GROWTH OF SnO_2:F BY CVD AND n^+SnO_2:F/n-Si (poly) SIS SOLAR CELLS

by

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CERTIFICATE

This is to certify that the thesis entitled "GROWTH OF SnO_2:F BY CVD AND n^+SnO_2:F/n-Si (poly) SIS SOLAR CELLS" by Mr. Anil K Saxena, submitted to the Indian Institute of Technology, Delhi, for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him under our guidance and supervision. The results presented in the thesis have not been submitted in part or full to any other University or Institute, for the award of any degree or diploma.

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ABSTRACT

The wide band gap semiconductors In_2O_3 and SnO_2 have received a great deal of attention owing to their property of simultaneous occurrence of optical transparency and electrical conductivity. These semiconductors show high transmission in the visible region. They are n-type materials and the electron concentration in the conduction band primarily arises from the lack of stoichiometry, produced by the deficiency of oxygen. The difference in the work function of SnO_2, In_2O_3 and that of n-Si, gives rise to a barrier at the interface. These properties make these oxide semiconductors suitable as a top conducting layer in SIS Si solar cells.

Films of In_2O_3:Sn, 10 wt.% Sn, were deposited by spray pyrolysis at a substrate temperature of 450°C. The dependence of Hall mobility, conductivity and crystallinity on the thickness of In_2O_3:Sn films was studied. These studies showed that the Hall mobility and conductivity increased with the increase in film thickness and saturated after a thickness of 500 nm. A further increase in the film thickness reduced the optical transmission. Scanning electron micrographs and x-ray diffraction patterns revealed that thicker films had better crystallinity.

The 600 nm thick film had the mobility of about $36 \times 10^{-4} m^2 V^{-1} s^{-1}$ and conductivity of about $37 \times 10^{4} \Omega^{-1} m^{-1}$. It was concluded that the optimum thickness of In_2O_3:Sn films prepared by spray pyrolysis is about 500 nm. It was also concluded that in thicker films, ionized impurity scattering mechanism was predominant.

The chemical vapour deposition (CVD) apparatus, for the deposition of SnO_2:F films was fabricated in our laboratory. A double temperature zone furnace was made by winding two independent heating elements on a quartz tube. The temperature of the furnace was controlled by electronic temperature controllers. The heating element was also wound on the bubbler and the connecting tubes, to prevent the condensation of vapours. $SnCl_4.5H_2O$ was used as the source material and 48% HF (electronic grade) as the doping material. Very pure oxygen gas was used as the carrier gas and as oxidising agent. Doping of F was done by mixing required amounts of HF in molten stannic chloride. A constant temperature zone, in the middle of the furnace, was maintained at a required temperature. The temperature of the bubbler containing stannic chloride and HF was maintained at 200^oC. A flowmeter was used between the oxygen cylinder and the bubbler to know the flow rate of the carrier gas.

A number of samples of SnO_2:F films on glass and quartz substrates were prepared at rough optimum doping level of fluorine and various substrate temperatures and oxygen flow rates. The best figure of merit decided the optimum substrate temperature of $350^{o}C$ and an optimum oxygen flow rate of about 2.5 $lit.min^{-1}$. The final optimum doping level of fluorine was found out to be 1.02 wt.%, for the samples of SnO_2:F films, having the best figure of merit, maximum optical transmission of 83% and minimum sheet resistance of 6 $\Omega/\square$. The carrier concentration and Hall mobility also attained a maximum value of $\sim 3 X 10^{26}\ m^{-3}$ and $\sim 29 X 10^{-4} m^2 V^{-1} s^{-1}$ respectively at 1.02 wt.% of F. Scanning electron micrographs also revealed that crystallinity of the films deteriorated for doping level other than the optimum doping level. X-ray diffraction patterns revealed that the films deposited with optimum doping level did not show a preferred orientation while the films of doping level other than the optimum doping level had preferred orientation. The optical studies gave a direct band gap of about 4.29 eV and an indirect band gap of about 2.7 eV.

The dependence of Hall mobility and conductivity on the thickness of films was studied. The optimum thickness of SnO_2:F films for maximum mobility and conductivity was found out to be about 900 nm.

The pure SnO_2 films and SnO_2:F films deposited under optimum conditions were subjected to annealing studies in oxygen and nitrogen atmosphere. These studies revealed that the resistivity of pure SnO_2 films varied a lot with annealing time while the resistivity of SnO_2:F films remained constant. This behaviour proved that SnO_2:F films were much more stable than pure SnO_2 films.

n^+SnO_2:F/n-Si (poly) SIS solar cells were prepared by CVD. Prior to the deposition of SnO_2:F films on Si, a back contact was made by electroplating of nickel. A thin insulating layer was then grown thermally on Si and SnO_2:F films were deposited by the CVD apparatus. The front contacts were made by evaporating silver through a metal mask. The dark I-V characteristics revealed that the dominant current transport mechanism was multistep tunnelling and C^{-2} vs V curve showed that the junction was abrupt. The best cell displayed V_{oc} = 0.505 V, J_{sc} = 240 Amp./m^2, F.F. = 0.61 and η = 9.2% under 800 W/m^2 insolation.

The spectral response (relative) was also high in a wide range of wavelengths and was better in the high energy region as compared to that of a p-n homojunction Si solar cell.

The thermal stress studies showed that $n^{+}SnO_2$:F/n-Si (poly) solar cells were more stable than SnO_2/n-Si solar cells.

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