§7. Extension of Theoretical Models of Sheath Structure in Negative-ion Plasmas

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Negative-ion-containing plasmas are of great interest for NBI development in fusion science. To control such plasmas more precisely, we have to take into account the physical properties of sheath. However, we do not have any standard theory to describe thoroughly how the existence of negative ions influences sheath behavior. The purpose of the present study is to specify the range of plasma parameters within which a conventional sheath theory holds true. This task is operated by comparing the theory with experimental observation of sheath in negative-ion-containing plasmas. Such attempt will hopefully lead to the creation of perfect theory for sheath in negative-ion-containing plasmas.

The experiments were performed in a double plasma (DP) device. The sheath potential ϕ (the difference between the floating potential V_f and the space potential V_s) was measured using a Langmuir probe. We compare the measurement with the conventional theory proposed by Shindo and Horiike[1]. The plasma parameters of interest are i) the negative ion concentration r, ii) negative ion-positive ion mass ratio μ, and iii) the plasma density n.

i. The value of r is controlled by the partial pressure of SF_6 gas and is evaluated from the decrease in the electron saturation current of *I-V* curves.
ii. The value of μ is changed by using Ar and Xe as the operating gas. From the fact that the dominant negative ion species is F^-[2,3], it follows that μ = 0.48 and 3.3, respectively.
iii. The value of n is controlled by adjusting the operating gas pressure. In Ar^+-F^- plasma, the operating Ar gas is introduced in the range from 18 to 72 mPa corresponding to the density $n = 1.5\times10^8$ to 2.6×10^9 cm^{-3}. In Xe^+-F^- plasma, the operating Xe gas is introduced in the range from 18 to 72 mPa corresponding to the density $n = 2.7\times10^9$ to 8.9×10^9 cm^{-3}.

The comparison results of experimental and theoretical values for Ar^+-F^- plasma are shown in Fig. 1, where the vertical and the horizontal axes represent the sheath potential ϕ and the negative ion concentration r, respectively. We see that low r provides a good agreement between the experimental and theoretical values. In the range of r higher than 0.5, however, these values tend to separate from each other. Moreover, higher r provides more discrepancy between these values. Fig. 2 shows the comparison for Xe^+-F^- plasma. Here the experimental and theoretical values also exhibit similar tendency that for low r these values are close but for high r they get separated. That is, the theoretical calculation can predict the experimental value of the sheath potential for low r, but this does not hold true for high r, and this tendency does not depend on μ. In addition, we have observed that the value of r where the separation of the experimental and theoretical value begins tends to become lower for lower n.

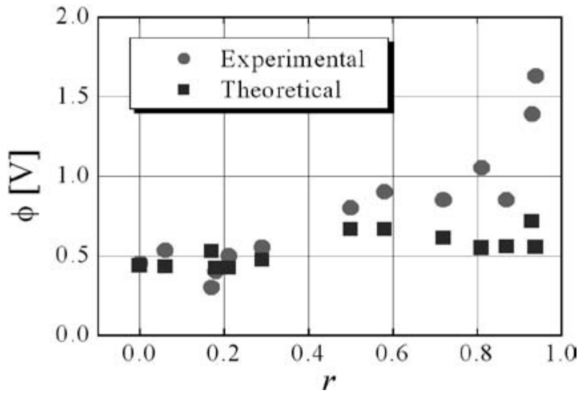

Fig. 1. Sheath potential as a function of negative ion concentration in Ar^+-F^- plasma. In the experiment, $n = 2.6\times10^9$ cm^{-3}.

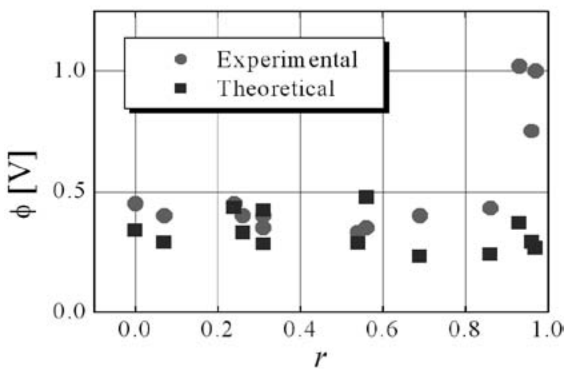

Fig. 2. Sheath potential as a function of negative ion concentration in Ar^+-F^- plasma. In the experiment, $n = 8.7\times10^9$ cm^{-3}.

We hope that continuing such comparison will specify the exact range where the conventional sheath theory for negative-ion-containing plasmas works.

1) H. Shindo and Y. Horiike, Jpn. J. Appl. Phys. **30**, 161 (1990).
2) R. Ichiki, S. Yoshimura, T. Watanabe, Y. Nakamura, and Y. Kawai, Phys. Plasmas **9**, 4481 (2002).
3) R. Ichiki, M. Shindo, S. Yoshimura, T. Watanabe, and Y. Kawai, Phys. Plasmas **8**, 4275 (2001).