§22. Optimization of RF Coupling to Produce High-Density Homogenous Plasma for Negative Ion Sources

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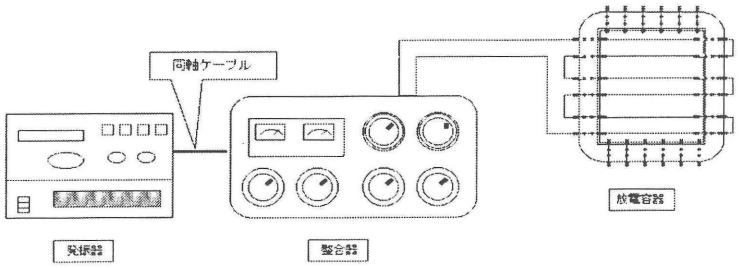
In the experiment in FY 1999, we found a grill-like antenna gave the most homogenous plasma when a set of straight antenna bars were connected to flow 13.56-MHz rf current in a zigzag way, as shown in Fig. 1. This year, we tested the configuration of the magnets buried in the bars to avoid the impingement of the plasma electrons.

A magnetic-multipole type plasma source with bore of 27 cm * 27cm and 15cm in depth was used. Six antenna bars were positioned on a flat plane in the plasma source with space of 2.5 cm or 4.5 cm alternately. A set of ferrite magnets were aligned in each antenna bar to form line cusps. The size of each magnet was 4 cm·1.2 cm * 0.6 cm and they were magnetized in the direction of 0.6 cm.

The discharge patterns recorded by a digital camera for four types of magnet arrangements were shown in Fig. 2; a) without magnets, b) N (S) pole in an antenna bar faced to S (N) pole in the next bar (NS type), c) N (S) pole in an antenna bar faced to N (S) pole (NN/SS type), d) magnetized direction of the magnets were perpendicular to the flat plane including the antenna bars and all N (S) poles were lined up (NS line-up type), and e) similar to d) but N and S poles were altered for each bar (NS alt type). All discharges were obtained in the same condition; 0.3-Pa air discharge by 50-W rf power.

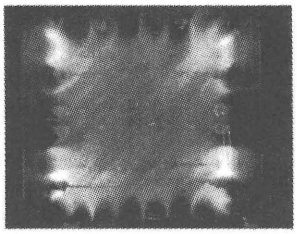
We see that NN/SS type gives the most homogenous and dense plasma, as shown in Fig 2c). This is due to the effective plasma expansion produced near the magnets along to the magnetic lines of force to the direction perpendicular to the flat plane including the antenna bars. NS line-up type gives a dense but inhomogenous plasma near the center (an inclined bright line in Fig. 2c)). This is probably due to the interference of the total magnetizations of all magnets in the antenna bars and the magnetic field of the plasma chamber.

In conclusion, the most homogenous and dense plasma was obtained with the magnetic configuration of NN/SS type in the grill-like antenna. Such an antenna would be applicable for industrial use such as the treatment of semiconductor, while substantial R&D's would be still required to realize negative-ion sources with this type of antenna for fusion applications.

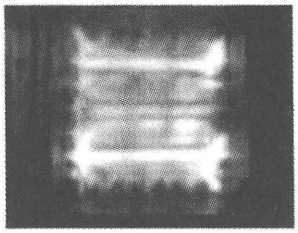


rf source matching system plasma source

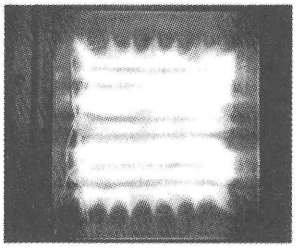
Fig. 1 Experimental setup



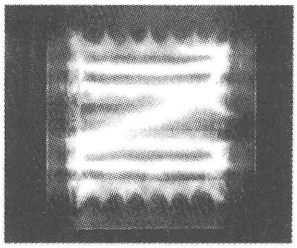
a) without magnets



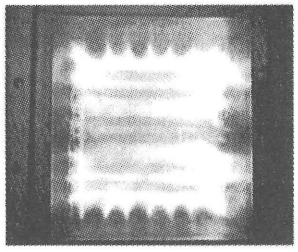
b) NS type



c) NN/SS type



d) NS line-up type



e) NS alt type

Fig.2 Discharge patterns for various magnet configuration