MISCELLANEOUS

Photos on Front and Rear Covers

Front Cover

Electrostatic Discharge Tests of Satellite Solar Panel

Greenhouse Gases Observing Satellite (GOSAT, "Ibuki") Solar Array Paddle Deployment
Courtesy of JAXA (Japan Aerospace Exploration Agency)

Although space is generally regarded as vacuum, it is filled with plasma. In terms of electrical insulation, being in space does not guarantee better situation than on the Earth. The plasma charges satellite surface as well as its interior. When a satellite encounters energetic electrons in orbit, the satellite body that can be regarded as a floating conductor in space is charged to a highly negative potential with respect to the plasma. The charging of the satellite body leads to build up of potential difference among various parts on a satellite, especially between surface insulator and the satellite chassis. As the differential voltage exceeds a certain threshold, electrostatic discharge (ESD) occurs at the edge of conductor and insulator exposed to space. The threshold differential voltage for ESD inception can be as low as one hundred volts.

Among the satellite components, solar panels are the most vulnerable to ESD. The conventionally designed solar panels are composed of many metallic parts exposed to space, such as solar cell electrodes, and a large area of insulator, such as coverglass. In the worst case, one ESD pulse may lead to catastrophic failure of the satellite power system as the pulse makes transition to an arc discharge in the solar array circuit resulting in the short-circuit of the power system.

Since the middle of 1990s, many satellite failures whose cause was identified to be ESD have been reported as the satellite power level increased to deal with the demand of more communication channels or diversified satellite missions. In Japan, the complete loss of ADEOS-II Earth observation satellite in 2003 due to arcing in the power system changed how satellite solar panels are designed and tested in Japan. Nowadays, it is a common practice not only in Japan but also in US and Europe, to test a solar panel design against ESD before its launch.

The purpose of the test is to investigate whether a given design of solar panel can withstand many numbers of ESD events expected in orbit. The test is done using a so-called solar array coupon shown in the bottom right of the front cover. The coupon is made of exactly the same material and procedures as the flight solar panel. The coupon is put in a vacuum chamber. Its surface is charged by an electron beam of several keV simulating the energetic electrons in orbit, such as aurora or substorm, or by a plasma simulating the ionospheric plasma. The coupon is connected to an external circuit simulating the satellite power system under power generation. The test investigates whether a pulse of ESD leads to the arc discharge or not.

The ESD tests of satellite solar panel in Japan has been carried out at Laboratory of Spacecraft Environment Interaction Engineering (LaSEINE), Kyushu Institute of Technology located in city of Kitakyushu. GOSAT (Ibuki) launched in 2009 was also tested at LaSEINE and its solar panel is working fine in orbit as shown in the top picture. LaSEINE is a world-leading institution in the field of spacecraft charging. Based on the test methods carried out at LaSEINE, a new ISO standard, ISO-11221, on ESD test methods of satellite solar panel has been established in 2010. Nowadays, LaSEINE carries out ESD tests for not only Japanese satellites, but also for satellites of other countries, such as USA, China and India.

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Rear Cover

Space Charge Formation by Irradiation of Visible Light in Polyimide under DC Electric Stress

Space charge distribution formed in polyimide (PI) film (Kapton®) under dc electric field is strongly affected by visible light illumination. The space charge formation in Kapton® film is investigated using a modified PEA (Pulsed Electro-Acoustic) system for measuring space charge distribution under various visible lights illuminations from LED. As shown in the upper figures, the space charge formations are clearly observed in the film under dc electric field (20 kV/mm) with visible lights illuminations, while it is not observed in it without light illumination. Furthermore, it is obviously found that the charge accumulation pattern in the film strongly depends on the wavelength of illuminated light. In the case of red light illumination, a small amount of hetero charges are observed in bulk of film near anode and cathode electrodes. In the case of green light illumination, only negative hetero charge near anode side is observed. On the other hand, the blue or violet light illumination makes homo space charge formation near cathode. It means that the relatively lower energy light illumination by red or green LED dominantly make a hetero charges while the higher energy light illumination by blue or violet LED seems to enhance charge injection from illuminated electrode. This phenomenon is also observed in opposite polarity of dc voltage application. Lower figures show the results obtained by green and blue lights illuminations from anode side. It is found that the positive hetero charge near cathode side is quickly formed with green light illumination, while the injected positive homo charge near anode side is gradually formed with blue light illumination from anode side. These results suggest that the visible light illumination must enhance the electric field in the bulk, and consequently it makes the breakdown strength lower than that without the illumination.

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