Highly charged ion beams applied to nano-scale fabrication

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The ion beam (IB) technology has been playing an important role in various fields and its application is still expanding to other fields, such as biomedical use. In those applications, single charged ions (SCIs), which are easily provided by commonly used ion sources, have been usually used. Highly charged ions (HCIs), which are provided by specialized ion sources, have been provided as a probe to investigate fundamental sciences. The series of investigations on HCIs have revealed their remarkably high reactivity with materials[1)] and the high reactivity enhances the irradiation effect, an example is shown in 2). HCI has high efficiency for acceleration, in addition. Based on those properties, the IB technology would be further developed by applying HCIs. In other to promote the application of HCI beams, the feasibility of HCI beams should be confirmed from the practical point of view.

Our research group has been confirming the feasibility of HCI beams to develop nano-scale fabrication by using the facility to produce and irradiate HCI beams built at Kochi University of Technology[3)]. The voltage for acceleration is variable up to 100 keV and element and charge state of ions can be selected by means of the magnetic rigidity. By using the facility, HCI beams were successfully applied to IB lithography[4)]. In case of fabrication of SOG, a reduction of processing time and an expansion of a fabricated depth were observed compared with SCI beams. In case of fabrication of Si crystal, the fabricated depth linearly increased with charge state of Ar ions with constant acceleration voltage of 60 kV, as shown in Fig. 1. The development of IB irradiation facility with small footprint is expected by using HCIs. HCIs were also applied to sputtering method. The sputtering rate of Ag-foil was observed as a function of charge state of Ar ions, and normalized sputtering rate $S(q)/S(q=1)$ is shown in Fig. 2. The result suggests the enhancement of the sputtering process by irradiating IB in higher charge states. The modification of surface properties is one of another popular applications of IB technology. We have observed IB-induced modification of mechanical properties of $Si0_2$ surface and the modification was found to be promoted by irradiating HCI beams[5)].

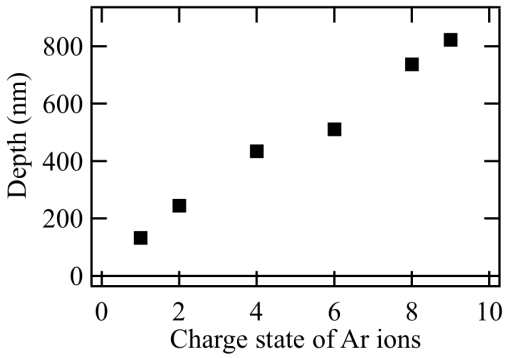

Fig. 1. Relation between fabricated depth of Si crystal and charge state of Ar ions accelerated by constant voltage of 60 kV.

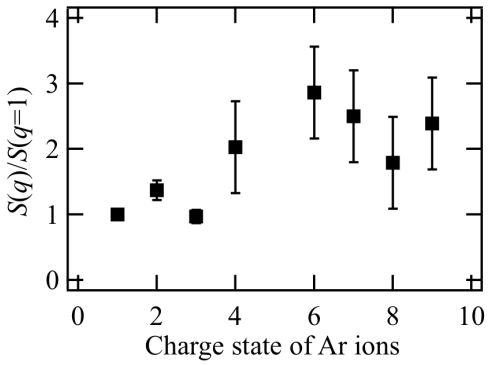

Fig. 2. Charge dependence of sputtering rate of Ag-foil by irradiating Ar ions.

The possibility of HCI beams for further development of IB technology has been shown in those investigations. However, such investigations have been limited by ion sources. There are few commercial ion sources, which can provide HCI beams, and the beam intensities are not enough for industrial applications at present. The present status of ion sources for HCIs will be also mentioned.

References

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