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Reactive magnetron sputtering of Ta-doped SnO2 at low temperatures: carrier transport and role of negative ion bombardment

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The benefits of SnO_2 compared to the often used tin-doped indium oxide (ITO) are its significantly lower costs and its higher chemical stability. In principle, low resistivities of doped SnO_2 are possible, caused by its conduction band, composed of isotropic 5s orbitals, advantageous for good transport properties [1]. Recently, Toyosaki et al. [2] achieved resistivities as low as $1 \cdot 10^{-4}$ Ωcm by pulsed laser deposition at 800 °C on sc-TiO_2. Low temperature deposition of TCO films are often required for temperature sensitive devices. Magnetron sputtering is accompanied by the possible formation of negative ions as soon as electronegative elements are present, which is the case for oxygen [3]. In this work we give a comparative study of the radial distribution of ion density in the magnetron discharge and of the electrical film properties.The SnO_2:Ta films were deposited at low substrate temperatures by reactive dc and rf magnetron sputtering from a ceramic target (Sn98at%Ta2at%O2) in Ar/O_2, Ar/N_2O, and Ar/H_2O gas mixtures. The as deposited films were X-ray amorphous for substrate temperatures below about 200 °C. While the amorphous films are remarkably conductive (≈5.10^{-3} Ωcm), the crystallized films exhibit higher resistivities, probably owing to the grain boundary scattering. The width of the process window is wider for N_2O and H_2O compared with O_2. Therefore, using N_2O and H_2O improves process stability and transparency of the films. A prospective application of such amorphous SnO_2:Ta films are low temperature transparent and conductive protection layers, e.g. to protect semiconducting photoelectrodes for water splitting.

[1] Hosono H., Thin Solid Films, 515, 2007
[2] Toyosaki H. et al., Appl. Phys. Lett., 93, 2008
[3] Welzel T. et al., J. Vac. Sci. Technol. A, 30, 2012

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