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Volumetric recombination of high density plasma in converging field following an ECR plasma source

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Atomic processes and transport of high-density plasmas in external magnetic field are significant processes for the divertor plasma study, where comprehensive understanding on volumetric recombination of high-density plasma flowing along the field line is required. We have developed a high-density plasma production method applicable to arbitrary higher magnetic field than the ECR magnetic field,[1] in which both trapped electrons and an overdens electromagnetic mode play important roles. Because resonantly accelerated electrons are trapped in a magnetic mirror generated between the ECR plasma production region and the higher magnetic field region, the electrons efficiently ionize before they diffuse to a chamber wall.

In experiments using an ECR plasma device NUMBER with a frequency 2.45 GHz microwave power supply. A right-hand circularly polarized microwave is injected from an end of the chamber, where a condition of high field side injection along magnetic beach is satisfied as shown in Fig. 1. Helium gas is supplied to both the production region and the higher magnetic field region (test region). Then a high-density $n_e \simeq 1 \times 10^{18}$ m^{-3} helium plasma in magnetic field $B \simeq 0.3$ T has been successfully obtained.

Particle fluxes are measured by the ion saturation current of Langmuir probes for various helium gas pressure. Particle flux at the middle of the test region monotonically increase with the helium gas pressure, while that at the end plate saturates for $p > 0.8$ Pa. Then the ratio of particle flux at the endplate normalized to that at middle of the test region increases with the gas pressure for $p < 0.5$ Pa, while it decreases with the pressure for $p > 0.8$ Pa. The phenomenon is similar to so-called the density roll over, which is observed in the plasma detachment from divertor targets. In suitable neutral gas pressure $p \simeq 1$ Pa, line emission spectra from highly excited states of helium atom, He I ($n \leq 13$), have been observed in the middle of the test region. These spectra are good indicator of volumetric recombination. Sufficiently low electron temperature $T_e \simeq 0.06$ eV to induce the recombination has been obtained from Boltzmann plot as shown in Fig. 2. While the volumetric recombination and the density roll over are often observed in DC arc discharge plasmas, this is the first time observation in ECR plasmas.[2] Then an open question is relaxation process for the energetic electrons generated by ECR.

In order to answer the question, the measurement of anisotropic electron energy distribution using a laser Thomson scattering system is ongoing as well as electrostatic measurement. Initial results on the electrostatic measurement of floating potential both in the ECR plasma production region and in the test region suggest higher electron temperature clump is transported into the higher magnetic field region.[3]

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References

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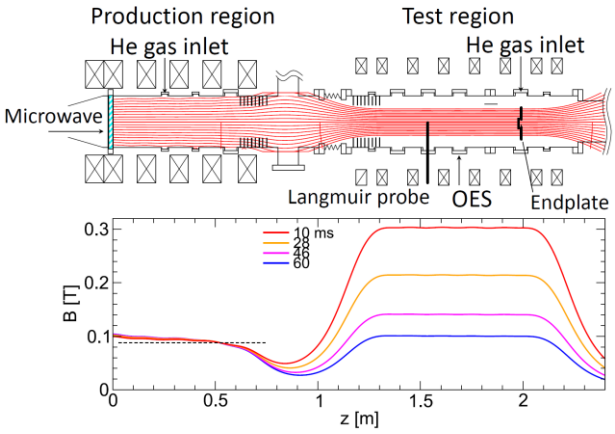

Figure 1 Schematic of NUMBER device and magnetic field profile on the chamber axis. OES denotes the position of optical emission spectroscopy.

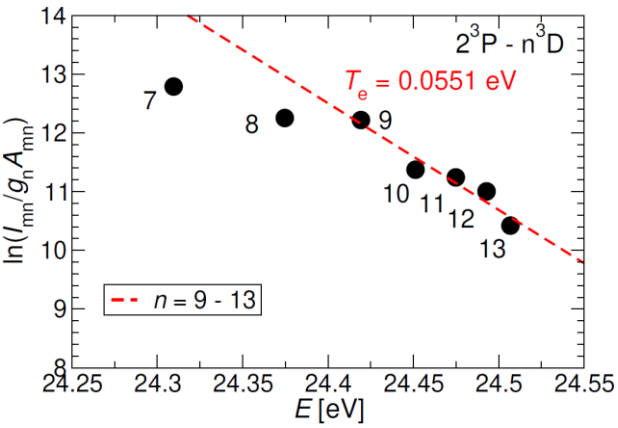

Figure 2 Boltzmann plot of He I line emission spectra.