T9-PL: Dominant factor limiting carrier transport of W-doped In_2O_3 polycrystalline films with thicknesses of less than 10 nm

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We have been investigating the effects of solid-phase crystallization (SPC) on the structural, electrical, and optical properties of Ce-, or W-doped In_2O_3 films [1-4] for widening their applications. We, recently, have reported that we achieved *n*-type doped polycrystalline In_2O_3 films showing high Hall mobility with thicknesses ranging from 5 to 100 nm [1,4]. In such films, we controlled carrier concentration to be set at almost 2× to 3×10^{20} cm^{-3} at any given thickness. The key technology is to fabricate amorphous films deposited on glass substrates without intentionally heating of substrates. Then, we carried out the SPC, postannealing process for 30 min. in a vacuum environment at temperatures of from 200 to 250 °C. Note that a postannealing under atmospheric pressure gives rise to a decrease in carrier concentration as a result of the in-film diffusion of oxygen atoms, a *n*-type killer, that are generated from oxygen (O_2) molecules with high electron affinity adsorbed at the surface of the films. In addition, the residual interstitial oxygen atoms cause reduced Hall mobility.

In this work, we used reactive plasma deposition with dc arc discharge (Fig. 1). The deposition method works very well because of high-speed film-growth rate, typically, 200 nm/min. The apparatus has been already commercial.

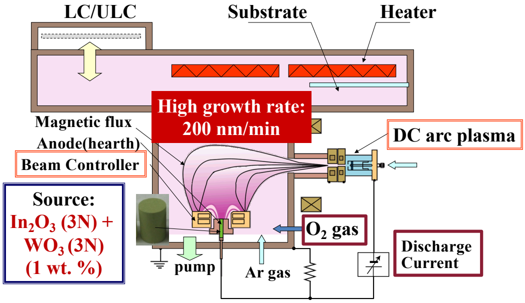

Fig. 1. Schematic diagram of reactive plasma deposition with dc arc discharge of which a feature is a high arc plasma density of $10^{12}/cm^3$.

We find the typically size effects on carrier transport of W-doped In_2O_3 films with thicknesses of less than 10 nm: a decrease in the thickness drastically reduces Hall mobility together with a decrease in the disorder parameter [5], a product of Fermi wave vector and the mean free paths of carrier electrons. The essential point is that the mean free paths of carrier electrons become larger than thicknesses for the ultra-thin films. We elucidate the dominant factor limiting the carrier transport from both theory and experiments such as Rutherford back-scattering spectrometry and X-ray reflection measurements.

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