Dust Abrasion Damage on Martian Solar Arrays: Experimental Investigation and Opportunity Rover Performance Analysis

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Abstract

Here we investigate the effects of erosion and weathering that occur on epitaxial lift off triple-junction cover-glass interconnected cells (CICs) after exposure to Mars dust storm conditions. The durability of these materials in a Martian environment is not well characterized so we perform analogous experimentation. To replicate the dust impingement, test coupons were placed in an enclosure and sandblasted with Mars dust simulant. We show the J-V response dependency on both incident angle and exposure times. We employ data-driven modeling to quantify the soiling contribution and power degradation of the photovoltaic cells on Mars through analysis of 4.95 Martian years of report-out of the power generation of the photovoltaic cells. We calculate the contribution and power degradation of the photovoltaic cells over time on the Martian surface thus informing future dust abatement systems.

Experimental Design

In the instance of a constant 45° angle with varying exposure time we see increased reflectance from 450-650nm (Fig 6a) and consequently a reduced normalized J-V characteristics of CICs after exposure to abrasion for varying angles at 5 minute exposure time with inset of cell orientation to dust flow.

Investigating Permanent Damage

The change in maximum power output for each CIC (pristine vs post sonication) is found to be 15.9± 6.4 percent, yielding a maximum degradation of 22.3% which is in agreement with the year-over-year limit of 23%.

Conclusions

- First experimental study of ELO 3i CICs performance in Martian Dust Storm Environments
- Operational cells on Mars experience a 21 Sol lag for dust settling post severe weather event.
- The presence of dust on cell surface results in increased reflection in visible wavelengths 450-650nm
- Optical losses due to presence of Mars dust are reversible if the cells incident angle is <80°.
- Cells with exposure angles ≥ 80° will require the development of a more rigorous dust protocol to recover optical performance, as the dust becomes imbedded in the cell and cannot be removed.
- Opportunity data analysis suggests maximum power output degradation rate of cells on Mars is below 23% per Martian year. This value is verified by dust exposure experiments power degradation not exceeding 22.3%.
- We recommend solar array’s for Mars be designed from 45-60° angle of incidence as these storms are most dust resilient in simulated dust storm conditions.

Acknowledgements

The authors thank MicroLink Devices, Inc. as well as interns Tristan Thrasher and Logan Abshire of the University of Oklahoma for preliminary data collection. The authors are grateful to Gianna Cantor, NASA LERCI intern, for optical characterization of cover glass. This work was funded by the NASA Glenn Research Center’s Space Technology Mission Directorate supported Center Innovation Fund.

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