# Properties of multilayer aluminum-doped indium saving ITO thin films deposited by sputtering method

**Petrovska S.S.[1], Sergiienko R.A.[2], Ilkiv B.I.[1], Nakamura T.[3], Ohtsuka M.[3]**

[1]*Frantsevich Institute for Problems of Materials Science of the NAS of Ukraine*
[2]*Physico-Technological Institute of Metals and Alloys of the NAS of Ukraine*
[3]*Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University,*
makoto.ohtsuka.d7@tohoku.ac.jp

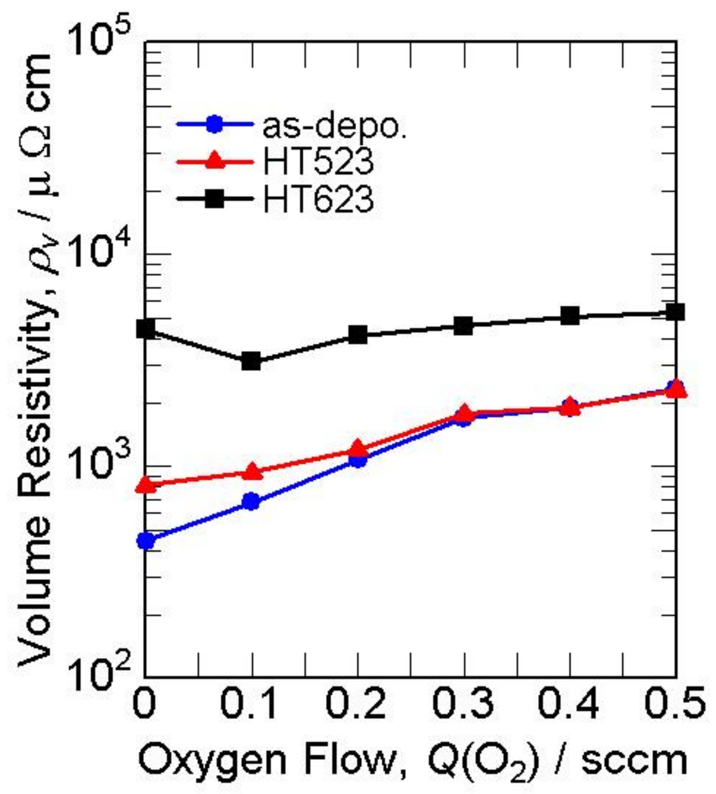
## Introduction

Indium-tin oxide (ITO) thin films have been widely used in a variety of electronic and optoelectronic applications because of the high transmission in the visible region and the low resistivity. However high demand for ITO thin films for industry and limited natural source of indium provoked its high price. Therefore, indium-saving ITO thin films which characteristics are comparable with the ITO electrical and optical properties, as well as being cost-effective attracted attention of investigators [1-5]. Multilayer (ML) aluminum-doped ITO thin films were produced by co-sputtering method onto glass substrates preheated at 523 K (ITO50:Al2O3 (PHS)) in order to improve optical and electrical properties of ITO thin films with reduced from 90 mass% to 50 mass% indium oxide usage in the target.

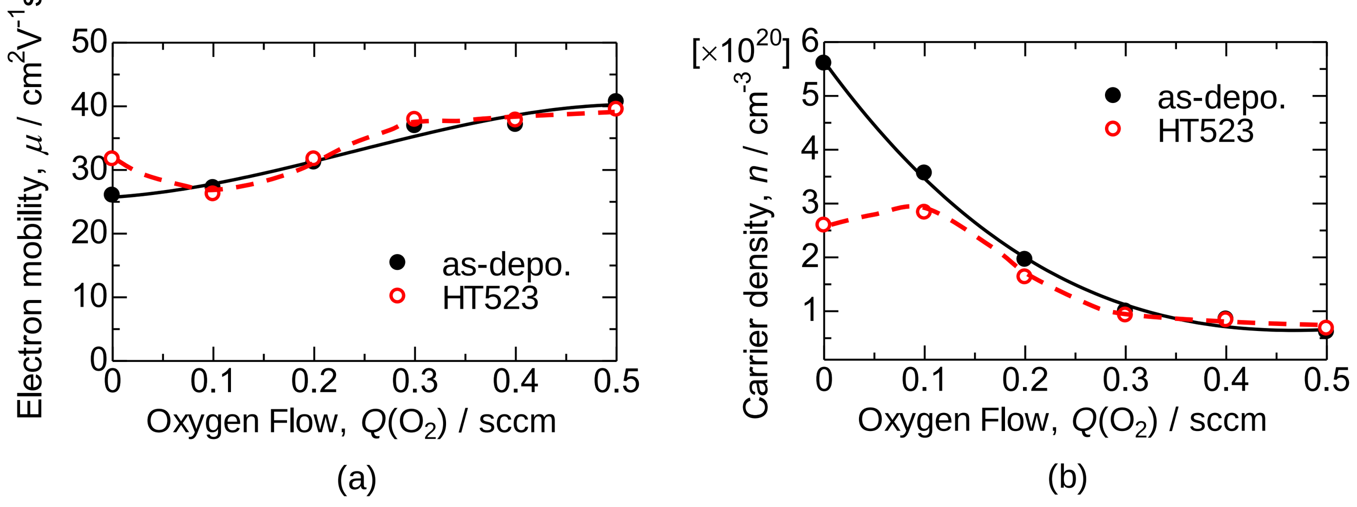
## 1. Experimental methods

Deposition of both ITO90 and ITO50:$Al_2O_3$ thin films was performed in a commercial sputtering system ULVAC, CS-200. The very thin layer of ITO 90 (≈ 12 nm) was sputtered using ceramic target (90 mass% $In_2O_3$ and 10 mass% $SnO_2$). The second ITO50:$Al_2O_3$ layer was obtained by co-sputtering of ITO50 (Mitsui Mining & Smelting, $In_2O_3$-48.9 mass% $SnO_2$) and $Al_2O_3$ (Kojundo Chemical Laboratory, 99.99 mass%) targets. The multilayer aluminum-doped ITO50 thin films were sputtered onto glass substrates (Corning EAGLE 2000, surface: 50 mm×50 mm, thickness: 0.7 mm) preheated at 523 K (PHS) under the rotation of the substrate holder in order to obtain a homogeneous deposition. The deposited films were heat-treated (HT) in air at 523-623 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 and X-ray diffraction.

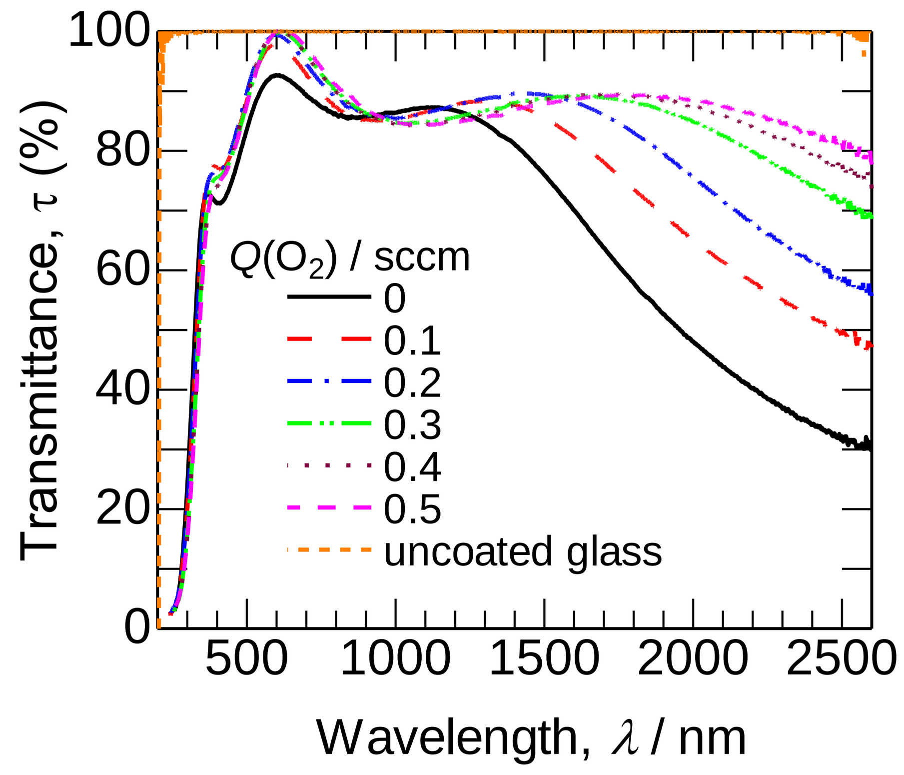
## 2. Results



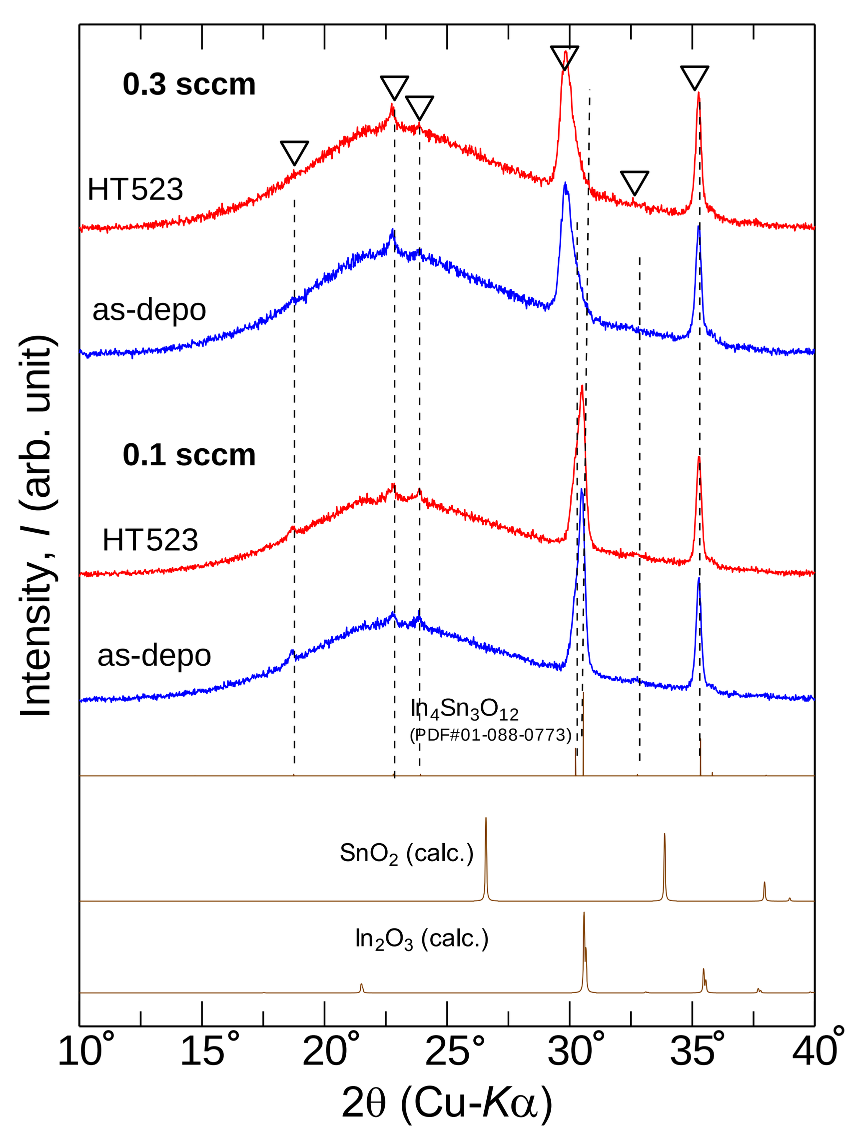

Volume resistivity of as-depo., HT523 and HT623 ML ITO50:$Al_2O_3$/ITO90 deposited at different $Q(O_2)$




The electron mobility (a) and the carrier density (b) of the as-deposited and HT523 ML ITO50:$Al_2O_3$ (PHS) thin films depending on oxygen flow rate




Effect of oxygen flow rate on transmittance of ML ITO50:$Al_2O_3$ (PHS) thin films




XRD results for as-deposited and heat-treated at 523 K ML ITO50:$Al_2O_3$ (PHS) thin films

## Conclusions

It was found that as-deposited ML ITO50:$Al_2O_3$/ITO90 thin films sputtered in pure argon showed the decrease of the volume resistivity (445 μΩcm) in 1.6 times in comparison with single layer (SL) ITO50:$Al_2O_3$ thin films deposited at optimal conditions in mixed argon-oxygen atmosphere and in 6.3 times as compared with SL ITO50:$Al_2O_3$ thin films sputtered in pure argon atmosphere. Minimal volume resistivity in ML ITO50:$Al_2O_3$/ITO90 thin films can be achieved when depositing in pure argon atmosphere in contrast to undoped ML ITO50/ITO90, iron-doped ML ITO50:$Fe_2O_3$/ITO90 thin films, which need mixed argon-oxygen atmosphere to reach minimal values of volume resistivity. ML ITO50:$Al_2O_3$/ITO90 thin films deposited in pure argon atmosphere showed average transmittance larger than 85 % in the visible range. On the other hand, these films deposited in mixed argon-oxygen atmosphere showed average transmittance larger than 90 %. ML ITO50:$Al_2O_3$/ITO90 thin films showed polycrystalline $In_4Sn_3O_{12}$ structure in the as-deposited state and after heat treatment at 523 K. Peaks corresponding to aluminum oxide were not revealed on XRD patterns of ML ITO50:$Al_2O_3$/ITO90 thin films.

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