Measurement of Au sputtering yields by Ar and He ions with a low-energy mass selected ion beam system

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Abstract. The Au sputtering yields by noble gas ions below 200 eV were measured with a low-energy mass selected ion beam system. Au sputtering yields by He and Ar ions were measured and found to increase monotonically with the ion injection energies. It was also found that the sputtering yields by He were much lower than those by Ar.

1. Introduction

Noble metals (e.g., Pt, Au) are widely used for semiconductor electrodes. In most cases, they are fabricated by sputter-deposition with noble gases. Therefore, measurement of sputtering yields of these metals by noble gas ions is important for various applications.

Au sputtering yields by noble gas ion injections have been reported in the energy range above 100eV in some papers [1-3]. However, in those previous papers the energy spectra of injected ions were not shown. In addition, in the energy range below 100 eV only a few data were reported [2, 3].

We have established a measurement system of Au sputtering yields by a quartz crystal microbalance (QCM) and a low energy mass selected ion beam system [4]. We reported the Au sputtering yields by Ne ions in the energy range below 200 eV in an earlier paper [5]. In this paper, we report the Au sputtering yields by He and Ar ions in the energy range of 25-200 eV measured with the system stated above.

2. Experimental set-up

The experiment is carried out in that system [4]. This system is consisted of a Freeman-type ion source, an extractor, a mass selector, a deflector, a decelerator, and a process chamber (see Fig. 2 of Ref. [4]). The ion beam is generated and extracted by high voltage (-15 kV), mass separated by magnetic field of the mass selector, decelerated near the end of the beam line and introduced to the process chamber. The species of injected ions can be chosen by magnetic field of the mass selector.

In the process chamber, a Faraday cup and a QCM, on which Au thin film (about 1 μm in thickness) is deposited, are mounted on a manipulator. Ion beam current can be measured by the Faraday cup. The sputtered Au mass decrement can be measured by the QCM. The number of incident
ions ($N_{\text{ion}}$) and sputtered Au atoms ($N_{\text{atom}}$) can be evaluated by these measurements. In addition, a plasma process monitor (PPM) is mounted on the process chamber to measure energy and mass spectra of ion beams. The sputtering yield, $S$, is defined by the following equations.

$$S = \frac{N_{\text{atom}}}{N_{\text{ion}}}$$

$$N_{\text{atom}} = \frac{A \times d \times D_{\text{Au}}}{m_{\text{Au}} / N_{\Lambda}}, \quad N_{\text{ion}} = \frac{I \times t}{e}$$

Here, $A$ is the area of Au thin film, $d$ is the thickness decrement by sputtering, $D_{\text{Au}}$ is the Au mass density, $m_{\text{Au}}$ is the Au mass number and $N_{\Lambda}$ is the Avogadro number. $I$ is the ion beam current and $t$ is the injection period, and $e$ is the elementary charge.

The sputtering yields were measured as follows. Firstly, the ion beam current was measured. Secondly, the manipulator was moved upward to guide the ion beam to the PPM. The energy and mass spectra of the ion beam were measured. Then, the QCM was moved to be irradiated by the ion beam and the Au thin film was sputtered. Finally, the ion beam current was measured again for the confirmation that the ion beam current did not change to a large extent during the yield measurement.

3. Results and discussions

Prior to sputtering yield measurement, the energy and mass spectra were measured by the PPM. Figure 1 shows the mass spectra of He and Ar ion beams. The mass numbers obtained from the spectra are 4 and 40, respectively. It was found that each ion beam has no impurity. Figure 2 shows energy spectra of Ar ion beams. The Full Widths at Half Maximum (FWHMs) of the spectra are about 5 eV. This result confirms that the ion beams used in our experiments are nearly monochromatic in energy distribution. Energy spectra of He were similar to those shown in Fig. 2.

Figure 3 shows the Au sputtering yields by He ion injection in the energy range from 104 to 203 eV. It was found that the yields increases monotonically with the increasing ion beam energy. Below 104 eV, the sputtering of Au was not observed.

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**Figure 1.** Mass spectra of (a) He and (b) Ar.

**Figure 2.** Energy spectra of Ar ions when the peak energies are 105 and 204 eV.
Figure 4 shows the sputtering yields by Ar injections in the energy range from 27 to 203 eV. The dependence of the sputtering yields on the ion energy is similar to that in the case of He injection (Fig. 3). It was found that the Au sputtering yield by He injection was much lower than those by Ar. It was also found that yields given in Fig. 3 and 4 are consistent with earlier data obtained by other groups [2, 3].

4. summary
We measured Au sputtering yields by He and Ar ion injections with the low-energy mass selected ion beam system. For the characterization of ion beams, the mass and energy spectra of ions were measured and the energy distribution of each ion beam was found to be monochromatic. The sputtering yields by He and Ar were measured and found to increase monotonically with the ion injection energies. The yields by He were much lower than those by Ar.

References
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