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Hot Cathode Current Mode Transitions[1]

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Hot cathodes are a key component of many plasma physics experiments and applications. Examples include thermionic converters, thermionic tethers, emissive probes, neutralizers (e.g. in thrusters), and the Large Plasma Device. In the literature, it is often assumed that when the thermionic current is limited, the sheath is "space-charge limited" (SCL) and ions accelerate into the cathode [1]. In recent studies we showed that SCL sheaths cannot exist at floating surfaces because charge-exchange (CX) ion trapping in the virtual cathode forces a transition to a state with an inverse sheath [2]. In this talk, we show on theoretical grounds, and with continuum kinetic simulation videos, that stable SCL sheaths cannot exist at biased hot cathodes either. Whenever a virtual cathode first forms, CX ions will start collecting at the potential minimum until the ion density reaches the electron density at a point. Further ion collection makes the new neutral region grow from the cathode sheath towards the anode, leading to the creation of another plasma where ions are confined and both electrodes have inverse sheaths. The transitions from temperature-limited mode to anode glow mode seen in previous experiments [3,4] and PIC simulations [4] of thermionic discharges are consistent with this explanation. We conclude that the existence of operating modes with inverse cathode sheaths needs to be considered for other plasma applications that rely on hot cathodes.
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