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Sensitive measurement of electric field in a collisionless dc sheath by laser-induced fluorescence-dip spectroscopy†

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Electric fields in sheaths between plasmas and solid surfaces play essential roles in plasma processing of materials. For the measurement of the sheath electric field, laser-aided spectroscopic methods are most promising because of the high spatial resolution and the non-intrusive nature. However, the sensitivities of conventional laser-aided spectroscopic methods are insufficient for the measurement of the sheath electric field in plasma processing. In the present work, we applied laser-induced fluorescence-dip spectroscopy [1] to Ar, in order to measure the strength of electric field in sheath and presheath regions of a low-pressure ICP Ar plasma

An Ar plasma was produced using a one-turn antenna installed inside of a vacuum chamber. An rf power of 100 W at 13.56 MHz was applied to produce an Ar plasma with an electron density of 3×10^{10} cm^{-3}. The Ar gas pressure was 5 mTorr. A metal plate was inserted into the plasma. The potential of the metal plate was biased using a dc power supply. The plasma potential measured using a Langmuir probe was approximately +20 V with respect to the ground potential. The strength of electric field in the region adjacent to the metal plate was measured by laser-induced fluorescence-dip spectroscopy. This method employed two tunable lasers, which excited Ar atoms to Rydberg states with principle quantum numbers up to 41. The strength of electric filed was deduced from Stark spectra of the Rydberg states [2].

A sensitive detection limit of 6 V/cm was achieved by laser-induced fluorescence-dip spectroscopy. By changing the distance between the metal plate and the measurement point, we obtained spatial distribution of the electric field strength in the sheath and presheath regions. When the metal plate was biased at –20 V with respect to the ground potential, the electric field at 0.3 mm from the plate was approximately 600 V/cm, while at a distance of 1.5 mm, the electric field was below 10 V/cm. The distributions of the electric field and the potential in the sheath region were roughly consistent with the conventional Bohm's theory.

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