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New insights into fundamental ion-surface interactions

MICHAEL GORDON, University of California - Santa Barbara

Collisions of ions with surfaces at low energy (<1 keV) are important in reactive ion etching of semiconductors, dielectrics, and metals. For example, ion bombardment strongly influences etch rates, anisotropy, and selectivity through physical sputtering, momentum-assisted product removal, and modification of reaction rates. Fundamental understanding of these issues requires detailed information about scattering dynamics. We report results from beam scattering experiments involving mass-filtered ions (F^+ and CF_x^+) with tunable energy (50-1000 eV) and high flux off several surfaces (Si, Al, Ag). Topics to be discussed include: (1) electronic excitations in hard collision events (inelastic losses and F^{++} formation); (2) pre-collision fragmentation of CF_x^+ ions which result in fast exit products such as C^+, F^-, and CF^-; (3) high yields of fast F^-; and (4) F_2^- formation via an Eley-Rideal mechanism. For instance, energy losses for single-scatter events of F^+ off Si and Al show that F^{++} can be formed through double electron promotion which "turns-on" above a critical collision energy. Velocity analysis of daughter fragments from CF_3^+ impact on Si and Ag point to projectile fragmentation before the hard collision step. Finally, energy spectra of F^+, F^-, and F_2^- leaving Si and Ag show three distinct scattering channels: single-scatter binary-like elastic events, another at low energy that cannot be explained as simple sputtering, and still another where fast F_2^- is formed via abstraction. These results illustrate that product species can suffer significant inelastic losses as well as show faster-than-SIMS behavior which may have dramatic effects on profile evolution in plasma etching.