

Photocurrent measurement in chemically deposited CdS: Li films

A G SHIKALGAR and S H PAWAR

Department of Physics, Shivaji University, Kolhapur 416 004, India

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Abstract. The dependence of photocurrent on the light intensity in CdS:Li films formed by chemical bath deposition technique is studied. The superlinearity observed is explained on the basis of increased lifetime of the photoexcited electron. The effect of oxygen adsorption in the film surface on the lifetime of the electron is studied.

Keywords. Photosensitivity; annealing; CdS:Li films; superlinearity; chemisorption.

1. Introduction

Polycrystalline thin films of CdS have received considerable attention because of their usefulness in many semiconductor devices. Photoconductive properties of CdS activated with group Ib impurities such as Cu, Ag and Au have been investigated by Pavaskar and Menezes (1970), and Wu and Bube (1974). Comparatively little attention has been paid to the photoconductive properties of CdS activated with group Ia impurities such as Li, Na and K. Tell (1971) measured various optical and electrical properties of Na- and Li-diffused CdS crystals and suggested that the alkali ions act as good acceptors in CdS crystals. The Li^+ ion has a smaller ionic radius of 0.68 Å than Cd ion (0.97 Å). Therefore, the possibility of CdS doped with a high concentration of lithium behaving as a *p*-type material exists. Lithium doped CdS films were prepared in the present investigation. However, type conversion is not observed. The paper presents the study on the dependence of photocurrent on the light intensity in CdS : Li films. The effect of oxygen adsorption in the film surface on the photocurrents is also studied.

2. Experimental

Lithium doped CdS films used were prepared by chemical bath deposition method (Shikalgar and Pawar 1979). For photocurrent measurement, the sample was mounted inside a metal cryostat and illuminated by a 500 watt tungsten filament lamp. To avoid heating of the sample due to light, a thick water filter was placed between the sample and the lamp and fitted with the cryostat itself.

3. Results and discussion

The most photosensitive sample of CdS:Li obtained by vacuum annealing was used for intensity versus photocurrent measurement at room temperature. The variation of photocurrent with light intensity for CdS:Li films is shown in figure 1. The sample doped with lithium and subsequently vacuum-annealed shows an onset of superlinearity over the whole range of measurements and only at very high excitations sublinear range is observed. This behaviour is explained by the relation

$$n = F / \{ VS_1 p_t + VS_2 (N_t - n_t) \} \quad (1)$$

where n is the free carrier density, F the excitation rate of carrier generation, V the average thermal velocity of electrons, N_t the density of trapping centres, n_t the density of trapped electrons, p_t the density of hole trapping centres and $S_1 S_2$ is the capture cross-section for recombination of free electron and a trapped hole and for trapping of a free electron respectively. At high light levels, n_t is comparable to N_t , whereas $VS_1 p_t$ is relatively small and $(N_t - n_t)$ decreases with increasing F ; hence n will increase faster than F and superlinearity is observed. Thus, $N_t \simeq n_t$ means that the photoexcited electron has no trapping states available which will increase the lifetime of the photoexcited electron. For very high excitation, hole density begins to increase sufficiently to make the electron traps act as recombination centres. As a consequence $(N_t - n_t)$ may actually increase with increasing F . However $VS_1 p_t$ is comparable to $VS_2 (N_t - n_t)$, and as a result n increases slower than F , and the material becomes sublinear in range. A similar phenomenon of superlinearity was reported for CdSe:I.Cv crystals (Bube 1957), CdS simple crystals (Avinor 1959),

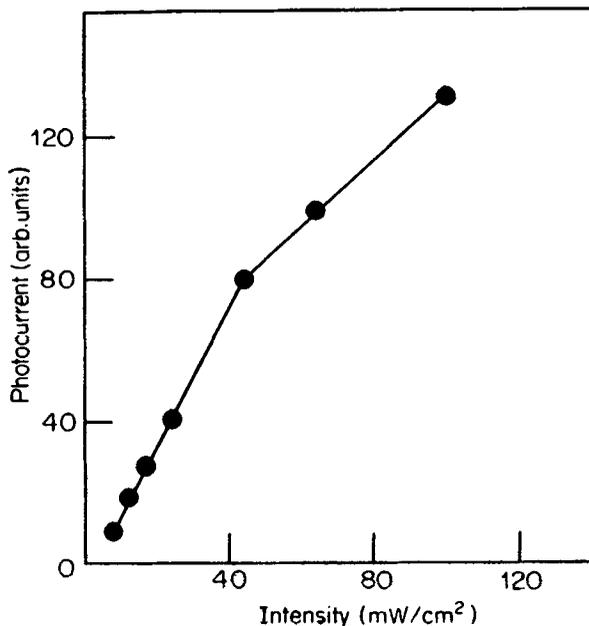


Figure 1. Variation of photocurrent with excitation intensity for CdS:Li films.

ion-implanted CdS films (Bhar 1973) and chemically-deposited CdS films (Sathaye and Sinha 1976). Thus our studies agree with those reported by others and are also supported by the increased lifetime of photoexcited carrier due to photo-desorption of oxygen.

The usual termination of the lifetime of a free carrier is by recombination. At any density of conduction electrons, the corresponding lifetime before recombination may be found from the light intensity curve versus photocurrent, since at equilibrium (steady-state) the rate of generation of electrons by the light must be equal to the rate of recombination. Thus, in steady-state, n is related to F and the free carrier lifetime τ by

$$n = F\tau. \tag{2}$$

The lifetime can then be evaluated from the slope of n versus F plot. However, this relation does not apply for non steady-state conditions. The dependence of excitation density on excitation time has been studied to produce a constant carrier density of 5×10^{15} carriers/cm³. The carrier density was evaluated from

$$n = \Delta I / (e\mu V w.d), \tag{3}$$

where ΔI is the photocurrent in amps (10^{-7} amp), l the length of the sample (1 cm), μ the mobility of electron ($0.05 \text{ cm}^2/V \text{ sec}$ obtained from thermoelectric measurement) w the width of the sample (0.3 cm), d the thickness of the sample (1.2×10^{-4} cm), and V the applied voltage across the sample (100 volts). The variation of excitation density versus excitation time is shown in figure 2 for vacuum-annealed CdS:Li and as-deposited CdS:Li films. From the linearity of the plot, the excitation density and time follows the relation

$$F = c t^{-b} \tag{4}$$

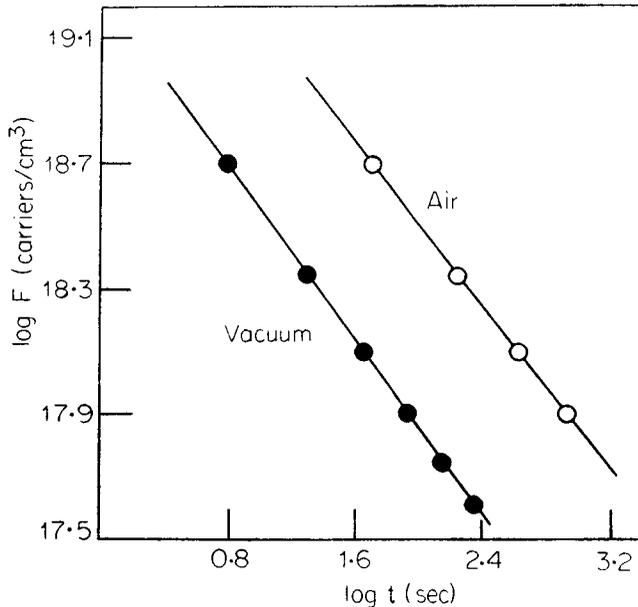


Figure 2. Plot of excitation intensity versus time (log-log scale) to generate carrier density 5×10^{15} carriers/cm³.

where b the constant depends on the photosensitivity of the material, and c , also a constant equal to $n/(\tau \cdot t^b)$ and is the intercept on $\log F$ axis. Thus, the lifetime of photoexcited electron evaluated from the intercept on $\log F$ axis is 2.8×10^{-4} sec for the vacuum annealed sample and 10^{-4} sec for the as-deposited sample. The latter was measured in air. This difference in lifetime values is attributed to thermal as well as photodesorption of oxygen on the surface of the film and the result is in good agreement with the result reported by Wu and Bube (1974).

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