20PA-005

Negative Hydrogen Ion Beam Extraction from a Low Frequency AC Discharge
低周波交流放電からの水素負イオンビーム引き出し

Yuki Okano, Naoki Miyamoto, Toshiro Kasuya, Motoi Wada
岡野祐樹, 宮本直樹, 粕谷俊郎, 和田元

Graduate School of Science and Engineering, Doshisha University,
1-3 Tatara Miyakodani,Kyotanabe, Kyoto, 610-0321, Japan
同志社大学大学院理工学研究科　〒610-0321　京田辺市多々羅都谷1-3

A plasma grid structure was installed to a Bernas-type ion source used for ion implantation equipment. A negative hydrogen (H^-) ion beam was extracted by an AC driven ion source by adjusting the bias to the plasma grid. The extracted electron current was reduced by positively biasing the plasma grid, while an optimum plasma grid bias voltage for negative ion beam extraction was found to be positive 3 V with respect to the arc chamber serving as the anode of discharge. Source operations with AC cathode heating show extraction characteristics almost identical to that with DC cathode heating .

1. Introduction

A hot cathode arc discharge has a limitation in the cathode lifetime, while it has advantages in stability and the wide dynamic range of extraction current density. To prolong the life of a hot cathode mechanism of cathode erosion had been investigated by several authors. Miyamoto *et al*. have modified Barnas-type ion sources employed for medium energy (around 100 keV) ion implanters to improve the performance through optimizing the cathode structure and the operation procedure for extending the cathode lifetime [1]. They have also shown the local concentration of filament erosion can be improved by running an AC filament heating current [2]. As the result of supplying an AC filament heating current in the frequency range from 20 Hz to 2 kHz, the life of a hot filament cathode has been prolonged as much as 1.4 times the original value.

Bernas-type sources are designed to extract positive ions, but implementing the capability to extract nagative ions may add another manufacturing process utilizing ion implanters. A Bernas-type ion source has the same structure as a Penning-type negative hydrogen (H^-) ion source as the source has reflection electrode and an axial magnetic field [3]. A commercially available Bernas-type ion source has been modified to see if the source can supply negative hydrogen ion beam by simply alternating the polarity of the extraction voltage. Characteristics of H^- ion beam extracted from a plasma excited by an AC driven filament cathode were investigated.

2. Experimental setup

Bernas-type ion sources serves as ion beam source for ion implanters in the semiconductor production field. Fig. 1 shows a schematic diagram of the experimental setup. A cylindrical vacuum chamber containing the Bernas-type ion source has 200 mm inner diameter and 400 mm length. The dimensions of the ion source arc chamber are 90 mm high, 36 mm wide and 29 mm deep. The front plate of the arc chamber confronts with an extraction electrode located 1 mm downstream from the front plate. The tungsten filament cathode is 0.3 mm in diameter and 90 mm in length, while the center 30 mm part is exposed to the plasma. The AC cathode heating currennt is produced by a power amplifier connected to a current transformer, and a function generator produces sinusoidal voltage input to the power amplifier. The produced heating cathode power was supplied through a transformer. An external magnetic field in the direction perpendicular to the beam extraction axis is formed by a pair of electromagnets set on both sides of vacuum chamber. The magnetic field of the intensity from 8 to 18 mT passes through the center of the ion source and makes a magnetic filter configuration to generate H^- ions efficiently. The extracted beam current of H^- ions is measured by a beam profile monitor composed of an array of the Faraday cups. The monitor contains 12 stainless steel plates, while only 8 plates located near the central area were used. The measured area was 5 x 39 mm^2, covered by a plate with 5 x 61 mm^2 opening. The distance from the ion source to beam profile monitor is 100 mm. Hydrogen gas supplied by a hydrogen electric generator is fed into the source through an opening one side of the arc chamber wall.

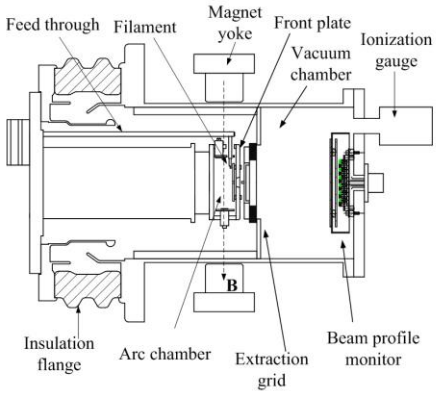

Fig. 1. Schematic diagram of the experimental setup

To decrease the amount of electron current in the extracted beam, a plasma grid is installed in the arc chamber. According to Bacal *et al*, bias between plasma grid and arc chamber reduces extracted electron current [4]. Fig. 2 shows a schematic diagram of the arc chamber equipped with the plasma grid. In order to change the potential between the plasma grid and the arc chamber, the two parts are electrically separated. The plasma grid can be biased both positive and negative with respect to the arc chamber by a bipolar electrical power supply. The plasma grid has a 3 mm diameter hole of the center.

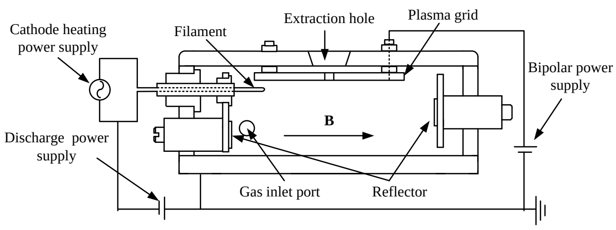

Fig. 2. Schematic diagram of the arc chamber

3. Results

Negative hydrogen ion beam was extracted from the Bernas-type ion source driven by AC heating current. An operation was compared with DC heated cathode condition. First, the bias voltage to the plasma electrode was changed to see the effect to reduce the electron current. Fig. 3 shows the bias voltage characteristics of the extraction current for various frequency. These data were obtained under the conditions of 80 V arc voltage, 1.8 A arc current, 0.04 Pa gas pressure, 1.5 kV extraction voltage and 18 mT external magnetic field. The minimum electron current was observed at positive 3 V bias voltage with respect to the arc chamber. The bias voltage characteristics of the negative ion beam current for various frequency are shown in Fig. 4. These data were obtained under the same conditions of the electron current measurement experiment. The maximum negative ion beam was observed at positive 3 V bias voltage. Comparing Fig. 3 and Fig. 4, the negative hydrogen ion beam increased as the electron current decreased. These results suggest that 3 V bias voltage is suitable for extraction of negative hydrogen ions for the Bernas-type ion source of present geometry.

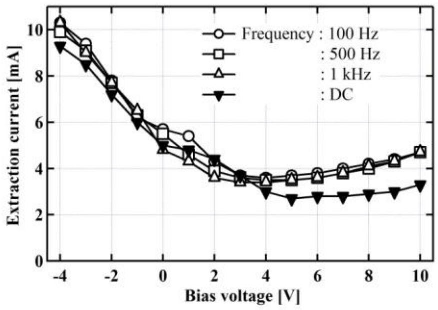

Fig. 3. Extraction current as a function of bias voltage for various frequency

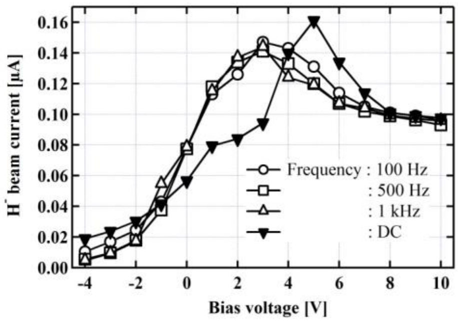

Fig. 4. H^- beam current as a function of bias voltage for various frequency

4. Summary

Negative hydrogen ion beam was extracted using an AC heating filament driven Bernas-type ion source with modified extraction geometry. The plasma grid structure succesfully reduced the extracted electron current. An optimum bias with respect to the arc chamber for negative ion beam extraction was found.

References

[1] N. Miyamoto, *et al.*: Rev. Sci. Instrum. 73, 819 (2002).
[2] Y. Takahashi *et al.*: Rev. Sci Instrum. 83, 02B910 (2012).
[3] K. Jimbo: Thesis (PH.D.)--UNIVERSITY OF CALIFORNIA, BERKELEY, 1982.
[4] M. Bacal, A. Hatayama, J. Peters, IEEE Trans. Plasma Sci.: 33, N° 6, 2005, 1845