§21. Evolution of Plasma Structures Accompanied by Local Production of Negative Ions

Ishiguro, S., Oohara, W., Hatakeyama, R., Sato, N.
(Dept. Electronic Eng., Tohoku Univ.)

We have investigated plasma dynamics associated with local production of negative ions by a laboratory experiment and a numerical simulation. Our preliminary measurements[1] are performed in our Q-machine plasma (density $n_p \simeq 5 \times 10^9$ cm^{-3}, electron temperature $T_e \simeq 0.2$ eV), where fullerene C_{60} (cage-like molecule composed of 60 carbon atoms, mass number $\simeq 720$) particles of temperature $T_{C_{60}} \simeq 0.058$ eV are introduced.[2] In the experiment, negative ions C_{60}^- are locally produced in the K^+(mass number $\simeq 39$, temperature $T_+ \leq T_e$)−electron plasma column as a result of sublimation characteristic and large electron affinity of the C_{60} particles.

A computer simulation has been performed by means of a one-dimensional electrostatic particle code based on a Q-machine configuration. As electrons and positive ions are emitted from the plasma emitter placed at one end of the system, they fill the system, providing a quasistationary state. After that, negative ions start to be produced in a localized region of the plasma in such a way that some of electrons attached to C_{60} particles are replaced by negative ions.

While the plasma is stable for a small rate of negative ion production, a large fluctuation is found to appear in some physical quantities for a large rate of negative ion production. Figure 1 shows the potential profiles (a) and the phase space distributions of negative ions (b) at $\omega_{ps}t = 127.6$ (top), 127.8 (second), 128.0 (third), and 128.4 (bottom) $\times 10^3$, which demonstrate the generation process of a large-amplitude solitary wave with negative potential around the center of the negative ion production region ($z/\lambda_{Ds} \sim 130$). A double layer is observed to be intermittently formed there. Negative ions are strongly accelerated by the double layer and a large-amplitude pulse of negative ion density is created by their bunching. The potential profile in the negative ion-rich region created in such a way becomes depressed or concave ($d^2\phi/dz^2 > 0$). This potential pulse propagates as a large-amplitude solitary wave with negative potential.

Detailed observations have shown that the double layer formation is triggered by a small negative potential pulse which is generated in the upstream region and propagates to the negative ion production region. This pulse is created by a positive-negative ion two-stream instability. Figure 2 shows the velocity space-time distributions of positive ions $f_+(v)$(top), negative ions $f_-(v)$(middle), and electrons $f_e(v)$(bottom) during $\omega_{ps}t = 114 \sim 154 \times 10^3$ in the region of $10 < z/\lambda_{Ds} < 80$. When the negative potential pulse is generated, the drift velocities of positive and negative ions approach each other. The created double layer accelerates negative ions and a large amplitude solitary wave with negative potential is thereby generated.

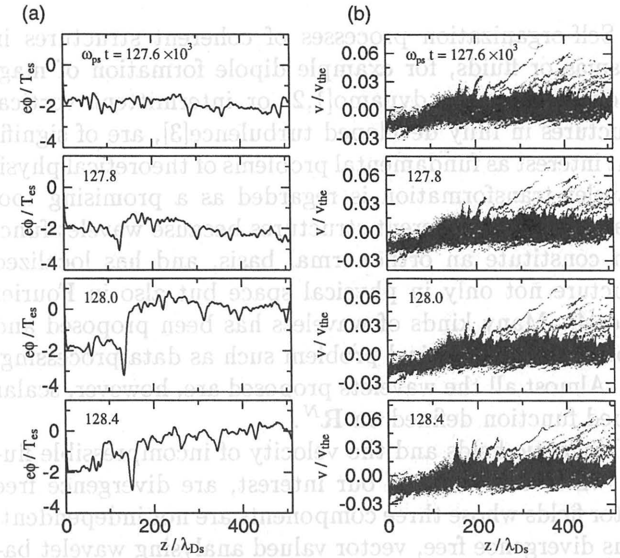

Fig. 1. Potential profiles (a) and phase space distributions of negative ions (b) at $\omega_{ps}t = 127.6$ (top), 127.8 (second), 128.0 (third), and 128.4 (bottom) $\times 10^3$.

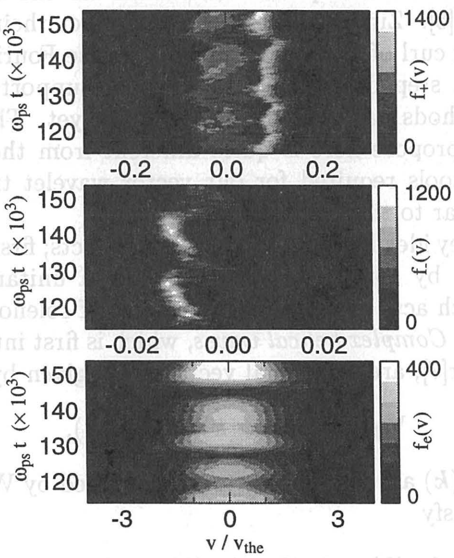

Fig. 2. Velocity space-time distributions of positive ions (top), negative ions (middle), and electrons (bottom) in the upstream region.

References
1) Oohara, W. *et al.*: in *Double Layers - Potential Formation and Related Nonlinear Phenomena in Plasmas* edited by Sendai "Plasma Forum" (World Scientfic, Singapore, 1997) p. 149.
2) Sato, N. *et al.*: Phys. Plasmas 1 (1994) 3480.