The Effect of $CdCl_2$ Annealing on Optoelectronic Properties of CSD- Grown CdS Films

A. E. Rakhshani, B. Pradeep and H. A. Ramazaniyan

Physics Department, Faculty of Science, P.O. Box 5969, Safat 13060, Kuwait

Chemical solution deposition (CSD) of cadmium sulfide (CdS) yields 100 to 200- nm thick films with an energy bandgap that differs from the bulk value (2.42 eV). The optical absorption has a tail (Urbach tail) whose characteristic energy (Urbach energy, E_u) depends on the extent of lattice disorder. The measured value of E_u is used to monitor the film quality as it approaches the bulk (single crystal) characteristics by annealing. Annealing in air or in an inert gas partially increases the tail steepness that corresponds to a decrease in E_u towards its bulk value (about 10 meV or less). However, this process reduces the bandgap energy below the bulk value. On the contrary, annealing in $CdCl_2$ vapor restores the bulk bandgap energy and effectively lowers the E_u value. Cadmium chloride annealing has a profound effect on the efficiency of CdTe/CdS solar cells. This is believed to be related to improvements in optoelectronic properties of CdTe due to grain growth.

Films of CdS have been deposited on glass substrate from an alkaline solution as described elsewhere [A. E. Rakhshani and A. S. Al-Azab, Appl. Phys. A 73 (2001) 631]. For annealing, samples are placed in parallel to a $CdCl_2$ source substrate (a few mm gap) in a tube furnace. The source is a dried layer of a $CdCl_2$ solution on glass. Modulated photocurrent spectroscopy has been used for measurement of E_u and bandgap energy, E_g. Figure 1 shows the effect of annealing at different temperatures on these two parameters. The annealing time is the same at all temperatures. It is 30 min with the $CdCl_2$ source in place followed by another 30 min without the source. The ambient atmosphere is air. The effect of annealing on the film resistivity in dark and under illumination (Air Mass 1.5 intensity, ELH lamp) is shown in Fig. 2. Annealing above 365 °C restores the bulk value for E_g and reduces E_u by a factor of five. This implies an improvement in the film crystalline structure possibly through grain growth. This improvement is also associated with a ten- fold increase in photoconductivity, indicating a reduction in the density of defects that behave as recombination centers. For these films the ratio of resistivity in dark to that in light exceeds $3x10^4$. The variation of E_u and E_g with the annealing time, at a fixed temperature, is also studied. The optimum annealing time at 400 °C is 10-15 min. Longer times yield a lower photoconductivity. In annealed samples, the photoconductivity activation energies are 0.02 and 0.09 eV and the temperature coefficient of bandgap energy (–0.5 meV/K) is the same as for bulk CdS.

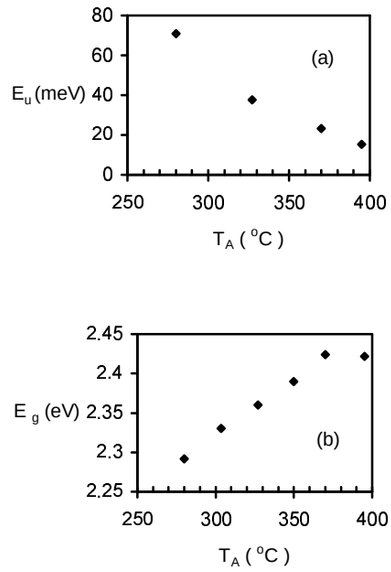

Fig. 1 Variation of Urbach energy (a) and bandgap energy (b) with annealing temperature, T_A .

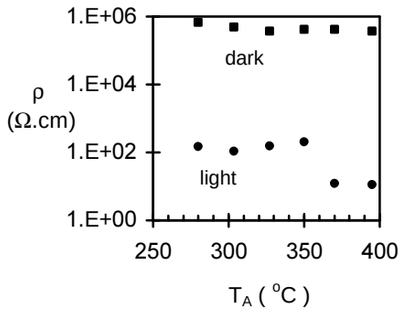

Fig.2. Effect of annealing temperature on the film resistivity in dark and inlight .