Characterization of the Ion Beam by Bipolar Pulse Accelerator
両極性パルス加速器によるイオンビームの特性評価

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We have developed a new pulsed ion beam accelerator named “bipolar pulse accelerator” for improvement of the purity of the intense pulsed ion beam. The system utilizes a magnetically insulated acceleration gap and was operated with the bipolar pulsed voltage. A coaxial gas puff plasma gun was used as an ion source, placed in the grounded anode. We demonstrated the first acceleration and obtained pulsed ion beam was current density of 70 A/cm^2 and pulse duration of ≈50 ns at 50 mm downstream from the anode surface.

1. Introduction

Pulsed ion beam (PIB) technology has been developed primarily for nuclear fusion and high energy density physics research [1,2]. Compared with the traditional ion implantation method to semiconductor materials, the PIB implantation enables the accumulation of energy in very short time into the near surface region while it maintains a low substrate temperature. Therefore, PIB has been received extensive attention as a tool for a new ion implantation technique named “pulsed ion beam implantation.”

We have developed a magnetically insulated ion diode using a gas puff plasma gun [3] or a vacuum arc plasma gun [4]. We obtained nitrogen and aluminum PIBs, with ion purity of ~94% and ~89%, respectively. In order to improve the purity of the intense PIB, we have proposed a new type of PIB two-step accelerator named “bipolar pulse accelerator (BPA)” and developed a prototype of BPA and a bipolar pulse generator as the power supply [5,6]. In this paper, we demonstrated the first-step acceleration of the ion beam and evaluated accelerated pulsed ion beam by the BPA.

2. Experimental Setup

Figure 1 shows the schematic configuration of the prototype BPA. The BPA utilizes a magnetically insulated ion diode with an ion source of a coaxial gas puff plasma gun with nitrogen (N_2) gas. The bipolar pulse generator consists of a Marx generator and a pulse forming line (PFL) with a rail gap switch on its end. The PFL is filled with the deionized water as a dielectric and charged positively by the low inductance Marx generator with maximum output voltage of 300 kV through the intermediate conductor. The rail gap switch is filled with pure SF_6 gas and its pressure can be adjusted to control the optimum trigger timing for each experimental condition. The bipolar pulse voltage (V_{OUT}) and charging voltage of the PFL (V_{PFL}) are measured by the resistive voltage divider and capacitive voltage divider placed near the rail gap switch, respectively. The beam ion collector (BIC) is installed inside the drift tube to measure the ion current density of accelerated ions in the 1st gap.

3. Principle of bipolar pulse accelerator

The BPA was designed for the two-step acceleration and improvement of purity of the ion beam. Figure 2 shows how to accelerate the ions using BPA. At first, the negative voltage of the bipolar pulse with a duration τ_p generated by a Marx generator and a PFL was applied to the drift tube. Ions on the grounded anode are then accelerated toward the drift tube. The applied voltage is switched to the positive voltage of duration τ_p when the front of the ion beam reaches the 2nd gap. As a result, the ion are accelerated again in the 2nd gap toward to the grounded cathode. The principle of how the ion purity could be improved is explained in the next section.

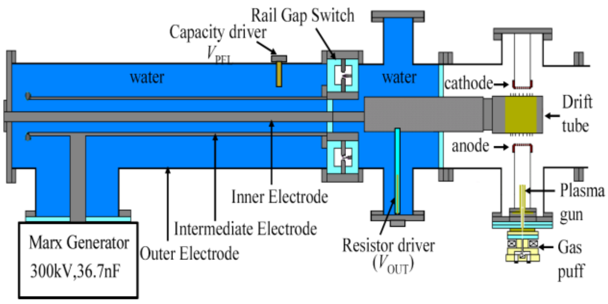

Figure 1. Schematic configuration of BPA.

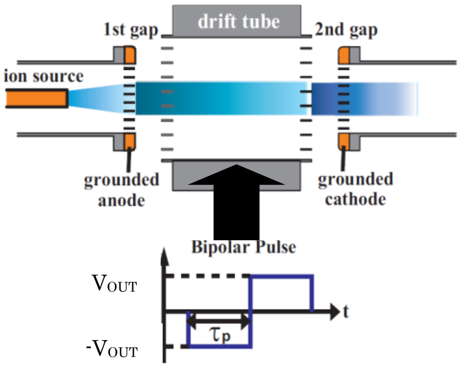

Figure 2. Principle of how the BPA works. See text.

4. Results and Discussion

The designed output of the bipolar pulse generator is the negative and positive of voltage ±200 kV with pulse duration of 70 ns each. Considering the acceleration of N^+ ions and H^+ ions as impurity. N^+ and H^+ ions were accelerated in the 1st gap toward the drift tube when negative voltage is applied to the drift tube. In Fig. 2, N^+ and H^+ beams are schematically described and the flight length of H^+ beams is much longer than that of N^+ because of the difference of the velocity. Assuming the length of the drift tube is same as that of N^+ beams accelerated by V_{OUT} with the duration of τ_p, the flight length would be 11.6 cm when V_{OUT} = 200 kV and τ_p = 70 ns. When N^+ beam reaches the 2nd gap, the polarity of the applied voltage to the drift tube is switched to the positive one. The N^+ ions are then accelerated again in the 2nd gap. In contrast, since length of H^+ beam is 43.3 cm, only 27% of H^+ beam is accelerated in the 2nd gap while no acceleration for the other 73%. As a result, the purity of the accelerated pulsed N^+ ion beam would be improved.

Figure 3 shows the typical waveforms of measured charging voltage and output voltage. Measured output voltage was about ±100 kV with τ_p = 70 ns. Assuming pure nitrogen ion beam, estimated ion energy from time of flight delay of the BIC signal was in reasonable good agreement with the applied acceleration voltage.

We are developing a Thomson parabola spectrometer to analyze the ion energy and species in accelerated ion beam. The two-step acceleration will be demonstrated and evaluated in the near future.

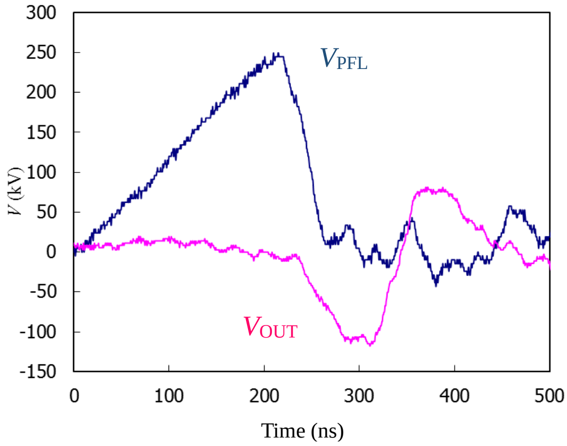

Figure 3. Typical waveforms of charging voltage of PFL (V_{PFL}) and output voltage (V_{OUT}).

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