Multilayer Fe_3O_4 doped ITO indium saving indium tin oxide thin films sputtered on preheated substrates

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Introduction

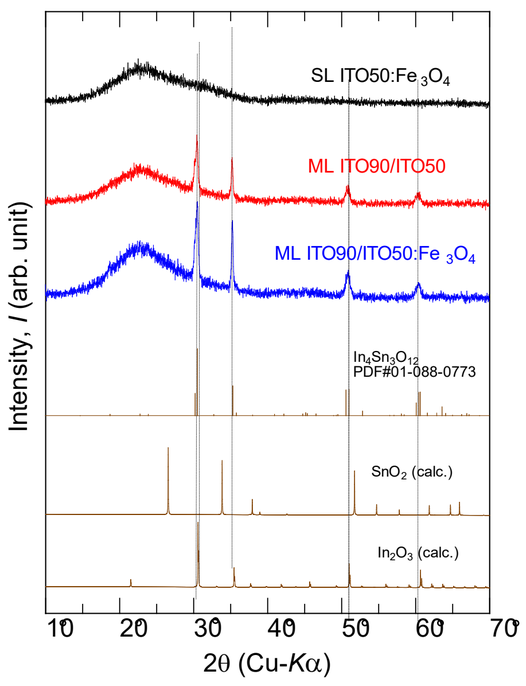
Indium tin oxide (ITO) thin films can be applied in the production of numerous optoelectronic devices such as liquid crystal displays, solar cells, optical solar reflectors etc. [1-5] since ITO has low resistivity and high visible light transmittance. However indium supply shortage provoked its high prices. Therefore it is necessary to find a material that is more cost effective, has better or maintains properties of conventional ITO (90 mass % In_2O_3 and 10 mass % SnO_2).

In this work, we report on the electrical, optical, and structural properties of indium saving sputtered ITO90/ITO50:Fe_3O_4 multilayer films. By sputtering a low-resistivity ITO90 first layer of very small thickness we realized cost-effective transparent thin films with low volume resistivity.

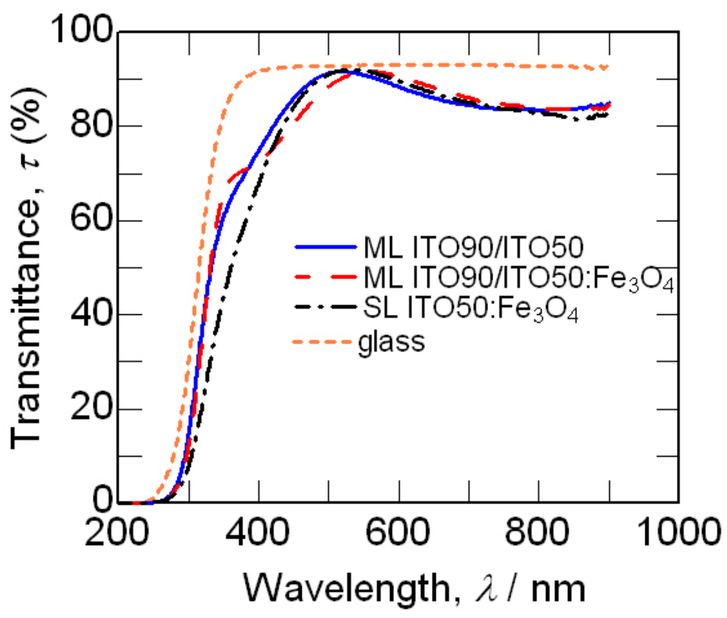
1. Experimental methods

The indium–tin target containing In_2O_3 and SnO_2 in a proportion of 90:10 mass% (ITO90) was used for deposition of the first layer. Target containing In_2O_3 and SnO_2 in a proportion of 50:50 mass% (ITO50) and Fe_3O_4 target were co-sputtered in order to obtain the second layer. The used substrates were the Corning EAGLE 2000 glasses (surface: 50 mm × 50 mm, thickness: 0.7 mm). The argon gas flow introduced into the chamber was fixed at 50 sccm. The flow rate of oxygen reactive gas was set at 0.2 and 0.1 sccm for sputtering of the first and the second layer, respectively. The DC power during the deposition of indium-tin oxide targets was fixed at 100 W and RF power for deposition of Fe_3O_4 target was set 20 W. The substrate temperature was set at 523 K. The substrate holder rotated with 40 rpm in order to achieve the homogeneous deposition. Thickness of ITO90 layer was 12 nm and thickness of ITO50:Fe_3O_4 layer was 138 nm. Thus total thickness of multilayer films was 150 nm. Single layer (SL) ITO50:Fe_3O_4 and ITO90 thin films were sputtered with thickness of 150 nm.

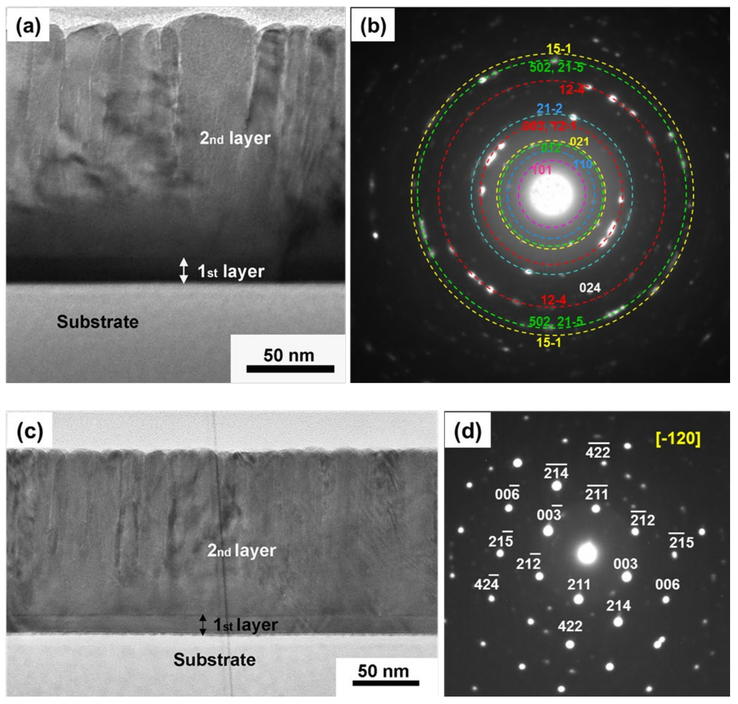
2. Results



XRD results for as-depo. ML ITO90/ITO50:Fe_3O_4 film deposited at $Q(Ar)/Q(O_2)_{ITO90}/\ Q(O_2)_{ITO50:Fe3O4}$ = 50/0.2/0.1 sccm and $W_{RF}(Fe_3O_4)$=20 W, ML ITO90/ITO50 film sputtered at $Q(Ar)/Q(O_2)_{ITO90}/\ Q(O_2)_{ITO50}$ = 50/0.2/0.3 sccm and SL ITO50:Fe_3O_4 film deposited at $Q(O_2)$ = 0.1 sccm and $W_{RF}(Fe_3O_4)$=20 W.



Optical transmittance of ML ITO90/ITO50:Fe_3O_4 thin film sputtered at $W_{RF}(Fe_3O_4)$=20 W and $Q(Ar)/Q(O_2)_{ITO90}/\ Q(O_2)_{ITO50:Fe3O4}$ = 50/0.2/0.1 sccm, ML ITO90/ITO50 thin film sputtered at $Q(Ar)/Q(O_2)_{ITO90}/\ Q(O_2)_{ITO50}$ = 50/0.2/0.3 sccm and SL ITO50:Fe_3O_4 thin film deposited at $W_{RF}(Fe_3O_4)$=20 W and $Q(O_2)$=0.1 sccm



(a), (c) Bright-field TEM images and (b), (d) their corresponding selected area electron diffraction patterns of the 2nd layer of as-depo. ML ITO90/ITO50:Fe_3O_4 (PHS) thin film deposited on the glass substrate under $Q(Ar)/Q(O_2)_{ITO90}/\ Q(O_2)_{ITO50:Fe3O4}$ = 50/0.2/0.1 sccm.

Conclusions

We developed transparent and conductive indium-saving thin films. Multilayer indium saving Fe_3O_4 doped ITO thin films showed the two and half fold (416 μΩcm) decrease of the volume resistivity in comparison with single layer Fe_3O_4 doped ITO50 films. An average transmittance larger than 85 % in the visible range was obtained for multilayer Fe_3O_4 doped indium saving ITO thin films. ML ITO50:Fe_3O_4 thin films sputtered under optimum conditions demonstrate lower volume resistivity and significantly higher transmittance than undoped ML ITO50 thin films deposited at the same oxygen flow rate. ML ITO90/ITO50:Fe_3O_4 thin films show polycrystalline $In_4Sn_3O_{12}$ structure. The TEM results indicate two layers. ITO50:Fe_3O_4 layer shows vertical columnar growth.

Acknowledgments

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[1] J. Hotovy, J. Hüpkes, W. Böttler, E. Marins, L. Spiess, T. Kups, V. Smirnov, I. Hotovy, J. Kováč, Appl. Surf. Sci. 269 (2013) 81-87.
[2] U. Betz, M. Kharrazi Olsson, J. Marthy, M.F. Escolá, F. Atamny, Surface and Coatings Technology 200 (2006) 5751-5759
[3] D.-W. Kang, A. Chowdhury, P. Sichanugrist, Y. Abe, H. Konishi, Y. Tsuda, T. Shinagawa, H. Tokioka, H. Fuchigami, M. Konagai, Curr. Appl. Phys. 15 (2015) 1022-1026.
[4] K.P. Sibin, N. Swain, P. Chowdhury, A. Dey, N. Sridhara, H.D. Shashikala, A.K. Sharma, H.C. Barshilia, Sol. Energy Mater. Sol. Cells 145 (2016) 314-322.
[5] Vinh Ai Dao, Hyungwook Choi, Jongkyu Heo, Hyeongsik Park, Kichan Yoon, Youngseok Lee, Yongkuk Kim, Nariangadu Lakshminarayan, Junsin Y., Current Applied Physics 10 (2010) S506–S509