

2.2 Thin films characterization

The optical transmission spectra were carried out by through Agilent technologies cray series UV-Vis spectrophotometer (cray 100 UV-Vis) in the wavelength between 300 and 800 nm.

3. Result and discussions

3.1 Optical properties

Figure 1 displays the optical transmission spectrum of cobalt oxide films fabricated using chemical spray pyrolysis. The measurements were conducted throughout the UV-visible spectrum, which encompasses wavelengths ranging from 200 to 800 nm. The figure clearly shows a zone of great transparency between 400 and 800nm. The transmission values for the samples prepared is around 79% correspondingly in the visible range. Conversely, the high-absorption area of cobalt oxide film corresponds to the fundamental absorption (λ<400nm), resulting from electronic transitions between bands.

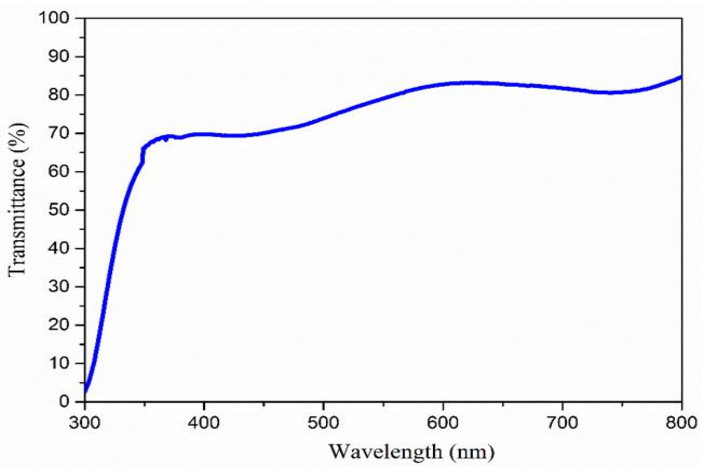

Fig.1: Transmittance spectrum of cobalt oxide film.

The Tauc formula can be used which imply the relationship between the absorption coefficient (α) and the incident photon energy ($h\nu$) as follows [12]:

$$(\alpha h\nu) = x(h\nu - E_g)^{\frac{1}{2}} \quad (1)$$

Where x is constant related with the nature of transition, α is the absorption coefficient, hν is the photon energy and Eg is the band gap energy.

By utilizing the transmittance and energy of the photon, we can calculate $(\alpha h\upsilon)^2$ based on the photon's energy E=hυ. We then extend the linear portion of $(Ah\upsilon)^2$ until it intersects the x-axis (i.e., when $(Ah\acute{\upsilon})^2 = 0$). In Figure 2, we observe the relationship between the square of the variation $(\alpha h\upsilon)^2$ and the energy of cobalt oxide film. The gap values exhibited a range of 3.91 eV.

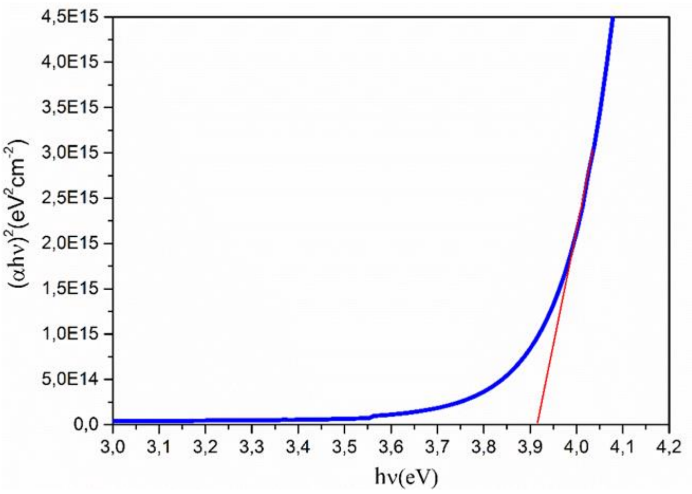

Fig.2: Tauc's plot of cobalt oxide film.

The refractive index (n) is an important parameter in optical components, optoelectronic applications. The refractive index (n) of the produced thin film is determined by applying the following formula. [13]:

$$n = \frac{(1+R)}{(1-R)} \pm \sqrt{\frac{4R}{(1-R)^2} - k^2} \quad (2)$$

$$k = \frac{\alpha\lambda}{4\pi} \quad (3)$$

Where, k, R, λ and α are Extinction coefficient, the reflectance, wavelength and absorption coefficient respectively.

Figure 3 displays the variation in the refractive index of cobalt oxide at varying concentrations across a range of wavelengths from 300 nm to 800 nm. As seen, the refractive index spectrum exhibits a distinct decrease about 400 nm, followed by a nearly constant value over the visible and near infrared range of wavelengths. The refraction index of pure cobalt oxide films, manufactured under the described experimental circumstances, is given at a wavelength of 550 nm. The refractive index of prepared sample is equal to 2.25.

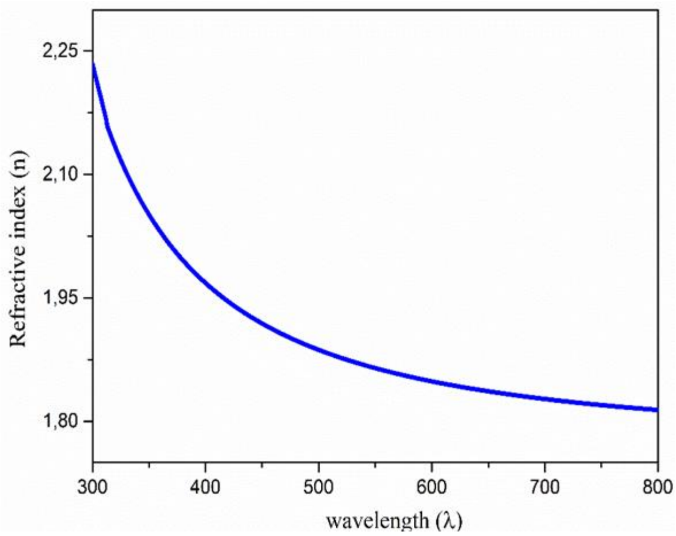

Fig.3: Refractive index as function of wavelength of cobalt oxide film.

Figure 4 illustrates the relationship between the extinction coefficient and the wavelength range of 300 nm to 800 nm for cobalt oxide sample. The extinction coefficient exhibits a strong wavelength dependency in the UV range, whereas it remains rather stable between the visible and near infrared spectrum (400-800 nm). Across all layers, we observe a drop in the k extinction coefficient as the wavelength increases, resulting in relatively low values in the visible and near infrared regions.

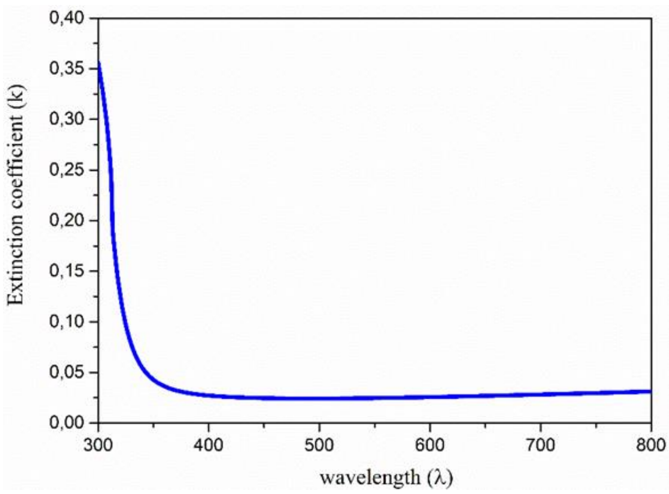

Fig.4: Extinction coefficient as function of wavelength of cobalt oxide film.

4. Conclusion

This study involves the deposition of cobalt oxide thin films onto glass substrates by the utilization of the chemical spray pyrolysis (CSP) process. The produced films were examined using a UV-visible spectrophotometer. The results exhibited a high level of optical transmission, approximately 79%. The estimated optical band gap was determined to fall within the range of 2.91. The refractive index and extinction coefficient both decrease as a function of wavelength.

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