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# Sheath transitions in the Two-Plasma mode of a Filament Discharge – Aid-Compete effects

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"Hot cathodes" emitting thermionic electrons are used to generate many laboratory plasmas. The cathode is negatively biased so that the emitted electrons accelerate towards the anode and ionize neutrals along the way. The achievable plasma density, electron temperature, plasma stability, and cathode sputtering rate depend in large part on the electrode sheaths.

Because sheaths are difficult to measure in experiments and the range of available operating conditions and electrode geometries is so large, a solid theoretical understanding backed by fully kinetic simulations can help gain a fuller understanding of hot cathode discharges including the role of sheath transitions.

We have numerically modelled the mode transitions of a hot-filament discharge in cylindrical geometry [1] using the 1D3V axisymmetric (radial) PIC-MCC code APE1PIC. We find that under the conditions of low energy deposition (bias and electron injection), and sparse neutral density (~10mTorr), the discharge strikes as a Two Plasma Mode (TPM). One plasma forms in the conventional upstream region through electron impact ionization of background neutrals. A second plasma, whose global effect on the discharge was not previously well understood, forms downstream through trapping of cold ions in the potential well of the filament's virtual cathode; a process enabled by ion-neutral charge exchange collisions. Three sheaths intersperse the electrode gap - an emissive sheath between the filament and trapped-ions plasma, a double-layer between the two plasmas, and an anode sheath between the upstream plasma and the outer wall. Fig. 1 is an illustrative example of a TPM from our simulation.

Coupling between the two plasma is understood via an "aid-and-compete" model [2] wherein the growth of one plasma enhances growth in the other, while concurrently exhibiting plasma expansion dynamics antagonistic to each other. Outcome of the aid-and-compete effect are mode transitions and instabilities that transform the sheath-system back and forth between Space Charge Limited (SCL), Marginally Space Charge limited (MSCL), Classical, and Inverse Sheath - Anode Glow Mode (AGM); the last two being the possible steady states for a small radius filament.

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References

[1] M. Sengupta and M. Campanell, "Sheath transitions in a cylindrical filament discharge: I. axisymmetric 1D3V PIC-MCC simulations", In Communication
[2] M. Sengupta and M. Campanell "Sheath transitions in a cylindrical filament discharge: II. Analytical model", In Communication

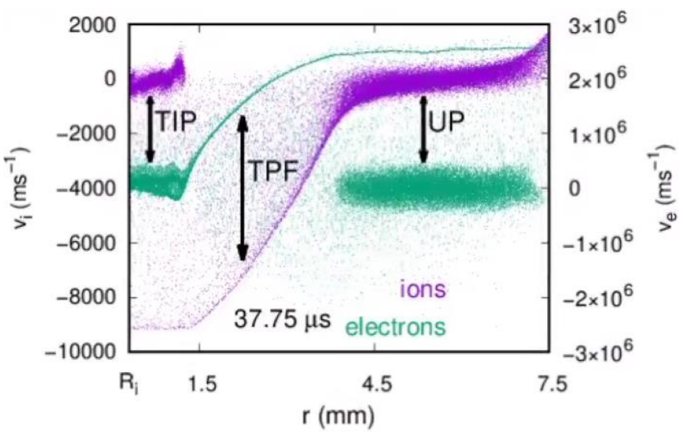


**Figure 1:** Scatter plots of electrons and ions in their respective phase spaces demonstrating a Two Plasma Mode. Acronyms: TIP for trapped-ions plasma, TPF for transmitted particle fluxes, and UP for upstream Plasma.