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Studies on InP Based Heterojunction Solar Cells: InP/ITO

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ITO/InP solar cells were fabricated with ITO films deposited on Zn doped InP (100) wafers by d.c. sputtering. The optimum values of the physical constants of the ITO window layers for preparing ITO/InP solar cells were obtained. Best cells were produced for ITO layers sputtered with 7% of oxygen and the open circuit voltages and short circuit currents of the devices were in the range 0.65 - 0.70 volt and 25 - 30 mA/cm^2 respectively with fill factor $\sim$ 0.60.

1. TEXT

Amongst different InP based devices, ITO/InP and (Cd,Zn)S/InP are considered to be of much importance due to the fact that devices with a high ($\eta >$ 10%) conversion efficiencies may be produced. In general, InP based devices created much interest for the production of efficient devices for space applications. ITO/InP solar cell with efficiency of the order of 19% was fabricated[1)] by using a p^+ InP buffer layer deposited by MOVPE.

We have reported here the characteristics of ITO/InP cells produced on Zn doped ($2.5 \times 10^{15} cm^{-3}$) InP wafers. ITO layers were formed at various partial pressures of oxygen in order to obtain window layers most suitable for the preparation of efficient ($\eta >$ 10%) solar cells. ITO films (80 $\sim$ 160 nm) were deposited onto the cleaned and etched InP surfaces (100) by sputtering of In-Sn alloy (5 wt% tin) target in argon + oxygen plasma using a d.c. field (5.5 kV, 50 mA). The oxygen partial pressure in the chamber was varied from 2$\sim$12% to obtain device grade ITO films. Chamber pressure during deposition of ITO was maintained at $\sim 10^{-3}$ to $\sim 10^{-4}$ torr and the rate of deposition was kept within 0.15 $\sim$ 0.20 nm/sec. A maximum of 15 k rise in temperature was observed during sputtering. Devices thus fabricated were characterized by I-V, C-V, spectral response and surface photovoltage measurements.

2. RESULTS AND DISCUSSION

The variation of transmittance and the absorption coefficient (α) with partial pressure (P) of oxygen indicated that with increase of P the transmittance (Tr) and electrical resistivity increase quite rapidly whereas the absorption coefficient decreases more or less steadily. So to produce ITO for ITO/InP devices, a compromise had to be made between the transmittance and the resistivity for the best performance of the cells. The variation of the band gap (E_{opt}) of ITO layer with partial pressure of oxygen was studied.

Figure 1 shows the I-V plot of a representative ITO/InP solar cell with efficiency (η) nearly $\sim$12%. The cell parameters for devices

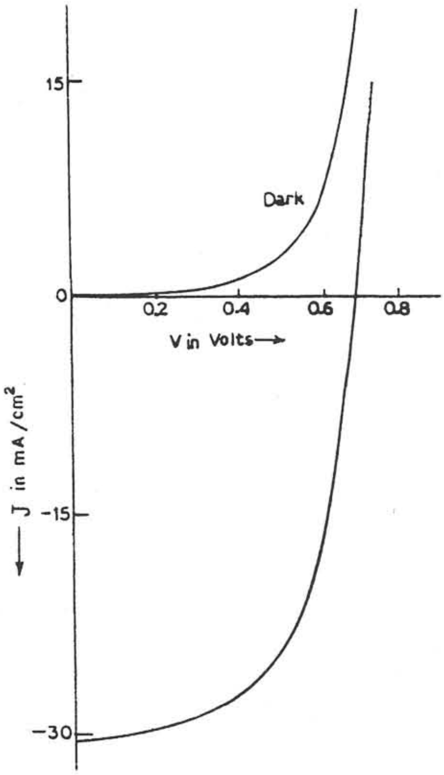

Fig. 1 The I-V plot of an ITO/InP device.

with efficiencies in the range 10 ~ 12% are shown in table I. It may be noted that the open circuit voltage (V_{oc}) varied in the range 0.65 - 0.70 volt.

Table - I : Cell parameters of devices

Cell No.	V_{oc} Volt	J_{sc} mA/cm^2	FF %	efficiency %
I-5	0.696	30.6	56.3	11.99
I-5BL	0.680	20.0	60.0	10.05
I-5CL	0.650	25.0	55.0	10.25

The short circuit current, J_{sc} (25-30 mA/cm^2) was very much dependent on the resistivity of ITO layer. The resistivity (ρ) and Hall mobility (μ) measurements of the ITO films producing the most efficient cell ($\eta \sim 12\%$) indicated $\rho \sim 2 \times 10^{-3}$ ohm-cm and $\mu \sim 8$ cm^2/V-sec. It was observed that the fill factor of our devices varied in the range of 0.55 to 0.60.

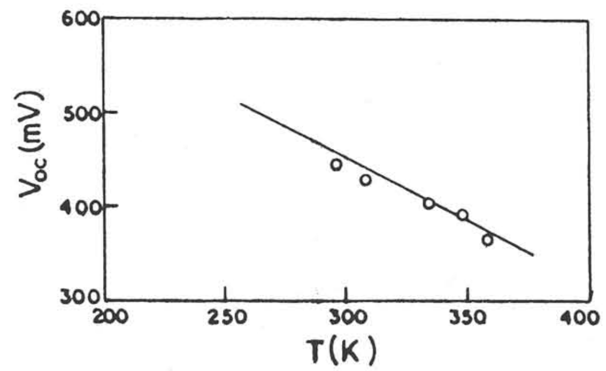

Fig. 2 The variation of V_{oc} with temperature for a representative ITO/InP device.

In order to study the temperature dependence of the open circuit voltage (V_{oc}), the I-V plot was recorded in the temperature range 290K to 360K. Fig. 2 shows the V_{oc}-T plot for a representative solar cell. The linear dependence of V_{oc} on temperature could be explained by the following relation,

$$V_{oc} = Y \ T + B$$

where Y is the temperature coefficient of the open circuit voltage.

The values of Y and B obtained from the slope and intercept in Fig. 3 are 1.34×10^{-3} V/K and 0.72 volt respectively.

The capacitance (C) versus bias voltage measurement of ITO/InP devices was carried out at a frequency of 10 MHz from +5 to -5 volt using a CV plotter (Micro Manipulator, Model 410). It was observed that our data showed a better linear fit with $1/C^2$ versus V plot (fig. 3) rather than $1/C^3$ versus V plot. The doping density, determined from the intercept of fig. 3 indicated good agreement with the known doping density of InP chips (2.5×10^{15} cm^{-3}). The value of the diffusion potential obtained from the intercept of the above plot was 1.18 V and was in good agreement with that (1.14 V) obtained from spectral response (Fig. 4) studies.

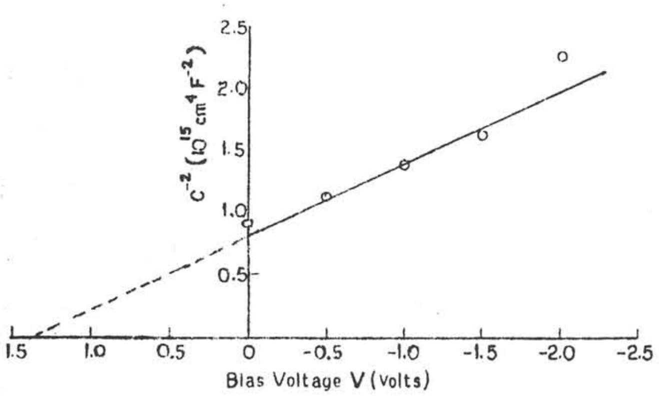

Fig. 3. $1/C^2$ versus V (reverse bias voltage) of an ITO/InP device.

The parameters of ITO/InP solar cells with high efficiency (> 10%) were compared with those obtained by others, from which it was observed that the most encouraging values of $\eta \sim 16.5\%$ with J_{sc} ($\sim$27.94 mA/cm^2) and FF (~ 74.8%) were obtained by Coutts et. al[1]. We have obtained $J_{sc} \sim 30.6$ mA/cm^2 for our best device for which V_{oc} (~ 0.696V) is less than that reported by Coutts et. al (~0.768 V).

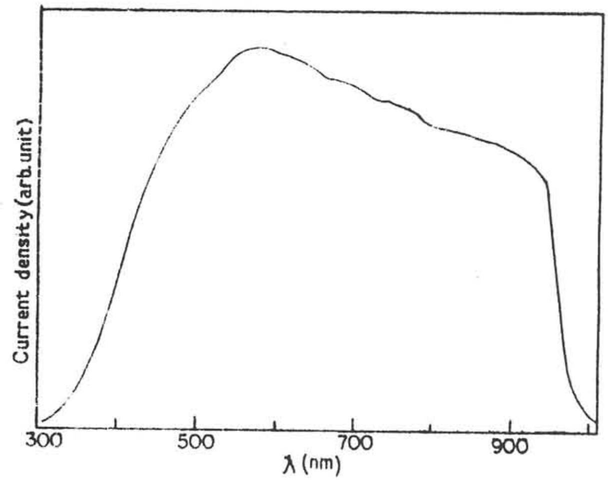

Fig. 4 Spectral response of an ITO/InP device.

From the above studies on ITO/InP devices it was concluded that the interface phenomena in the junction mainly determines the device parameters and as such the overall performance. To improve the cell characteristics further, a clear understanding of the defect states at the interface which controls the recombination of carriers, is required.

3. REFERENCES

1) X. Li, M.W. Wanlass, T.A. Gessert, K.A. Emery, and T.J. Coutts, Appl. Phys. Letts, 54, 2674 (1989).