Iron-doped indium-saving indium tin oxide thin films deposited by DC sputtering method using Fe_3O_4 target

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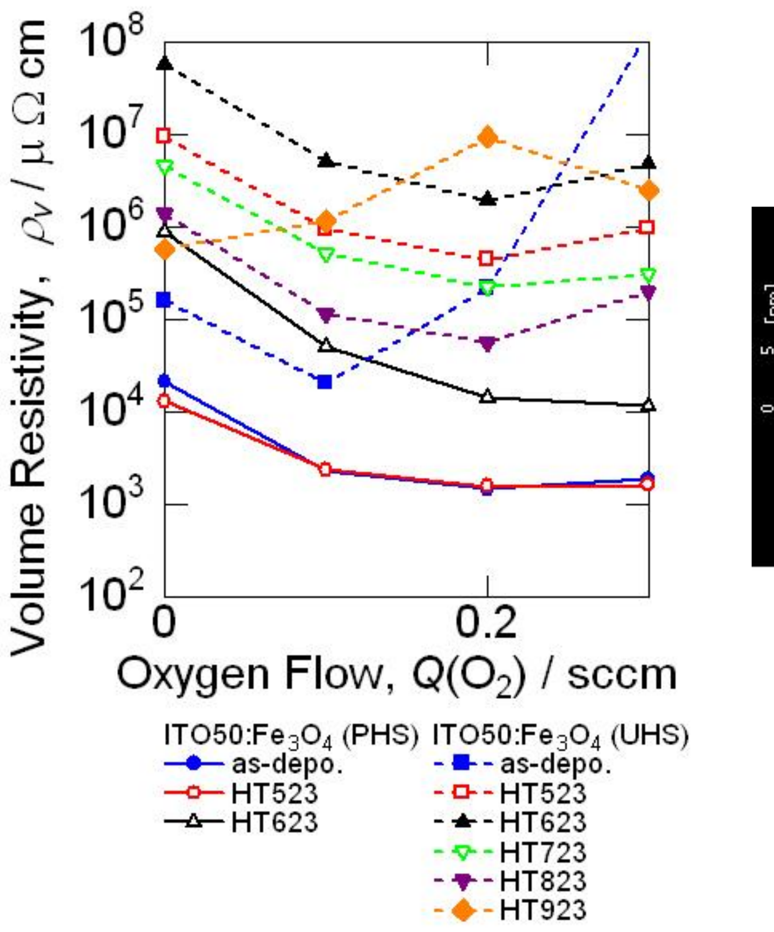
Introduction

Indium tin oxide (ITO) thin films exhibit excellent visible light transparency and high electrical conductivity. ITO thin films are widely used as a transparent electrode for solar cells, liquid crystal displays and for optical solar reflectors. However high demand for ITO thin films for industry and limited natural source of indium provoked its high price. Therefore in order to decrease the use of indium during the production of ITO films, a new target, which considers a smaller quantity of In_2O_3 in its composition and maintains or improves its properties, is required to be developed. Iron-doped ITO thin films using Fe_3O_4 target were produced by co-sputtering method onto substrates preheated at 523 K (ITO50:Fe_3O_4 (PHS)). In order to reduce the indium usage in ITO50 films, an amount of indium oxide in the target was decreased from 90 mass% to 50 mass%. Film properties were measured as a function of oxygen flow rate and heat treatment temperature.

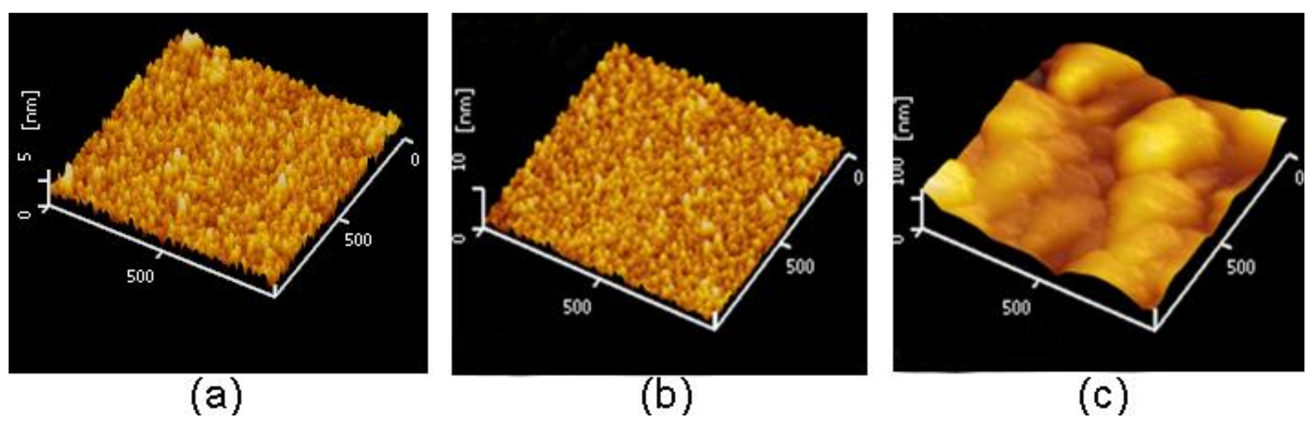
1. Experimental methods

Iron-doped ITO50 (ITO50:Fe_3O_4) thin films were deposited by using a commercial sputtering system ULVAC, CS-200. Ceramic ITO50 (Mitsui Mining & Smelting, In_2O_3 and 48.9 mass% SnO_2) and Fe_3O_4 (Kojundo Chemical Laboratory, 99.9 mass%) targets were co-sputtered on preheated at 523 K glass substrates (PHS) (Corning EAGLE 2000, surface: 50 mm×50 mm, thickness: 0.7 mm) and unheated ones (UHS). The deposited films were heat-treated (HT) in air at 523-923 K for 60 min and cooled at room temperature. The obtained thin films were characterized by means of four-point probe, Ultraviolet-Visible-Infrared spectroscopy, scanning probe microscopy and X-ray diffraction.

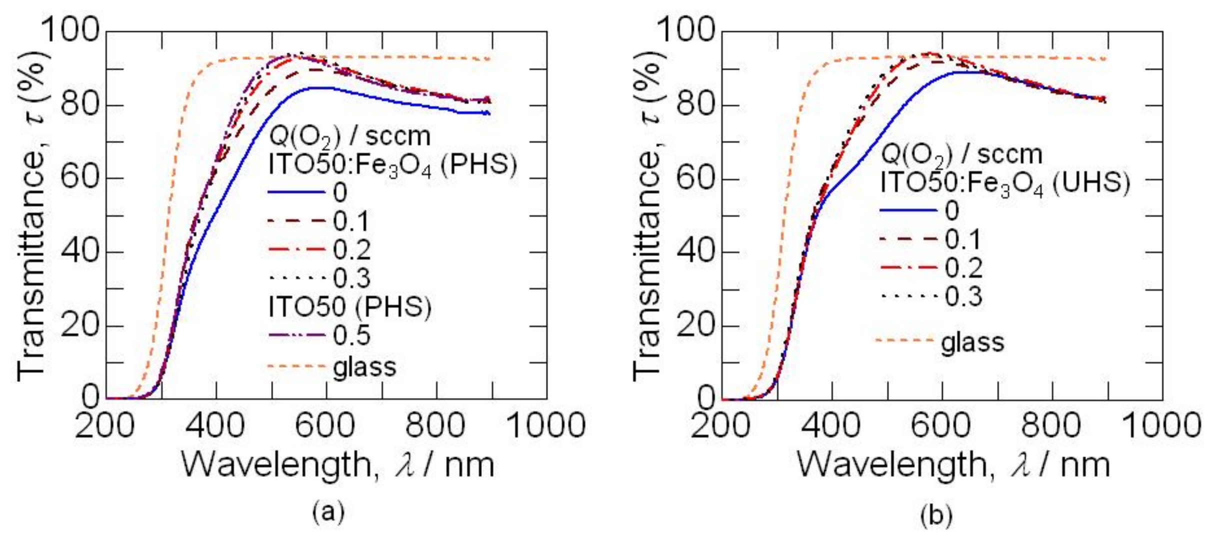
2. Results



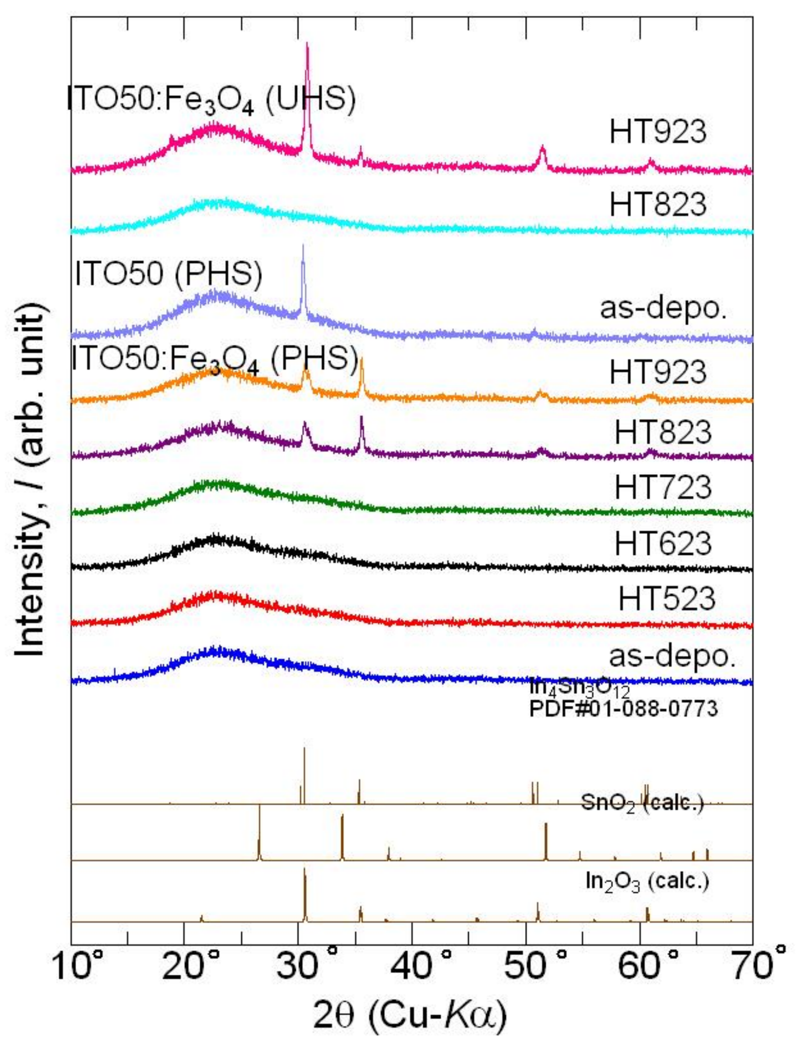
Effect of oxygen flow rate and HT temperature on volume resistivity of ITO50:Fe_3O_4 (PHS) films and ITO50:Fe_3O_4 (UHS) films.



Surface analysis results for thin films deposited under optimum conditions: (a) ITO50:Fe_3O_4 (PHS) at $Q(O_2)$ = 0.2 sccm, (b) ITO50 (PHS) at $Q(O_2)$ = 0.5 sccm and (c) ITO90 (PHS) at $Q(O_2)$ = 0.2 sccm.



Effect of oxygen flow on transmittance of (a) as-depo. ITO50:Fe_3O_4 (PHS) films and comparison to undoped as-depo. ITO50 (PHS) deposited under optimum conditions at $Q(O_2)$ = 0.5 sccm, (b) as-depo. ITO50:Fe_3O_4 (UHS) films.



XRD results for ITO50:Fe_3O_4 (PHS) films, ITO50:Fe_3O_4 (UHS) films and ITO50 (PHS) sputtered at the same oxygen flow rate $Q(O_2)$ = 0.2 sccm.

Conclusions

It was found that minimal value of volume resistivity was obtained for ITO50:Fe_3O_4 thin films deposited on preheated substrates (PHS) at oxygen flow rate of 0.2 sccm that is 14 times lower than that of ITO50:Fe_3O_4 thin films deposited on unheated substrates (UHS) at the same oxygen flow rate. Doping of indium saving ITO thin films with Fe_3O_4 allows increasing transmittance. The transmittance of both ITO50:Fe_3O_4 (PHS) and ITO50:Fe_3O_4 (UHS) thin films was improved with increasing oxygen flow rate. Average transmittance was above 85 % in visible range for both ITO50:Fe_3O_4 (PHS) and ITO50:Fe_3O_4 (UHS) thin films. ITO50:Fe_3O_4 (PHS) thin films crystallizes at lower heat-treated temperature than ITO50:Fe_3O_4 (UHS) thin films, however undoped ITO50 (PHS) thin films deposited at the same oxygen flow was crystallizes in as-deposited state. Doping with Fe_3O_4 does not change the structure of undoped ITO50 (PHS) thin films. Arithmetical mean height (S_a) and root mean square height (S_q) of the as-deposited ITO50:Fe_3O_4 (PHS) thin films were 0.52 nm and 0.67 nm, respectively, whereas arithmetical mean height (S_a) and root mean square height (S_q) of the as-deposited ITO50 (PHS) thin films sputtered at optimal conditions were 0.49 nm and 0.61 nm, respectively.

Acknowledgments

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