[Abstract Guideline (Leave two lines for presentation number)]

Size Effects and Carrier Transport in Highly Conductive W-Doped In_2O_3 Films with Thicknesses Ranging from 5 to 50 nm

*T. Yamamoto[1,2], P. Rajasekaran[1], H. Makino[2]
[1] Materials Design Center, Research Institute, Kochi University of Technology, [2] Graduate School of Engineering, Kochi University of Technology
*yamamoto.tetsuya@kochi-tech.ac.jp
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We have achieved polycrystalline W-doped In_2O_3 (*p*-IWO) films with thicknesses (t) ≤ 10 nm showing high Hall mobility (μ_H) ≥ 57.7 $cm^2/(Vs)$. In such samples, we find t-dependent carrier transport. For ultra-thin films of less than 7 nm where t is smaller than the mean free path of carrier electrons (λ_{MFP}), especially, μ_H is very sensitive to t. With increasing t from 5 to 10 nm, μ_H sharply increases to 76.3 $cm^2/(Vs)$. With furth increasing t to 20 nm, μ_H slowly increases to 86.9 $cm^2/(Vs)$. At t of more than 30 nm, μ_H remains almost constant, 97 to 98 $cm^2/(Vs)$. In this work, from both theoretically and experimentally approaches, we discuss the t-dependent dominant factors that determine the carrier transport where such a size effect is apparent.

In this study, firstly, amorphous IWO (*a*-IWO) films with the various t were deposited on alkali-free glass substrates without intentionally heating of the substrates by reactive plasma deposition with dc arc discharge (RPD). Then, the *a*-IWO were subjected to under-vacuum solid phase crystallization in the RPD chamber at a pressure of 5×10^{-4} Pa without any additional gas for 30 min at 250 °C, to realize *p*-IWO films. Structural, electrical, and optical properties are characterized by X-ray diffraction and reflectivity (Rigaku SmartLab), Hall-effect combined with the van der Pauw geometry (Nanometrics HL5500PC), and spectrometer measurements (Hitachi U-4100), respectively. For achieving *p*-IWO film showing high μ_H, flat surfaces of the IWO films and reduced roughness of film/substrate interface are essential at any given t. Resolutions to the above issue are follows: (1) to control the flux energies of flying particles such as positively charged indium (In^+) ions; (2) to optimize the flow rates of oxygen (O_2) gasses introduced into the deposition chamber during the film growth, which will prevent the agglomerate deposition of low-melting-point indium metals near the film/substrate interfaces at the early film-growth.

We investigate t-dependent structural and electrical properties and elucidate the cause of the high carrier transport, on the basis of the analysis of the data determined by high resolution Rutherford Backscattering Spectrometry (HR-RBS) and hydrogen forward-scattering spectroscopy measurements and combined with classical size-effect theoretical models. The analysis of the data determined by HR-RBS measurements shows the depth profiles of O atoms with high density in the vicinity of the surfaces of postannealed *p*-IWO films and near the film/substrate interfaces compared with those of *a*-IWO films deposited on glass substrates. The above depth profiles imply the charge transfer from In atoms to those O adatoms mentioned above that perturbs the surface and interface potential, causing the enhanced contribution of diffuse scattering to carrier transport (Fig. 1). In such cases, reduced μ_H would be observed.

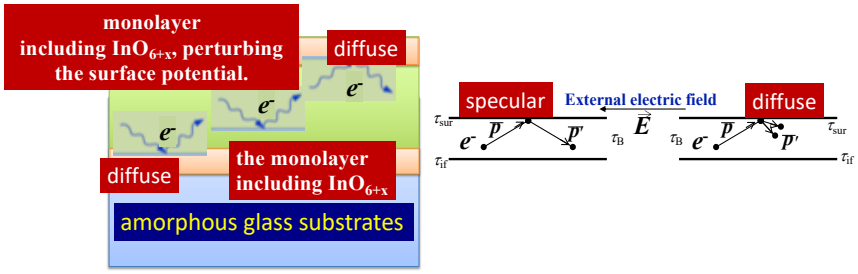

Fig. 1. (left) Schematic diagram of *p*-IWO films/substrates and (right) difference between specular and diffuse scattering at the IWO-film surface and film/substrate interface.

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