Light Absorption Enhancement with Bio-inspired Nanostructures

Bringing nature into light-trapping for space solar cells

Executive Summary

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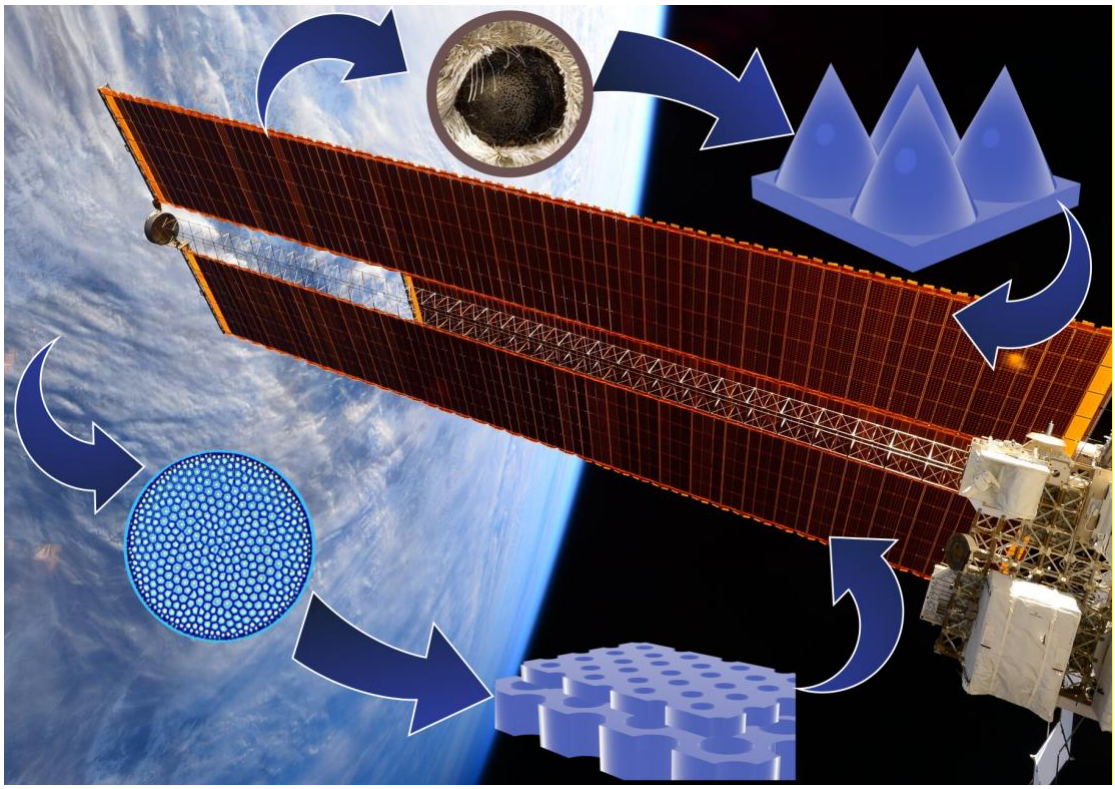
Picture:



Motivation

The reliability of space missions is compromised by the reduction of the solar cell end-of-life efficiency due to the relatively higher radiation level of space environments. Bio-inspired photonic designs provide a route to solve this problem.

Methodology

Light-trapping helps enhancing the light absorption in space solar cells and hence to reduce their thickness to increase the radiation hardness. We have optimized light-trapping structures (LTS) inspired in the diatom frustule and moth's eyes. As a solar cell reference, we use the commercial 3G30C model from Azure Space Solar Power GmbH. We have developed a physical model to describe the solar cell absorption and derive the efficiency. The optical description relies on the Fourier modal method and the solar cell performance on the detailed balance limit. The LTS are optimized by means of the parallel global multi-objective framework implemented in pygmo. The LTS is placed between the solar cell absorbing layers and the cover glass. Care has been taken to account for and model an interstitial mirror between the middle and bottom junction. Realistic damage introduced in the solar cell is described by the Monte Carlo framework Geant4.

Results

- Bio-inspired light-trapping structures increase the absorption allowing for a reduction of the middle junction thickness by a factor three without penalty in the beginning-of-life efficiency.
- The interstitial mirror plays a key role in providing spatially confined guided modes which allow for an efficiency coupling of the incoming radiation assisted by the LTS.
- Actual experimental implementations of the optimal structures can be realized although their impact on the solar cell cost still needs to be evaluated as the savings in epitaxy can be compensated by other processing costs.
- Radiation damage weakly depends on the thickness of the solar cells or the bio-inspired light-trapping structure.

Publications

- Thomas Vasileiou, José M. Llorens, Jerónimo Buencuerpo, José M. Ripalda, Dario Izzo and Leopold Summerer "*Light absorption enhancement for space solar cells – Diatoms and moth eyes as model organisms for bio-inspired engineering*", In preparation.
- José M. Llorens, Thomas Vasileiou, Andrés Raya, José M. Ripalda, Jerónimo Buencuerpo, Dario Izzo, and Lepopold Summerer "*Bio-inspired light-trapping structures for space solar cells*", In preparation.

Highlights

Through bio-inspired photonic engineering, a pathway is defined allowing to significantly reduce the thickness and epitaxial costs of space solar cells. The achieved reduction in solar cell thickness has positive effects on radiation hardness and EOL efficiency. The additional device processing steps make a short-term commercial implementation challenging, but our proposal defines a pathway to address these challenges and allow for further enhancements of space solar cell performance.