2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Development of compact retarding field energy analyzer for measuring ion energy distribution in planar magnetron discharge

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A problem in planar magnetron sputtering deposition using an oxide target is deterioration of the film quality on the substrate surface opposite to the target eroded region, that is, film composition deterioration and deterioration of crystallinity. It is considered that this is because the high energy oxygen negative ions released from the oxide target eroded region and accelerated in the target sheath are incident on the counter substrate. To elucidate the sputter deposition process of the oxide target, it is extremely important to grasp the particle and energy fluxes incident on the substrate. Detection of negative ions from sputtering targets has been reported using expensive mass spectrometers that have energy analysis functions and require differential pumping [1, 2]. On the other hand, a compact and relatively inexpensive multi-grid retarding field energy analyzer (RFEA) has been used to measure ion energy distribution in various plasmas [3,4], but there are few applications to sputtering deposition process.

The primary purpose of this research is to investigate the ion energy flux incident on the substrate during the magnetron sputtering deposition of the oxide target using RFEA and to explore the possibility and the problem of this measurement method. The second purpose is to deepen the understanding of the magnetron sputtering deposition process of oxide targets. In this report, we report the details of our multi-grid RFEA and the investigation results of the basic operation characteristics of multigrid RFEA in RF magnetron sputtering of Ga-doped ZnO target.

The analysis part of the produced RFEA head consists of multiple mesh grid (entrance grid EG, repeller R, discriminator D, collector repeller CR) and an ion collecting electrode C. Each electrode was insulated with a thin plastic (PEN) sheet. The distance from the entrance grid to the collector is 2.4 mm. The RFEA head is installed 38 mm in front of the target and can move parallel to the target surface using a linear motion manipulator.

In a 13.56 MHz RF magnetron discharge generated under the condition of an Ar flow rate of 20 sccm, a pressure of 1 Pa and an RF input of 10 W, an operation of the RFEA was tested at a radial position of 20 mm from the target center axis. As a result of measuring the current flowing into each electrode and measuring the transmittance of the ion current in RFEA, it was found that the ion current attenuated by about ¼ each time it passed through each grid. This value is slightly smaller than the optical transmittance (28%) of one grid. Since enough collector current could not be obtained with 4 grids, we removed EG this time and used only three grids. A positive ion current flowing into C was measured by setting EG to a floating potential (~0 V), applying -60 to 70 V to D, -250 V to CR and -60 V to C. Figure 1 shows the change in C current with respect to D potential and the energy distribution function of positive ions obtained by differentiating the current waveform with D potential.

It is confirmed that the time-averaged plasma spatial potential is about 20 eV and it is incident on the floating electrode as an ion beam of about 20 eV. Low energy components are thought to be due to charge exchange. In addition, when the retarding potential with respect to the negatively charged particles was set to -60 V, the current due to the negatively charged particles was always observed in C, and therefore, the presence of negative ions having an energy of 60 eV or more was confirmed. The comparative investigation of the spatial distribution of the current due to the positive ions and the negatively charged high energy particles showed a clear difference in the spatial distribution of both.

This research was supported by JSPS KAKENHI Grant Number 16K04995.

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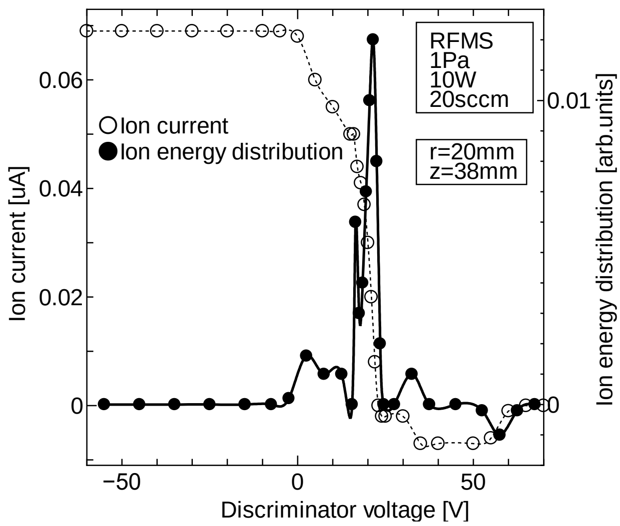

Figure 1. Collector current vs discriminator voltage and energy distribution function of positive ions