MODELING AND SIMULATION OF 3-D SPACE-CHARGE EFFECTS IN GATED FIELD EMISSION ARRAY CATHODES

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The motivation of this work stems from use of Field Emission Arrays (FEA)s in electric micropropuslion applications. FEAs offer an alternative to thermionic hollow cathodes because they are small and efficient. At high current densities space charge effects may affect the emission process and give rise to a large current collected by a gate electrode.

A multi-scale model is developed for the operation of an FEA in a plasma. Jensen's model for a hyperbolic shape FE tip is used to obtain the electric field at the tip apex. The emitted electron current density is evaluated from the Fowler-Nordheim expression as a function of the gate potential. The emitted electron beam and the background plasma are modeled with a particle-in-cell method.

The theoretical model is implemented within an unstructured 3-D Particle in Cell (PIC) methodology. Simulations of FE cathode operation are performed in order to quantify space-charge effects and the formation of a virtual cathode. The computational domain incorporates a boundary that represents a circular FE cathode surface with an applied potential V_g . Cold electrons are emitted with a drifting Maxwellian distribution from the cathode with velocity corresponding to the gate potential. The anode current I_{anode} is measured as a function of V_g.

A parametric investigation examines the impact of the emission and background plasma conditions on the anode and gate currents. Simulations show that some electrons are reflected by the virtual cathode and collected by the emitter. The simulations show a good agreement with theoretical predictions and demonstrate also 3d effects not present in theoretical estimations.

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