§7. Study on Shock Waves Leading to Investigation of Sheath in Negative-Ion Plasmas

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1. RESEARCH PROJECT

An important issue of the plasmas containing considerable amount of netative ions is to make clear the physics of sheath-forming in them. Research of the sheath in negative ion plasmas is promising to contribute to further development of negative ion sources for NBI technology and high-density plasma processing.

Our project is to contribute the advancement of understanding sheaths formed in negative ion plasmas through a study on shock waves excited in such plasmas. The research project is based on our original idea, i.e. ion acoustic shock waves can have a negative amplitude theoretically and the theory predicting the negative-amplitude shock is quite analogous to the theory of sheath[1]. Here, we investigate characteristics of shock excitation in a double plasma device, especially in plasmas with high negative ion concentration.

2. ADVANCEMENT OF RESEARCH

First, we numerically evaluated the range of possible Mach numbers of negative-amplitude shocks following the theory of Sagdeev potential[2]. As a result, it was first uncovered that the range of possible Mach numbers depends strongly on the negative ion concentration r, and the gray zone shown in Fig. 1 was proved to be the possible region.

Fig. 2 shows a schematic of excitation mechanism of shock waves in the double plasma device, called the double plasma method. Biasing a positive ramp voltage to the anode of the driver region moves positive ions toward the target region to excite compressive density fluctuation. On the other hand, a negative ramp voltage produces a rarefied fluctuation which develops to a negative-amplitude shock wave.

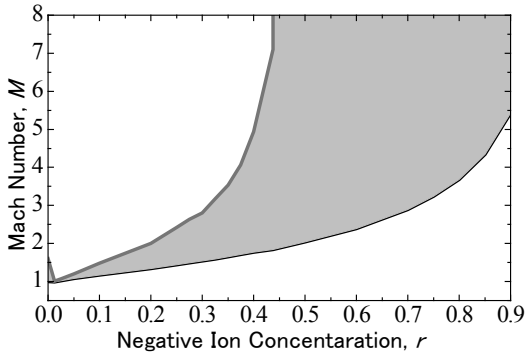

Fig. 1 Theoretically evaluated range of possible Mach number of negative-amplitude shock waves in negative ion plasmas.

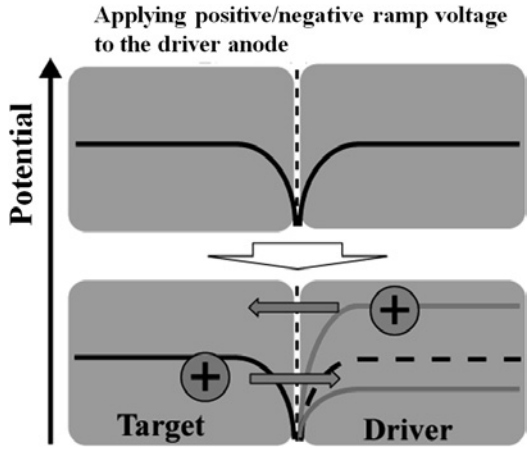

Fig. 2 Schematic of the double plasma method to excite ion acoustic shock waves.

We observed the electron saturation current with a plane Langmuir probe to detect excitation and propagation of negative-amplitude shocks. When the negative ion concentration was 0.79, a shock-like signal shown in Fig. 3 was observed. This signal has a negative fluctuation and involves negative steepening of the wave front. Investigating the Mach number by the time-of-flight method revealed that the ramp voltage above 7 V is necessary to be applied for negative shock propagation. Consequently, we succeeded in exciting the negative-amplitude shocks in plasmas with high negative ion concentration.

We believe that such phenomenon has common physical properties to sheath in negative ion plasmas so that to examine the negative-amplitude shocks leads us to comprehending sheath behavior clearly.

1) R. Ichiki, Dr. Thesis, Kyushu Univ., 2004.
2) F. F. Chen, *Introduction to Plasma Physics and Controlled Fusion 2nd ed.*, Plenum Press, 1984.

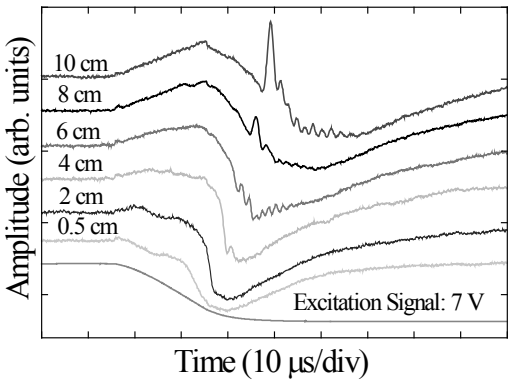

Fig. 3 A shock-like signal observed in the double plasma device for the negative ion concentration as high as 79%.