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PREPARATION OF TIN-DOPED INDIUM OXIDE THIN FILMS BY THERMAL DECOMPOSITION OF METAL OCTANOATES

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Tin-doped indium oxide thin films have been prepared by thermal decomposition of metal octanoates at 400-600°C. Typical films are 2000-5000 Å thick with a sheet resistance of 350-850 ohm/square and a specific resistivity of 1.7×10^{-2} ohm-cm, and with a light transmission of more than 90 %.

Transparent and electrically conductive thin films are required in many modern opto-electronic devices. Tin-doped indium oxide films are widely used because of the low visible light attenuation, high electrical conductivity, stability, and good adherence. The films have generally been obtained by sputtering[1,2)] and spraying[3)]. In the present work, tin-doped indium oxide films were prepared by thermal decomposition of metal octanoates. This method is similar to that described for the preparation of tin oxide films by Matsushita et al.[4)].

To indium octanoate[5)], $(C_7H_{15}COO)_3In$, tin octanoate[6)], $(C_7H_{15}COO)_2Sn$, was mixed from 0 to 30 % in terms of Sn/Sn+In atomic ratio, to which linoleic acid and benzene were added to obtain solutions containing 10 wt% each of metal octanoates and linoleic acid in 80 wt% of benzene.

The substrate used was a 25 x 75 mm soda lime glass plate which had been immersed overnight in soapy water to remove surface grease and subsequently for 10 hours in chromic acid mixture solution to leach alkali metal ions from the surface of glass, rinsed by distilled water and then dried in a desiccator. It was very important that the substrate was cleaned as described above.

A solution was applied on a substrate as follows: a small quantity of the solution was dripped on the substrate and extended uniformly all over the upper surface of the substrate. The application was also made by dipping a substrate into a solution and withdrawing it with a controlled rate. The applied solution on a substrate was dried at room temperature to expel benzene and then at 110°C for 1 hour. Linoleic acid was partially oxidized by the latter treatment, and the coating on the substrate became a yellowish and hard film with 25-60 μm thickness. The coated substrate was put into an electric furnace which was kept beforehand at a certain temperature ranged from 400°C to 600°C to obtain an oxide film. The heat treatment time was varied from 20 minutes up to 2 hours.

The resulting films had thicknesses ranging from 2000 Å to 5000 Å and exhibited greater than 90 % transmission in the visible range of wavelength.

The general morphology of the films was found to be smooth and fine-grained surfaces with a few defects by electron microscopic observation.

X-ray and electron diffraction analyses revealed that the films consisted of polycrystalline with random orientation. X-ray diffraction patterns of samples with 10 atomic percent of tin or less corresponded with that of cubic indium oxide. In addition to this phase, very weak peaks due to tetragonal tin oxide were detected in samples containing more than 20 atomic percent of tin. Since the Sn/Sn+In atomic ratios of the oxide films were confirmed by chemical analyses to be practically identical with those of original solutions, it is considered that tin substitutes indium in the oxide lattice up to 10 atomic percent.

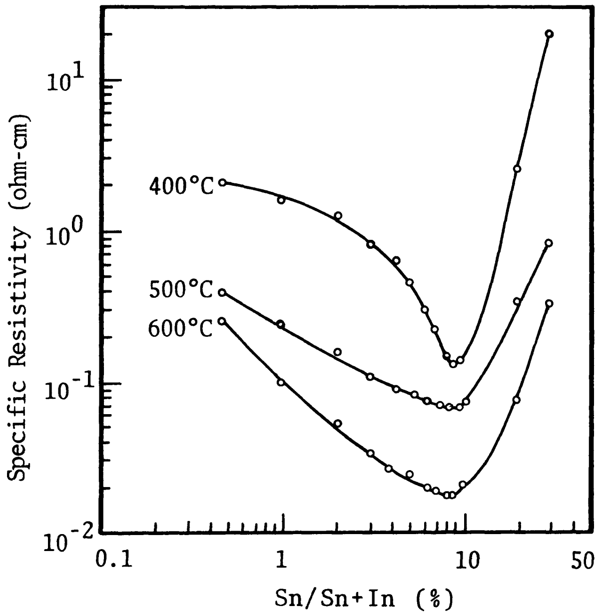

Fig. 1. Specific resistivities of Sn-doped In_2O_3 thin films as a function of additive concentration of Sn. The films were obtained at 400-500°C for 1 hour and at 600°C for 20 minutes.

The film resistance was measured between two gold electrodes which had been deposited onto the film surface by the vacuum evaporation technique. Resistivities of films are plotted as a function of atomic percent of tin in Fig.1. The films without addition of tin showed specific resistivity of 3-8 ohm-cm. The resistance was seen to decrease as the dopant input increased up to about 10 atomic percent, and also as the temperature increased. When more than 10 atomic percent of tin was added, the resistivity increased rapidly. The optimum dopant concentration was found to be within the range of 7-9 atomic percent. The lowest specific resistivity was 1.7×10^{-2} ohm-cm for the film obtained at 600°C with 8 atomic percent of tin, which corresponded to 350-850 ohm/square as sheet resistant values.

Thus the present work has established that tin-doped indium oxide thin films with high light transmission and high electrical conductivity are readily obtained by thermal decomposition of metal octanoates. The simplicity of film preparation and the economic advantages of low equipment cost make it feasible to use these films in a number of electronic devices.

References and Notes

* Now with Showa Wire and Cable Co., Ltd., Odasakae, Kawasaki 210.

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