Photon-Enhanced Thermionic Emission

Executive Summary

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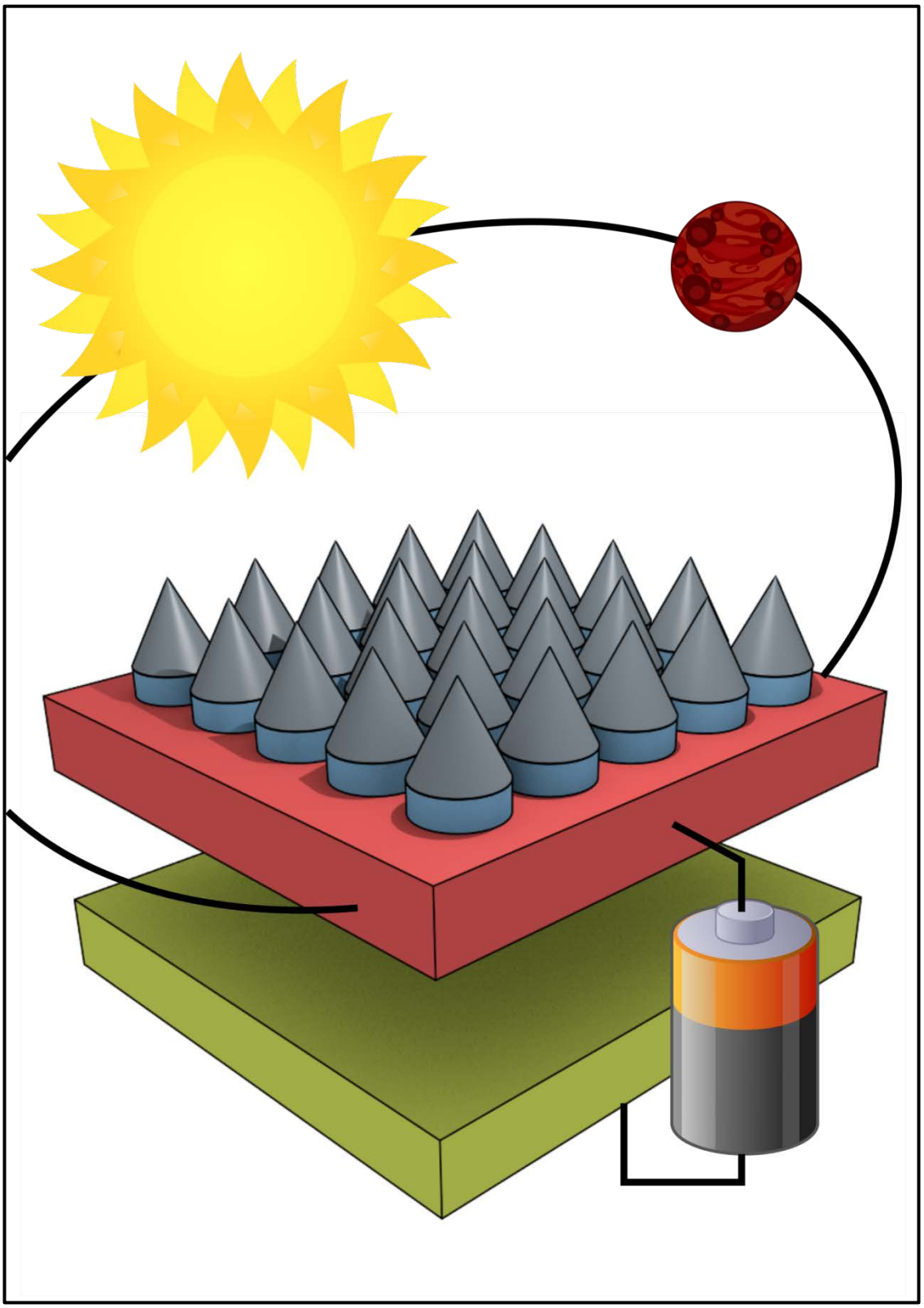
Picture:



Motivation:
The photon enhanced thermionic emitter is a new solar energy harvester suitable for operations at high temperatures. We propose the use of a bio-inspired light-trapping structure to enhance the solar flux collection.

Methodology:
We have optimized a photonic crystal structure acting as a light-trapping structure with a global optimizer. The physical model describing the operation of the photon enhanced thermionic emitter is based on semi-analytical models. Three different models have been implemented:

(i) The absorption of the solar flux is computed with Fourier Modal Method
(ii) The transport of the carriers in the device is described through a diffusion model equation
(iii) The electrostatic potential created by the emitted electrons is described with the Langmuir space charge theory

This study was performed in joint collaboration with the Instituto Italiano di Technology(IIT) as part of the dual Ariadna project on Photon-Enhanced Thermionic Emission. Both studies were executed in parallel with the IMM contribution (this report) focused on the photon absorption and cathode carrier transport. Using an iterative approach, the calculated cathode electron emission was used by IIT as boundary condition for the gap transport calculations using COMSOL to determine the overall device efficiency. For details on the second study, interested readers are referred to IIT final report (Ariadna ID: 14/2101b).

Results:
- A maximum efficiency of 16% can be reached for a 25 nm GaAs photon enhanced thermionic emitter operating at 700 K using an ideal Lambertian diffuser
- The photon enhanced thermionic emitter can operate iso-thermically which would allow the use of submicrometer vacuum gap to separate the cathode from the anode
- We have shown that a 2% increase in the efficiency is actually attainable by using a photonic crystal light-trapping structure vs. the state-of-the-art space anti-reflective technology
- The higher the solar flux, the narrower the vacuum gap to obtain an efficiency of 10%

Publications:
- J. Buencuerpo, J. M. Llorens, P. Zilio, W. Raja, J. Cunha, A. Alabastri, R. Proietti Zaccaria, A. Martí, and T. Versloot. “Light-trapping in photon enhanced thermionic emitters”, Vol. 23, Issue 19, pp. A1220-A1235 (2015) doi: 10.1364/OE.23.0A1220

Highlights:
In the current study, we have used GaAs as cathode material given the reliable and accurate optical characterization of this material from 20 to 750 K. Materials of larger band-gap and better reliability at high temperature should also be studied. The isothermal operation of the device should also be explored.