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Two-stage acceleration of intense pulsed heavy ion beam by bipolar pulse accelerator

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1. Introduction

Intense pulsed heavy ion beams (PHIB) is expected to be applied for materials sciences including semiconductor implantation and surface modifications. However, in the conventional PHIB accelerators, the purity of the beam is usually very poor [1]. In addition, the producible ion species, however, is limited to the material of electrode (anode), since the anode plasma is produced by a high-voltage flashover and an electron bombardment to the anode surface. Hence, the application of the PHIB has been extremely limited. For those materials processing applications, it is very important to develop the accelerator technology to generate ion beams with various ion species and high purity. To improve the purity, bipolar pulse accelerator (BPA) has been proposed and developed in our laboratory [2]. In this study, we report the experimental results on the energy evaluation of the pulsed ion beam accelerated by the bipolar pulse.

2. Bipolar Pulse Accelerator (BPA)

Figure 1 shows the conceptual drawing of the BPA. It consists of a grounded ion source, a drift tube and a grounded cathode. The BPA is a 2-stage accelerator and operated with a bipolar pulse. When the bipolar pulse (V_0) is applied to the drift tube, ions produced in the grounded ion source are accelerated in the 1st gap toward the drift tube because at first the negative voltage pulse with the pulse duration τ_p is applied. After τ_p the polarity of the pulse is reversed and the positive voltage with the duration τ_p is applied to the drift tube. As a result, the ions are again accelerated in the 2nd gap toward the grounded cathode. In the BPA improvement of the purity of the ion beam is expected [2]. In addition ion source can be installed on the grounded anode. This seems to be favorable for the active ion sources where ion source is powered by an external power supply.

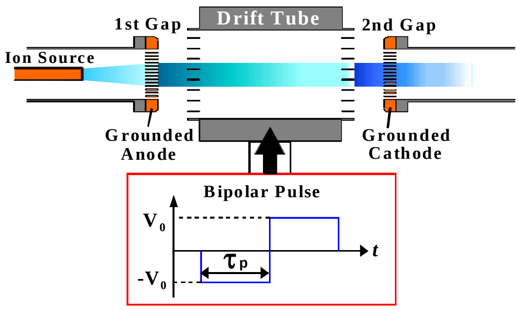

Figure 1 Conceptual drawing of bipolar pulse

3. Experimental Setup for BPA

The system consists of a bipolar pulse generator and an accelerator. The bipolar pulse generator consists of a Marx generator and a pulse forming line (PFL). The designed output of the bipolar pulse generator is the negative and positive pulses of voltage ±200 kV with pulse duration of 70 ns each. In the system, the double coaxial type is employed as the PFL for the formation of the bipolar pulse. The line consists of three coaxial cylinders with a rail gap switch on the end of the line, which is connected between the intermediate and outer conductors. The characteristic impedance of the line between the inner and intermediate conductors and one between the intermediate and outer conductors are 6.7 Ω and 7.6 Ω, respectively. The PFL is charged positively by the low inductance Marx generator with maximum output voltage of 300 kV through the intermediate conductor. The system utilizes a magnetically insulated acceleration gap and was operated with the bipolar pulse. A coaxial gas puff plasma gun was used as an ion source, which was placed inside of the grounded anode.

4. Experimental Results

We used a solid track detector CR-39 as an evaluation of the ion energy of the accelerated ion beam. The track core size and formability formed by the irradiation of the charged particles depend on the stopping power of the material, ion species, valance, and ion velocity. The range of ions can be calculated by multi-step etching technique for observing the growth of the track by performing etching treatment in several hours. The ion energy is estimated by comparing the ion range obtained by the experimental result with the SRIM results. In addition, we evaluate the energy spectrum of the ion beam by using a magnetic energy spectrometer. Table 1 shows the N^+ ion energy evaluated by two methods, where the bipolar pulse with voltage of about –170 kV and +150 kV and pulse duration of about 70 ns each was applied to the drift tube. The ion energy of N^+ was in almost agreement with the acceleration voltage. The high-energy N^+ ions are considered to be produced by the charge exchange of doubly ionized nitrogen ions. Thus, we can say that the pulsed nitrogen ion beam is successfully accelerated by the bipolar pulse.

Table 1 Ion energy of accelerated N^+ ion beam

Energy spectrometer	E_N = 240 ～ 705 keV
Etching technique	E_N = 110 ～ 385 keV

References
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[2] H. Ito, *et al.*, "Bipolar pulse generator for intense pulsed ion beam accelerator", Rev. Sci. Instrum., Vol.78, 013502 (2007).