GEC09-2009-000082

Abstract for an Invited Paper
for the GEC09 Meeting of
the American Physical Society

Sheath dynamics and energetic particle distributions on substrates

MICHAEL A. LIEBERMAN, UC Berkeley

The energy and angular distributions (EAD's) of energetic particles arriving at a substrate determine crucial plasma processing characteristics; thus knowledge and control of the EAD's are vital for nanoelectronics design and fabrication during scale-down to the ultimate 4–6 nm transistor gate lengths over the next 15 years. We review the history and state-of-the-art of measurements, simulations, and analyses of ion, fast neutral, and ballistic electron EAD's. Ion measurements have been made using electrostatic energy analyzers, cylindrical mirror analyzers, and retarding grid analyzers, often now coupled with quadrupole mass spectrometers to compare different ions in the same discharge. The state-of-the-art for capacitive rf sheaths has advanced greatly since the first observation of a bi-modal ion energy distribution (IED) over 50 years ago. More recently, measurement techniques and models have been developed to determine fast neutral distributions. Monte Carlo, and particle-in-cell simulations with Monte Carlo collisions (PIC-MCC) have been used to study IED's since the late 1980's. Recently, PIC-MCC simulations were used to obtain ballistic electron EAD's. Analytical models of the IED for collisionless rf sheaths have emphasized the role of τ_i/τ_{rf}, the ratio of ion transit time across the sheath to rf period, with separate models for the low and high frequency regimes. Various simplifications and bridging models now exist. For collisional rf sheaths, the important role of λ_i/s, the ratio of ion-neutral mean free path to sheath width, in modifying the collisionless bi-modal IED was demonstrated in the early 1990's. Surface charging effects on insulating substrates are important for low frequency rf discharges or for pulsed transient sheaths; the latter are found during plasma ion implantation processes. Analytical models of the IED for plasma ion implantation have been extended to insulating surfaces and compared with experimental results.