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# Characteristics of high-voltage breakdown on spacecraft insulator surface and calculation of its ablation phenomena

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In the future, LEO spacecraft will be larger and higher powered. Because of the balance of leakage currents through ambient space plasma, their main conductive body will have a higher negative potential without plasma contactor operation. When spacecraft operate with a higher voltage, more intensive arcing is suspected to occur on the surface.

In this study, ground-based experiment was carried out to understand the arcing phenomenon and to examine influences of ambient space plasma on the arcing process. Simulating plasmas were generated by electron cyclotron resonance discharge. When arcing occurred on negatively-biased anodized aluminum sample (AAS) plates in the plasma environment, the time variations in arc current and bias voltage were measured. Arc spot diameter was also measured. The single arcing characteristics showed that both the peak arc current and the total charge emitted by arcing increased with initial charging voltage and neutral particle number density. The diameter of arc spots increased with initial charging voltage although it was almost constant regardless of neutral particle density. The repetitive arcing characteristics showed that the arc rate gradually increased with arcing number. Lots of overlapping arc spot were observed after 1,000 arcings, and its number increased with arcing number. Accordingly, arc tends to occur at a same location as increasing arcing number. Influences of initial charging energy on arcing characteristics were also examined by widely changing capacitance and initial charging voltage. The arc spot diameter widely increased with initial charging energy, and the fitting line could be evaluated.

Unsteady physical processes inside an arc spot, such as ablation and heating of insulator, and plasma generation and acceleration etc, were studied using Computational Fluid Dynamics (CFD). Direct-Simulation-Monte-Carlo Particle-In-Cell (DSMC-PIC) plasma simulation was also carried out to examine influences of ambient space plasma on plasma expansion processes outside the arc spot. The calculated arc current increased with time; had a peak and then decreased. Inside the arc spot, the calculated plasma resistance rapidly decreased with time; was kept low level and jumped just before extinguishment of arc. As a result, the plasma resistance characteristics agreed with the arc current characteristics. The calculated ablation rate rapidly increased with time; had a peak and then gradually decreased, although the calculated arc spot diameter gradually increased with time. Furthermore, the calculated arc spot diameter gradually increased with initial stored energy, although it was smaller than experimental ones. Both the neutral particle number density and the electron number density were the highest near arc initiation and decreased with time. Both the number densities were relatively high inside the arc spot compared with those outside it. The temperature of insulator surface in contact with plasma rapidly increased up to 5000 K near arc initiation and gradually decreased to 4000 K. Outside the arc spot, neutral particles in addition to charged particles around spacecraft played an important role in expansion of arc plasma by intensive ionization near the arc spot.

Accordingly, high voltage operation of LEO spacecraft might bring drastic degradation of insulator surface by arcing, depending on spacecraft capacitance, insulator material properties and ambient plasma conditions.