OPTIMISATION OF SPRAY DEPOSITED Sno_2 THIN FILM FOR SOLAR CELL FABRICATION

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ABSTRACT

The use of conducting tin-oxide (SnO_2) films for fabrication of solar cell is becoming increasingly important because of reasonably high efficiency and ease in fabrication. The role of the thin-oxide film is very critical for high efficiency. Resistivity, thickness and transmittance of the film should be of correct order. The most favourable conditions for fabrication of SnO_2 layer with low resistivity and high transmittance is reported in this paper. Effect of doping and annealing on these properties has also been studied. It is observed that doping with antimony gives better layer with sheet resistivity of approximately 60 ohm/square (Ω/◊) and transmittance of the order of 80%. Annealing in air and vacuum shows a decrease in resistivity while it has negligible effect on its transmittance. Attempts have also been made to fabricate Sn_2/Si solar cell with the present set up, and efforts are being made to optimize its performance.

1. INTRODUCTION

The cost reduction and simplification of technology involved in fabrication of solar cells are two major areas where research efforts are to be concentrated. Silicon solar cells which are most commonly used are made up of a single crystal semiconductor, and junction is formed using diffusion technique, which involves sophisticated technology and high cost.

There exist a number of low cost processes by which simicon Solar cell can be produced. In the last few years SnO_2/Si and ITO/Si solar cells are gaining importance due to its ease in fabrication and low cost. SnO_2 layer could be deposited in a number of ways, of which the chemical spraying technique is rather attractive due to its simplicity. The salient feature of the SnO_2, is that it only absorbs in the UV and therefore acts as a window for sunlight [1]. In this device the barrier is located at the interface and therefore reduces surface recombination.

The performance of the SnO_2/Si solar cell depends mostly on the proper fabrication of the $sn0_2$ layer. Spraying technique together with suitable doping and annealing, has achieved high conversion efficiency [2-6].

We have successfully set up and used spraying technique for the fabrication of SnO_2 /Si solar cell. Efforts have also been made to optimize conditions that can yield $sn0_2$ layer suitable for cell fabrication. Effect of doping and annealing is also studied. Finally, the behaviour of SnO_2/Si junction is also reported.

2. EXPERIMENTAL DETAILS

The undoped SnO_2 films were prepared by spraying a solution containing Tin chloride, propanol and Hydrochloric acid, on a glass substrate. The substrate was placed on a heater which has a temperature control unit. The experimental set up is shown in figure 1. The carrier gas used was compressed air. The solution contains equal volumes of O.7M $SnC1_4.5H_20$, 10M propanol and required amount of O.1M HCl to keep the pH value of the solution approximately 1. Ordinary glass slide cleaned and etched was used as substrate. The temperature of the substrate was varied between 35^{0}C to 500^{0}C keeping it in direct contact with the heater. The solution was sprayed onto the substrate at various temperatures and pressures. Resistivity and transmittance of each sample were measured to optimize the temperature and pressures to obtain good quality films with reproducible characteristics. Subsequently. The films were doped with Antimony by adding $SbCl_3$ in the main solution. Characterization of these doped films was done as before. This was repeated for various Sb concentrations. Effect of annealing of the films at different temperatures was also studied to obtain films with low resistivity and high transmittance.

Finally, the films were deposited on Si substrate to form Sno_2 /Si hetero junction. The back ohmic contact was formed on an n-type Si wafer using electroless technique [7]. One side of the wafer was masked and then dipped into palladium solution for about 3 minutes at 60-65 ^{0}C. It was then immersed in the electroless nickel solution for 4 minutes. When the back contact was formed, the mask is removed and the front surface is thoroughly cleaned and etched. The wafer is immediately taken to the spraying chamber for sno_2 deposition.

3. RESULTS

The sheet resistivity was measured in each of the samples. Transmittance was measured using an IR spectrometer. The measurements revealed that temperature of 450 ^{0}C and pressure 1.5 bar yielded the best quality films with sheet resistivity 100Ω/◊ and transmittance of approximately 90% Effect of doping concentration on the films is shown in figure 2. It is observed that resistivity decreases rapidly with the addition of $SbCl_3$ up to 30mg in 15c.c. of the main solution. Thereafter, the resistivity is found to increase slowly with increase in the Sb content. The films thus obtained had sheet resistivity 60Ω/■ and transmittance 80%. The spectral transmittance of the films is shown in figure 3.

To reduce resistivity further, the samples were annealed at 200 ^{0}C [8]. Figure 4 shows the effect of annealing on the resistivity of the films. The lowest resistivity is obtained on annealing these films for 4 hours at a temperature of 200°C.

The basic characteristics of SnO_2/Si junction in dark is shown in figure 5. The junction was exposed to artificial light to study its behaviour as a solar cell.

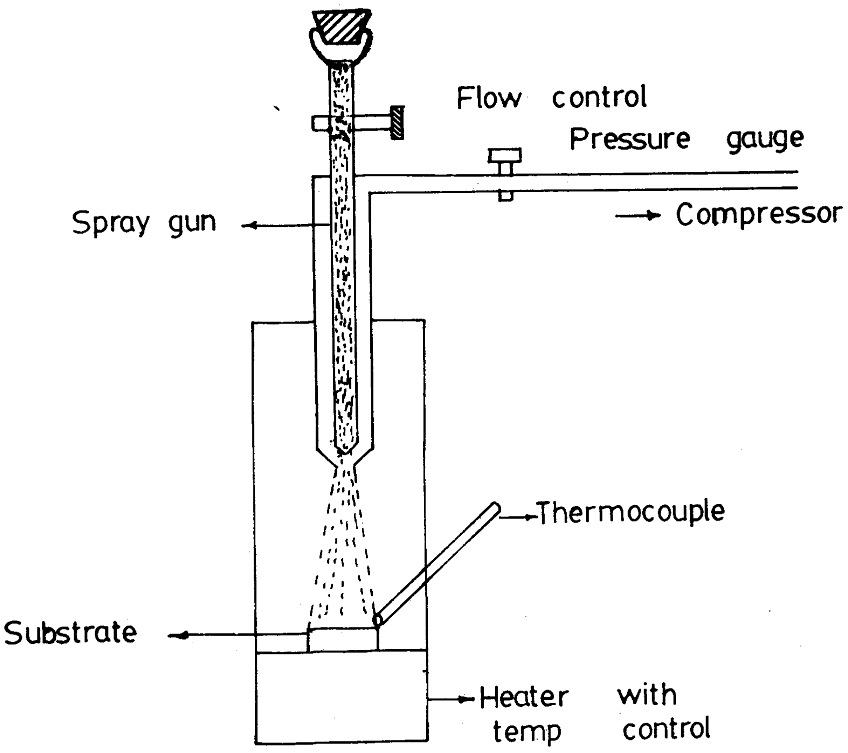

Fig 1 Experimental set up

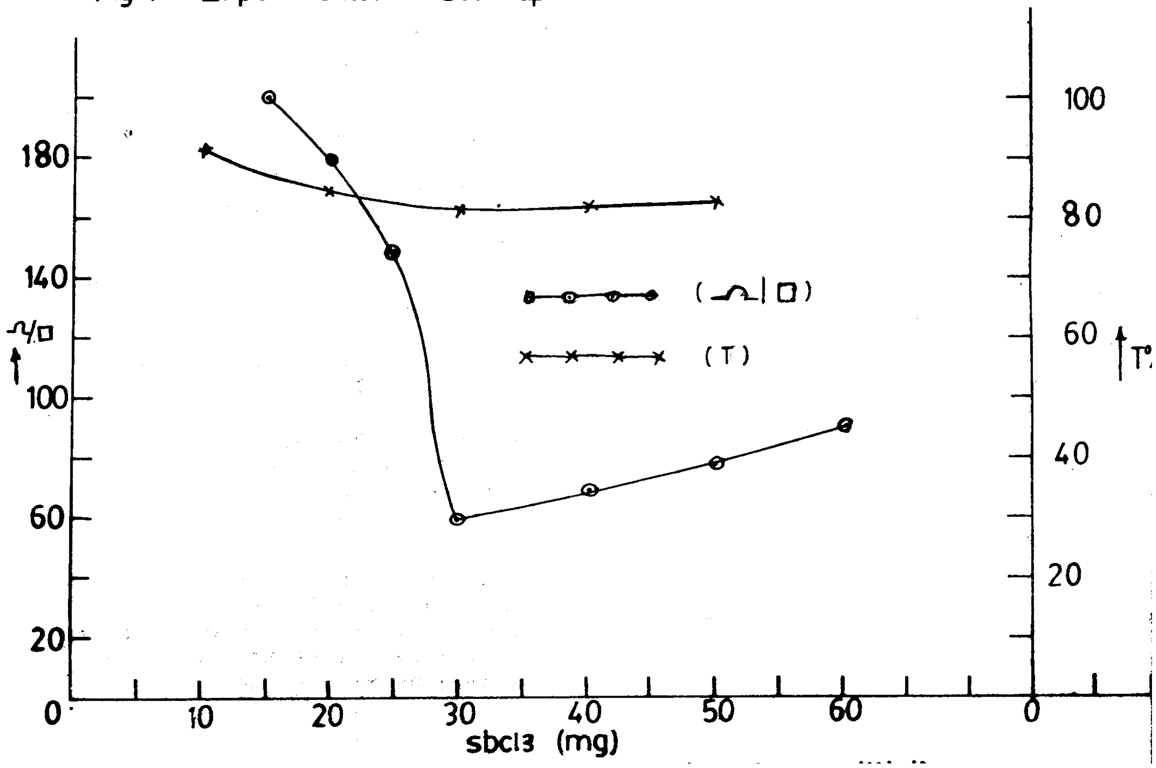

Fig 2: variation of resistivity and transmittivity with doping concentration of sbcl3

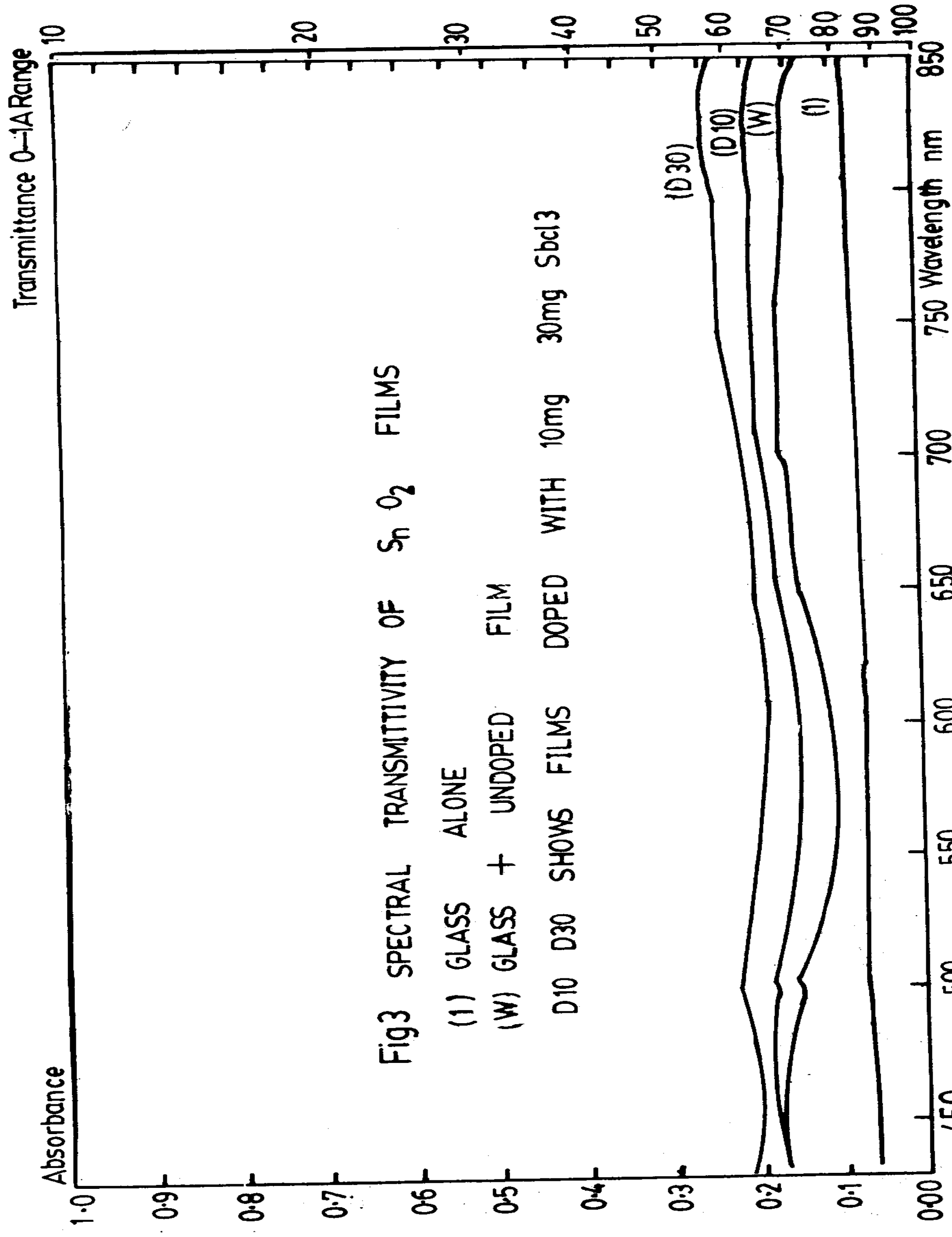

Fig3 SPECTRAL TRANSMITTIVITY OF $S_n O_2$ FILMS
(1) GLASS ALONE
(W) GLASS + UNDOPED FILM
D10 D30 SHOWS FILMS DOPED WITH 10mg 30mg Sbcl3

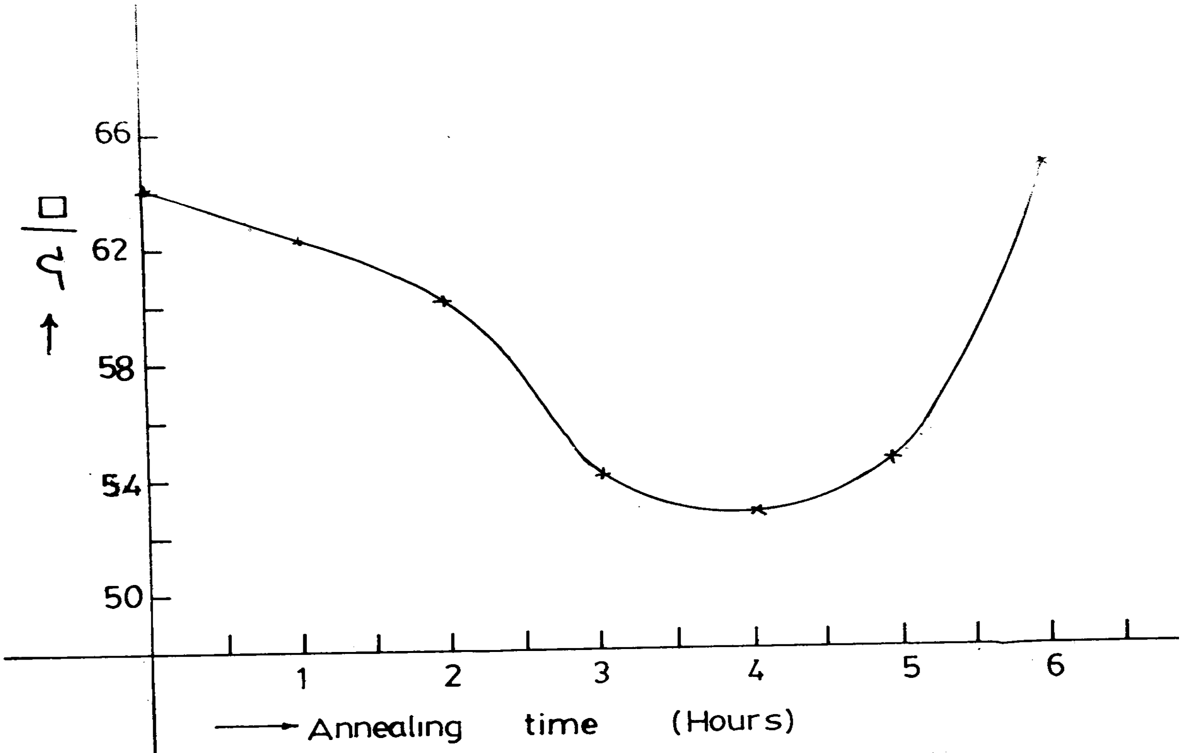

Fig 4 Variation of resistivity with annealing

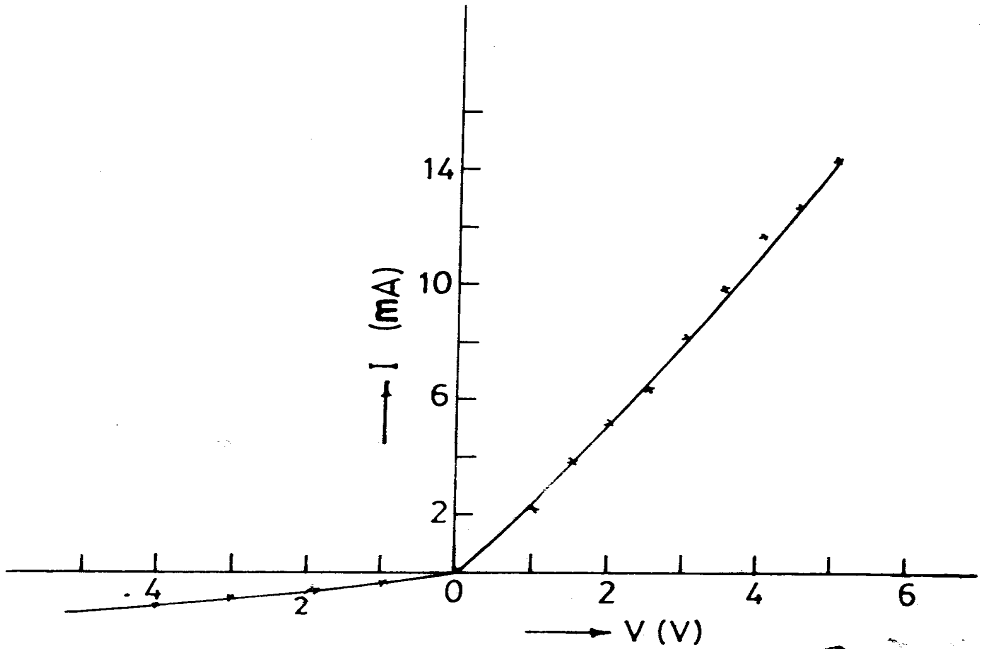

Fig 5 V–I Characteristic of SnO_2/Si Junction in dark

Measurements were made of the open circuit voltage and the short circuit current under 0.5 sun illumination using a digital multimeter. Open circuit voltage of 200mv and short circuit current of 1.0mA/cm^2 were obtained.

4. DISCUSSION AND CONCLUSION

The variation of electrical and optical properties of tin oxide films was studied as a function of antimony concentration and annealing time. The sheet resistivity of pure $Sn0_2$ is found to be rather high (100Ω/◊).Decrease in resistivity up to 30mg $SbCl_3$ doping is due to increase in carrier concentration. Further increase in $SbCl_3$ content, increases resistivity. This should be due to increased disorder that results in high activitation energy of the donor and the subsequent decrease in carrier concentration. Decrease in resistivity up to 4 hours of annealing in air is due to removal of defects such as grain boundaries and vacancies. Further increase in resistivity upon prolonged annealing may be due to formation of oxide of the dopant. Vacuum annealing is expected to eliminate this. Approximately 50% reduction in resistivity is the combined effect of the two processes. Increase in $SbCI_3$ concentration results in small decrease in transmittance. However, this is not a serious drawback, since the appreciable decrease in resistivity carries greater credit.

The carrier gas used here was air which may be the cause of high resistivity. Use of inert gas may help reduce the resistivity. Also, cleaning of silicon substrate is important in achieving good results. The low quality of the junction could be attributed to contamination of the wafer surface at the time of spraying due to absence of clean, inert atmosphere. Moreover, the exposure of Si to air at 450^{o}C might result in the formation of SiO_2 layer on its surface. This SiO_2 layer plays an important role in the behaviour of the junction [9]. Attempts are being made to control the SnO_2 layer thickness to improve the performance of the junction.

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