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Characterization of Transparent Conductive Thin Films of In_2O_3:Sn by Spray Pyrolysis Technique

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Abstract: Highly conductive transparent In_2O_3:Sn (ITO) thin films were prepared onto glass substrate using the spray pyrolysis technique. It is observed that these films are polycrystalline with the preferred orientation of [400]. The extent of this orientation increases with substrate temperature. The results show that films with a sheet resistance as low as 35Ω/cm^2 and with a transmittance as high as 90% in visible range can be achieved by controlling the substrate temperature and other preparation process.

Key words: In_2O_3: Sn, spray pyrolysis, TCO, ITO

INTRODUCTION

Highly transparent and electrically conducting thin films are useful in a wide variety of applications such as heat reflecting films for solar thermal collectors, electrodes for photovoltaic solar cells, transparent heating element etc. The properties of Transparent Conducting Oxide (TCO) films are sensitive to the preparation conditions[1]. Film properties can also be modified by annealing in either oxidizing or reducing atmospheres[2]. In recent years various methods of preparation have been tried for developing TCO films owning to their many practical applications. Several authors have reported properties of indium tin oxide films prepared by different technique[3-5].

MATERIALS AND METHODS

The spray pyrolysis is a simple and less expensive for the preparation of the films compared with other methods. In this report, we have characterized the physical properties of ITO films with respect to substrate temperature. The deposition of ITO ([Sn] / [In] =10wt %) films was performed by the spray pyrolysis technique. The spraying equipment and the preparation of the solution are described elsewhere[7].

The study of crystallization of ITO was investigated by X-ray diffraction technique (Philips-Pw-1830). The optical transmittance was also measured by a spectrophotometer (UV/VIS-2100 Shimadzu). The thickness of the films was determined by multiple beam interfering method[6].

RESULTS AND DISCUSSION

In this study the polycrystalline ITO films were prepared on Corning 7059 glass substrates. The thickness of the films was found to lie in the range 4000 to 4500Å.

To observe the influence of substrate Temperature (T_s) on ITO films, the electrical sheet Resistance (R_{sh}) was measured for films deposited at various temperatures ranging from 300 to 600°C, in steps of 50°C. From Table 1, it is clear that films prepared at lower substrate temperatures (below 350°C) exhibit high sheet resistance. The increasing substrate temperature enables us to obtain the maximum transmission (~90 %) and minimum sheet resistance (Rsh=35Ω/□ at T_s=525°C) for a given ITO film by adjusting the substrate temperature and other preparation conditions[7].

The decrease in sheet resistance is probably due to the increase in the number of oxygen vacancies with the rise in substrate temperature. A similar behavior for the dependence of resistance on substrate temperature has been obtained by Qadri *et al.*[1].

Figure 1 shows the dependence of room temperature visible transmission (at 550 nm wavelength) of ITO films with respect to substrate temperature. Films deposited at lower substrate temperature (less than 350°C) exhibited a slight dark milky tint due to the low wavelength absorption at a low temperature deposition .As shown in Fig. 1 the optical properties of the ITO films changed significantly by increasing substrate temperature and reaches to a maximum transmission of 90 % for ITO film deposited at 525°C. The improved transmission could be due to improved structure coupled with a reduction in the number of charge carriers[8]. Results of XRD analysis (Fig. 2) Revealed that the ITO films prepared at a substrate temperature less than 400°C gave no observed diffraction peaks and become polycrystalline when deposited at higher substrate temperature (T_s=425°C) .

Table 1: Variation of substrate temperature with sheet resistance

Substrate Temperature °C	300	350	400	450	500	525	550	600
Sheet Resistance Ω/cm^2	4×10^7	1×10^4	280	80	60	35	40	45

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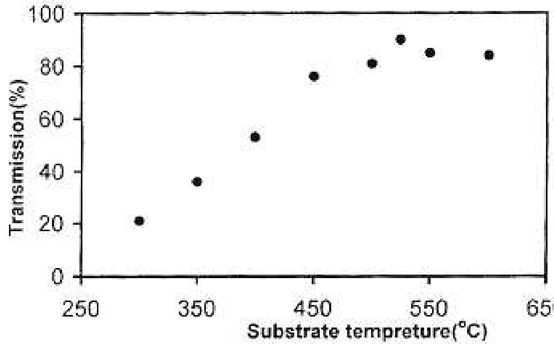

Fig. 1: Variation of visible transmission of In_2O_3:Sn

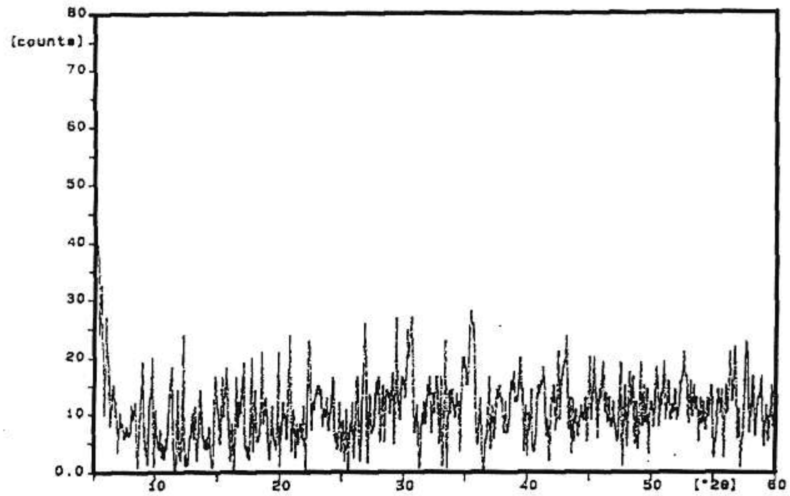

Fig. 2: XRD pattern of In_2O_3:Sn thin films deposited at 350°C

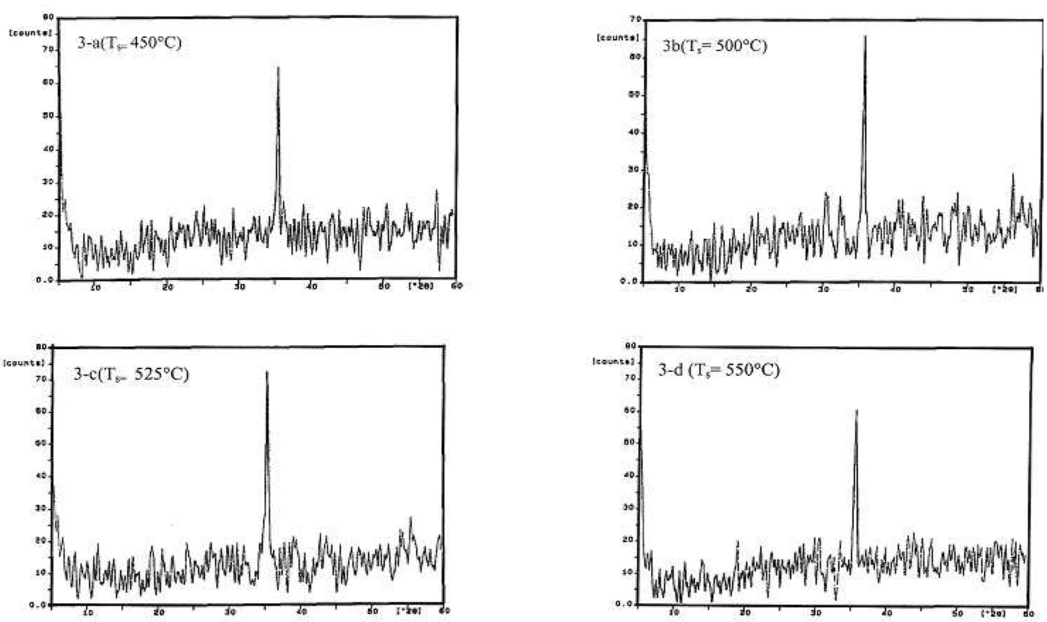

Fig. 3: XRD patterns of In_2O_3:Sn thin films deposited at different substrate temperature

In the useful range of deposition (i.e. 450 to 550°C) the orientation of the films was predominant [400]. The X-ray diffraction patterns of these films are shown in Fig. 3 (a-d).

CONCLUSION

In summery highly reproducible ITO films can be prepared by spray pyrolysis technique within a wide range of substrate temperature. ITO films deposited at 525°C exhibit good optical and electrical properties. ITO films in this work have been used as transparent electrodes successfully[9].

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