Electric Field Breakdown Properties of Materials Used in Ion Optics Systems

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Measurements are presented of the electric field at breakdown for perforated flat plates fabricated from carbon-carbon (CC) composite, Poco graphite, pyrolytic graphite (PG), and molybdenum. The perforated flat plates represent electrodes used in ion sources and ion thrusters and measurements are made with and without ion beamlet extraction through the perforations. A ranking of the materials is presented of their suitability in ion source applications in terms of their electrical breakdown characteristics. For effective use in space missions, materials for ion optics systems must be capable of withstanding moderate electric field stress for long periods of time. In this regard, a simple analysis is presented where thrust density is shown to vary with the square of the electric field. This result suggests that a 50% increase in electric field will result in 125% higher thrust density and a thruster area reduction factor of 0.44. The reduction in thruster area would enable a commiserate decrease in thruster and gimbal specific mass. Experimental data are presented on the field emission onset, electric field enhancement factor, and electrical breakdown properties of the materials listed above as a function of conditioning state, grid spacing, and charge transfer level per arc. Tests results are presented for both beginning of life electrodes and for electrodes that have been heavily worn.

Nomenclature

A_e	=	Effective emitting area
β_{FE}	=	Electric field enhancement factor
β_w	=	Weibull slope parameter
C	=	Capacitance
E	=	Applied Electric Field
E_m	=	Microscopic electric field acting at protrusion tip
f	=	Thrust Density
F	=	Thrust
g	=	Acceleration due to gravity
I_{sp}	=	Specific impulse
J	=	Ion current density
J_{FE}	=	Field emission current
ℓ_g	=	Grid gap spacing
m_dot	=	Propellant flow rate
m_+	=	Mass of a propellant ion
η	=	Characteristic life
η_u	=	Propellant utilization efficiency

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