PREPARATION AND APPLICATIONS OF INDIUM TIN OXIDE IN PHOTOTHERMAL AND PHOTOVOLTAIC ENERGY CONVERSION

BY

AHMAR RAZA
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DEPARTMENT OF PHYSICS

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Ahmar Raza

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ABSTRACT

The high optical transparency and high electrical conductivity of indium tin oxide semiconductor have stimulated great deal of interest in display technology, electronics and solar thermal/photovoltaic energy conversion. The oxide semiconductors which transmit solar radiations but reflect thermal radiations are coated on the inner side of the coverplate of the flat plate collector. The radiation losses from the flat plate collector thus can be reduced and the efficiency of the collector can be enhanced.

The concept of a heterojunction solar cell, comprised of a conducting transparent window material on an active semiconductor substrate, offers the possibility of manufacture at low cost of solar cells with performance characteristics suitable for large scale terrestrial applications. In principle the window transmits the solar radiation directly to the active substrate with little or no attenuation, and the difference in the work functions of the different materials provides the bending of the energy bands at the interface, necessary for the production of photocurrent. In addition the window can serve simultaneously as the front contact and as an antireflection coating of the active substrate.

In the work reported in the thesis, the preparation of indium tin oxide (ITO) by a pyrolytic decomposition method has been described. 273.3 gms of $InCl_3.3H_2O$ was dissolved in a litre of butyl acetate. This solution was sprayed through a preheating furnace on to a heated glass substrate. A suitable double nozzle sprayer having a spray rate of 30 ml per minute was used. The substrate temperature, the preheating temperature, the spray rate, the distance between the sprayer and the substrate and Sn:In ratio (doping was done by adding $SnCl_4$ solution in the spray mixture) and the thickness of ITO was optimised for minimum sheet resistance, maximum optical transmission and maximum infrared reflection.

The effects of adding up to 50 mole % of tin to pyrolytic In_2O_3 coatings were investigated. Up to 10% doping the resistivity is found to decrease with the corresponding increase of carrier concentration. Further additions increase the resistivity and decrease the carrier concentration. X-ray diffraction and electron microscope observations indicated that (400) is the strongest peak. The films with low resistivities had very low activation energies for electrical conduction.

Because of the high transmission in the visible, and high infrared reflectivity ($\gtrsim$ 78%) the ITO films will find important applications in the solar energy conversion. When applied to the cover of the flat plate collector, the films will reflect the thermal infrared back to the collector, while the visible part will be almost completely transmitted. In order to assess the suitability of these conductors for photothermal conversion, the effective absorptivity, α_{eff} and the effective emissivity, ϵ_{eff} have been evaluated. α_{eff} ($\sim$ 0.80) and ϵ_{eff} ($\sim$ 0.14) are comparable to black coatings.

The 5000 Å ITO films with sheet resistivity of 50 ohms per square and 90% transmission were deposited onto n and p type silicon wafers (0.1 to 10 ohm cm) at 550^{o}C. In n-Si wafers (1-10 ohm cm) 10-12 mil thick, the V_{oc} was 210 mV, I_{sc} was 9.4 mA/cm^2, fill factor of 0.65 and quality factor 2.3 were obtained. The nickel was deposited on the back of the wafer by electroless method and contact was taken by making a grid on ITO. For n-Si wafers with resistivity 0.1-1 ohm cm an efficiency of 10.4% was obtained with V_{oc} = 445 mV, $I_{sc} \approx$ 18.0 mA/cm^2 and FF = 0.65. With p-Si, very poor efficiencies were obtained. A 5000 Å thick ITO film was deposited onto 5.6 ohm cm, 500 mil thick n-GaAs wafers at 450^{o}C. After lapping the back of the wafer Au-12% Ge was alloyed for taking the back contact. The solar cells with efficiencies of $\eta \sim$10.7% were fabricated.

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