Plasma-surface interaction studies: Development and application of advanced laser-based diagnostics

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Understanding how plasmas interact with solid and liquid surfaces is of central importance in many fields such as microelectronics and biophysics, and industrially in environmental and biomedical technologies. Improving processes, such as the growth and etching of materials and surface modification, requires a comprehensive understanding of the kinetics of the transient intermediates involved at the plasma-substrate interface. The experimental approaches currently available provide an incomplete picture of plasma-surface interactions due to relatively low sensitivity, low time resolution, and restricted multi-species capability.

We use a state of the art mid-infrared frequency comb (FC) to provide novel spectroscopic data on plasma-surface problems. Broadband direct frequency comb spectroscopy (DFCS), based on FCs as the light source, can detect many transient species simultaneously yielding comprehensive data on their kinetics in the plasma and their interactions with a surface down to the microsecond timescale. The measurement of the plasma environment close to a surface with the high sensitivity and time resolution of DFCS will provide new fundamental insights into the physics and chemistry of the interfacial region. Moreover, the sensitivity of DFCS can be further greatly enhanced by combining it with a high finesse optical cavity, suggesting unprecedented opportunities for ultra-high sensitivity plasma analysis over large spectral bandwidths. We demonstrate the capabilities of the advanced laser-based diagnostics by showing the latest results on the spectroscopic investigations of plasma nitrocarburizing processes with mid-infrared DFCS. We will discuss the workings of DFCS and the influence of process parameters, such as pressure, screen plasma power, and gas mixture, on the concentrations of the key process species such as NH_3, C_2H_2, C_2H_6, HCN, and CH_4 molecules.