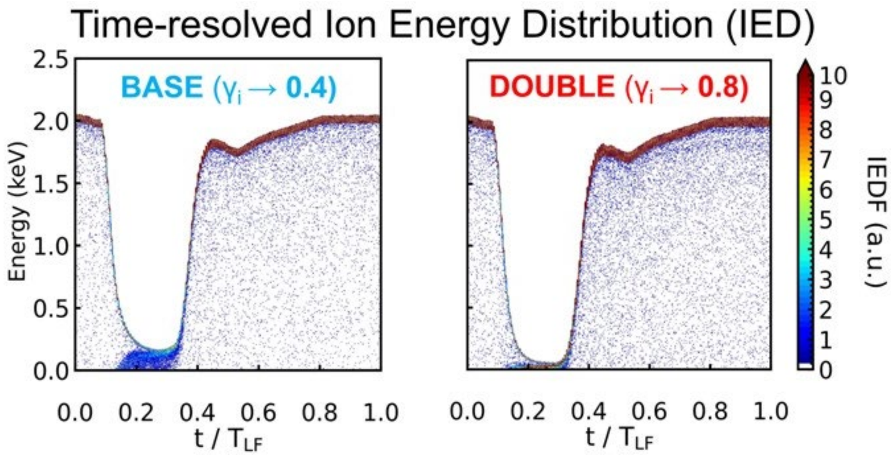
PLATHINIUM
PLASMA THIN FILM INTERNATIONAL UNION MEETING
22-26 September 2025
Antibes, French Riviera
www.plathinium.com

PLASMA RESPONSES TO TAILORED VOLTAGE WAVEFORMS IN CAPACITIVELY COUPLED PLASMAS

A. Lietz[1], S. Zulqarnain[1], N. Tabassum[1], B. Peete[1], J. Prager[2], T. Ziemba[2], P. Melnik[2], J. Perry[2], S. Shannon[2]
[1] North Carolina State University - Raleigh (USA)
[2] EHT Semi - Seattle (USA)

Because of developments in pulsed power supplies, tailored voltage waveforms are becoming available for semiconductor etching tools. This feature was initially proposed to provide nearly monoenergetic ion energy distributions at the wafer surface. However, this has also enabled flexibly changing the waveform shape to tailor the ion energy distribution (IED), incidentally modifying other plasma behavior. Etching depends not only on the IED, but also on the plasma chemistry and the electron energy and angular distributions at the wafer. In order to leverage these emerging capabilities, a detailed understanding of the effect of waveform tailoring on each of these is required.
In this study, simulations and fast camera imaging of a capacitively coupled plasma with waveform tailoring are used to investigate the plasma dynamics in response to these tailored waveforms. Modern semiconductor processes, especially those used to produce high aspect ratio features, are approaching such low pressure and high voltage that fluid approximations fail and a fully kinetic approach is required. Therefore a particle-in-cell Monte Carlo collision (PIC/MCC) model, EDIPIC [1] was used to simulate the plasma dynamics in a reactor with tailored voltage waveforms. A dual frequency capacitively coupled plasma at 5-10 mTorr of Ar is modeled with a range of conditions. The results of these simulations, with varying conditions such as waveform shape, operating pressure and voltage amplitudes are analyzed in detail.
The IEDs and electron energy distributions will be discussed, along with their implications for etching (wafer side) and erosion (upper electrode). The role of secondary electron emission was also explored by varying yields and for incident electrons and ions. For example, time resolved ion energy distributions for varying ion-induced secondary electron yields are shown in Figure 1. Fast camera imaging in the sheath also provides insight into the plasma dynamics, especially the role of high frequency in the sheath dynamics.

References
[1] Sydorenko, Dmytro, Khrabrov, Alexander, Janhunen, Salomon, Villafana, Willca, and Ethier, Stephane, EDIPIC-2D. https://github.com/PrincetonUniversity/EDIPIC-2D



Time resolved ion energy distributions.