Abstract- It is necessary to develop the technology of large current cluster ion beam, because of increasing the productivity of processing using cluster ion beam. In order to get the large current cluster ion beam, the cluster generation, ionizer and ion transportation were studied. The efficient cluster generation was realized by increase of source gas pressure. The efficient ionization and extraction were realized by structural improvement of the ionizer. As a result, the maximum beam current of 500µA was achieved.

INTRODUCTION

A cluster is an aggregate of a few to several thousands atoms. Because many atoms constituting a cluster ion bombard a local area, high-density energy deposition and multiple-collision processes are realized. Because of the interactions, cluster ion beam processes can produce unusual new surface modification effects, such as surface smoothing, high rate sputtering and very shallow implantation [1-4]. Various outstanding applications of the cluster ion beam have included so far: high quality tin doped indium oxide (ITO) films obtained by O₂ cluster ion assisted deposition at room temperature [5], smoothing of diamond films by Ar cluster beam [6,7], formation of an ultra shallow junction by using B₁₀H₁₄ ion implantation [8]. It is necessary to develop the technology of large current cluster ion beam, because of increasing the productivity of processing using cluster ion beam.

Fig. 1 shows a schematic diagram of the cluster ion beam irradiation system. Adiabatic expansion of a high-pressure gas through a nozzle is utilized for the formation of gas cluster beams. When the high-pressure gas is ejected into the vacuum through a nozzle, the momenta of the atoms align with the beam direction. The temperature equivalent to the relative velocity among them goes down and the gas becomes supersaturated. A phase transition occurs in the supersaturated gas due to the fluctuation effect. When the nucleus radius becomes larger than...
the critical radius, the cluster is stable and grows. When a supersonic flow ejects from the nozzle, shockwaves are generated [9]. The supersonic flow changes to a subsonic one at the boundary where the temperature, velocity and pressure are discontinuous. These shockwaves disturb the generation of neutral cluster beams. To avoid formation of such shockwaves, the skimmer was developed. The skimmer extracts the core of the supersonic flow and the cluster beam is introduced into high vacuum. The neutral clusters are ionized by the electron bombardment method. The ionizer consists of filaments and anode. Electrons ejected from hot filaments are accelerated toward the neutral cluster beam and ionize clusters. The ionized clusters are extracted and accelerated towards targets.

**EXPERIMENTAL**

In order to generate large current cluster ion beam, it is important to generate many neutral clusters, ionize the clusters efficiently, and transport the cluster ions without loss. Therefore, optimization of cluster generation conditions, optimization of ionization conditions, and improvement of extraction method were studied. When the intensity of neutral beam increase, a lot of gas flows into the process chamber where an ionizer and targets are set. It is necessary to evacuate the process chamber with high-speed pumps for keeping high vacuum during irradiation.

Fig. 2 shows the picture of the test machine for developing the technology of large current cluster ion beam. A supersonic flow ejects from a nozzle and cluster beams are generated in a source chamber. In order to keep a good vacuum level in the process chamber during irradiation, the cluster beams go into the process chamber through a differential pumping chamber. The process chamber is evacuated with two cryopumps. The pumping speed of one cryopump is 2500 ℓ/s. The pressure in the process chamber is less than $1 \times 10^{-4}$ Torr during Ar cluster irradiation. The pressure is low enough to generate cluster ion beams without any vacuum discharge. The acceleration voltage can be increased to 25kV. Thus, the technology of large current cluster ion beam can be studied by using the test machine.

**FIGURE 2. Picture of the test machine for developing the technology of large current cluster ion beam.**
RESULTS AND DISCUSSION

Neutral beams were generated from two kinds of laval nozzle. These are glass nozzles. The diameter of the throat of both nozzles is 0.1 mm. The Ar gas flow from nozzle A is several times larger than that from nozzle B at same gas pressure. Fig. 3 shows the gas flow dependence of neutral beam intensity. The pressure measured by an ion gauge on the beam line in process chamber was regarded as the neutral beam intensity. The neutral beam intensity increased with the gas flow. The intensity generated from nozzle B was several times higher than that generated from nozzle B.

In order to confirm that the neutral beams are clusters, the mass distributions were measured with a Time-of-Flight (TOF). Fig. 4 shows the cluster size distributions of the beams generated from the nozzles. The size distributions prove that the neutral beams include clusters with the size up to 40000. These results indicate that the intensity of cluster beams increase with the gas flow from nozzles and the size distributions depend on the nozzle structure.

The neutral clusters were ionized by the electron bombardment method. Fig. 5 shows the electron emission current dependence of ionization efficiency. The ionization efficiency increases with the emission current. When the emission current is 100mA, the ionization efficiency reaches about 80%. This result shows that the emission current of 100mA is
necessary for ionization of the cluster beam.

In order to extract cluster ions from the ionizer efficiently, the anode was shortened and the structure of extract electrode was changed. The structural improvements of ionizer suppressed the ion expansion and realized the extraction of large current cluster ion beams. Fig. 6 shows the source gas pressure dependence of cluster beam current just after ionizer. The beam current increased with gas pressure. When the gas pressure was 15000 Torr, the beam current reached 500 uA.

CONCLUSION

In order to generate large current cluster ion beam, cluster generation, cluster ionization, and improvement of extraction method were studied. When the gas pressure was 15000 Torr and the electron emission current is 300 mA, the beam current reached 500 uA.

REFERENCES