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## Photocapacitance of Schottky Barriers on Zinc Cadmium Selenide Solar Cells

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### Abstract

*Schottky barriers on Zinc Cadmium Selenide  $Zn_x Cd_{1-x} Se$  mixed crystals grown from the vapor phase have been investigated. The barrier height and uncompensated donor density have been determined in this composition. Deep levels were also investigated in these diodes using photo capacitance techniques, which revealed the presence of two of about dominant levels with activation energies 0.2, 0.4, 0.55, 0.85 eV above the top of the valence and one with an activation energy at about 0.85 - 0.95 eV below the conduction band.*

Keywords: Photocapacitance , Schottky , Barriers , Solar Cells , Deep levels

### 1-Introduction

(The viability of the  $Zn_x Cd_{1-x} Se$  single crystal system has been known for some time and the full range of composition ( $0 < x < 1$ ) was demonstrated as early as 1951 [Forgue et al, 1951(2)] since the band gap varies from 1.74 eV to 2.67 eV, covering most of the visible and near infra-red parts of the electromagnetic. As a consequence it has received some interest as a phosphor material for color television screens [Lehman, 1961](1) The single crystals of  $Zn_x Cd_{1-x} Se$  has obvious potential for photo-electronic applications. Single crystal growth from the vapor phase was reported in 1969 and more recently by [Burger and Roth, 1984] (3) and by [Bassam et al, 1988]. (4-6)

The structure of  $Zn_x Cd_{1-x} Se$  undergoes a transition from Wurtzite to Sphalerite at  $x = 0.5$ , being hexagonal when  $x > 0.5$  and cubic when  $x < 0.5$ . The lattice parameter was found to vary linearly with composition up to the transition point. The result to be described in this paper relate to the properties of Schottky diodes of the  $Zn_x Cd_{1-x} Se$  solar cells with compositions where  $x = 0.5$

and 0.55. The barrier height were characterized using photoelectric, and current- voltage measurements. Photo capacitance studies were also carried out to provide a preliminary survey of some deep levels in the material.

## 2-Experimental

The single crystal materials used in this study were grown from the vapor phase [Piper and Polich, 1961]. Samples (4 x 4 x 2 mm<sup>3</sup>) were cut from the boules and mechanically polished down to a grit size of 1 mm using alumina powder. After cleaning and a final etch in 2% bromine in methanol solution for about 2 minutes and then for a further 2 minutes in concentrated HCl, the samples were loaded into a vacuum coating system and a 1 mm diameter gold dot was evaporated into one of the large one faces to form the rectifying contact. Indium was deposited on the reverse face for use as an injecting contact.

Dark current-voltage (I-V) characteristics were measured at room temperature, capacitance-voltage (C-V) measurements were made using a boonton 72 B capacitance meter. The spectral dependence of the steady state photo capacitance was measured using a barr stroud type VL2 prism monochromator with a tungsten light source and Boonton 72 B differential capacitance meter.

### 3.1 Electrical Characteristics

The electrical characteristic of Au Zn<sub>x</sub>Cd<sub>1-x</sub> Se diodes could be measured for compositions  $x = 0.5$  and  $x = 0.55$  gave good rectifying characteristics with little reverse bias leakage. The results are shown in Figure 1.

Figure: 2 shows, a plot of the logarithmic dark current versus the applied bias for Au - Zn<sub>x</sub>Cd<sub>1-x</sub>Se single crystals with  $x = 0.52$  and  $x = 0.58$ . The ideality factor can be determined from the forward bias I-V characteristics.

Thus, from the plot of  $\ln I$  against  $V$ , the ideality factor ' $n$ ' can be calculated where  $I$  is the dark saturation current density and equal to the  $\ln I$  intercept. From the slope of the plot of  $\ln I$  against forward voltage, the values of the ideality factors ( $n$ ) were calculated. The values of  $n$  fall in the range 1.0 - 1.2

According to (Card and Rhoderick, 1971).(7) the deviation from the ideal situation ( $n = 1$ ) can be described to many reasons, for instance the presence of surface states and an oxide layer. The ideality factor increases with an increase in the insulating layer thickness which was present after the etching process prior to the deposition of the gold. The spectral response of the photocurrent has been measured as a function of wavelength in the range 320. <720 nm.

**Table 1**

Sample	$J_s$	(n)	I-v (eV)	Photo current (eV)
Zn <sub>0.52</sub> Cd <sub>0.48</sub> Se	$1 \times 10^{-5}$	1.1	0.65	1.28
Zn <sub>0.58</sub> Cd <sub>0.42</sub> Se	$3 \times 10^{-4}$	1.1	0.6	1.32

The barrier height was determined from the long wavelength side of the response curves by plotting the quantity R against photon energy  $h\nu$ . The results are shown in Figure: 3. and summarized in Table 1.

According to (Al-Bassam, 1990.) (5,8,9) the barrier heights found from the current voltage measurement were sometimes in disagreement with those determined from capacitance voltage and photocurrent measurement. They suggested that the disparity between these estimates of barrier heights can be attributed to the pres interfacial layer between the gold contact and the semiconductor. Similarly, the capacitance voltage characteristic usually produce straight lines. The uncompensated donor density  $N_d$  was calculated from the slope of the C-2 versus V plot and is given in table (2).

**Table 2:**

Sample	$N_d$ (x16 cm)	$V_d$ (eV)	$\phi_{C-V}$ (ev)	$E_c - E_f$ (eV)
Zn <sub>0.52</sub> Cd <sub>0.48</sub> Se	0.8	1.76	1.9	0.135
Zn <sub>0.58</sub> Cd <sub>0.42</sub> Se	12	1.6	1.73	0.124

The un compensated donor density  $N_d$  increases with increasing x, and its behaviour as a function of composition is similar to that observed for Cd<sub>1-x</sub> Zn<sub>x</sub> Se, in that case, it was suggested as due to reduction in the carrier mobility, possibly because of alloy scattering, and resulted in a very large increase in the resistivity. Also the carrier density decrease as the zinc content increase. (Kwok and Chau 1980) (10) and (Chow et al. 1981) (11) showed that the carrier density increased. Initially, with increasing zinc, also found that the carrier density decreases as the zinc content of Cd<sub>1-x</sub> Zn<sub>x</sub> Se Zn<sub>0.52</sub> Cd<sub>0.48</sub>..

### 3.2. Photo Capacitance Results:

Figure 4. shows photo capacitance (PHCAP) spectra taken from Au – Zn<sub>0.5</sub> Cd<sub>0.5</sub> Se The first threshold leading to an increased PHCAP was observed at photon energy of about 1.0 eV, indicating that there is process excitation of the electron from a level 1.04 eV below the

conduction band. As the photon energy was increased, a second threshold was observed at  $h\nu = 1.7$  eV at 285 K and  $h\nu = 1.6$  eV at 85 K corresponding to the emptying of an acceptor at about 0.38 and 0.52 eV above the valence band.

the results are in good agreement with, results which have been reported for  $Zn_{0.25}Cd_{0.75}Se$  crystal by (Lewis et al 1986) (12) and (Burger and Roth, 1984 (3) for  $Zn_{0.3}Cd_{0.7}Se$  who identified a level located at 0.49 eV below the conduction band. They attributed this center to Cd vacancy - Cu interstitial pairs. (Lewis et al) reported that five deep levels have been observed, two electron traps with activation energies of 0.54 and 1.04 eV with respect to the conduction band, and three with activation energies of 0.2, 0.55 and 0.85 eV relative to the valence band. They suggested that the activation energy of this level is close to that widely reported at about, 0.62 eV above the valence band edge in CdSe (Ture et al. 1985) (13) which has been associated with double ionised Cd vacancies. The other principal center observed here at 1.0 eV may be related to the trap reported by (Al-Bassam, et al 14-18) with an activation energy of 1.04 eV with respect to the conduction band. Lewis et al suggested that this level would be primarily, an electron trap.

#### 4-Conclusion:

Schottky barriers on Zinc Cadmium Selenide  $Zn_xCd_{1-x}Se$  mixed crystals grown from the vapor phase have been investigated. The barrier height and uncompensated donor density have been determined in this composition. Photocapacitance of Schottky Barriers on Zinc Cadmium Selenide Solar Cells. were also investigated in these diodes using photo capacitance techniques, which revealed the presence of two of about dominant levels with activation energies 0.2, 0.4, 0.55, 0.85 eV above the top of the valence and one with an activation energy at about 0.85 - 0.95 eV below the conduction band.

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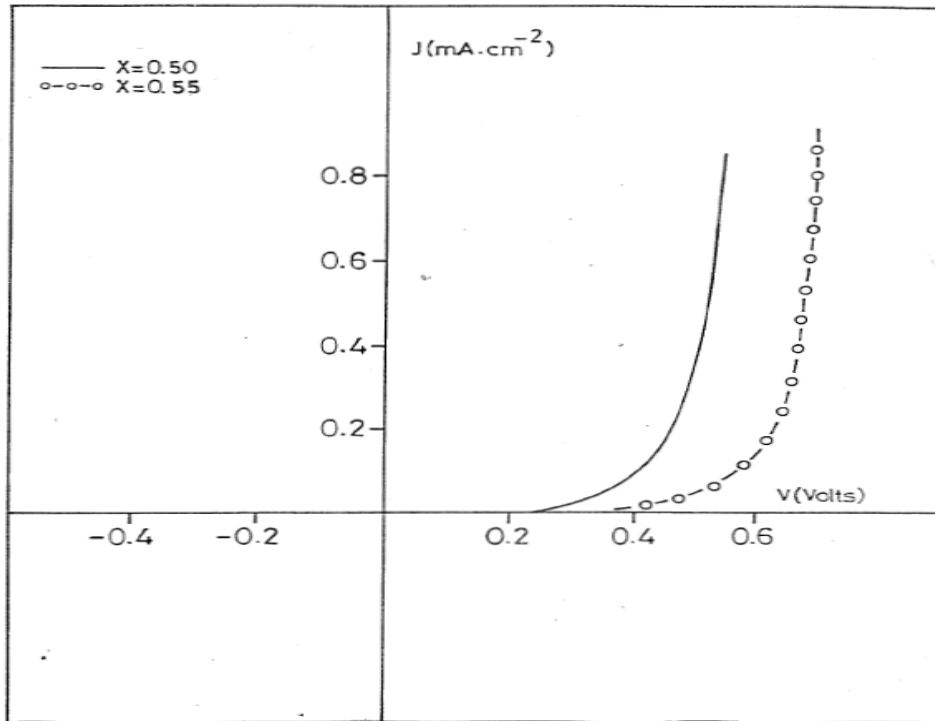


Figure: 1 Dark I -V characteristics for Au - Zn<sub>x</sub> Cd<sub>1-x</sub> Se

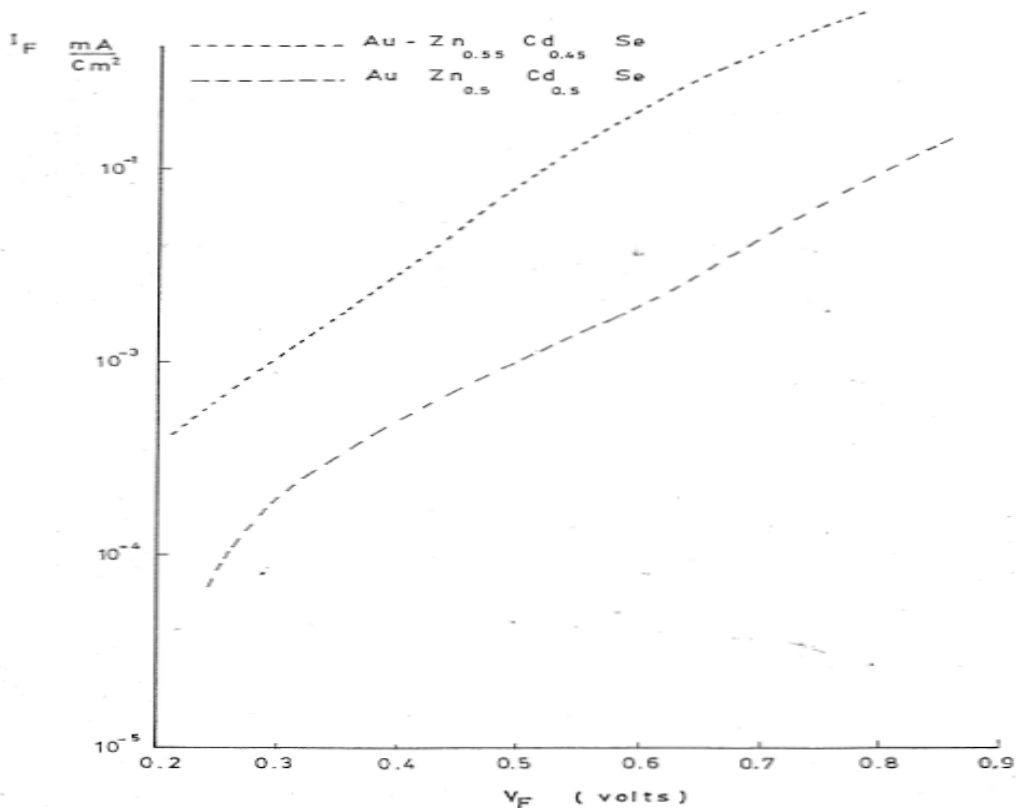


Figure:2 Log I - V for Au -Zn<sub>x</sub> Cd<sub>1-x</sub> Se

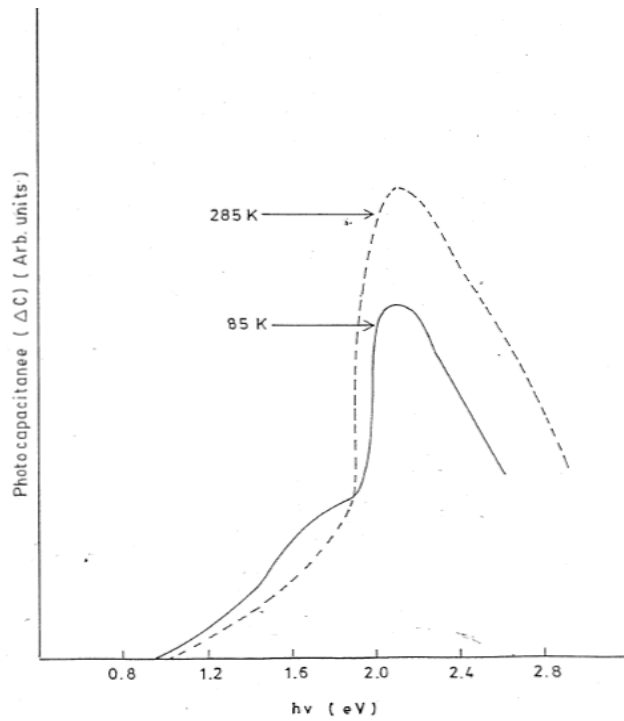


Figure:4 Photocapacitance spectra for Au - Zn<sub>0.5</sub> Cd<sub>0.5</sub> Se at 285 k and 85 k.

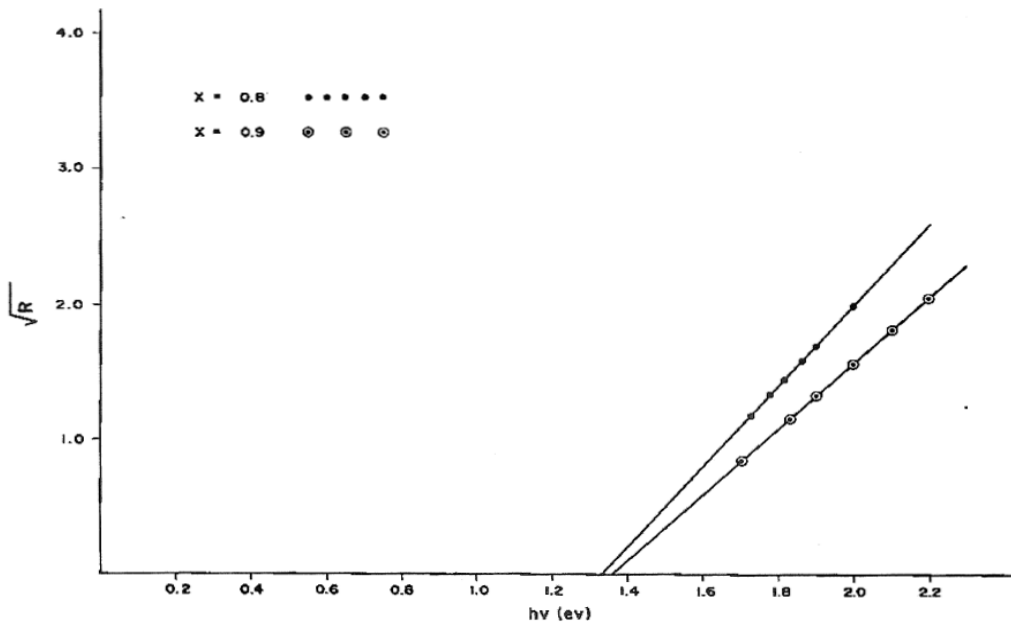


Figure 3. Squareroot of the Normalized Photocurrent R as a Function of Photon Energy for Zn<sub>x</sub>Cd<sub>1-x</sub>Se (0.8 < X < 1) Schottky Diodes.