ISOTYPE (n^+-In_2O_3 : Sn, F/n-Si) SIS SOLAR CELLS

by

S. P. SINGH
DEPARTMENT OF PHYSICS

SUBMITTED IN FULFILTENT OF THE
REQUIREMENTS OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

APRIL, 1985

CERTIFICATE

This is to certify that the thesis entitled "ISOTYPE (n^+ In_2O_3:Sn,F/n-Si) SIS SOLAR CELLS" by Mr. S.P. Singh, 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 this thesis have not been submitted in part or in full to any other University or Institute, for the award of any degree or diploma.

O.P. Agnihotri 22.4.1985

Professor O.P. Agnihotri)
Department of Physics
Indian Institute of Technology
Delhi (India).

L.M. Tiwari

(Dr. L.M. Tiwari)
Assistant Professor
Department of Physics
Indian Institute of Technology
Delhi (India).

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to Professor O.P. Agnihotri and Dr. L.M. Tiwari for their invaluable guidance, continuous encouragement and inspiration during all stages of this work.

Thanks are due to my colleagues of materials research group, especially Drs. R. Thangaraj, A.Raza, A.K. Raturi, P. Raja Ram, Messrs A.K. Saxena, Rajesh Rampal, J.P.Mangalhara, P.K. Sharma, S.K. Samdarshi, Aquil Sheikh and Miss Nisha Bindal for their intensive cooperation and objective criticisms. Thanks are also due to Mr. Som Dutt, Mr. Durga Prasad and Mr. Rakesh Kumar for their help.

Financial support to this work from DNES, Ministry of Science and Technology, DRDO, Ministry of Defence and Department of Space, Government of India, is gratefully acknowledged.

I am also thankful to Mr. N.S. Gupta for his neat and efficient drawing work and to Miss Neelam for her skillful and efficient typing of the manuscript.

Finally, I would like to thank my parents, wife and son Gautam for their forbearance to all my eccentricities.

SP Singh

(S.P. SINGH)

LIST OF PUBLICATIONS

1) Fluorine doped indium oxide films prepared by spray pyrolysis, Silver Jubilee Physics Symposium on Nuclear and Solid State Physics, B.A.R.C. Bombay, Dec. 28, 1981-Jan. 1,1982, p.507.

2) "Characterization of fluorine-doped In_2O_3 films synthesized by spray pyrolysis", Thin Solid Films 105(1983),131-138.

3) Optical investigations of In_2O_3:F films, presented at ICTF-6, Stockholm, August 13-17, 1984. Accepted for publication in Thin Solid Films.

4) SnO_2:F/n-Si and In_2O_3:Sn/n-Si SIs solar cells. Accepted for publication in Thin Solid Films.

Other Related Publications:

1) Thickness dependence of the electrical and structural properties of In_2O_3:Sn Films, Thin Solid Films 117(1984)95-100.

2) Characterization of SnO_2:F films synthesized by CVD. Thin Solid Films, Communicated (1985).

ABSTRACT

Window-absorber configuration consisting of an oxide semiconductor as window and silicon as absorber has drawn considerable attention recently because of its simplicity of fabrication and good performance. An oxide semiconductor apart from having good transparent conducting properties must have a suitable work function to give high barrier with an absorber. The SnO_2 and ITO/n-Si configurations are reported to exhibit good photovoltaic properties. In the present thesis, fluorine is introduced to enhance the conductivity and stability of indium oxide films. An optimum doping and substrate temperature of 11.4 wt% of NH_4F and $310^{\circ}C$ respectively were found to give a sheet resistance of $\sim$ 10 ohm/square with a transmission of > 90%. The films showed preferred orientation with (100) planes parallel to the substrate. The optical measurements were used to evaluate the Moss Burtein-shift and plasma frequency and further to deduce the effective mass of the carriers. The effective masses of the conduction band and combined of the valence band and conduction band was found as 0.24 and 0.49 m_o respectively.

The simultaneous dopings of Sn and F in indium oxide reduced the sheet resistance to 5-7 ohm/square without affecting the transmission of the films. X-ray diffraction studies of In_2O_3:F or In_2O_3: Sn,F show an extra phase due to the presence of (112) InF_3 peak. XPS studies also reveal the presence of

InF_3 phase embedded in In_2O_3 matrix. Annealing studies of the above films reveal that an excess oxygen dissolution model can explain the decrease of the sheet resistance after annealing in N_2 and increase of that after annealing in oxygen. A sheet resistance of 1.9 ohm/square with 89% of transmission was obtained after annealing at 500°C in N_2 for a film of In_2O_3: Sn,F deposited at 380°C.

Solar cells of SnO_2:F or In_2O_3: Sn or In_2O_3:F/SiO_x/n-Si with SiO_x layer grown by treating Si in concentrated HNO_3 at 60°C yielded efficiencies of around 10%. The deposition temperature of the window materials were 310, 380 and 330°C for the three systems respectively.

The solar cells were also fabricated on semi-crystalline silicon and an efficiency of 8% was achieved. The low efficiency was due to the low diffusion length of minority carriers in these cells. The current transport mechanism in the devices is attributed to the multistep tunneling. Thermal degradation of these devices showed that In_2O_3:F/n-Si interface was more stable than In_2O_3:Sn/n-Si interface.

CONTENTS