Topic number

Measurements of nitrogen and oxygen atom density in N_2/Ar sputtering plasma for fabrication of high-mobility amorphous In_2O_3:Sn films

Masaharu Shiratani[1], T. Takasaki[1], H. Wang[1], K. Matsushima[1], H. Seo[1], K. Koga[1], K. Takeda[2], M. Hori[2], and N. Itagaki[1]

[1] *Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan*
[2] *Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*

Aiming at clarifing effects of nitrogen on a-ITO film growth in N_2/Ar sputtering plasma, we measure absolute density of nitrogen and oxygen atoms in the plasma. X-ray diffraction analysis show that ITO film is changed from polycrystalline to amorphous by introducing N_2 into the deposition atmosphere. Electron Hall of a-ITO films increases from 14 to 55 cm^2/Vs with increasing N_2 /(Ar + N_2) from 1.5 to 5%, whereas the absolute density of nitrogen atoms in the plasma increases from 1.2×10^{10} to 7.9×10^{10} cm^{-3}. Since the nitrogen composition ratio of a-ITO films is almost constant for N_2 /(Ar + N_2) of 1.5–5%, adsorption/desorption behavior of nitrogen atoms on the growing surface probably brings about changes in film properties.

1. Introduction

Amorphous In_2O_3:Sn (a-ITO) has attracted attention because of the advantages such as surface smoothness, high etching rate, and low internal stress. However, the mobility of conventional a-ITO films, which are generally fabricated by lowering the deposition temperature (<150°C), is much lower than that of polycrystalline ITO films, limiting the use of a-ITO films in practical devices. We have recently developed a new fabrication method of a-ITO films with a high mobility of 61 cm^2/Vs. Here, aiming at clarifing effects of nitrogen and oxygen atoms on a-ITO film growth, we measure the absolute density of nitrogen and oxygen atoms by vacuum ultraviolet absorption spectroscopy (VUVAS) [2].

2. Experimental

ITO films were fabricated on quartz glass substrates at 150°C by radio-frequency (RF) magnetron sputtering. N_2 /(Ar + N_2) of 0–10% was used. The total gas pressure was 0.9 Pa. The supplied RF power was 100 W. Absolute density of nitrogen and oxygen atoms were measured by the VUVAS method.

3. Results and discussion

First, we performed X-ray diffraction analysis of ITO films fabricated at various N_2 /(Ar + N_2). The diffraction peak intensities of In_2O_3 (222) and (400) planes decreases with increasing N_2 /(Ar + N_2) from 0 to 0.65%, and finally there is no peak detected for N_2 /(Ar + N_2) ≥ 1.5%. Figure 1 shows the absolute density of nitrogen and oxygen atoms as a parameter of N_2/(Ar + N_2). The density of nitrogen atoms increases linearly from 1.3×10^{10} to 1.6×10^{11} cm^{-3} with increasing N_2 /(Ar + N_2) from 0 to 10%, whereas the density of oxygen atoms is in the range of 3.9×10^{9}–1.5×10^{10} cm^{-3}. These results suggest that nitrogen atoms inhibit crystallization and disorder the In_2O_3 bixbyte crystal structure, and thus leading to a-ITO films. Electron Hall mobility of a-ITO films increases from 14 to 55 cm^2/Vs with increasing N_2 /(Ar+N_2) from 3 to 5%, while the nitrogen composition ratio of the films is almost constant (10–11 atomic %). Therefore, the improvement in the mobility of a-ITO films for N_2 /(Ar + N_2)=3–5% is caused not by the nitrogen incorporation, but by the adsorption/desorption behavior of nitrogen atoms on the growing surface.

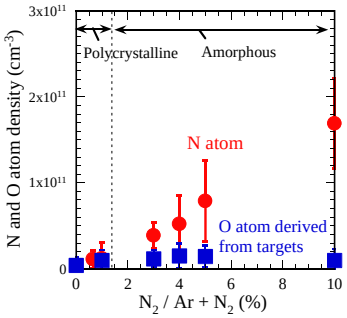

Fig. 1. Absolute density of nitrogen and oxygen atoms in sputtering plasma as a parameter of N_2 /(Ar + N_2).

4. References

[1] T. Takasaki, et al., Proc. 68th GEC/9th ICRP/33rd SPP 60, 9, GT1, 150 (2015).
[2] S. Takashima, M. Hori, T. Goto, A. Kono, M. Ito, and K. Yoneda, Appl. Phys. Lett. 75, (1999) 3929.

5. Acknowledgement

This work was supported by JSPS KAKENHI Grant Number 15H05431.