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

Kojima, A., Hanada, M., Yoshida, M. (JAEA),
Kisaki, M., Tsumori, K., Nakano, H.

Giant negative ion sources for fusion research are required to accelerate large negative ion current over several 10 A up to beam energies of 180, 500 and 1000 keV for LHD, JT-60SA and ITER, respectively. In order to guarantee the long-time acceleration of such high energy and large current beams, one of critical issues is a voltage holding capability of high energy accelerators which consists of multi-stage and multi-aperture grids. In order to achieve higher capability and reduce a breakdown probability, physics of breakdowns should be clarified.

As for the vacuum breakdowns without beam, a dark current due to field emitted electrons is generated at the cathode edge of the aperture, and strongly correlate with the breakdown probability. Therefore, the voltage holding capability of the multi-stage and multi-aperture grids might be restricted by the superposition of the breakdown probability determined by each aperture.

However, considering the beam acceleration, much higher current of the negative ions is accelerated than the dark current. At the same time, several percent of the beam directly hits on the acceleration grids. Actually, the degradation of the voltage holding capability has been observed due to the beam acceleration in many ion sources. However, the mechanism of the breakdown due to the beam acceleration is not clarified. In order to understand and predict the voltage holding capability with the beam acceleration, the voltage holding capability has been investigated by using the ion sources for LHD, JT-60SA and the MeV accelerator for ITER R&D.

This time, the breakdown probability of the LHD ion source (#3) has been obtained after enough conditioning with cesium seeding as shown in Figure 1. The breakdown probability is defined by the number of the breakdown per a shot with the pulse length of 2 seconds. The ion source was operated at the perveance matched condition with beam, and at a half of the operational pressure without beam. As observed in other ion sources, the breakdown probability with the beam acceleration is higher than that without beam. The estimated voltage degradation defined by the ratio of the beam energy at same probabilities is about 3 %.

In order to compare the voltage degradation in these ion sources, the relations between the acceleration current and the voltage degradation are investigated as shown in Figure 2. In this figure, the voltage difference (ΔV) from that obtained in vacuum are investigated with and without beam. In vacuum case ($\Delta V > 0$), the dark current has been observed in these ion sources. However, when a hydrogen gas is injected to the ion sources, the dark current is decreased with the increase of a hydrogen gas pressure, and then the acceleration voltage can be increased. This effect is considered to be a suppression of a surface oxidization which enhances the field emission current. Therefore, this slope of the relation between the voltage and current is considered to be the contribution of the electron component.

In the case of the beam acceleration ($\Delta V < 0$), the voltage degradation due to the increase of the acceleration current has been observed in these ion sources. At first, the slopes with beam acceleration is mainly caused by negative ion component, which seems to be different from the electron contribution. However, detail analysis by the evaluation of the heat load component on the grids is required to understand the difference of these slopes.

Moreover, the voltage degradation of the LHD ion source is smaller than the other ion sources. Considering the superposition of the breakdown probability of each aperture, the smaller degradation of the LHD ion source might be caused by the number of the acceleration stages, since the JT-60 ion source and the MeV accelerator have 3 and 5 acceleration stages. This is the first results of the effect of the multiple acceleration stages on the voltage degradation due to the beam acceleration.

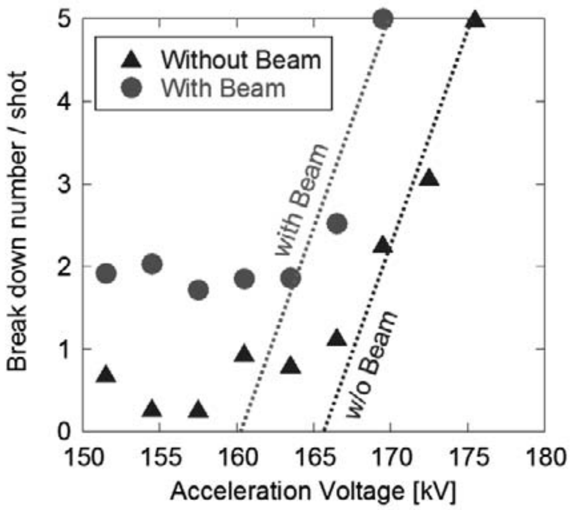

Figure 1. The breakdown probability of LHD-NBI3

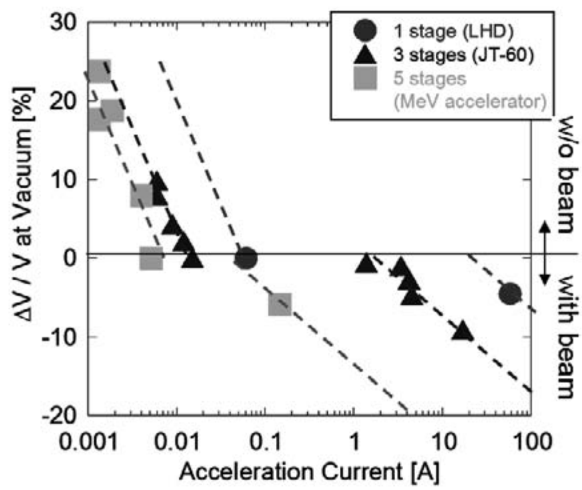

Figure 2. Voltage degradation characteristics depending on acceleration current. V denotes the acceleration voltage.