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RESEARCH ARTICLE

Optical characteristics of CuO thin film prepared by Chemical spray pyrolysis

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Abstract

CuO thin films have been grown on cleaned glass substrates at 350 C° using spray pyrolysis deposition technique, UV -VIS spectra of the films were recorded using the optical absorbance measurements which were taken in the spectral region from 190 nm to 1100 nm. The ref1ectance spectrum of the films in the UV -VIS region were studied. Optical Constants such as optical energy gap, absorption coefficient and extinction coefficient, were evaluated from these spectra. The film was found to exhibit high absorbance values at ultraviolet region which they decrease rapidly in the visible / near infrared region. The optical allowed gap energy for direct transition was found 2.113 eV.

Introduction:-

Semiconductors are of current interest due to their unique optical and electronic properties which are different form that of the materials in the bulk form[1].A good amount of literature is available on the preparation and characterization of semiconductor chalcogenide materials.

The development of semiconductors thin films is one of the key technologies for pn-junction based devices such as diod ,transistors and light emitting diods[2].

Copper Oxide (CuO) material is known p-type semiconductor in general which useful for constructing junction devices such as pn junction diodes [3,4,5], Copper Oxide has been studied as a semiconductor material because of natural abundance of starting material (Cu); low cost production processing; non-toxic nature; and reasonably good electrical and optical properties [6,7]. Apart from this semiconductor applications, this material (CuO) has been studied for photoconductive and photo-thermal applications, it has attracted much interest in recent years because it is the basis of several high-Tc super conductors [8]. Copper Oxides have been used as electrode materials for lithium batteries, heterogeneous catalytic materials[9,10],photovoltaic cells[8],electrochromic devices ,nanoscale quantum dots[9,11],batteries[7,8,9],solar energy conversion,gas sensing and low-friction materials[11,12,13].

Copper forms two well-known oxides tenorite (CuO) and Cuprite(Cu2O),Both the tenorite and Cuprite were p-type semiconductors having band gab energy of 1.21 to 1.51eV and 2.10 to 2.60eV repectively[14].

Thin films of Cuprite oxide have been prepared by a number of techniques including spray pyrolysis [15],sol-gel synthsis[16],chemical vapor deposition[15,17], pulsed laser deposition[18] and electro deposition[3].

In this study, CuO thin films prepared by a spray pyrolysis because the spray pyrolysis method is simple, fast,inexpensive ,vacuum less process and is suitable for mass production among all of these[19,20,21].

Experimental:-

Cupric chloride dehydrate ($CuCl2.2H2O$) was used in making the precursor solution for CuO thin films ,To obtain 0.1 molarity concentrantion of $CuCl2.2H2O$ solution an amount of 4.262 g of $CuCl2.2H2O$ was dissolved in 250 ml of distilled water then the solution was stirred in a magnetic stirrer at room temperature for 10 minutes in order to get a transparent and well-dissolved solution .

Microscope glass slides were used as substrate cleand with organic solvents ,The substrate temperature was fixed at 350 C◦ ,the spray rate was usually in the rang 2.1 ml/min ,The distance between substrate to spray nozzle was 30 cm and air pressure was 0.35 bar.

The optical measurements of the CuO thin films are calculated from the transmittance and absorbance spectrum at normal incidence over the rang (190-1100)nm by using UV-VIS Spectrophotometer type (SHIMADZU)(UV-1650).

From the absorbance data, the absorption coefficient α. was calculated in the fundamental absorption region .using Lambert law [3,7,22]:

$$\alpha = 2.303\frac{A}{d} \qquad (1)$$

Where A the optical absorbance and d the film thickness.
Extinction coefficient (k) of prepared films was calculated by .using the relation[2,23]:

$$k = \frac{\alpha\lambda}{4\pi} \qquad (2)$$

Where λ is the wavelength of the incident photon.
The reflectance has been found by using the relationship [6,23]:

$$R + A + T = 1 \qquad (3)$$

From the reflectance data, the refractive index (n) was calculated by using the following relationship [24]:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \qquad (4)$$

From the below relation we can calculate the optical conductivity σ[25,26]:

$$\sigma = \frac{\alpha n c}{4\pi} \qquad (5)$$

Where c is the velocity of light.
The nature of transition (direct or indirect) is determined by using the relation[15,6,27]:

$$\alpha h\upsilon = A(h\upsilon - E_g)^n \qquad (6)$$

Where hv is the photon energy, Eg the band gap energy, A and n are constants. For allowed direct transition, n = 1/2 and for allowed indirect transition, n =3/ 2.

Results and Discussion:-

The absorption spectrum of CuO films is shown in fig.(1).

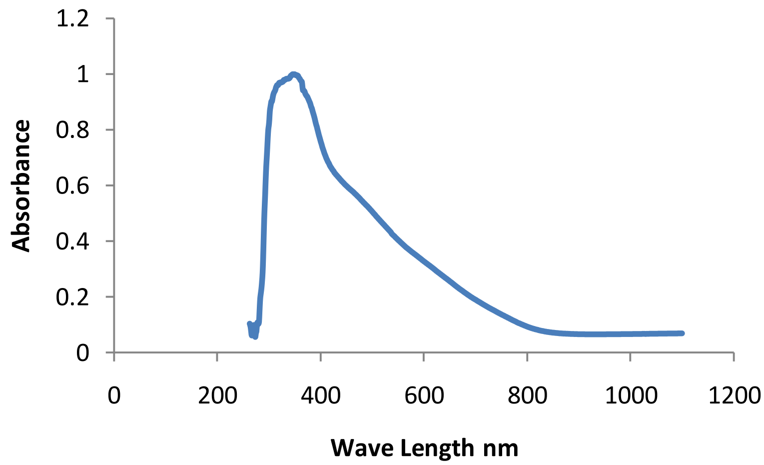

Fig. (1) Absorption spectrum of CuO thin film.

From figure(1) it can noticed that at high absorbance at ultraviolet region, then it decrease rapidly in the visible near infrared region from 300 nm to 1100nm, the absorption studies revealed that the fabricated films are very low absorptive at the visible region and is more suitable for the fabrication of solar cells[3,7].

Absorption coefficient(α) was obtained using equation (1) and it is shown in Fig.(2).

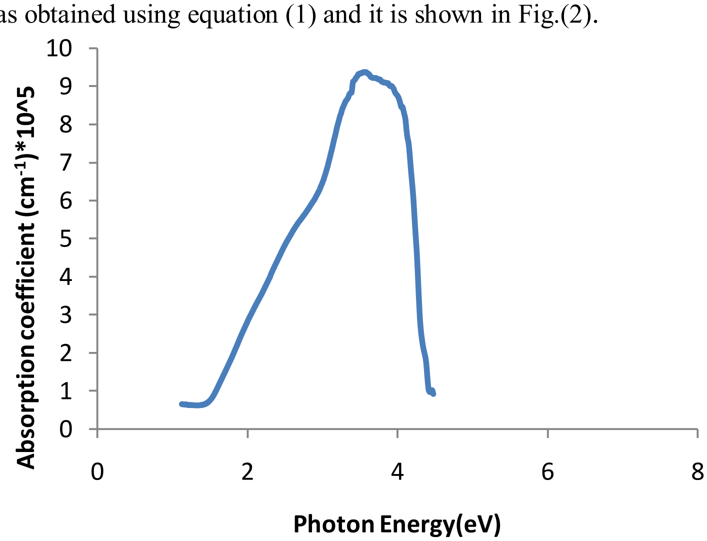

Fig. (2) Absorption coefficient vs. photon energy of CuO thin film.

Fig.(2) shows the variation of absorption coefficient in the low energy range then its value increases rapidly beyond absorption edge region . It can evidently see that CuO thin film has high value of absorption coefficient (α > 104 cm-1) which be conducive to increasing the probability of direct transitions occurrence.

Variation of extinction coefficient(k) as a function of photon energy is shown in fig. (3).

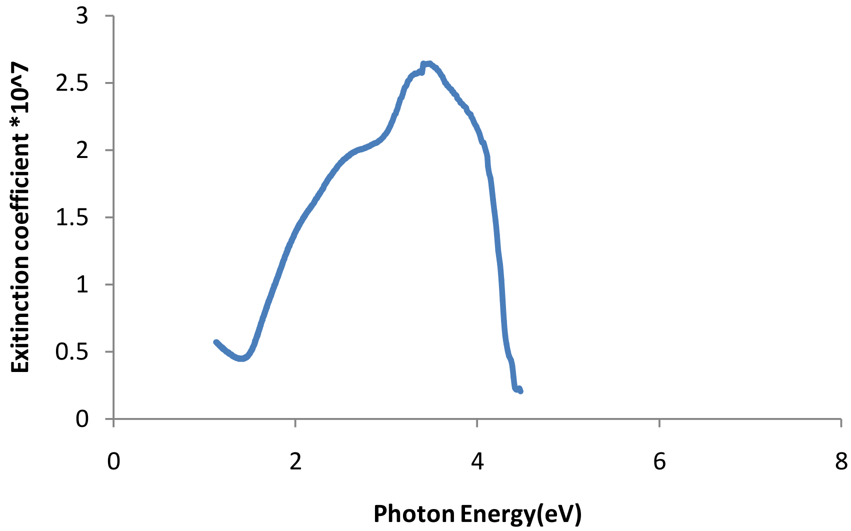

Fig. (3) Extinction coefficient vs. photon energy of CuO thin film.

The extinction coefficient of prepared film has values in the range (0.5077 – 0.202). The rise and fall in the extinction coefficient is directly related to the absorption of light [20,23].This leads to non-~zero value of k for photon energies smaller than the fundamental absorption edge.
Fig.(4) shows the optical reflectance spectra for CuO thin film.

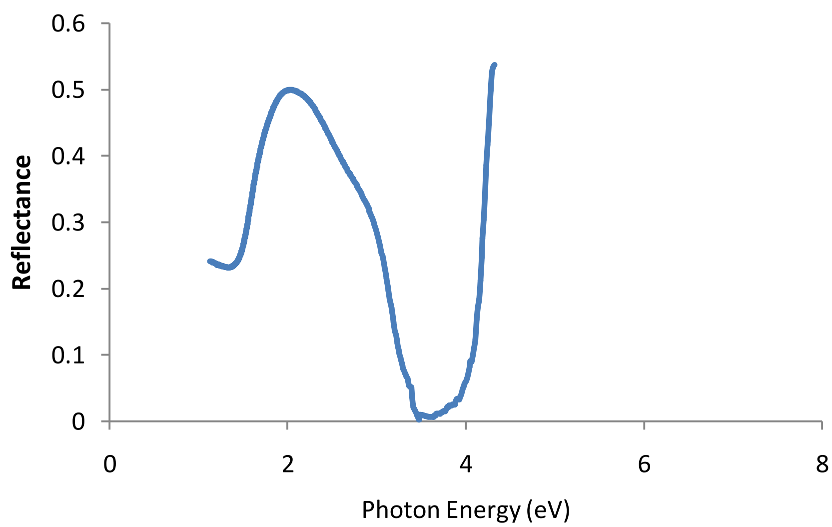

Fig. (4) Reflectance vs. photon energy of CuO thin film.

Figure(4) also shows that the film reflectance increases rapidly at the low energies and then it is have a peak at the energies which is corresponding to the energy gap of the film, then decreases at the photon energy of larger values this behavior is attributed to the very low absorbance of the film at the photon energies less than the forbidden energy gap ,and when it becomes more than or equal to the energy band gap a clear value of absorbance appears because the material electrons interaction with the incident photon which has enough energy to make the electronic transition take place this result is agree with[23] .
Fig.(5) shows the variation of refractive index with photon energy of CuO thin film.

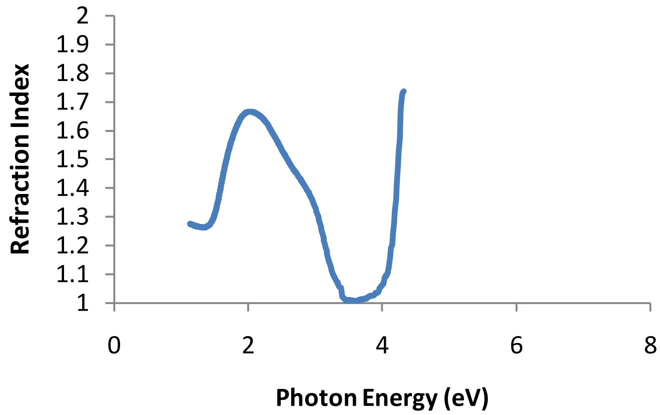

Fig. (5) Refractive index against photon energy of CuO thin film.

The behavior of refractive index is similar to the behavior of reflectance spectrum shown in fig (4), because of the strong dependence of the refractive index values on the reflectance values obeying the equation(4),where the refractive index increases rapidly at the low energies then it will decreases at the photon energy which is larger than energy band gap because of the increasing the direct electronic transition at that energies. The results show that the refractive index values of prepared film have values in the range(1.264-1.735) .
The optical conductivity versus photon energy is shown in fig.(6).

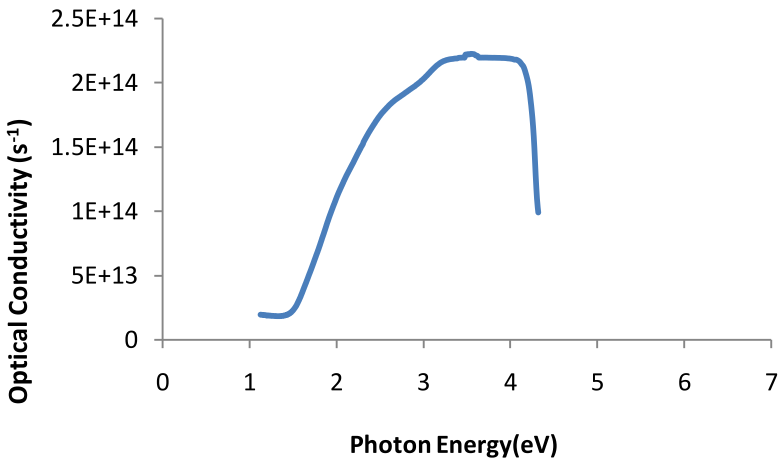

Fig. (6) Optical conductivity against photon energy for CuO thin film.

It can be noticed from the fig.(4) the that the variation of optical conductivity in the low energy range is slowely then its value increases rapidly beyond absorption edge region, because of the high increasing of the absorbance in this region.

Study of material using means of optical absorption provides a simple method for explaining some features concerning the band structure of material. In the present investigation, optical absorption (fig.1) in CuO films were studied in the wave length (190-1100) nm.
The plots of (αhv)2 against photon energy are shown in figures (8) for CuO film.

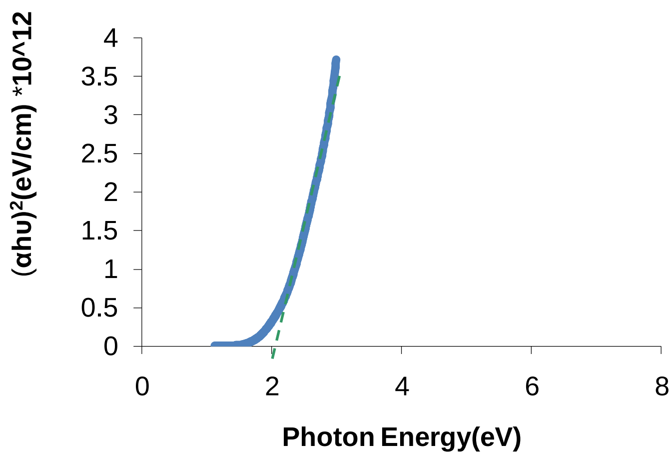

Fig. (7) Variation of(α.hυ)2 with photon energy for CuO thin films.

The linear behavior of the plot curve shown in fig.(7) is indicates the existence of direct transitions ,from the straight line obtained at high photon energy the direct allowed energy gap could be determined which was equal(2.113 ev). This result was good agreement with the results mentioned reference[4,8,16] .

Conclusion:-

CuO thin film was prepared using spray pyrolysis technique using a solution of CuCl2.2H2O , the film was deposited on to glass substrate at temperature (350°C). The film exhibits high absorbance values at ultraviolet region which they decrease rapidly in the visible / near infrared region, the film shows a direct transition which was (2.113eV) for allowed energy gap. The film has high values of absorption coefficient(α > 104 cm-1), spray pyrolysis method for the production of thin solid films is a good method for the preparation of thin films which are suitable for scientific studies and for many applications in technology and industry.

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