

# Electrostatic Discharge Test on the Cu (In, Ga) Se<sub>2</sub> Solar Cell Array

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**The boundary part of dielectric material, conductive material, and space, known as the triple junction, causes electrostatic discharge. Because the triple junction does not exist on the Cu (In, Ga) Se<sub>2</sub> solar cell surface, it should be free of electrostatic discharge. Electrostatic discharge tests on Cu (In, Ga) Se<sub>2</sub> were performed in a vacuum chamber which simulated the plasma environment in low Earth orbit and the high-energy electron environment in geostationary orbit. Contrary to the theoretical expectations, electrostatic discharge occurred on the surface of Cu (In, Ga) Se<sub>2</sub> and Cu (In, Ga) Se<sub>2</sub> suffered degradation of electric performance. The arc track was investigated to make clear the degradation mechanism of Cu (In, Ga) Se<sub>2</sub>. The arc track worked as a leak resistance because the PN junction collapsed and the materials of front and back surfaces electroded adhere along the arc track.**

## Nomenclature

$C_{ext}$	= external capacitance, F
$C_p$	= current waveform, A
$dI_{leak}$	= differential of leak current, A
$I_{leak}$	= leak current, A
$I_{leak,after}$	= leak current after experiment, A
$I_{leak,before}$	= leak current before experiment, A
$I_{peak}$	= peak of primary arc current, A
$N_{arc}$	= total number of arcs
$N_{cis}$	= number of primary arcs at CIGS surface
$N_{ele}$	= number of primary arca at electrode
$P_{max}$	= maximum power of solar cell, W
$P_{max,after}$	= maximum power after experiment, W
$P_{max,before}$	= maximum power before experiment, W
$P_{peak}$	= peak of primary arc power, W
$Q_{arc}$	= charge of primary arc current, C
$R_r$	= resistance, $\Omega$
$R_s$	= series resistance of solar cell, $\Omega$
$R_{sh}$	= parallel resistance of solar cell, $\Omega$
$T_{i1}$	= start time of primary arc current, s
$T_{i2}$	= end time of primary arc current, s
$T_{p1}$	= start time of primary arc power waveform, s
$T_{p2}$	= end time of primary arc power waveform, s
$V_b$	= bias voltage, V
$V_p$	= voltage waveform, V
$W_{arc}$	= energy of primary arc, J

## I. Introduction

**A** THIN-FILM solar cell, constructed of amorphous silicon or Cu (In, Ga) Se<sub>2</sub> (CIGS), is considered a promising candidate as a future space solar cell because of its low mass and high light conversion efficiency [1]. The efficiency of CIGS (12% at air mass 0) is greater than that of any other type of thin-film solar cell. Because it is possible to deposit the solar cell on a thin metal sheet and a polyimide sheet, the thin-film solar array provides greater mass reduction and higher storage efficiency than the currently used solar arrays [2].

To construct a CIGS solar array paddle, the durability of CIGS when exposed to space radiation and space plasma needs to be investigated in terms of degradation of electric performance. Through the flight investigation onboard the MDS-1 (Tsukuba) satellite, CIGS demonstrated high durability against space radiation [3]. However, discharge on solar array due to spacecraft charging has recently become a serious concern, as the solar cell can potentially suffer degradation of electrical performance [4,5].

The cross-sectional view of a solar array of conventional design is shown in Fig. 1. There is a so-called triple junction which is the boundary of dielectric, conductor, or semiconductor and space. When a substorm event occurs in the geostationary orbit (GEO), the spacecraft potential with respect to ambient plasma becomes several kilovolts due to the incoming high-energy electrons. The potential of the dielectric surface (such as cover glass) on the solar array becomes positive with regards to the spacecraft body because of the secondary electron emission. The potential gradient inside the dielectric is called the inverted potential gradient.

In low Earth orbit (LEO), the spacecraft charges due to ionospheric plasma. The spacecraft body has negative potential with respect to the ambient plasma because of the difference of mobility between ions and electrons. The potential of the dielectric part on the solar array becomes positive with respect to the spacecraft body due to ion collisions. Thus, an inverted potential gradient is generated in LEO inside the dielectric material in a similar way to the case in GEO.

The triple junction enhances the intensity of the electric field. Because of the electric field emission phenomena, the electrons are emitted by the conductor or semiconductor near the triple junction. This electron emission leads to the discharge [6], which is known as primary arc.

The cross-sectional view of CIGS is shown in Fig. 2. Although CIGS is deposited on the glass substrate, the conductive materials, such as CIGS, molybdenum, and ZnO, are exposed to space.

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