Characteristics of incident particle flux determining growth rates and electrical properties of indium tin oxide films deposited by ion-plating with dc arc discharge

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1. Introduction

Reactive plasma deposition (RPD) is a commercially available ion plating system with dc arc discharge for thin film deposition, which enables us to achieve high-quality transparent conductive oxide (TCO) films, such as indium tin oxide (ITO) and Ga-doped zinc oxide (GZO), deposited on amorphous substrates at low temperature [1, 2]. We have investigated the factors limiting growth rates and electrical properties of 150-nm-thick ITO films deposited on glass substrates (@200°C) by RPD.

2. Experimental Methods

We measured the incident particle fluxes during film growth under the preparation conditions; the working pressure ranged from 0.18 to 0.71 Pa and the discharge current of 150 A. The carrier concentration (N) of the ITO films was 1.0×10^{21} (±3 %) cm^{-3}. We measured the incident particle fluxes of the neutral atoms such as In and O as host atoms and their ions at the substrate level using a mass-energy analyzer (Hiden, EQP300), a Langmuir probe and a diaphragm gauge during the ITO film deposition [3]. To clarify the factors limiting the growth rate and Hall mobility (μ_H) of ITO films, we analyzed the relationship between the growth rates, μ_H, and the incident fluxes of In and O species.

3. Results and Discussion

As the working pressure increased, the intensity of fluxes of In^+ ions with their energy of more than 10 eV (h-In^+ ions) decreased, resulting in a decrease in the growth rates of ITO films from 376 to 294 nm/min, whereas the intensity of fluxes of In^+ ions showing their energy of less than 10 eV (l-In^+ ions) increased. Assuming that the sticking coefficient of In species should depend on the incident energy of their fluxes to the substrate, we concluded that the h-In^+ ions was a dominant factor that limits the growth rate of films. On the other hand, we found that an increase in the intensity of fluxes of h-In^+ ions and/or O^+ ions with their energy of more than 10 eV (h-O^+ ions) enhanced μ_H of ITO films from 44.7 to 47.1 cm^2/Vs. Note that Hall effect measurement results yield that the above growth conditions affects N little; N retained almost constant, 1.0×10^{21} cm^{-3}. These, thus, resulted in a decrease in the electrical resistivity (ρ), which is inversely proportional to a product of μ_H with N, of ITO films from 1.41× to 1.34×10^{-4} Ωcm. The above results show that RPD enables us to tailor ρ of ITO films with maintaining N. We will discuss the cause of the increase in μ_H in terms of the incident particle fluxes of neutral species and ions.

References

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