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Multi-Layer Flow Structure Formed by Interaction of Plasma and Neutral Gas

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Plasma is generated by applying electromagnetic pressure to a neutral gas, but it is not clear what factors determine the shape of the plasma. In a vacuum vessel, the supplied neutral gas spreads out in the vessel, and the applied electromagnetic pressure also spreads spatially. The shape of the plasma reflects the interaction between the spatial extent of the electromagnetic pressure and the flow of the neutral gas. When helium gas flows in a vacuum vessel and an AC voltage is applied, multi-layer flow (MLF) is observed in the cylindrical plasma, where the axial flow velocity varies and layers form in the radial direction. In this study, we attempted to clarify the experimental conditions and physical mechanisms by which the MLF structure is formed in the plasma.

The vacuum vessel consists of a thin quartz tube and a thick quartz tube [1]. Figure 1 shows the photographs of the plasma flow without and with MLF formation. When helium gas was supplied as the plasma source at a gas flow rate of 0.25 slm and the background static pressure was changed from 52 to 500 Pa, MLF structure appeared. The cases at 52 and 500 Pa are the absence and presence of MLF structure, respectively. Figure 2 shows the radial distribution of plasma emission intensity in the white dashed line in Figure 1. The total plasma emission in the vacuum vessel does not change with or without MLF. When MLF appears, the intensity of plasma emission in the radial direction is distributed so as to be concentrated in the center. As shown in Figure 3, when MLF is formed, the fluctuation of plasma emission changes in the radial direction. When the fluctuation of the plasma emission has a plurality of maximum and minimum values, it is judged that MLF is formed. As a result, the MLF structure is formed at high background static pressure. Consequently, the occurrence of MLF depends on the change of the dynamic pressure of the supplied helium gas and the background static pressure of the vacuum vessel. The dynamic pressure of the supply gas flow rate of 0.25 slm is calculated to be 0.46 Pa. In addition, the electron thermal pressure in the helium plasma was measured by continuum spectral analysis to be 0.8 Pa near the powered electrode in the upper thin quartz tube of the upstream side. As the plasma leaves the powered electrode and diffuses downstream, the electron thermal pressure also decreases. The electron thermal pressure of the plasma is a static pressure and acts as a wall against the flow of neutral gas. Therefore, when the electron thermal pressure of the plasma and the dynamic pressure of the neutral gas flow are close in value, they will interfere with each other, causing the neutral gas flow to be split at the plasma wall, forming a multi-layer flow structure.

References

[1] K. Yambe *et al*, AIP Adv. **10**, 025210 (2020).

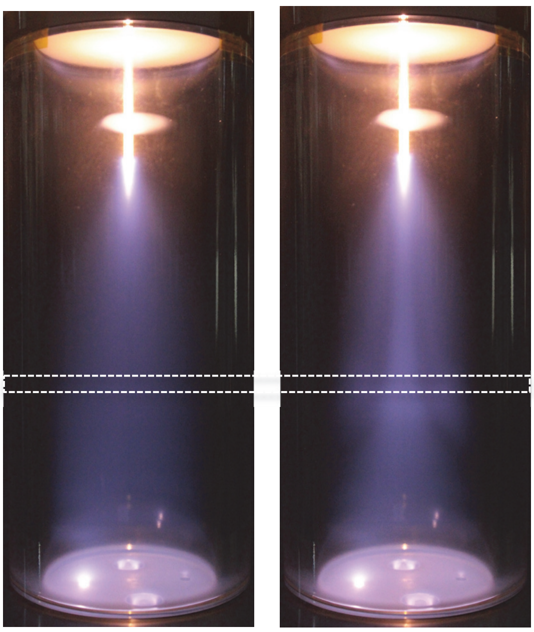

Figure 1. Photographs of plasma flow without (left: 52 Pa) and with (right: 500 Pa) multi-layer flow formation.

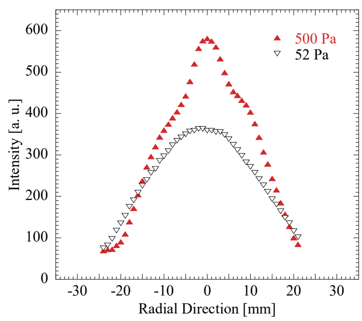

Figure 2. Radial distribution of plasma emission intensity in the white dashed line in Figure 1.

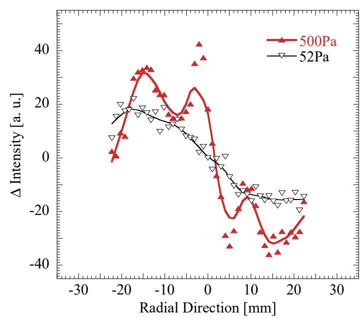

Figure 3. Radial distribution of fluctuations in plasma emission intensity.