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4P29 - PIC simulation of ion beam expansion in a drift cone configuration for RFEA measurements.

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Ion energy distribution function (IEDF) plays a significant role in numerous plasma enhanced manufacturing processes in the semiconductor industry. To measure the IEDF, retarding field energy analyzers (RFEA) have been widely used. To extend the capability of measuring higher ion energies and minimize impact on manufacturing processes, a traditional RFEA was redesigned and embedded in the bias cathode of a plasma reactor. One design element is a differentially pumped drift cone between the cathode surface and RFEA that allows for recessed placement of the probe and uniform delivery of facilities such as water cooling and He backside cooling for manufacturing processes.

Significant ion current reduction was observed in this design due to Coulomb expansion of the beam and ion collisions with background gas. A 2D particle-in-cell (PIC) code, XOOPIC1, was used to quantify the impact. For the collisionless case, the trajectory of ion beam was solved analytically assuming single-energy flux. The solution used Dawson function to implicitly give the outer radius of ion beam as a function of distance. The solution matched the results obtained from XOOPIC.

For the collisional case, to accurately model small-angle scattering, angular differential cross section was derived by incorporating polarization scattering into collision integral based on impulse approximation, which was then used to replace the isotropic cross section in XOOPIC. The updated model performed better by reducing the large-angle scattering, especially at high pressure regime. However, at small pressure regime (˜0.12mTorr), Coulomb expansion dominates the significant current reduction.

This work presents a pathway to compensate the RFEA measurements in a drift cone configuration, enabling measurement with minimal process perturbation. In addition, the derived angular differential cross section can be used in Monte Carlo simulation of elastic scattering between ions and neutral particles to give a better result for cases where small-angle collisions can be significant.

Authors: DU, Yao (North Carolina State University); Dr TALLEY, Matthew (North Carolina State University); SHANNON, Steven C.; RANJAN, Alok (Tokyo Electron Limited); VENTZEK, Peter (Tokyo Electron Limited)

Presenter: DU, Yao (North Carolina State University)

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