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THE OPTICAL STUDIES OF COPPER OXIDE THIN FILM

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Abstract - The optical studies of CuO films by UV-VIS-NIR double beam spectrophotometer estimated the energy band gap as 1.5ev. This showed maximum extinction coefficient in the photon energy range 1.5ev. Optical conductivity was maximum value $2.52x10^{3}$ S^{-1} and minimum value $2.0x10^{3}$ S^{-1}. The real part of dielectric constant increases with increase in photon energy. Then absorption coefficient had a maximum value in the wavelength range 400nm.

Key words: Thin films ,Optical conductivity, absorption coefficient

I. INTRODUCTION

The optical properties of a solid emanate from its interactions with electromagnetic waves and are manifested in optical frequencies. The knowledge of optical properties of solid films has widely contributes to the phenomenal growth of their applications in scientific, technological and industrial applications. Thin films are used in optical devices such as mirror coatings, interference filters, antireflection coatings, absorption filters, optical and thermal detectors etc[1]. Optical properties of films have been studied because of their applications in various optical and electro-optical devices and it has found that there is often a considerable deviation of optical parameters from that of a bulk material. Optical characteristics of the thin films are strongly influenced by the process parameters and the deposition method optical films are primarily characterized by absorption/transmission and refractive index. Discrepancies in the optical behavior of the films have often been attributed to their physical state viz., crystalline or otherwise, in homogeneity, compositional deviations etc.

The optical study of a solid concerns not only with the physical phenomena such as refraction, reflection, transmission, absorption, polarization, interference of light but also the interaction of photon energy with matter and the consequent changes in the electronic states. From reflection, transmission, and absorption process it is possible to evaluate the optical constants such as refractive index (n), absorption index or extinction coefficient (K), and absorption coefficient (α) of a solid. The study of refractive index also provides an understanding of the chemical absorption studies, on the other hand, provides a sample means for the evaluation of absorption edge, optical energy band gap, optical transitions which may be direct or indirect, allowed or forbidden and also of the nature of the solid material[1-2].

II. EXPERIMENT.

In this study, the Cu_2O thin films were prepared using the chemical bath deposition technique. The following constitutes the chemical bath system for optimum deposition: 30ml of 0.1M copper nitrate [Cu(NO3)2], 30ml of 0.1M Hydrazine (NH2NH2), and 6.5ml of 1M triethanolamine (TEA) which is the complexing agent[4].

2.1. Absorption coefficient and Band gap.

The optical absorption and transmittance studies are useful for the identification of band gap, impurity states, refractive index, extinction coefficient, etc. The optical absorption spectra of

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semiconductors generally exhibit a sharp rise at a certain value of the incident photon energy, which can be attributed to the excitation of electrons from the valance band to the conduction band. In the optoelectronic applications of thin films[3], the optical absorption studies play an important role giving an insight into the nature of transitions, either direct or indirect. The absorption coefficient α can be calculated using the relation,

$$\alpha = \frac{2.303A}{t}$$

Where A is the absorbance value at a particular wavelength and t is the thickness of the semiconductor film. Similarly, the absorption coefficient α can be estimated from the optical transmittance spectra using the relation,

$$\alpha = \frac{2.303\log(1/T)}{t}$$

Where T is the transmittance.

2.2. Extinction Coefficient and Refractive Index.

The refractive index of thin films often differs from that of bulk material. The refractive index of a material at optical frequencies is mainly determined by polarizability of its valance electrons. In compounds the types of bonding also influence the index[4].

The analysis of the wavelength dependence of the optical constants n and k of considerable interest due to its optoelectronic applications. The optical parameters can be estimated by means of the equations corresponding to the propagation of electromagnetic waves through the layers of plane parallel faces consisting of an absorbing thin semiconductor films[5] and a transparent glass substrate. The value of k can be calculated from the formula,

$$\alpha = \frac{4\pi k}{\lambda}$$

$$T = \frac{n_2}{n_1} = \frac{[(1+\delta_1)^2(1+\delta_2)^2]}{[1+\delta_1^2\delta_2^2 + 2\delta_1\delta_2\cos\Gamma]}$$

Where $\delta_1 = \frac{(n_0^2 - n_1^2)}{(n_0^2 + n_1^2)}$, $\delta_2 = \frac{(n_1^2 - n_2^2)}{(n_1^2 + n_2^2)}$ and $\Gamma = \frac{2\pi n_1 t}{\lambda}$

Where, λ is the wavelength of the incident radiation n_0, n_1 and n_2 are the refractive indices of air, film and glass respectively.

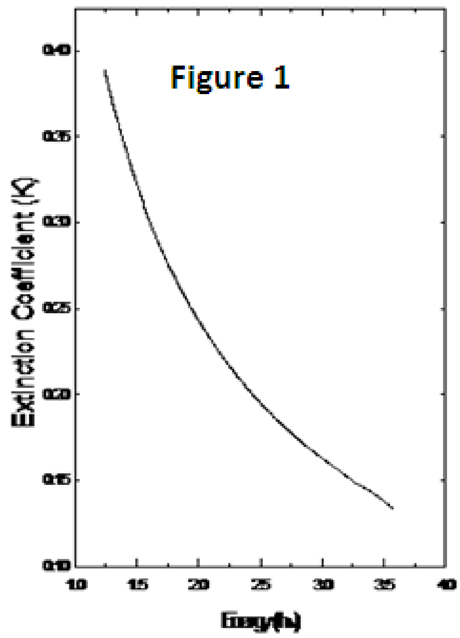

Figure 1. Curve of extinction coefficient and photon energy

Figure 1 gives the extinction coefficient (k) of the CuO thin film against the photon energy (hν). The extinction coefficient can be calculated from the equation,

$X = e^{-at}$

By solving this equation,

$\alpha = 4\pi k/\lambda$

i.e., $k = \alpha\lambda / 4\pi$

Where α- is the absorption coefficient and λ- is the wavelength of the radiated energy.

From the graph the extinction coefficient (k) is inversely proportional to energy (hν) at 1.25ev the extinction coefficient value has maximum value of 0.39.

At 3.6 e.v the extinction coefficient value has minimum value of 0.125.

2.3. Optical band gap studies.

The energy band gap of semiconductors is extremely useful for the wide and varied preparation and applications of electronic components[1-6].

Reflection, transmission, and absorption properties were studied using spectrophotometer are given below:

The optical transmittance, absorbance and reflectance of Copper Oxide thin film were recorded in the wave length range 0 to 1000nm using UV-VIS-NIR double beam spectrophotometer.

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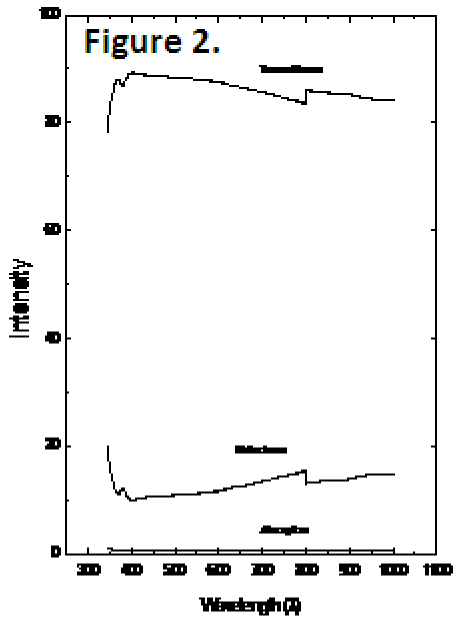


Figure 2.Transmission, absorption and reflection curves of CuO thin film

From the figures 2 that transmittance shows a constant value from 380nm to 1000nm. the absorbance of the film is found to be constant value. the reflectance have a nearly a constant value in the region 200nm – 1000nm and remains constant reflectance[2-7].

Figure 5.5 shows the absorption coefficient (α) against the wavelength, which is determined from transmittance measurements by using the formula,

$\alpha = -1/t \ln(T)$

Where T is the normalized transmittance and t is the film thickness.

From the plot, it is observed that the absorption coefficient (α) shows sharp increase of the absorption coefficient in the wavelength region 350nm and there is a sudden decrease of absorption coefficient from 350-375nm and has maximum absorption coefficient at 400nm. From wavelengths of 400-850nm absorption coefficient decreases gradually.

2.4.Energy band gap.

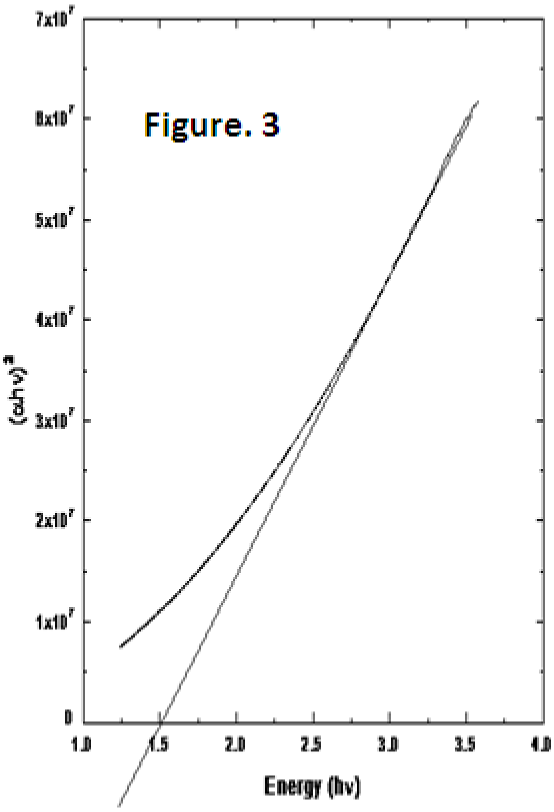
Figure 3 shows the graph of $(ah\nu)^{1/2}$ verses photon energy(hν) to find out the band gap energy .From the values of a and hν, $(ah\nu)^{1/2}$, can be calculated and hence (ahν) verses hν graph plotted. From the graph the band gap energy of CuO thin film is found to be 1.5ev[8].

Figure 4 indicate the plot of real and imaginary parts of dielectric constant (e_r) verses photon energy hν for CuO thin film. The real part of the dielectric constant increases with increase of photon energy from 1.5 e.v to 3.1 e.v and then decreases upto 3.25 e.v. The maximum value of real part of dielectric constant is 3.6.

The imaginary part of dielectric decreases gradually from 1.25ev to 3.6ev

Fig 5 indicates the plot of optical conductivity against the photon energy[9]. It has maximum value 40nm and minimum value at 800nm

Fig 6 shows the variation of refraction index with wave length. It has maximum value at 350nm and a sharp decrease in the region 350nm to 800nm.



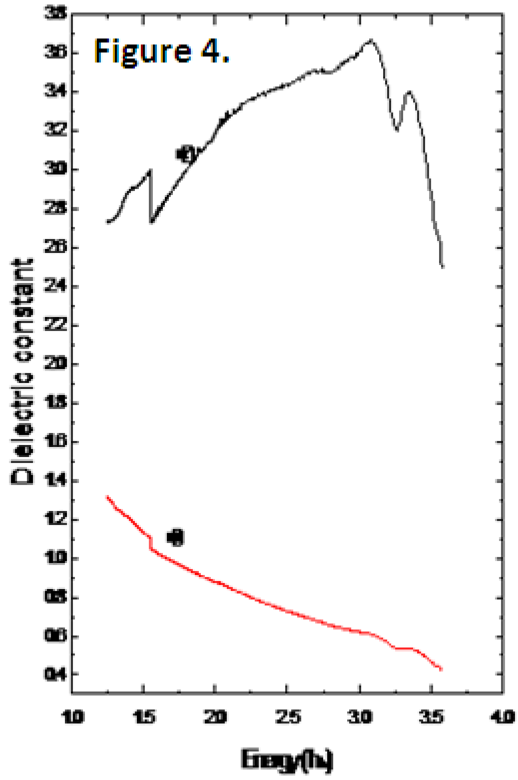
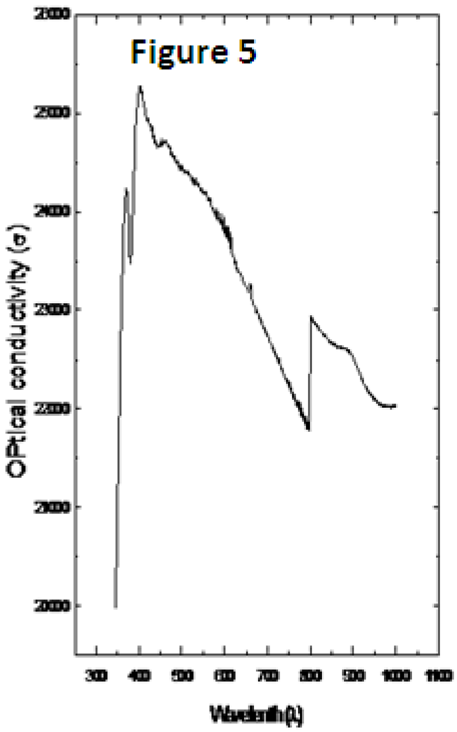


Figure3. Graph for determination of optical energy band gap
Figure 4. Plot of real and imaginary parts of dielectric constant



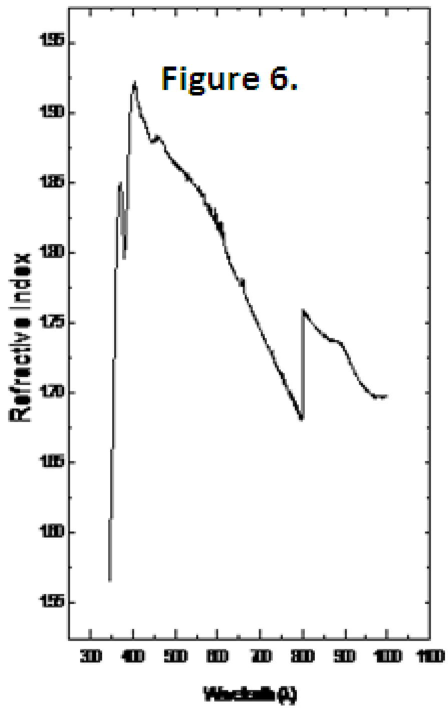


Figure 5.Plot of optical conductivity against the photon energy
Figure 6. Variation of refractive index with wavelength

III. CONCLUSION AND DISCUSSION.

The parameters like Temperature, reaction time, and reactant concentrations play an important role during deposition. These parameters were changed so as to form metal compound films of better quality for each combination of reactant. It is observed that the absorption coefficient (α) shows sharp increase of the absorption coefficient in the lower wavelength region and there is a sudden decrease of absorption coefficient and has maximum absorption coefficient at 400nm.

The variation of refraction index with wave length has maximum value at lower side of wavelength and a sharp decrease up to 800nm.the energy band gap of film is about 1.5 eV

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