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High Power and Long Pulse Negative Ion Production by Suppressing of Arcing for JT-60SA

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Reliable and stable operation of a hydrogen negative ion source to produce 500 keV, 22 A for 100 s is required for a neutral beam injector (NBI) for plasma heating and current drive of JT-60 Super Advanced (JT-60SA). The chamber to produce the negative ions is a semi-cylindrical multi-cusp source, so-called KAMABOKO source. Though 100 s long pulse operation was already performed, many anomalous and local discharges, i.e., arcing, limited the input power, and consequently, beam current was limited up to 15 A in long pulse operation. The arc power of this shot was about 160 kW, however the arc power of 200 kW is required to achieve beam current of 22 A. To achieve higher current without arcing, we have investigated causes of the arcing in the several aspects. In the past study, it was clarified that impurities in plasmas or excess cesium induce the arcing. On the other hand, it looks that the arcing positions were influenced the magnetic field configuration, which passes over the filament cathodes. In this study, the filament positions were changed to make clear the influence of the magnetic field to the arcing at the filaments using a small KAMABOKO source. As the result, the better filament position was clarified in this study, which can increase the discharge power to 40 % without arcing. It means this improvement may increase achievable arc power to 220 kW from 160 kW. Applying this better filament position, over 100 s long pulse operation with 30 kW could be achieved at MTF in QST Naka.
The arcing positions on the filaments were located not only in the hottest region on the filament but also in the region inside the multi-cusp magnetic field near the chamber wall. In a three-dimensional electron trajectory analysis, there is a direct path of electrons from the filament to the chamber wall along the multi-cusp magnetic field and there is a localization of electrons in this region. When the filament is inserted deeply to the chamber to avoid the electron emission inside the multi cusp, the electron localization is suppressed. To confirm whether this direct path to the chamber wall is one of causes of arcing, the filament positions were varied by changing the insert depth of filaments in the experiment. As the result, it has been found that changing the insert depth of filaments could improve the arc power without arcing from 30 kW to 40 kW (30 % improvement) in the small KAMABOKO source. In addition, it was also found from simulation that electron localization is suppressed by changing insert direction of filaments from equatorial direction to obliquely upward direction because of difference of the magnetic field distribution around filaments. Changing the insert direction of filaments in addition to changing the insert depth of them could cause another 10 % increase in the arc power without arcing: from 40 kW to 44 kW. At the same time, it is also found in a Langmuir-probe measurement that electrons nearby the chamber wall was decreased to a half with the insert depth of filaments from 10 mm to 50 mm as expected in the simulation. The demonstration test of this improvement was performed at MTF in QST Naka. In this test, we could achieve the long pulse plasma generation of 30 kW and 300 s, which is enough long compared with required value, 100 s, for JT60SA ion source. This result will be applied for JT-60SA ion source to achieve stable high power and long pulse operation.

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