Response of potential new solar cells on the surface of Mars for assessing future habitability: a space weather and materials modelling study (Poster Flash Talk)

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1. Introduction

Planning manned missions to planets such as Mars require not only efficient shielding of astronauts to harmful radiation such as energetic particles from solar and galactic sources, but also a future vision of how to sustain life on the planet itself. Arrays of solar cells, possibly different from those used on spacecraft, should be conceived and studied in order to explore possibilities for power generation, in particular for generating electricity and possibly creating hydrogen.

Traditional methods to study radiation damage of solar cells rely on Monte Carlo tools, well accurate to study the primary damage. Such tools give an overall loss of efficiency and are often used to study the damage of the commonly used solar cells on spacecraft (based on GaAs or Si) [1,2].

Dye-sensitized solar cells, although under intense study by the whole international community working on solar cells since several years, have been considered only by very few studies for space applications [2]. This is mainly because of their efficiencies (still to be improved considerably), the use of liquid electrolytes and long-term degradation mechanisms, which have prevented them from much consideration for applications as spacecraft components.

However, their potentiality to create energy and sustain humans on the very surface of Mars must still be investigated. Recent advances in nanocrystalline dye-sensitized solar cells lead encouraging results and stimulate the investigation of their potential for power generation. Indeed, they could provide light-weight, low-cost arrays for power generation.

Designing new solar cells is a challenge. Investigating possible solutions involves a combination of particle transport tools and detailed results of the changes in the electronic/optical properties via first principles tools which go beyond the description of the primary, averaged damage obtained by Monte Carlo tool. Such first-principles tools allow to study the details of the structural and electronic changes in the microscopic description of the response of the materials.

1.1. Radiation damage of TiO2 as main component of future solar cells on Mars

We report a first space environment characterization of TiO2, the main component of dye-sensitized solar cells. TiO2 is considered as exposed to different simulated space environment conditions at the surface of Mars, assuming different solar activity scenarios.

The space radiation environment analysis is the first step to determine the particle spectra that emerge after having passed through the atmosphere of Mars and are thus directly impinging on the solar cell. Different types of solar activity scenarios might lead to effects of different magnitudes in target materials [3].

The Space radiation environment and the particle transport through the Mars atmosphere are calculated via SPENVIS (SPace ENVironment Information System [4,5]), which is a web application used worldwide to model the Space environment (galactic cosmic rays, trapped particles, solar energetic particles, plasmas, debris and meteoroids) around Earth, Mercury, Mars and Jupiter, in the interplanetary medium and to plan space missions.

The radiation passing through the atmosphere and impinging on the material is calculated using PLANETOCOSMICS [6], a Monte Carlo Geant4 tool included in SPENVIS. The performance of the material is evaluated by looking at the energy deposited and the effects of structural damage induced by the impinging particles, the latter being analyzed via first principles tools from the materials science community [7].

2. Results

The results show how the induced change in the electronic levels influences the possibility of generating hydrogen and the trapping of charge carriers which might limit the output current. The effects of induced vacancies, the introduction of deep/shallow electronic levels [8,9] in the material, the change in the electronic and optical band gap and the potential to absorb photons of different energies and to generate hydrogen are presented.

The study is a first exploration of the combination of traditional methods used in space environment modelling and particle transport with microscopic first-principles description of the induced changes in the target. It encourages further studies for assessing the future potential of new solar cells for power generation and for sustaining human life on Mars.

3. References

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Short Summary

Assessing the future habitability of Mars also implies the study of how humain life can be sustained. Here we present a study of the radiation damage and potential power generation by future TiO2-solar cells under different space weather scenarios, via a combination of Space environment modelling and first-principles materials modelling.