Indian J. Phys. **51A**, 197–200 (1977)

A microwave study of heat treatment effects in ceramic CdS pellets

R. K. Sinha, P. Basu, C. Neogi, P Sircar and H. Saha

Department of Physics, University of Kalyani, Kalyani

(*Received* 18 *May* 1976)

Ceramic pellets of polycrystalline CdS are used for the fabrication of solar cell and LDR. One of the essential steps for fabrication of these devices is to heat treat the CdS pellet for sometime in an inert atmosphere, leading to some significant changes in their physical properties (Phillips 1971 and Hadley *et al* 1959). Usually the CdS samples are deliberately doped with some impurities, e.g., Cu, before the heat treatment (HT) so that the observed changes after HT is principally due to the changes caused by the impurities present. It would, however, be interesting to investigate how the bulk property of the ceramic CdS itself may change as a result of such heat treatments. The purpose of the present communication is to report the results of such an investigation on ceramic CdS, which has been used for the fabrication of solar cell and LDR (Deb *et al* 1974) The investigations have been carried out in the microwave range in order to (a) get rid of problems of making ohmic contact to the sample, and (b) bypass the effects of contact resistances and contact capacitances which may become important in the d–c and low frequency measurements of polycrystalline samples.

4·0 gms of CdS of requisite purity were pressed at about 8 tons/cm^2 in a suitably constructed jig to form rectangular pellets of $25 \times 12 \times 3$ mm size which were then sintered in a furnace at about 700°C for one hour in closed nitrogen atmosphere. The samples were then lapped with carborundum powder and etched with chromic acid for obtaining clear smooth surface and to fit snugly inside the X-band waveguide. The conductivity and the permittivity of the samples were then measured at different temperature in the X-band microwave range following Von Hippel's technique (Roberts *et al* 1940). The samples were then heat treated at a particular temperature (T_A) in the furnace for about one hour. The conductivity and permittivity measurements were repeated over the entire range of temperature (30°–150°C) for different values of T_A.

The d.c. conductivity and Hall mobility of the samples were also measured at room temperature employing the Hall Four-Probe technique (Green *et al* 1972). Ohmic contacts to the four probe points were made by melting Indium at the points of contact.

Figures 1 and 2 show the variation of conductivity (σ) and relative permittivity (ϵ_r) of the ceramic CdS samples with temperature for different temperatures (T_A) of HT. Over the range of temperature between 30°C and 150°C, remains

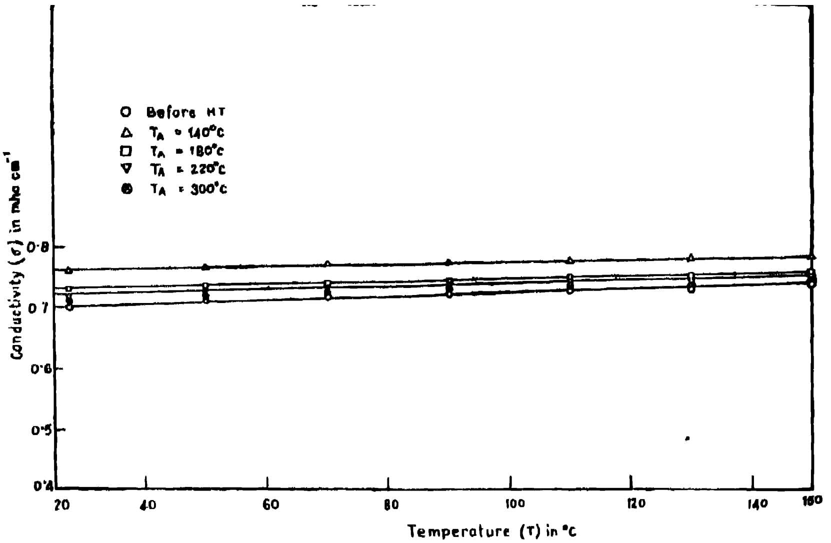

Fig. 1 Variation of conductivity of CdS pellet with temperature (T) for different heat treatment temperature (T_A).

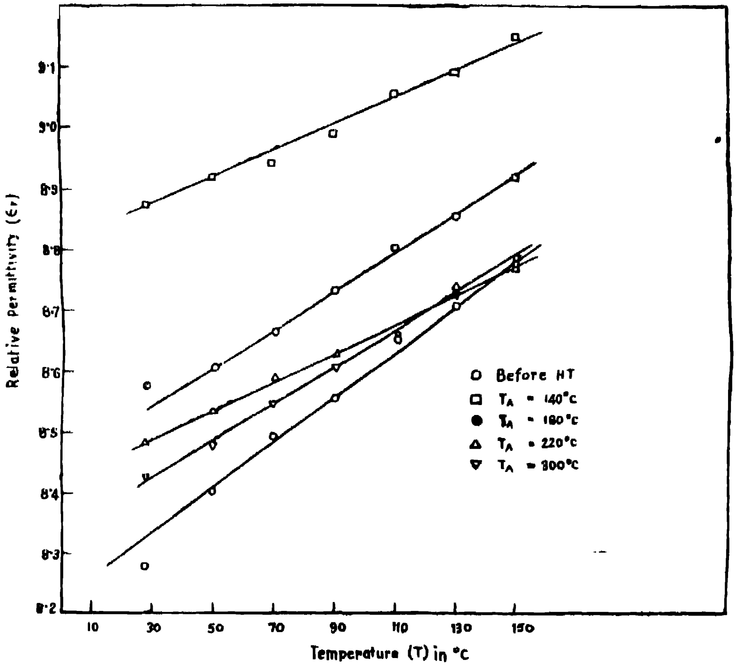

Fig. 2. Variation of relative permittivity of CdS pellet with temperature (T) for different heat treatment temperature (T_A).

more or less constant although there is a slight tendency for an increase in its value (about 2–3%). The ϵ_r, however, increases almost linearly with temperature in all cases. For example with $T_A = 140°C$, ϵ_r increases from 8·9 at 30°C to 9·4 to 150°C.

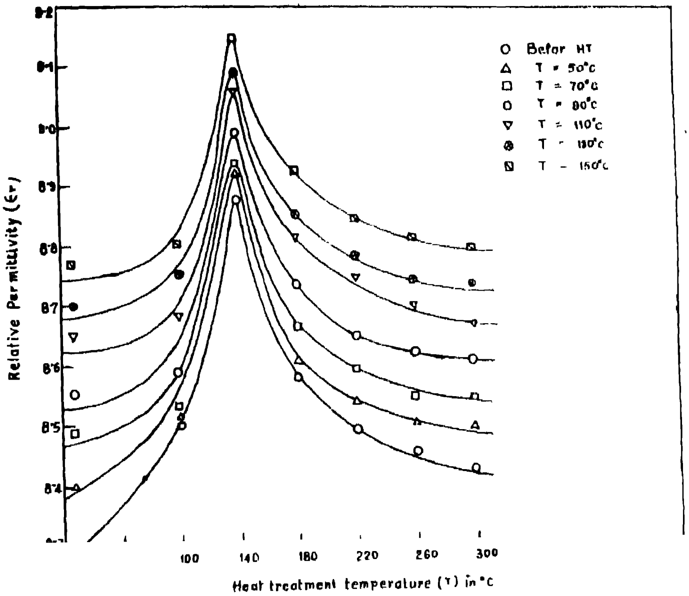

Fig. 3. Variation of relative permittivity with the heat treatment temperature (T_A) at different ambient temperature (T).

Figure 3 shows the variation of ϵ_r with T_A for different ambient temperatures. It is very interesting to note that ϵ_r has a peak value corresponding to a particular $T_A = 140°C$ for all cases.

From the room temperature d.c. measurements, the Hall mobility (μ_H) is $\sim$10 cm^2 V^{-1} sec^{-1} and the electron concentration (n) is $\sim 10^7$ cm^{-3} for these samples.

Since the conductivity of the samples remain approximately constant over the range of heat treatment, the remarkable changes in conductivity observed during the fabrication of LDR and solar cell are due to diffusion of Cu into the CdS which act as sensitising centres. Since $n \sim 10^{17}$ cm^{-3}, any further change in electron concerntration during heat treatment is unlikely.

The observed variation of relative permittivity with the heat treatment temperature is rather difficult to explain. If n is assumed to be constant, ϵ_r varies directly with τ^2 (Champlin *et al* 1964). For a polycrystalline material τ may be expressed as $\tau = \tau_0 e^{-\Delta E/kT}$ where τ_0 is a constant independent of temperature and ΔE corresponds to the potential barrier height existing at the grain boundaries (Petritz *et al* 1956). The height of the potential barrier depends upon the number of electrons trapped at the grain boundary which in turn depend upon the two competing processes viz., (1) release of trapped electrons from the traps at the barrier, and (2) capture of free electrons into the same traps. Since both these processes are thermally assisted, we propose that ΔE may increase or decrease depending upon the new equilibrium values of the processes (1) and (2) at the temperature of heat treatment. This may lead to the observed variation of c_r with T_A. Since c_r is directly related to the absorption coefficient, the spectral response of the ceramic CdS samples may vary with different heat treatment temperature. In fact, the shifting of the abosprition edge towards both higher and lowerr energy sides of the normal vaue has already been observed for Ge films for different annealing temperatures (Masatava *et al* 1974). Such an optimisation of the optical properties of ceramic CdS by prior heat treatment may be useful for the fabrication of LDR and solar cell.

The experiments were performed under the sponsorship of University Grants Commission, sanction No. F.6-3(5101)/73(SF-I). The authors wish to thank Prof. S. Deb, Department of Electronics and Telecommunication, Jadavpur University, for many helpful discussions.

REFERENCES

Champlin K. S., Armstrong D. B. & Gunderson P. D. 1964 *Proc. IEEE*, **52**, 677.

Deb S., Mukherjee M. K. & Saha H. 1974 *Proc. Conf Photovoltaic Power Generation*, 25–27 Sept., 1974, Hamburg, p. 281

Green M. A. & Gunn M. W. 1972 *Solid State Electronics* **15**, 577.

Hadley C. P. & Fischer E. 1959 *RCA Review* **20**, 635.

Masatake H. *et al* 1974 *Jap. J. Appl. Phys.* **13**, 40.

Petritz R. L., Humphrey J. N., Lummis F. L. & Scanlon W. W. 1956 *Phys. Rev.* **104**, 1508.

Phillips L. S. 1971 *Electronic Components* **8**, 1.

Roberts S. & Von Hippel A 1940 *Phys. Rev.* **57**, 1056.

Indian J. Phys. **51A**, 200–204 (1977)

K-surface and diffuse X-ray reflections from 1,8-dihydroxianthraquinone

S. K TALAPATRA, B. N. MUKHERJEE*, S. B. SARKAR AND
MANJUSREE BANERJEE

Department of Physics, Jadavpur University, Calcutta-700032

(*Received* 11 *June* 1976)

The variation of diffuse scattering intensity of X-rays from points round a reciprocal lattice node is conveniently expressed as a surface known as K-surface,

---

* Permanent address : Central Glass & Ceramic Research Institute, Calcutta-700032.