Interaction of Non-Equilibrium Plasma with Surfaces: Low Pressure Plasma for Atomic Layer Etching of Electronic Materials And Atmospheric Pressure Plasma for Modification Of Model Polymers

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The control of plasma-surface interactions is required for successful application of non-equilibrium plasma to materials processing, but key aspects of the challenge strongly differ depending on plasma source, gaseous environment and material being treated. We review two examples of recent work performed in our laboratory: First, use of low pressure plasma surface interactions aimed at achieving atomic precision in etching materials in the semiconductor industry. We show that by employing steady-state Ar plasma in conjunction with periodic injection of a defined number of C_4F_8 molecules for fluorocarbon surface deposition and synchronized plasma-based Ar^+ ion bombardment one tenth of a nanometer precision in etching of SiO_2 is possible by virtue of the temporal variation of the chemically enhanced SiO_2 etch rate for Ar^+ ion energies below 30 eV. Application of this approach to other, more reactive materials, e.g. silicon and silicon nitride, presents additional challenges which will be discussed. We then discuss the application of cold atmospheric pressure plasma (CAPP) sources for plasma-polymer surface modifications. We compare differences in surface-interaction mechanisms of noble gas-based kHz- and MHz powered atmospheric pressure plasma jets (APPJ) operated using $Ar/N_2/O_2$ gas mixtures with a kHz powered surface micro-discharge source (SMD) using N_2/O_2 interacting in well-controlled gaseous environments with a set of model polymers. These CAPP sources can strongly differ in their operating conditions, the reactive particle fluxes that surfaces being treated are exposed to, polymer etching, vacuum-ultraviolet effects and the resulting plasma-modified polymer surfaces.

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