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Temporally-resolved ion velocity distribution measurements in a radio-frequency plasma sheath

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The ion velocity distribution function (IVDF) above and within a radio-frequency (RF) biased plasma sheath is studied experimentally with a pulsed laser-induced fluorescence (LIF) diagnostic in an industrial plasma etch tool. Temporally-resolved measurements taken at 8 different phases of the 2.2 MHz bias waveform show the ion dynamics to vary dramatically throughout the RF cycle (the ratio of the average ion transit time through the sheath to the RF period is $\tau_{ion}/\tau_{RF} = 0.3$). The position of the pre-sheath/sheath edge is constant throughout the RF cycle and the ion flux is conserved within the sheath region. Modeling results depict ion dynamics in agreement with experimentally observed results. The characteristic bimodal structure of the time-averaged ion distributions found in previous experiments is observed to arise from the time-dependent ion dynamics, in accord with existing theory. The large temporal variation of the IVDF has implications for the plasma chemistry and etching quality.