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Diagnostics of low Energy Ion Beams Formed by Wire Extraction Electrode
タングステンメッシュ電極による低エネルギ-イオンビームの調査

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To investigate argon ion beam formed by thin tungsten wire electrodes with less than 50 eV energy, ion energy distribution functions with respect to extraction potential from 5 V to 50 V at 0.019 Pa at constant discharge 50 V have been measured and analyzed using a retarding potential analyzer. Beam energy spread was typically below 2 V. At the 40 V extraction potential, the energy spread was 1.27 V, which was 2.7 % of the extraction beam energy. Ion beam profile measured from the emittance equipment with collinear apertures was also investigated.

1. Introduction

In the field of semiconductor processes low energy ion beam has gained considerable attention [1]. However, transport of low energy ion beam is difficult due to space charge effects. One way to achieve efficient transport of low energy ion beam less than 50 eV is let ion beam propagate through a low density plasma. Based on this idea, a pair of thin wire mesh electrodes has been designed [2] and put into the operation. High transparency of these electrodes enable electrons in the upstream region to penetrate into the downstream region. These neutralizing electrons in downstream region can mitigate the space charge effect caused by positive ion beams. As the effectiveness of the thin mesh wire electrodes has been already reported briefly in the previous paper, [2] more precise transport characteristics of low energy argon ion beam less than 50 eV has been investigated.

2. Experimental set up

2.1 Ion source

A 56 mm diameter and 80 mm long stainless steel cylinder was used as the ion source chamber. Eight permanent magnets were attached on the outer surface of the side wall. Discharge gas was introduced from a port attached on the side wall. The plasma was produced by thermal electrons from two hairpin-type shaped of ϕ 0.3 mm diameter and 80 mm long tungsten(W) wires.

A 0.1 mm diameter W wire was pulled parallel of a wire extraction geometry. It was kept in tension to realize with the section set parallel with 1 mm spacing across the area of 23 mm aperture. The spacing distance between the electrodes was maintained at 0.7 mm. These two W wire electrodes separate the ion source plasma from the downstream vacuum chamber. In normal operation, discharge voltage was maintained 50 V, while extraction potential was changed from 5 V to 50 V. Discharge current was 0.05 A and gas pressure was kept constant at 0.019 Pa.

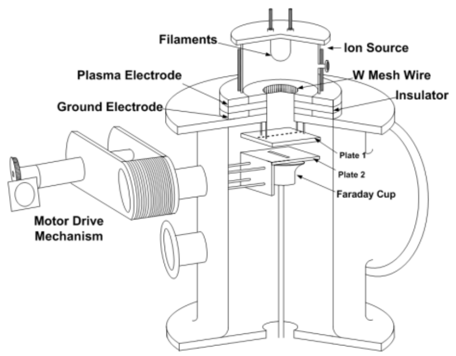

Figure 1. Experimental set-up with the beam emittance measuring system.

2.2 Ion beam measurement set up

In order to measure ion energy distribution function (IEDF), a retarding potential analyzer (RPA) [2] was inserted from the bottom of vacuum chamber as the diagnostic tool. The distance of RPA from the ground electrode was maintained 22.5 mm. Figure1 shows the experimental system with the emittance measurement set-up. The first plate was fixed at 70 mm from the ground electrode. On the first plate eleven 1 mm diameter apertures were opened with equal distance. Each distance between apertures was 7 mm. The second plate, with 0.2 mm wide 20 mm long slit, was placed 20 mm downstream from the first plate. The second plate was connected to the motor drive mechanism that moves the second plate in the direction perpendicular to the ion beam direction. A Faraday cup was attached behind the second plate to measure the ion current.

3. Results

3.1 Ion energy distribution functions

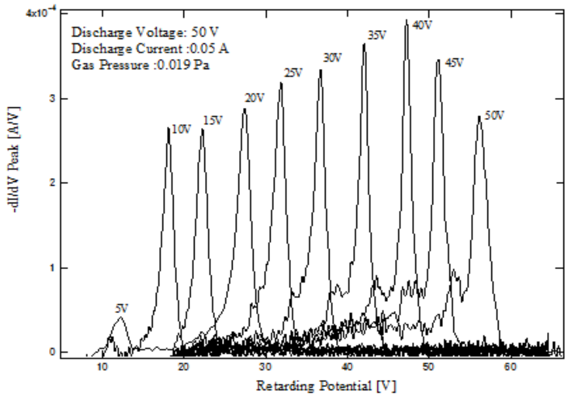

Figure 2. IEDF obtained from *–dI/dV* peak for different potentials.

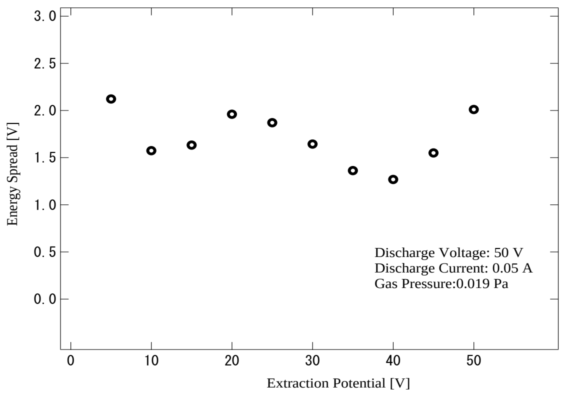

Figure 3. Energy spread of ion beam with respect to extraction potential.

Figure 2 shows *–dI/dV* or the IEDF obtained from I-V trace measured the RPA for different extraction potentials. The peak value of *–dI/dV* increased in accordance with extraction potential from 5 V to 40 V. After 40 V, the peak decreased. The energy spread of the IEDF can be also obtained from Fig. 2 by taking the full width half maximum (FWHM) of the IEDF peak. Figure 3 shows the energy spread with respect to extraction potential. From 20 V to 40 V, the energy spread decreased linearly against increase in extraction potential. For the case of 40 V extraction potential, the energy spread was 1.27 V which was 2.7 % of the extraction beam energy. The ion beam current density was 2.9 μA/cm^2 at that time. For the lowest extraction potential of 5 V, ion beam current density was 0.231 μA/cm^2, and energy spread was 2.12 V or 17.3% of the extraction beam energy.

3.2 Measurement of beam broadening

Figure 4 shows the data of beam profile with the slit measurement system. For the case of 0.05 A discharge current and 20 mm distance between first and second plates, the measured widths of beamlets were below 3 mm. Thus, the broadening of the beam does not severely affect the shapes of beamlet with low current density operation.

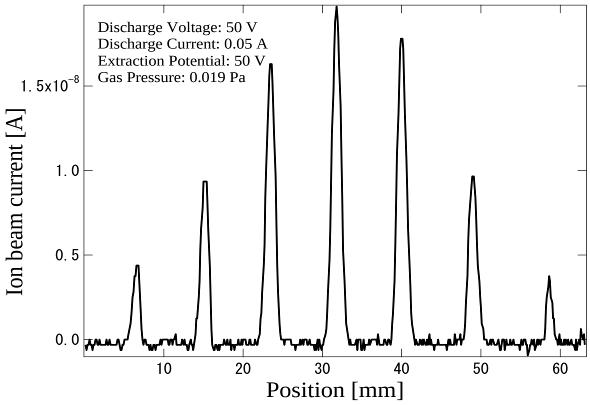

Figure 4. Beam profile measured from the beam emittance measuring system.

4. Summary

Peak height and the width of IEDF of low-energy Ar ion beam extracted by W mesh wire electrodes have been studied. Typical energy spread was below 2 V. In the case of lower extraction potential, beam divergence was larger with respect to beam energy as seen from the energy spread measurement. At low extraction potential, space-charge seemed to affect beam strongly. Accordingly, spatial broadening of the beam did not appear severe in the present investigation.

References

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