Effect of Substate Vibration on the Properties of Dip Coated Indium Tin Oxide Thin Films

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Abstract

Thin films of indium tin oxide (ITO) were deposited on glass substrates using a dip coating unit, from a solution of indium chloride. Characterization of the films were done by X-ray diffraction, electrical resistivity measurement and optical transmission spectroscopy. The effect of substrate vibration on film properties was examined and observed that vibrations of small amplitudes do not deteriorate the film qualities much.

Keywords: *Indium tin oxide films, Dip-coating, Sol-gel, Substrate vibration*

Introduction

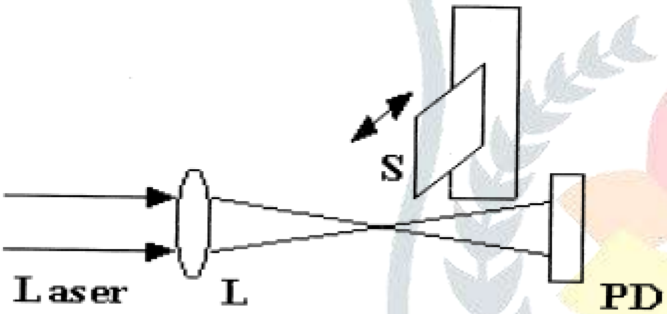
Sol-gel dip-coating can be used to produce thin films of any shape with simple and cheap instrumentation. Dip-coating cycle involves dipping and withdrawing the substrate in and from the sol at a uniform velocity, drying the sample, annealing and repeating this cyclic process. Technological applications of ITO films involve solar cells, anti-static coatings, flat panel displays, electro-luminescent devices and sensors. ITO films were prepared by a sol-gel process using metal salts and organic solvents as raw materials. A homemade dip coating unit has been used for the coating process with programmability of parameters like dip velocity, withdrawal velocity, dip time, drying time, drying temperature, number of dips, etc. The resistivity as a function of tin dopant concentration of ITO films was measured and the optical properties were investigated. The transmittance and resistivity as a function of the mean oscillation of the substrate about the equilibrium position of the optimized films were measured. It has been found that these parameters do not show much variation up to certain amplitude of vibration.

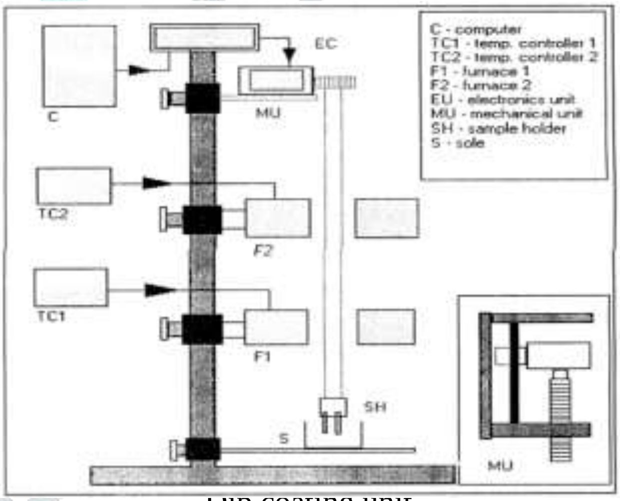
Experimental Details

The homemade dip-coater uses a stepper motor, controlled through the parallel port of a personal computer. The motor is placed on a sliding platform and it rotates a threaded bolt over which two nichrome wires hanging a tungsten sample holder are wound. The position of the holder in the horizontal plane remains unchanged during the process. The wires pass through two temperature controlled tubular furnaces, one for drying and the other for annealing the sample. Anhydrous indium chloride solution was prepared using acetyl acetone as solvent. The solution was refluxed at 80ºC for about one hour. Tin chloride was dissolved in ethanol and this solution was mixed with the refluxed solution at room temperature for doping. The molar ratio of indium chloride to acetyl acetone was fixed as 1:8 in the present study. The dip process was done in open atmosphere. The glass substrates were dipped into the solution for one minute. The dip velocity and withdrawal velocity were same. After the dip process, the substrates were dried in the drying furnace at 260ºC for about 10 min. This process was repeated by changing tin addition wt%. For 10 dip cycles, the films were found to have desirable properties regarding thickness, resistivity, transmittance, etc.

After dip process the films were annealed for about 1 hour at 500ºC. Four-point probe and Hall probe were used to measure electrical properties of the films. Spectrophotometer was used to study optical transmission studies in the 300-800 nm region. The thickness of the film was measured using multiple beam interferometer technique. X-ray diffractometer analyzed crystal structures. The stepper motor drive in the dip coating unit imparts considerable substrate vibration, which can be reduced by increasing the load on the sample holder. The maximum load is limited by mechanical strength of the nichrome wire and the torque of the drive. The amplitude of vibration is measured using an optical interruption technique. A laser beam detects the interruption caused by the vibrating holder. Corresponding to the maximum load, the minimum possible amplitude of vibration is 0.25 mm.

Helium-neon laser beam is focused using a convex lens (L) and a knife-like part of the sample holder (S) interrupts it. Photodiode (PD) senses the interruption. Laser, L and PD are placed on a micrometer-controlled X-Y translation

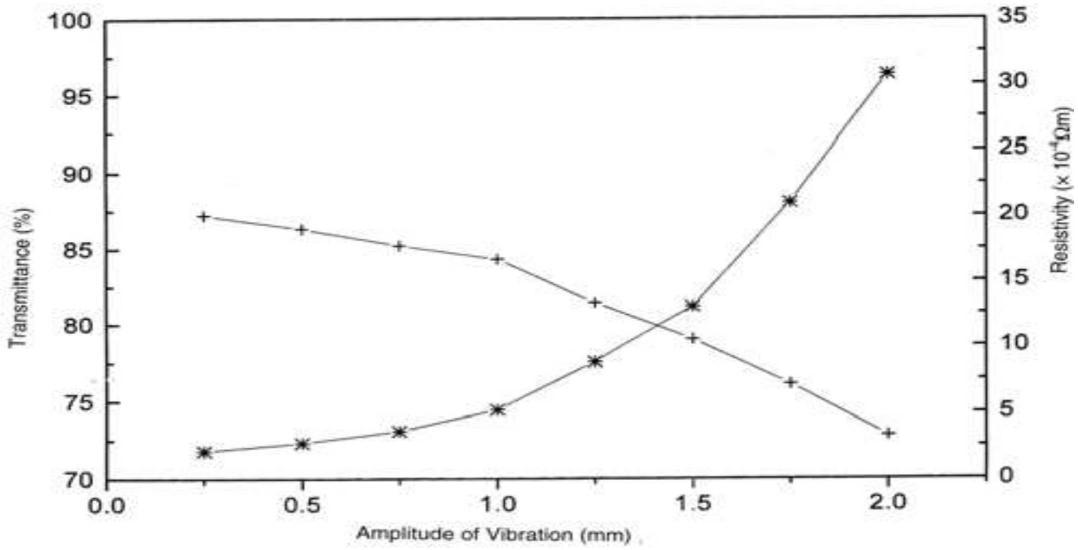




Dip coating unit

Effect of substrate vibration

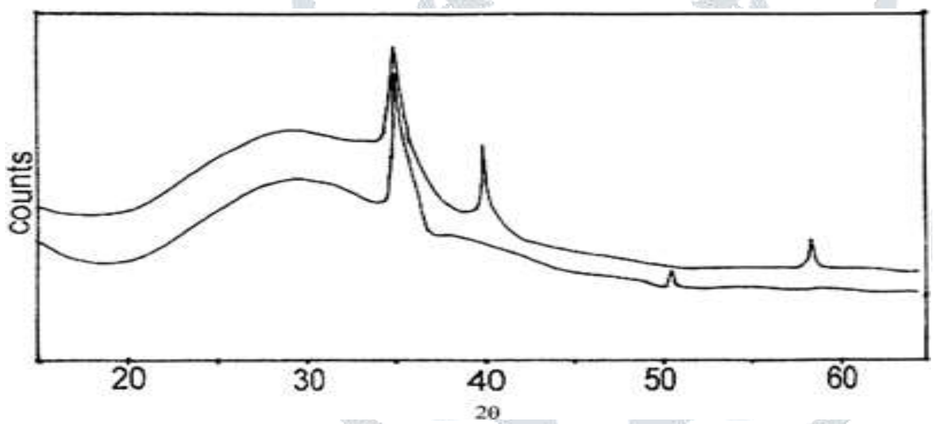
It has been observed that the optical and electrical properties of dip-coated ITO films are considerably affected by substrate vibration. The transmittance and resistivity of the 5 wt% tin doped ITO films have been studied as a function of amplitude of substrate vibration. The transmittance remains almost unchanged up to amplitude of vibration of 1 mm and thereafter transmittance decreases. The resistivity increases almost exponentially with increase in amplitude of vibration. The observed variation in resistivity and transmittance with amplitude of substrate vibration may be due to decrease in the crystallinity of ITO films with increase in amplitude of substrate vibration.



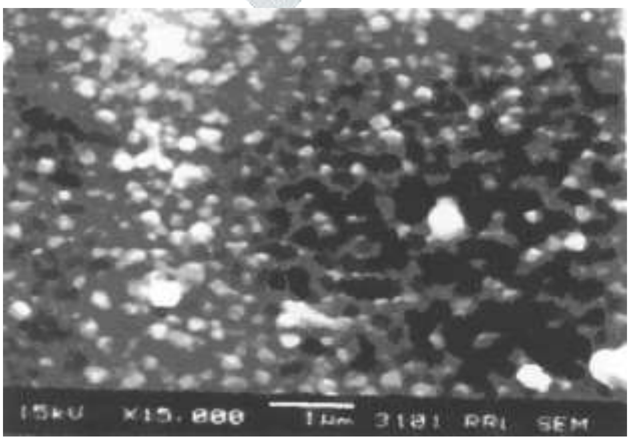
Variation of transmittance (+) and resistivity (*) of optimized ITO films
with amplitude of substrate vibration

Structural properties

Figure shows the XRD spectrum of 5 wt% tin doped ITO films. The peaks in the spectrum correspond to the cubic structure of indium oxide films. No phase corresponding to tin or other tin compounds were detected showing that tin simply substitutes for the indium atoms in the lattice.



XRD spectra of ITO films with 5 wt % (top) and 7.5 wt % (bottom) tin dopant concentrations



SEM of 5 wt % tin doped ITO film

Figure is the scanning electron micrograph of the 5 wt% tin doped ITO film. The figure shows uniform polycrystalline nature of the film. Thickness measurement using interferometer technique revealed that this film has a thickness of about 77 nm.

Conclusions

ITO films have been deposited on glass substrates using a homemade, programmable dip-coater. Films with 5 wt% tin dopant concentration were found to show maximum desirable properties. The resistivity and transmittance of ITO films depend strongly on tin dopant concentration. The minimum amplitude of substrate vibration is about 0.25 mm. Up to amplitude of vibration of about 0.75 mm, the electrical properties and up to 1mm the optical properties of the optimized film remain almost constant. The low-cost programmable equipment, in open atmosphere, produces good quality ITO films in spite of considerable sample vibration.

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