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ELECTRON-EMITTING FILM, AN EFFECTIVE MITIGATION OF SPACECRAFT CHARGING THROUGH THE FIELD EMISSION

Abstract

The size and load of geostationary (GEO) satellites has been increasing dramatically since the end of the last decade. Nowadays, power level of 10 kW is very common among commercial GEO telecommunication satellites. To satisfy the demands, the bus voltage generated by the solar array should be more than 100 V which, in lieu, decrease cable mass and increase electrical power transmission efficiency. However, electrostatic discharge (ESD) on spacecraft surface, especially on solar array, is one of the primary causes of spacecraft on-orbit power system failure. ESD occurs when spacecraft surface potential becomes highly negative with respect to the ambient plasma due to encounter with substorm or aurora which is enriched with energetic electrons. Under this condition, coverglass (insulator) of solar array potential becomes positive with respect to the spacecraft chassis (called as inverted potential gradient) by several hundred volts. While the inverted potential gradient is developing, the electric field at the triple junction (where the insulator and conductor are exposed to space plasma) increases. If the electric field exceeds a certain level, ESD occurs. If spacecraft surface potential is maintained close to the ambient plasma potential even when a spacecraft encounters substorm or aurora, the risk of ESD can be effectively reduced. Recently, we have developed a device (named as ELectron emitting Film, ELF) that emits electrons via field emission from triple junction. The electron emission raises the spacecraft potential near to zero producing so-called normal potential gradient, where ESD inception thresholds is 10 times lower than the inverted potential gradient.

The ELF is made by micro-etching process that ensures a polyimide film with a thickness of less-than 100 m on copper substrate. ELFs are glued on spacecraft via conductive adhesive so that the metallic part of ELF has the same potential as the spacecraft chassis. It has many advantages over the previously proposed methods. First of all, it is capable of complete passive operation. It does not require any power

source as the power is provided by the electric field generated by the surface charging and charging of spacecraft's capacitance with respect to the ambient plasma. It does not require any sensor to initiate its operation as the surface charging starts the field emission. It does not require even wire harness. Therefore it is easy to install and amendment of the present satellite design is expected to be very small. It requires no ambient gas to generate electrons. Moreover, it is very light in mass.

Field emission characteristics and robustness of ELF coupons of various sizes have been investigated in vacuum (2.0-5.7x10-4 Pa). The coupon was biased to -5 kV to imitate the space environment under substorm or aurora. An electron beam of 5.5 keV with emission of 50 μA was set to turn the ELF surface to positive potential by producing secondary electrons. Hence, Inverted gradient potential was created which started field emission from triple junction. Recently, electron emission performance of ELFs under long time (100 hours) beam irradiation has been completed. The details of experimental results approaching to improve the performance of the ELF device will be presented at the conference.