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Development of 1 mA cluster ion beam source

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Abstract

High ion dose is needed to realize the nano-level smoothing and etching of hard materials using cluster ion beam. Large current is needed to increase the productivity of processing. In order to get the large current cluster ion beam, the cluster generator, ionizer and ion extraction has been studied. The intensity of neutral beams generated from various shapes of nozzles was measured and the orifice diameter of skimmer was adjusted. As a result, the 10 times stronger neutral beams could be generated and a maximum beam current of 2.4 mA was achieved at the acceleration voltage of 45 kV with the source gas pressure of 15,000 Torr. The ratio of monomer ion in the beam was 58%. This result indicates that the beam current of cluster ion except monomer ion is about 1 mA. With this beam current, 12-in. wafers can be treated with 2×10^{15} ions/cm^2 in about 4 min. The process speed is high enough so that the cluster beam is available for next generation processes.

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1. Introduction

A cluster is an aggregate of a few to several thousands atoms. When many atoms constituting a cluster ion bombard a local area, high-density energy deposition and multiple-collision processes are realized. Because of the unique interaction between cluster ions and surface atoms, new surface modification processes, such as surface smoothing [1–3], shallow implantation [4,5] and high rate sputtering [6], have been demonstrated using gas cluster ions. In order to increase the productivity of these cluster processes, high throughput and large area irradiation must be provided. In addition high ion dose is needed to realize the nano-level smoothing of hard materials. Therefore, large

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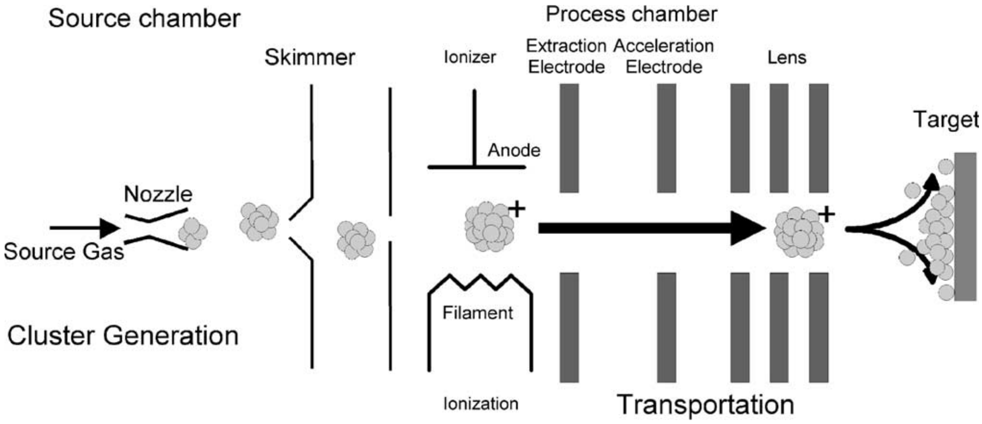

Fig. 1. Schematic diagram of the cluster ion beam irradiation system.

current cluster ion beam is required for effective processing.

Fig. 1 shows a schematic diagram of the cluster ion beam irradiation system. Adiabatic expansion of high-pressure gas through a nozzle is utilized for the formation of Ar gas cluster beams [9]. The cluster beam was introduced into high vacuum through a skimmer. The neutral clusters were ionized by electron bombardment. The ionized clusters were accelerated and transported to targets. In order to get the high current cluster ion beam, the cluster generator, ionizer and ion extraction have been studied [7,8]. It was reported that neutral beam intensity from the large size of metal nozzle was larger than that from usual glass nozzle. In this paper, new metal nozzles were constructed and the orifice diameter of skimmer was adjusted to beam diameter.

2. Experimental

In order to get high intensity of neutral cluster beam, two kinds of nozzle B and C were made from metal. These were conical nozzles and each orifice diameter was 0.1 mm. Nozzle C was larger than nozzle B. The neutral beams from the metal nozzles were introduced into high vacuum through various orifice diameters of skimmers. The skimmer orifice diameter dependence of neutral beam intensity was measured and orifice diameter of skimmer was adjusted to beam diameter. The mass distributions were measured with a compact time-of-flight (TOF) system. The system can be set in the cluster irradiation machines and used for the cluster size monitor.

3. Results and discussion

Fig. 2 shows the skimmer diameter dependence of neutral beam intensity from the metal nozzles B and C. The source gas was Ar. The pressure measured by an ion gauge on the beam line in process chamber was regarded as the neutral beam intensity. The orifice diameter of skimmer (D_s) was changed from 1.2 mm to 5.0 mm. The neutral beam intensity increased with the orifice diameter of skimmer. The neutral beam intensity at the skimmer diameter of 2.0 mm was about two times larger than that at the skimmer diameter of 1.2 mm, but the neutral beam intensity from metal nozzle B at the skimmer diameter of 3.0 mm was almost similar to that at the skimmer diameter of 2.0 mm. This result indicates that the diameter of neutral beam from nozzle B is about 2 mm and the diameter of neutral beam from nozzle C is larger than 3 mm. When the orifice diameter of skimmer was 5.0 mm, the neutral beam intensity from nozzle C was 10 times larger than that from usual glass nozzle A.