§9. Voltage Holding Capability with Beam Acceleration of Large Negative Ion Current

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Giant negative ion sources have been developed for high power neutral beam injectors (NBI) for LHD, JT-60SA and ITER, since the negative ion beams have an advantage of high neutralization efficiency even in higher energy than several 100 keV. In the negative ion sources, multiple beamlets with beam current of several 10 A are accelerated through 1000 apertures on large-size grids (> 1 m^2) up to the beam energy of about 170 keV per 1 acceleration stages. In order to achieve these parameters, one of key factors is voltage holding capability in acceleration gaps. However, the voltage holding capability of the large-size multi-aperture grids have been not clarified yet. The design of the acceleration gaps has been based on some experiences and the results on the sustainable voltage of small electrodes. Therefore, the clarification of the voltage holding capability of the large-size multi-aperture grids is required to obtain higher performances because the gap configurations should be optimized in terms of voltage holding capability and the beam optics.

So far, the voltage holding capability of large-size multi-aperture grids has been studied in the JT-60 negative ion source [1]. As for the vacuum insulation, the experimental results showed that integration of electric field profile on the grid surface strongly affected the voltage holding capability. As for the beam accelerations, the voltage holding capability was degraded by about 10 % from that without beams, and the key factors to determine the achievable beam energy has not been clarified yet. Therefore, achieved high voltages with and without beams are investigated in a wide range of current density by using the JT-60 (~170 A/m^2) and LHD (~300A/m^2) negative ion sources.

In this study, the voltage degradation due to the beam acceleration has been investigated. In the normal operation, acceleration gap is kept in the order of 10^{-4} Pa in vacuum condition initially. In this phase, small amounts (several 10 mA) of the charged particles exist in the acceleration gap, which is so-called dark current. On the other hand, during the beams acceleration, the vacuum pressure at the acceleration gap is raised by H_2 gas-feeding up to 0.01~0.1 Pa and large amounts (several A) of the charged particles flows in the acceleration gap. This flow is mainly composed of the accelerated negative ions and co-accelerated electrons, and can be divided into 2 kinds of the currents. One is the current (Ip) which pass through the apertures and go to downstream. The other one is the current (If) flowing to the grids, where the beam directly impact. The voltage degradation due to the beam acceleration might be caused by these currents.

In order to investigate the voltage degradation due to these currents, the experimental results on JT-60 ion source has been analyzed as shown in Figure 1. At first, the sustainable voltages are normalized by the vacuum level where the I_p ~ 0.1 A and I_f ~ 0.3 A. When only the source plasma was produced without beam accelerations, the dark current was reduced from the vacuum level of 0.4 A to 0.14 A. Although this reduction of the current might be obtained by surface physics of the field emission, it caused the 10 % increase of the sustainable voltage. In case of the beam acceleration, the voltage degradation of 3% was observed at the beam currents of I_p ~ 3 A, I_f ~ 1 A. Although these current actually degrade the sustainable voltage, the individual impact on the degradation has not been clarified yet.

In order to investigate the degradation due to these currents, the voltage degradation in the range of higher beam current (I_p) at lower heat load (I_f) is required, which will be obtained by LHD ion sources and 1/3-size ion source. For the 1/3-size ion source, the grounded grid has been prepared to examine the voltage degradation on round-shape aperture (see Figure 2).

1) Kojima, A.: Rev. Sci. Instrum. 83, 02B117-1~5 (2012).

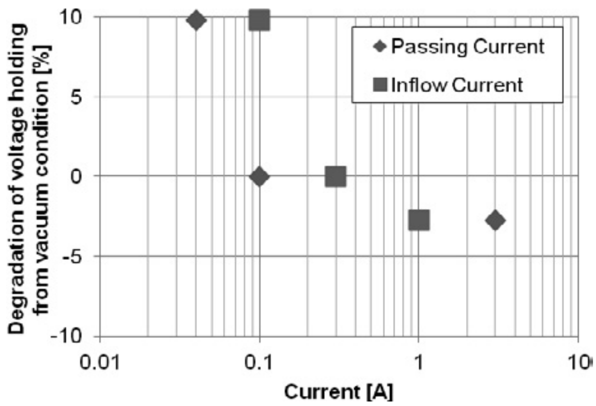

Figure 1. Voltage degradation due to passing and inflow currents.

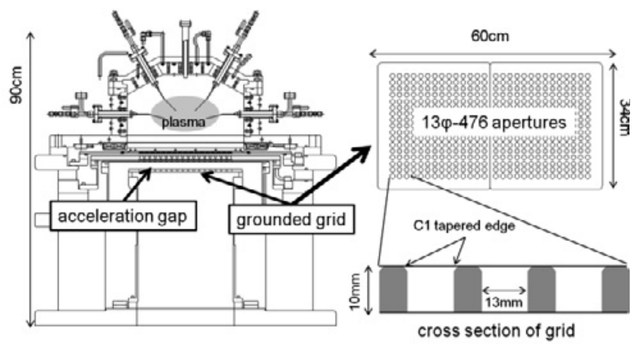

Figure 2. Grounded grid with C1 tapered edgefor 1/3-size ion source.