Fabrication of low resistive amorphous ITO films using Ar / N₂ sputtering: Effects of target-substrate distance

We have recently developed a new fabrication method of amorphous In₃O₃:Sno₂ (a-ITO), nitrogen mediated amorphization (NMA), where a-ITO films are obtained by just introducing N₂ gas into the sputtering atmosphere [1,2]. The NMA method enables us to make a-ITO films with high mobility of 50 cm²/Vs as well as high thermal stability, where the films maintain the amorphous nature even after annealing at 300°C. Since the flux ratio of N atom to the sputtered atoms changes with the change of target/substrate configuration, the distance between target and substrate (d_{T-S}) should have significant influences on the film properties. Here, aiming to further improvement of the film quality, effects of T-S distance are studied through the analysis of a-ITO films fabricated at various N₂/Ar flow rate ratios.

ITO films were fabricated on quartz glass substrates at 150°C by radio-frequency (RF) magnetron sputtering. d_{T-S} was varied from 55 to 115 mm. In₃O₃:Sno₂ (10 wt.%) targets were used, and the supplied RF power was 100 W. N₂/Ar flow rate ratio was 0–5%, and the total gas pressure was 0.9 Pa. The film thickness was 50 nm.

All the samples fabricated in this study show no x-ray diffraction peaks, indicating that all ITO films are amorphous, due to the low substrate temperature.

Figure 1 shows the electrical properties of a-ITO films as function of d_{T-S} for various N₂/Ar flow rate ratios. N₂ addition brings significant increase in the mobility from 12–18 to 40–45 cm²/Vs. We also found that d_{T-S} affects on the electrical properties. Especially at N₂/Ar =1%, the carrier density decreases with increasing d_{T-S}. Since the flux of sputtered atoms decreases with increasing d_{T-S} [3] whereas d_{T-S} have little effect on N atom flux [4], the flux ratio of N atom to sputtered atoms should increase with d_{T-S}. This might contribute to the deactivation of Sn donors, and thus to the carrier density decrease. As a result, a-ITO films with lowest resistivity of 7.5×10⁻⁴ Ω·cm was obtained at N₂/Ar = 1% and d_{T-S} = 55–85 mm.

This work was supported in part by JSPS KAKENHI 18H01206 and NTT collaborative research.