§11. Fundamental Study on Ion Separation by Control of Bias Voltage in Magnetized Plasma

Shinohara, S., Kawaguchi, M., Terasaka, K.
(Interdis. Grad. Sch. Eng. Sci., Kyushu Univ.),
Fujisawa, A., Ida, K., Iguchi, H.

Understandings of transport barrier and its formation mechanism, which have been actively investigated in NIFS, are crucial in the future nuclear fusion studies. Plasma rotation driven by so-called ***E*×*B*** drift has been also studied in relation to improvement of the magnetic confinement. Therefore, investigations of the dynamic process of the electric field and its effect on transition phenomena in plasmas are very important.

Concerning the density transition phenomena in simple magnetized plasmas, different ion separation is also attractive from a practical viewpoint. We have been trying to control the density transition phenomena along with plasma rotation and density profile modification, using ten concentric circular rings as biased electrodes [1-5]. Here, dynamic changes of ion trajectory were studied by applying the steady or pulsed bias voltages [6]. Fundamental principle of mass separation is based on the ion trajectory in the presence of the crossed electric and magnetic fields: below (above) the critical electric field ions can be trapped in the plasma core (can escape from the plasma core). From simple calculation, the azimuthal rotation velocity is written as follows.

$$v_\theta = \frac{\omega_{ci} r}{2}\left(-1 \pm \sqrt{1 - 4E_r / rB_z\omega_{ci}}\right). \qquad (1)$$

In the case of the parabolic potential profile, critical mass, above which ions are not trapped, is proportional to $a^2 B / V_0$, where a, B and V_0 are plasma radius, magnetic field and the central potential, respectively. Figure 1 shows an example that argon ion is trapped, whereas Xe ion is not trapped with B = 1,000 G and V_0 = 50 V [positive term in eq.(1)]. If V_0 is raised to 120 V, argon ion is also detrapped.

Figure 2 shows the azimuthal rotation velocity as a function of V_0. Here, open and closed circles are cases from the particle simulation. The velocity from eq. (1) (theory) along with E×B drift velocity are also shown. It is clear that with increasing V_0, the velocity of Xe ion (simulation) slows down near the critical voltage, shown in a dotted line, and cannot be trapped above this line.

Experiments were carried out in the following conditions: With a pressure P (argon and xenon) of ~ 0.16 mTorr in the cylindrical chamber, 45 cm in diameter and 170 cm in axial length, plasma was produced by a RF wave of 7 MHz. Plasma parameters were measured by a Langmuir and the Mach probe, whose data were stored with a data logger. Typical plasma density and electron temperature were 2.5 × 10^9 ~ 1.4 × 10^{10} cm^{-3} cm^{-3}, 3 - 6 eV, respectively.

Using this system, initial results showed that the above-mentioned behavior such as the rotation velocity predicted was qualitatively supported.

In conclusion, we have investigated the detailed profiles of plasma parameters to demonstrate the different ion separation, relating to the transitions by voltage biasing. Obtained results are consistent with the expected behavior from simple simulation and theory. These understandings will be expected to contribute to the plasma confinement and stability control.

References
1) S. Shinohara *et al.*, Trans. Fusion Technol. **39** (2001) 358: Phys. Plasma **8** (2001) 1154, **9** (2002) 1834.
2) S. Matsuyama and S. Shinohara, J. Nucl. Fusion Res. **4** (2002) 528.
3) S. Shinohara, Phys. Plasma **9** (2002) 4540: Rev. Sci. Instrum. **74** (2003) 2357.
4) S. Shinohara *et al.*, Thin Solid Films **506-507** (2006) 564.
5) S. Shinohara *et al.*, Eng. Sci. Rep, Kyushu Univ. **27** (2006) 355.
6) S. Shinohara *et al.*, Jpn. J. Appl. Phys. **46** (2007) in press.

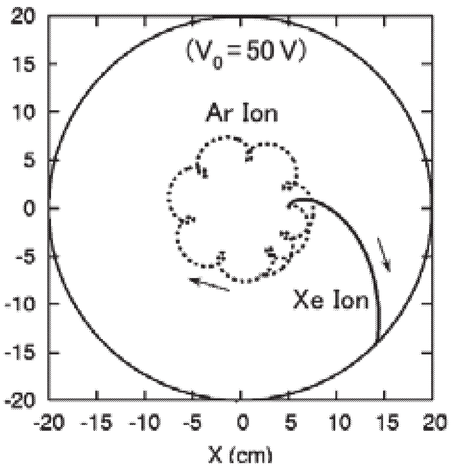

Fig. 1. Argon and Xe ion trajectories.

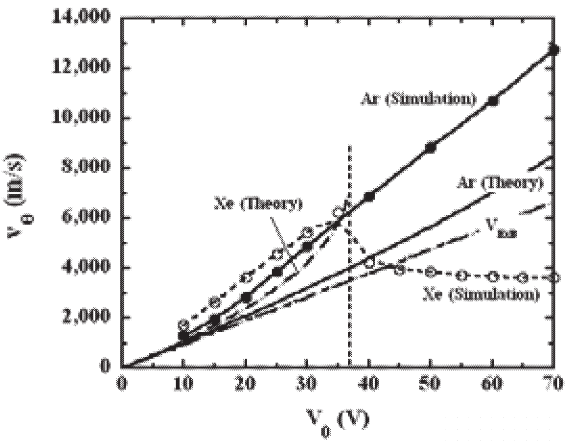

Fig. 2. Azimuthal rotation velocity as a function of the central bias voltage.