PHOTOVOLTAIC PROPERTIES OF In_2Se_3:Si HETEROJUNCTION

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Abstract

In_2Se_3:Si heterojunction is developed using the evaporation technique. It shows a photovoltaic behaviour. Photovoltaic spectrum shows a broad band around 740 nm with a exponential tail towards higher wavelength side. Current--voltage characteristics and output characteristics are reported. Fill factor value is 29%.

In_2Se_3 compound is discovered as early as 1910[1]. Its crystalline and thin film characteristics are reported in detail[2-12]. So far no attempt has been made for a heterojunction in this material. In recent years heterojunctions are showing a considerable research interest in the area of photovoltaic devices. We made the attempt to develop the heterojunction of In_2Se_3 on silicon base using evaporation technique and studied their photovoltaic behaviour. Results are reported here.

The substrate is an p-type silicon single crystal wafer with a resistivity $10^2\,\Omega$cm, doped with boron, having $n \simeq 3 \cdot 4 \times 10^{16}$ atom oxygen/cm^3. It is mechanically polished using the Alumina powder of grain size 0.1 and 0.06, respectively; washed with water, Aceton, and Trichloroethylene;

finally, chemically etched in a solution of HF : HNO_3=1 : 10, rinsed in the deionized water and dried rapidly. A gold film is evaporated onto one side for a back contact.

n-type polycrystalline In_2Se_3 is obtained using direct synthesis of pure Indium and Selenium in stochiometric proportion in our laboratory[9-11]. It is pounded into small pieces and evaporated onto the silicon wafer, using a mask of 2 cm open diameter. The thickness of the film is 1100 ∓ 100 nm. For an ohmic contact, Indium film is deposited onto it using the cross mask of small size. During all the evaporations the order of vacuum is $1{,}33 \cdot 10^{-2}$ Pa Silver paste is used for contacts.

At low forward bias the current is given by

$$I = I_o \exp(eV/nKT) - 1 \quad ,$$

where I_o is the saturation current, e the electronic charge, V the applied bias, n factor determined experimentally, K the Bolzmann constant and T the absolute temperature.

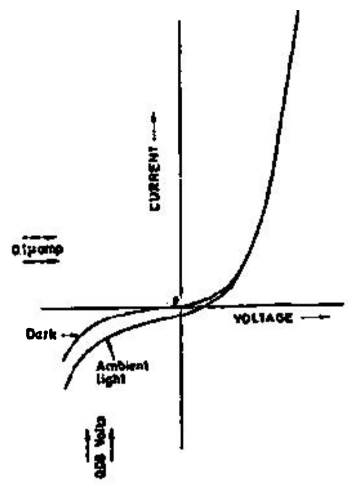

Fig 1

Figure 1 shows the current - - voltage characteristics of the junction at room temperature (26°C) in dark and in ambient light, respectively. It shows a good diod characteristics. n-factor value calculated from the above equation is 1.49 and the I_o value deduced from this figure is 3.8×10^{-8} amp.

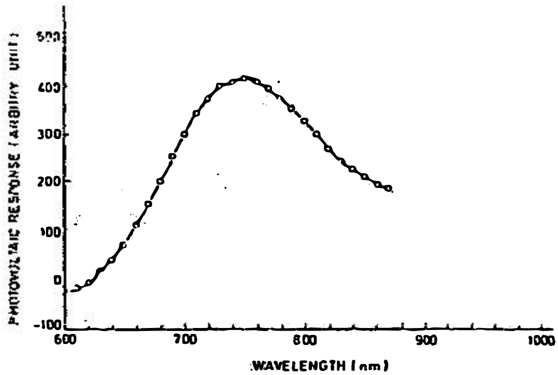

Fig. 2

Figure 2 shows the photovoltaic spectrum i.e. photovoltage as a function of wavelength, for the heterojunction of In_2Se_3 : Si. It has a broad band peaking at 740 nm with a exponential tail towards the higher wavelength side. Earlier similar behaviour is observed for the photovoltaic spectrum of a p-n junction in $GaAs_{0.85}P_{0.15}$ and the exponential behaviour is correlated with the abruptness of the junction[13].

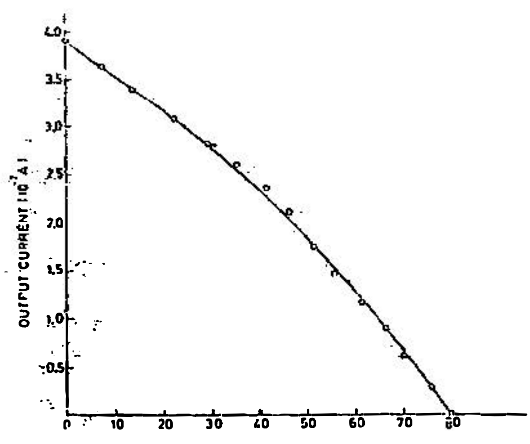

Fig 3

Figure 3 shows the output characteristic of the junction measured in ambient light at room temperature. The fill factor value deduced from the figure is 29%.

Current - voltage characteristics, spectral photovoltaic response and the fill factor value of In_2Se_3 : Si heterojunctions shows good photovoltaic properties and diod characteristics. It makes the possibility for solar device application on improving powder output e.g. reducing the series resistance. This is possible on improving the fabrication technology.

The In_2Se_3 film is deposited onto the silicon substrate at room temperature and the film has the amorphous nature. Earlier work[12] on In_2Se_3 thin film shows that the amorphous structure changes slowly to polycrystalline nature on heat treatment and also its resistivity value becomes lower by an order of magnitude. Therefore, the further work in this direction may improve the power output.

It is well known that heterojunction with appropriate electron affinities, good lattice and crystal match and negligibly small difference in the thermal expansion coefficient will form good photovoltaic devices. Also earlier experimental data indicated good performance of some oxide semiconductors and base semiconductor, which is not as yet completely understood, the strains due to crystal structure, lattice parameter and perhaps thermal expansion coefficient mismatch, thus in effect grading one side of junction into the other. A basic theory of ITO / silicon heterojunction solar cell operation with an interfacial layer or an SIS solar cell has been proposed in terms of minority - carrier tunnel current transport through the interfacial layer where one semiconductor is in non-equilibrium mode. The thermal expansion coefficient of In_2Se_3 and silicon are 6.8×10^{-6} per ^{o}C, 2.44×10^{-6} per ^{o}C, respectively. Silicon is a diamond structure with a lattice constant 5.431 Å while In_2Se_3 is a hexagonal structure with the unit cell dimensions[9] at 25°C $a = (4.025 \pm 0.005) \cdot 10^{-1}$ nm and $c = (19.235 \pm 0.05) \cdot 10^{-1}$ nm. In this case it is difficult to conclude the picture of junction formation and the process phenomena involved on the basis of present results only. Perhaps there may be an interfacial layer at the junction and the case may be treated as SIS with a possibility of tunneling. Further experimental work on I-V characteristics and C-V measurements at different temperatures will make the better understanding.

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