§8. Investigation on Propagation of Ion-acoustic Shock Waves in Plasmas with Negative Ions

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1. BACKGROUND

An ion-acoustic shock wave having a negative amplitude (called rarefaction shock) is predicted to propagate only in plasmas with negative ions.[1,2] The authors believe that the investigation of "the negative shock" can contribute to the sheath study of negative ion plasmas. This idea is based on the fact that the theoretical models of sheaths and negative shocks are quite analogous.[3] Elucidating the mechanism of sheath in such plasmas should lead to further advancement of plasma technologies. In this project we have developed the double plasma device for shock experiments and performed excitation of negative shocks as a preliminary experiment for the next project using the HYPER-I device of NIFS.

2. EXPERIMENTAL RESULTS

2-1. Double Plasma Device

Figure 1 shows the double plasma device constructed in Oita University. The device measures 45 cm in diameter by 100 cm in length. The device was successfully fitted with a vacuum system, gas supply lines, and electric circuits. The chamber is evacuated to less than 10^{-3} Pa by a diffusion pump. The driver and the target region are each fitted with eight W filaments of 5 cm in length, used as the hot cathode.

2-2. Production of Negative Ion Plasmas

Ar gas is bled through a needle valve and its partial pressure is 0.1 Pa. The discharge voltage and current are 50 V and 60 mA, respectively. Consequently, a collisionless Ar plasma of 10^8 cm^{-3} in density was produced in the device. Negative ions were produced in the Ar plasma by adding SF_6 gas to the plasma at a flow rate below 0.1 sccm. Figure 2 shows that the negative ion concentration is controllable by changing the SF_6 flow rate. We have achieved to control the concentration from 0 to 90 %.

2-3. Wave Excitation and Detection

Figure 3 shows the evolution of a negative density perturbation excited by applying a ramp voltage to the driver anode. The negative ion concentration was 40%. The signal was the ion saturation current detected by a plane Langmuir probe. We can see that the negative perturbation develops to a sharp (discontinuous) density jump. This steepening phenomenon indicates that the excited signal is a shock wave or, at least, a shock-like wave having a negative amplitude. Moreover, the measurement of the propagation velocity using the time-of-flight method revealed that the Mach number is $M = 1.2$, meaning that the wave propagates faster than the ion acoustic velocity. This is another evidence that the observed wave is a shock wave. Furthermore, such a negative signal turns out not to exist in Ar plasmas when negative ion is absent.

1) Y. Nakamura, *Proc. 2000 Intl. Cong. Plasma Phys.* Vol. 2, 396 (2000).
2) R. Ichiki, Dr. Thesis, Kyushu Univ., 2004.
3) F. F. Chen, *Introduction to Plasma Physics and Controlled Fusion 2nd ed.*, Plenum Press, 1984.

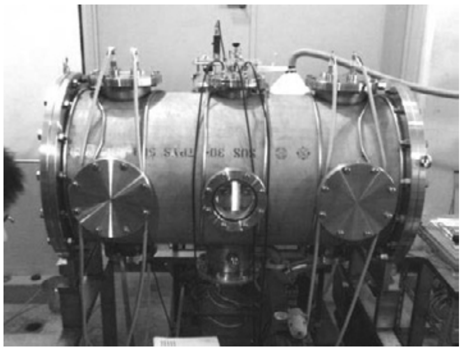

Fig. 1 Constructed double plasma device.

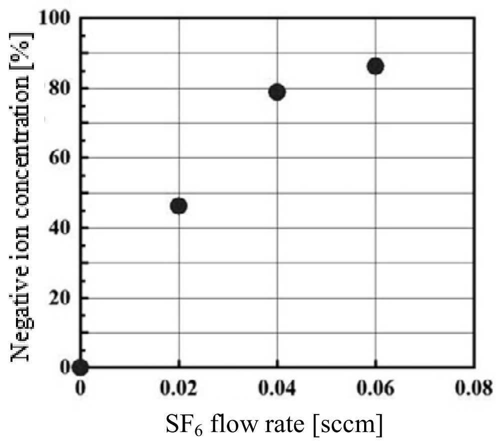

Fig. 2 Controlling negative ion concentration by changing SF_6 flow rate to Ar plasma.

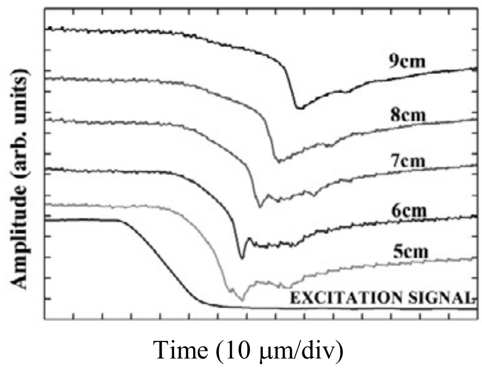

Fig. 3 Observed negative density perturbation developing to a shock-like wave.