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UV TESTING OF INTELSAT-VII, VIIA, AND VIII SOLAR CELLS[1]

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Extended Abstract

A 4000 hour experiment, conducted in late 1992 through mid 1993, confirmed earlier results on the ultraviolet damage effects in covered solar cells of various types being used, or proposed for use, in INTELSAT programs. Two different UV test systems were used to identify systematic errors and to study the effects of UV source-bulb age on degradation rate.

After correction for contamination and UV source-bulb aging, the extrapolated degradation rates for irradiated and unirradiated INTELSAT-5, -6 single AR (SAR) coated cells and INTELSAT-7, -7A, -8 double layer AR (DAR) coated cells[2] in both the 1993 tests confirm the following hypotheses resulting from the 1992 experiment.

a. Irradiated cells display significantly more UV degradation than do the unirradiated cells for tests exceeding 2000 hours. [The new data indicates that degradation effects from electron irradiation are proportional to t^2 (the square of the UV hours), at least for times $\leq$ 3000 hours.]

b. This difference does not depend upon antireflective coating, cell resistivity, or manufacturer within the sensitivity and reproducibility of the experiment.

c. There is a clear difference in degradation rate between single AR coated cells (TiO_X) and double layer AR coated cells (SiO_X and Al_2O_3?). At 100,000 hours (11.4 years) the DAR coated cells display more degradation than do the SAR coated cells, even though at 1,000 hours the DAR cells display less degradation.

d. UV degradation rates, to modern covered silicon solar cells, at the beginning of bulb life drop from ~2 times the average rate to near zero after 2000 hours (average end-of-life for the xenon short-arc lamps used in the tests).

The effects of 1 MeV electron irradiation (10^{15} e^-/cm^2) prior to UV exposure are clearly indicated in the plot of percent change in cell open circuit voltage (Voc) versus percent change in short circuit current (Isc) during the UV test and post-test cleanup of the cells (Figure 1). The heavy lines indicate the trends of the data for both unirradiated and pre-irradiated cells (different cell types and resistivity show the same trend). The slopes of

[1] This work was supported by the International Telecommunications Satellite Organization (INTELSAT) and by COMSAT Corporation.

[2] The tested INTELSAT-5, -6, and -7 cells are German and the INTELSAT-7A and -8 cells are Japanese.

the trend lines differ between the unirradiated and irradiated cells during UV exposure but not during the post-test removal of contamination. Clearly, extended UV testing produces a permanent photo-induced redegradation of previously irradiated cells. However, this photo-induced redegradation may be caused by the long-wavelength light, not the UV light.

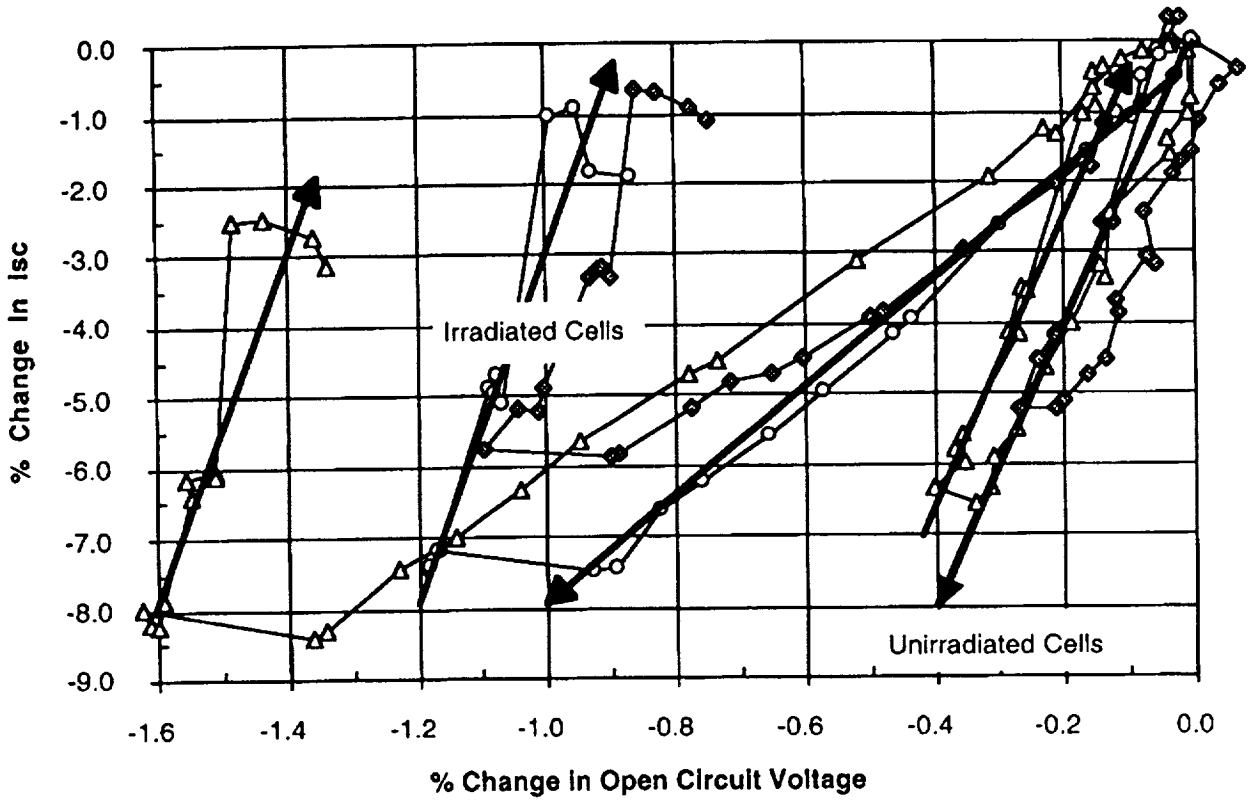

Figure 1. The % change in cell open circuit voltage versus % change in Isc during the UV test and post-test cleanup of unirradiated and irradiated (labeled), 2- and 10- ohm-cm (clear and filled symbols respectively) solar cells.

Figure 2 is representative of the reduced data obtained in the two 1993 tests reported here. The corrections to the data include: normalization against control cells, to adjust for any long-term intensity or spectral drift of the solar simulator; modification of the time base, to adjust for changes in the damaging portion of the UV test source spectrum; and, subtraction of the contamination that accumulated on both the quartz window and coverslides during the extended test.

A comparison of the results for SAR and DAR coated cells from the one 1992 and the average of two 1993 Tests (in the table) indicates their level of agreement and the spread in data and extrapolations of the tests. The very high degradation seen in the extrapolated result for irradiated DAR coated cells is partially an artifact of the assumption that photo redegradation of preirradiated cells does not saturate.

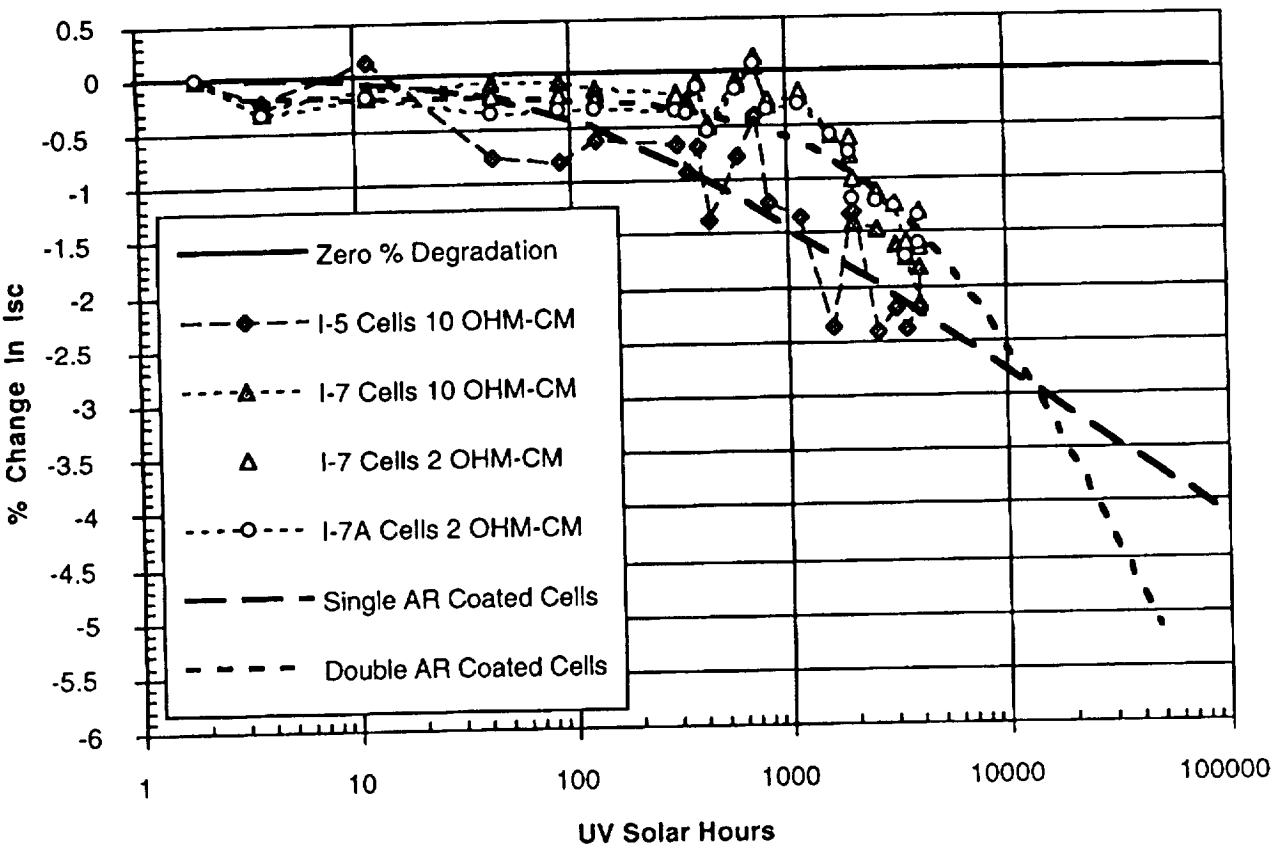

Figure 2. Corrected UV degradation, data and extrapolations, for the unirradiated cells of Test 1 in the 1993 experiment.

Comparison of 1992 and 1993 Test Results for SAR and DAR Coated Cells

Cell Configuration	% ΔIsc at 1000 hours	% ΔIsc at 10,000 hours	% ΔIsc at 100,000 hours
UNIRRADIATED	1992 /1993	1992 / 1993	1992 / 1993
SAR	-1.7/ -1.6 ± 0.5	-3.8 / -2.5 ± 1	-5.9 / -3.3 ± 1.5
DAR	-0.5 / -1.5 ± 0.5	-2.5/ -3.5 ± 1	-6 / -6 ± 2
IRRADIATED			
SAR	NA / -2.2 ± 0.5	NA / -4 ± 1	NA / -5.7 ± 1.5
DAR	-0.8 / -1.5± 0.5	-5 / -5.2 ± 1	-14 / -10 ± 2

Eleven years exposure to the space UV environment should degrade unirradiated I-5,6 cells by 4.5 ± 1.5% and I-7,8 cells by 6 ± 2%. At 4000 hours, 10 and 2 ohm-cm, preirradiated cells display ~1.8 and ~2.4% greater loss than do the corresponding unirradiated cells. Therefore, degradation of the preirradiated cells at 100,000 hours should be ≥ 6.5 ± 2% for I-5,-6 cells and ≥ 8 ± 2% for I-7,-8 cells. It is not yet determined which set of laboratory data corresponds to space experience in a radiation environment.