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OPTICAL PARAMETERS OF CHEMICALLY DEPOSITED CADMIUM SULPHIDE THIN FILMS

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ABSTRACT

CdS films are prepared by using chemically spray method. Aqueous solution of 1C3T (one part of Cadmium Chloride mixed with three parts of Thiourea) is sprayed on aborosilicate glass at 400^0C. The optical parameters include refractive index, n, extinction coefficient, K, real and imaginary parts of the dielectric constants, ϵ_1, ϵ_2 are obtained from the analysis of the reflection and transmission data in the range (400-800)nm. Direct allowed transition at 2.4 eV is recognised in terms of the imaginary part ϵ_2 of the dielectric constant.

المستخلص

تم تحضير اغشية رقيقة من كبريتات الكادميوم بطريقة الرش الكيميائي . رش محلول مائي (من خلط جزء واحد من كلوريد الكادميوم مع ثلاثة اجزاء من الثايـــوريا) على قواعد زجاجية مسخنة الى درجة حرارة 400 مم . تم استخراج الخواص الضوئية المتضمنة معامل الانكسار n ، معامل الخمود، K، الجزء الحقيقي والجزء الخيالي لثابت العزل الكهربائي ، ϵ_1 ، ϵ_2 من تحليل طيف النفاذية والانعكاسية في مدى الاطوال الموجية من 400 - 800 نانومتر. كما تم التعرف على نوع الانتقال الالكتروني المباشر عند الطاقة 2.4 الكترون-فولت بدلالة الجزء الخيالي من ثابت العزل الكهربائي ϵ_2 .

INTRODUCTION

Recently, thorough research have been made to study the optical properties of CdS as thin films, because it is found to be a great technological interest owing to their potential application in photo-cells, photo-detectors and optoelectronic devices [1-2].

There are many reports concerning the methods of preparation. The most commonly used methods are vacuume evaporation [3], sputtering [4] and spraying [5] methods. The first two methods can be used to prepare films with high transmittance and low electrical resistivity, but with a high cost and in addition a high working temperature is needed. The third one provides films with desired properties with a low cost.

CdS films prepared by evaporation method are noticed to be inconvenient for hetrojunction fabrication, but in general, these are used for solar cells and photodetectors applications [3].

Several investigations have been done on the dependence of the optical and electrical properties of CdS films on the film thickness, the rate of deposition, the substrate temperature and the impurity doping levels using different deposition mathods [6-8].

Das and Saha [2] have obtained nearly same values of energy band gap of the chemical deposition CdS films by using optical and electrical methods. They have attributed the energy gap deviation from the standard single crystal value (2.42 eV) to the strains developed in the film during the preparation, presence of impurities and lattice defect. In present work, CdS films are prepared using chemical spray deposition technique. The optical properties are studied in more details than those mentioned above. These properties comprise the refractive index, extinction coefficient and the fundemantal absorption edge in the band-to-band transition in terms of the imaginary part of the dielectric constant. Moreover the spectral variation of the real and imaginary parts of the dielectric constant is obtained.

FILM PREPARATION

CdS thin films with a thickness around 1 μm have been deposited using spray pyralysis technique. The experimental arrangement is similar to that described previously [9,10]. An aqueous solution of one part of 0.2 M of $CdCl_2$

mixed with three parts of 0.2 M of $(NH_2)_2CS$ known as 1C3T, form a soluble complex $CdCl_2$ $(NH_2)_2CS$ are sprayed on a heated glass substrate. Each spraying period tades about 10 sec. followed by 4min. waiting to avoid the excessive cooling of the hot substrate due to spraying. This composition was found to show a good crystallinity and maximum photosensitivity [11]. The spraying process was done under the normal atmospheric condition with proper spraying rate which gives a characteristically yellow and adherent films according to the following chemical reaction [12].

$$CdCl_2(NH_2)_2CS + 2H_2O \longrightarrow CdS\downarrow + 2H_2Cl\uparrow + CO_2$$

The preperation parameters such as distance between the sprayer and the substrate, spraying rate and the substrate temperaturs should be kept constant on the values 30 cm, 5 mil./min. and 400^0C respectively during the preparation process. It is found that a change in the spraying rate will cause defects such as stacking faults and vacancies in the film which may increase the internal stress and also the effect of phase transformation [13].

The absorption of the films concerned was measured by employing a technique which is different from the ratio recording technique, that is based on direct measurment of the ratio transmission of films with different thicknesses. Reflection correction to the absorbance data was applied in order to eliminate the reflection losses in the λ high region.

RESULT AND DISCUSSION

The transmittance of the normal incidence for weakly absorbing coating depositions on a transperent substrate are given by [14],

$$T = \frac{B}{2R_{af} R_{fg} \cos\Psi + R^2_{af} R^2_{fg} e^{-\alpha t} + e^{\alpha t}} \quad \text{.....(1)}$$

Where

$$R_{af} = (n_f - 1)(n_f + 1)^{-1},$$

$$R_{fg} = (n_f - n_g)(n_f + n_g)^{-1},$$

$$B = 16\, n^2_f\, n_g\, (n_f + 1)^{-2}\, (n_f + n_g)^{-2},$$

$$\Psi = \frac{4\pi t}{\lambda}$$

R_{af} , R_{fg} are air-coating, coating substrate reflections, and n_f , n_g coating and substrate refractive index respectivily, α is the absorption coefficient, t is the thickness. The cosine term is due to the interference effect.

The absorbance of the films concerned is measured by employing a technique which gives similar results as given by using the ratio recording technique.

In the region of the band to band transition the absorption so large that made $\exp(\alpha t) >> R^2_{af} R^2_{fg} \exp(-\alpha t)$ and the interferance term is very small, therefore equ. (1) can be written as

$$T = Be^{-\alpha t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

and

$$\alpha t - \text{Ln } B = 2.303 \text{ A} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where A is the absorbance; A = - Log T.

A correction term to the absorbance data is used to eliminate the reflection losses (background absorption) in the high region of λ .

This method is similar to that used by Moser et al [15], which is summerized by substracting the straight line portion of the absorption spectrum tail extrapolated to the short λ side. The absorption coefficient is related to the absorbance A by $\alpha = (2.303/t)$ A, and it

is used to calculate: K:the extinction coefficient from, $K = (\alpha\lambda) / (4\pi)$, the reflectance R at an absorbing medium in air for normal incidence is related to the optical indices n,k by:-

$$R = \frac{(n-1)^2 + K^2}{(n+1)^2 + K^2}$$

Where n is the refrective index.

Figure (1) shows that the refractive index of the films is a photon energy dependent in which the peak that is appeared at 1cm energy is mainly related to the maximum reflectance. The spectral variation of the refractive index shows qualitative similarity to that of the single crystal [16]. In the same figure, a sharp increase in the extinction coefficient can be observed. This increase is refering to the position of direct band gap.

The electronic transition is discussed by relating the dielectric constant to the optical properties according to Maxwell's equation,

$$\epsilon_1 = n^2 - k^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$\epsilon_2 = 2nk$$

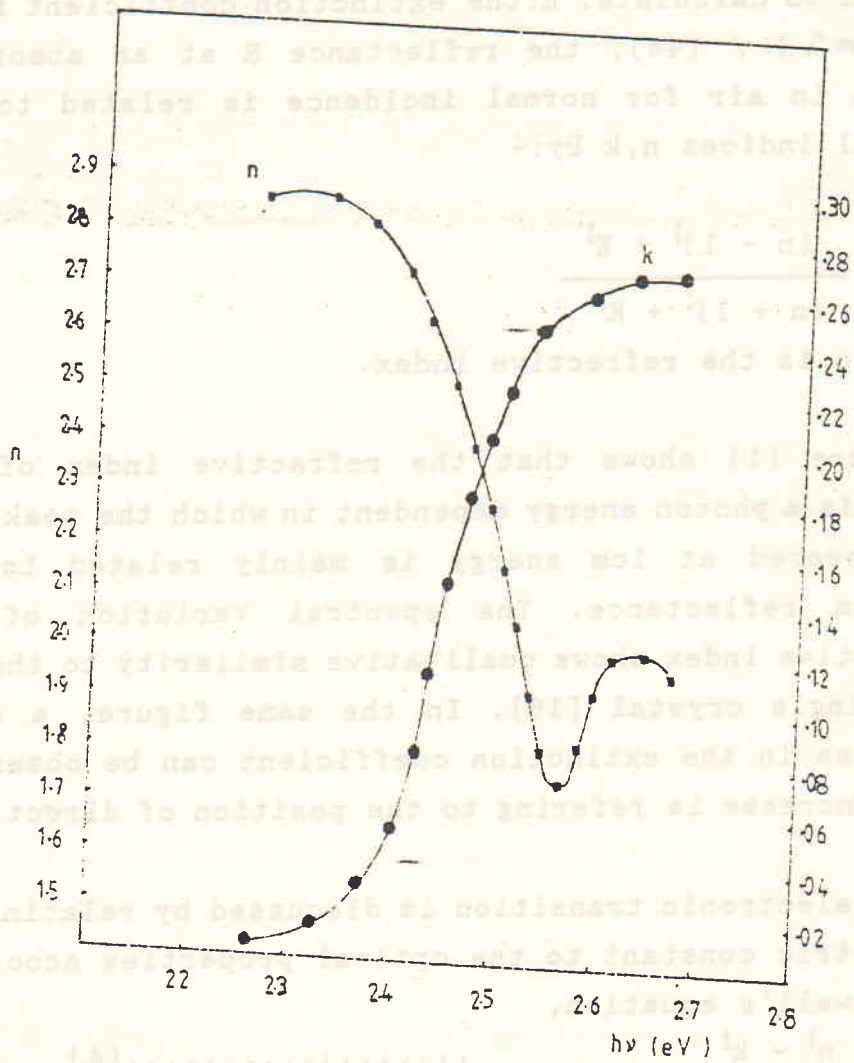

Figure (1): Refractive index and extinction coefficient of CdS films versus photon energy.

Figure (2) shows that the real and imaginary parts of the dielectric constant is frequency dependent.

The variation of $\epsilon 2$ with the photon energy for the direct allowed band to band transition according to [17] is given by,

$$(h\nu)^{\frac{1}{2}} \epsilon 2^{\frac{1}{2}} = c\,(h\nu - \Delta E) \qquad h\nu \geq \Delta E$$
$$\epsilon 2 = 0 \qquad h\nu < \Delta E$$

Where c is a constant nearly independent of photon energy. The plote of $(h\nu)^{\frac{1}{2}} \epsilon 2^{\frac{1}{2}}$ versus photon energy is shown in Figure (3) giving a straight line at high energy which shows a good fit to the above equation. Extrapolation of the straight line to $(h\nu)^{\frac{1}{2}} \epsilon 2^{\frac{1}{2}} = 0$ gives a band gap of 2.4 eV.

This value is in a good agreement with that obtained by Gupta [18] by plotting $(\alpha h\nu)^2$ versus photon energy. However the value of the absorption coefficient in CdS films as shown in Figure (4) referes only to the direct transition. This result is due solely to the crystal structure of CdS as a direct band gap semiconducters.

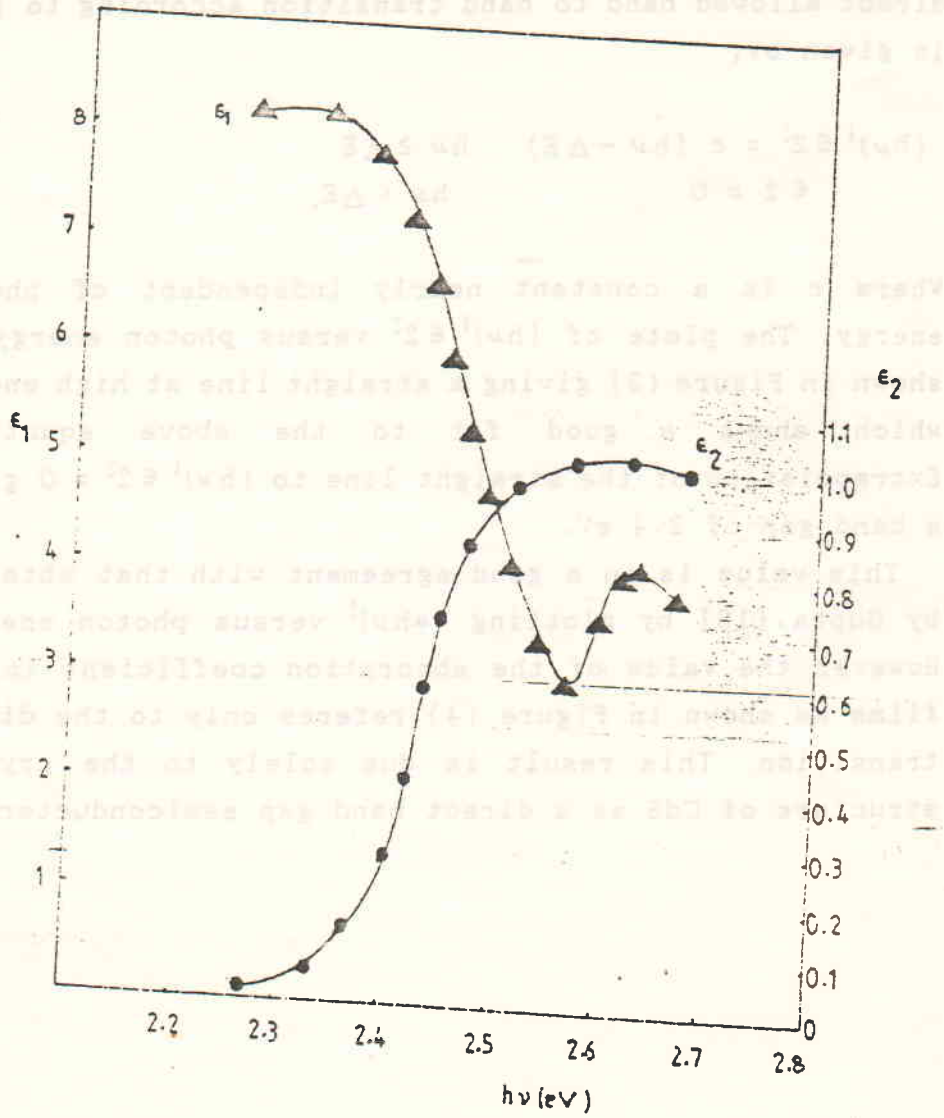

Figure (2): Real and imaginary parts of the dielectric constant versus photon energy of CdS films.

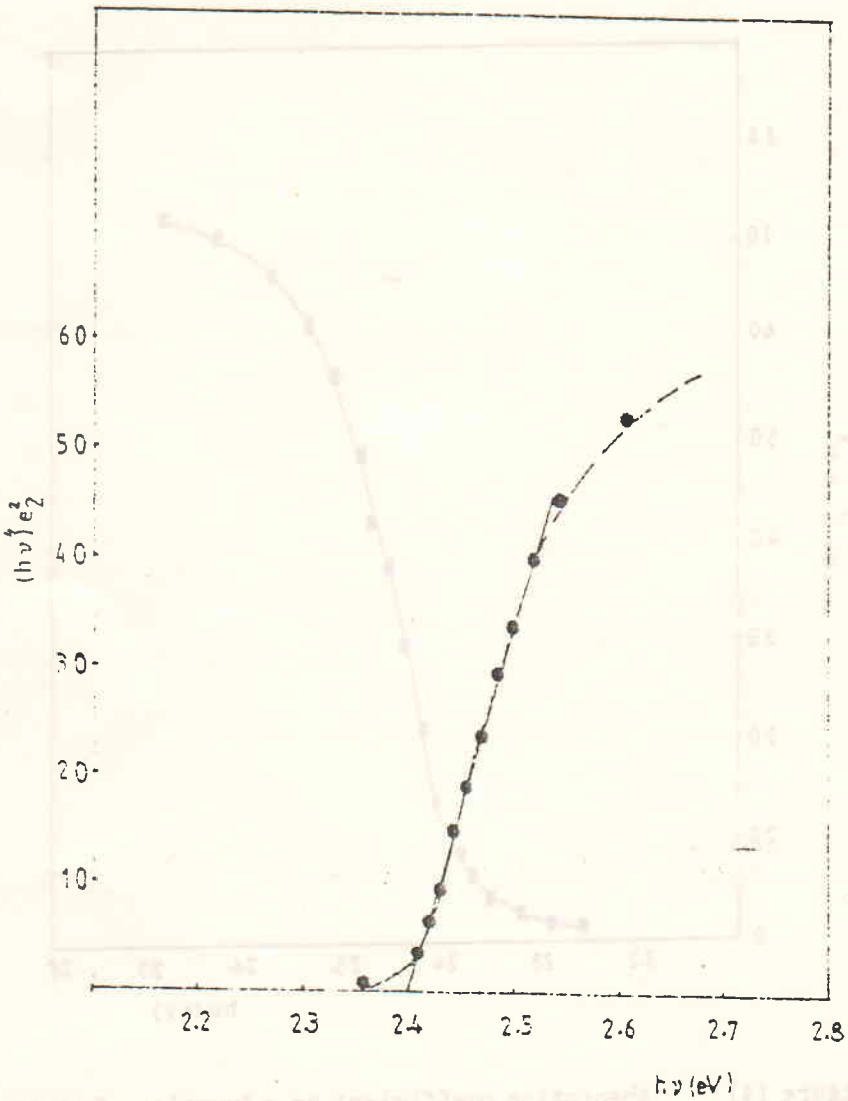

Figure (3): The plot of $(h\nu)^{\frac{1}{2}}\epsilon_2^2$ as a function of photon energy in the absorption region showing the onset of direct transition 2.4eV.

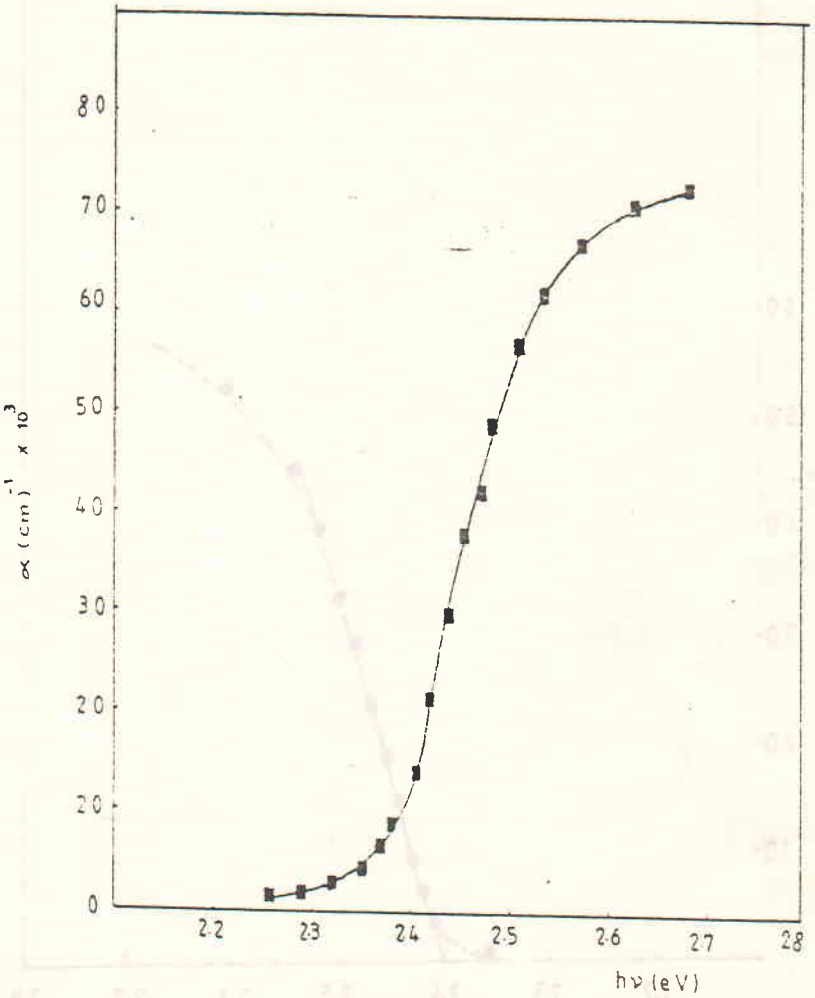

Figure (4): Absorption coefficient as a function of photon energ of CdS films.

CONCLUSION

The optical parameters of sprayed CdS films have been calculated at room temperature by depending on transmition and reflection measurements. Also, the method of correction was employed to eliminate the reflection losses from the absorbance data. Finally the electronic transition is a direct allowed one which is appeared at 2.4eV and it is recognized by dealing with the imaginary part of the dielectric constant.

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