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Influence of magnetic field on high-energy negative ion behavior in magnetron plasma with oxide targets

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Transparent Conductive Oxide (TCO) is commonly used for optoelectronic devices. As one of TCOs, indium tin oxide (ITO) is quite popular material because of its low resistivity and high optical transmittance greater than 80%. So far, ITO films are used in many industrial applications, such as solar cell, touch panel, flat panel display, image sensor, and so on.

Magnetron sputtering is widely-used method for the ITO deposition. In general, energetic particles from the sputtered target such as backscattered rare gas atoms or oxygen negative ions (O^-) are thought to induce physical and chemical damages as well as surface roughening to the deposited film surface during the sputtering processes. So far, we have investigated suppression of such energetic particles during ITO film deposition by superposition of 40 MHz VHF power to conventional DC magnetron sputtering.(1) However, absolute-value evaluation of O^- flux to the deposited film has not been investigated. Furthermore, in magnetron plasmas, O^- ions are possibly influenced by the magnetic field for the magnetron plasma production. In this study, heat flux is measured using a thermocouple probe and, based on this technique, O^- flux is evaluated in the DC-VHF magnetron sputtering and influence of the magnetic field on the spatial profile of high energy O^- ion is investigated.

Schematic of experimental apparatus has been shown elsewhere.(2) Ar gas is introduced into a cylindrical chamber (30 cm in diameter, 28 cm in height) at a pressure of 0.4 Pa. VHF (<250 W) and DC (<250 V, <0.3 A) powers are applied to a magnetron sputtering ITO target (119 mm in diameter) through a matching box. Target DC voltage can be controlled by the VHF power applied to the target. Thermocouple probe is located at a position of 10 cm away from the target for the heat flux measurement. Heat flux is separated into non-directional and directional components using a shutter on the probe. Non-directional heat flux is composed of charged particles and directional one is mainly composed of high-energy O^- with small contributions from backscattered Ar, and heat radiation flux, From the directional heat flux measurement, the O^- particle flux is calculated with careful consideration of heating efficiency.

In the process of high energy O^- production, O^- ions are produced on the oxide target surface with very low kinetic energy. However, O^- are accelerated by cathode fall potential in front of the target up to a few hundred eV, depending on the target bias potential. In the course of the ion transport from the target to the substrate, O^- ions are deflected by the magnetic field. To simulate the ion deflection, a trajectory simulation has been carried out using Runge Kutta method. Before the simulation, spatial profile of the magnetic field (B_r: radial component) is experimentally obtained using a Gauss meter as shown in Figure 1. In the figure, the origin of the coordinate is determined on the center of the target surface. B_z is obtained from the data of fig. 1 based on div$\boldsymbol{B}$=0. Figure 2 shows trajectory of O^- ion projected on r-z plane, assuming the axi-symmetric configuration of the magnetic field and the plasma. At lower target bias voltage (V_T) of 100 eV, deflection of O^- ion toward positive r direction is clearly observed. To confirm the simulated result, radial variation of the heat flux is measured by the thermocouple at different target DC voltages. From the measurement, clear shift of the heat flux profile is observed. The results suggest that spatial uniformity of the sputtered film varies depending on the target voltage.

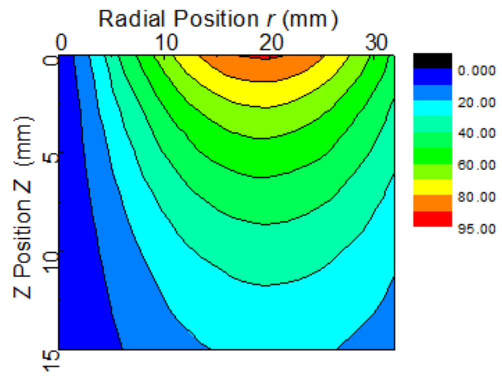

Fig.1. Spatial distribution of radial magnetic field B_r.

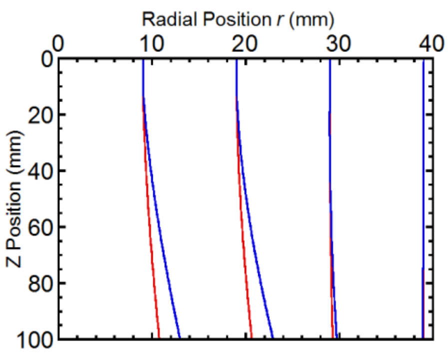

Fig.2. Calculated O^--trajectory
(Red: V_T=250 V, Blue: V_T = 100 V).

References

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