§34. Development of Laser-Induced Fluorescence-Dip Spectroscopy of Argon for Sensitive Measurements of Electric Fields in Plasmas

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Measurement of electric field is an important issue in fusion plasmas as well as low-temperature plasmas for industrial applications. In the present work, we developed a sensitive method for measuring electric fields in various plasmas. This technique is based on laser-induced fluorescence-dip (LIF-dip) spectroscopy, which was demonstrated by Czarnetzki and coworkers in several years ago.[1] Czarnetzki and coworkers employed H atoms as the probe particle. In this work, we applied LIF-dip to Ar.[2-4] The use of Ar as the probe particle enables us to apply LIF-dip to various plasmas.

The principles of LIF-dip of Ar have been reported elsewhere. It is a sort of laser Stark spectroscopy, and the structure of energy levels of Ar high Rydberg states is measured by a two-step excitation scheme using two tunable lasers. An electric field induces the Stark effect in the structure of high Rydberg states. The strength of the electric field is determined from the measurement of the energy level structure of high Rydberg states.

The usefulness and the sensitivity of LIF-dip of Ar were demonstrated by using an inductively-coupled plasma (ICP) source. A movable planar electrode was inserted in plasmas produced by an internal ICP antenna activated by an rf power supply at 13.56 MHz. The electrode was connected to a dc power supply. The distribution of the electric field in the sheath in front of the planar electrode was measured by LIF-dip spectroscopy. The operating gas was the mixture of Ar and SF_6. The degree of electronegativity (the density ratio of negative ion to electron; $\alpha = n_-/n_e$) was varied by changing the partial pressure of SF_6, and we measured the distributions of sheath electric fields at various values of α. We used a dye laser and an optical parametric oscillator (OPO) for the LIF-dip spectroscopy.

A sensitive detection limit of 3 V/cm has been obtained by the LIF-dip spectroscopy of Ar, which is the champion detection limit in the measurement of electric field in plasmas. Figure 1 shows the distributions of sheath electric fields observed at various values of α. As shown in Fig. 1, it has been found for the first time that the distribution of sheath electric field in an electronegative plasma has a multistage structure. This multistage structure may be attributed to the reflections of negative ions and electrons at different distances from the electrode.

References
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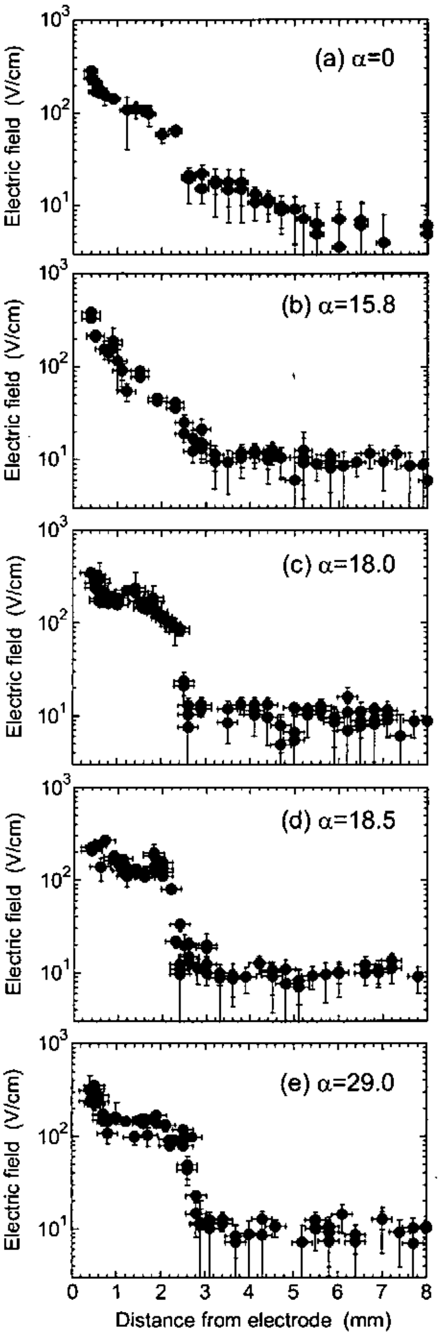

Fig. 1 Distributions of sheath electric fields observed in Ar/SF_6 ICP plasmas at various partial pressures of SF_6.