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CATHODOLUMINESCENCE INTERFERENCE EFFECT IN EVAPORATED CdS FILMS

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Abstract:

Cathodoluminescence (CL) spectra of thermally evaporated cadmium sulfide (CdS) films onto glass substrates were studied for different film thicknesses. CdS films of thicknesses higher than 5-6 um gave two broad smooth CLbands: the green band (GB) with $\lambda_{max} \sim 510$ nm and the red band (RB) with $\lambda_{max} \simeq 680$ nm. A modulation of the CL spectra has been observed for samples of thicknesses less than 3 μm keeping the band peak at the same position. The modulation of the CL spectra of both the green and red bands, which appeared in the form of regular small peaks, was accompanied by an overall decrease of the CL intensity. The observed peaks are attributed to double-beam interference. Accordingly, they can be utilized in film thickness determination. The obtained values of the film thickness were in good agreement with those estimated by other methods.

Introduction:

Recently, local cathodoluminescence of semiconductor crystals as well as thin films has recieved a great interest (1-6), because of the development of electron-excited lasers. One of the most promising semiconducting materials is cadmium sulfide. The main interest includes the nature of the cathodoluminescence as well as the parameters that may affect it.

However, the present work presents the application of CL spectra in the determination of the film thickness.

Experimental Procedure:

(i) Film preparation

A number of CdS films of different thicknesses (2-8 μm) were prepared by thermal evaporation on glass substrates held at room temperature during the deposition process in vacuum of 10^{-5} Torr. The rate of deposition was relatively small 40 nm/minute. CdS films appeared black-grey (then became yellow-orange after annealing).

(ii) Film structure

The structure of CdS thin films deposited on glass substrates was investigated using a computer-controlled X-ray diffractometer (Diano Corporation, USA).

(iii) CL Spectra

Cathodoluminescence spectra in CdS films were obtained using an electron microprobe analyser (CAMEBA). The beam current was kept at about 10^{-7} Amp. and the beam diameter was between 10-50 μm. The operating accelerating voltage was about 25 KV. All experiments were performed at room temperature either before or after film annealing.

Results and Discussions:

X-ray studies of CdS films deposited on glass substrates showed that they have polycrystalline structure of hexagonal type with a preferred orientation (with the c-axis perpendicular to the substrate surface). The degree of the preferred orientation increases with increasing the film thickness. The obtained data was similar to that reported before (7). Cathodoluminescence spectra as performed for CdS films of thicknesses higher than 5-6 μm showed two broad smooth CL bands: the green band (GB) with $\lambda_{max} \sim 510$ nm and the red band (RB) with $\lambda_{max} \sim 680$ nm. These bands as attributed before (8, 9) were due to intrinsic transitions as well as to transitions involving structural defects. Typical representation of such CL spectra is illustrated in Fig. (1) for a 7 μm thick CdS film. For CdS films of thicknesses less than 3 μm, two essential features were observed: (i) Modulation of CL spectra appeared as regular small peaks in both green and red bands and (ii) A decrease in CL intensity throughout the whole spectrum as shown in Fig. (2). The observed peaks can be explained in the two-beam interference model. Therefore, they can be used for the determination of the film thickness. For this purpose, the wavelengths at which these peaks locate were precisely determined. Using the wavelengths λ_1 and λ_2 corresponding to two successive peaks, either in GB or in RB, in conjunction with the corresponding values of the refractive indices, n_1 and n_2, determined before (10) for CdS thin films having the same stoichiometry, the order of interference m can be determined, as (11):

$$m = \frac{n_1/\lambda_1}{n_2/\lambda_2 - n_1/\lambda_1}, \quad \lambda_1 > \lambda_2$$

knowing, the order of interference m, the film thickness t can be calculated from:

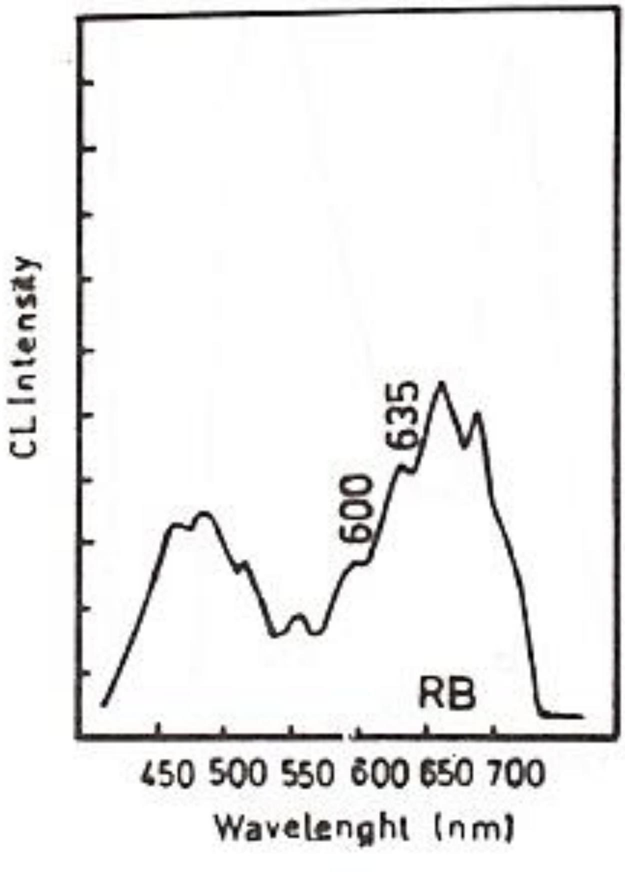

Fig.2: CL spectra of evaporated CdS films.
Thickness (measured) = 2.40 µm.
Thickness (calculated) = 2.227 µm.

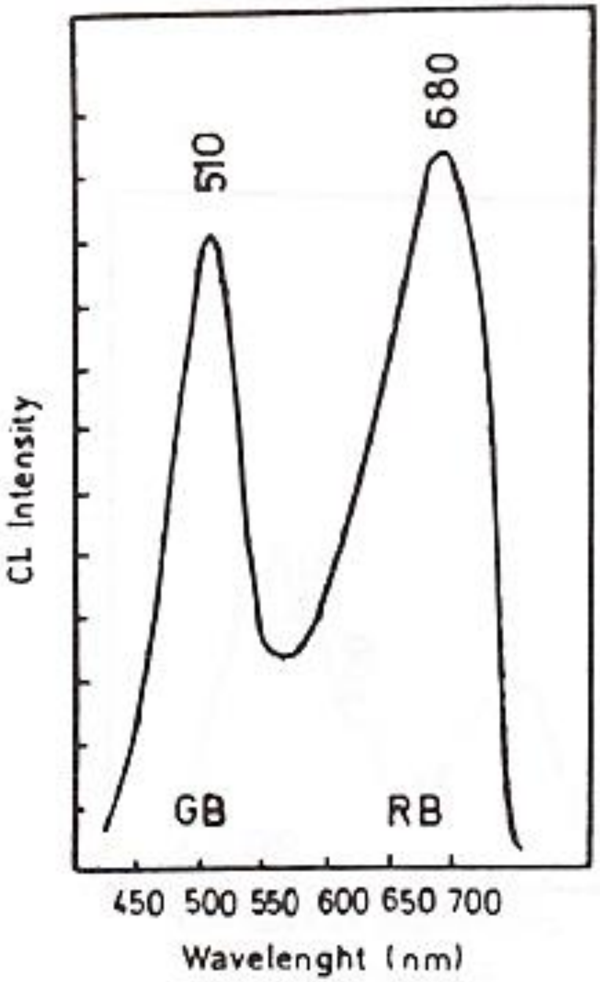

Fig.1: CL spectra of evaporated CdS films.
Thickness (measured) = 7 µm

$$m \lambda_1 = 2 n_1 t$$

$$\text{or} \quad (m+1) \lambda_2 = 2 n_2 t$$

As a representative example, using the two peaks located at 635 and 600 nm, Fig. (2), at RB. The refractive indices n_1 and n_2 are respectively 2.281 and 2.290. Both m and t were found to be 16 and 2.227 μm respectively.

The obtained result for the film thicknesses is in good agreeement with the film thickness estimated by other methods (12).

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