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Harvesting of IR solar energy by thermoplasmonic nanoantennas

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Mono-junction photovoltaic cells have intrinsic limitations:

- Non-absorption of low energy photons (<Eg);
- Thermalization of high energy photons (>Eg);
- Heating of the cell while operating, which reduces its efficiency.



Context

Hybrid photovoltaic-thermoelectric (PV-TE) devices have been shown to increase the energy conversion efficiency by compensating the thermal losses in a PV cell [1-3].

Several studies aimed at optimizing the efficiency of PV-TE by including a **photothermal interface** (PTI) in between the PV cell and the thermoelectric generator [4-5].

Objective of the PhD: to design a PTI using thermoplasmonic nanoantennas to convert solar IR radiation into heat.



Characteristics of an optimal PTI:

- High absorption and matching with the solar IR spectrum;
- High thermal conductivity;
- Electrically insulating.

Figure 2: Schematic representation of a PV-TE device including a photothermal interface made of thermoplasmonic nanoantennas.

Perfect structures

Optical simulations

Realistic structures

We use numerical simulations to study isolated nickel nanoparticles of different shapes and sizes, in order to find the structure which is best suited for IR solar harvesting.

- The absorption and scattering cross-sections of these particles are extracted from discrete dipole approximation (DDA) calculations, using the open-source code DDSCAT [6]
- The absorption spectra are compared to the AM1.5G spectrum to calculate the absorbed solar power over the range 0.875-2.5 μ m.





We developed a process to fabricate Ni nanoantennas on Si substrate using e-beam lithography, and study the impact of the fabrication defects.

- SEM and AFM characterization to reconstruct the surface topology of a real particle
- DDA simulations on the realistic structure





[1] B. Lorenzi, M. Acciarri, & D. Narducci, "Analysis of Thermal Losses for a Variety of Single-Junction Photovoltaic Cells: An Interesting Means of Thermoelectric Heat Recovery", J. El. Mat., 44, 6, 1809-1813 (2014) [2] B. Lorenzi et al., « Practical development of efficient thermoelectric – Photovoltaic hybrid systems based on wide-gap solar cells », Applied Energy, 300, 117343 (2021) [3] G. Contento et al., « Efficiency enhancement of a-Si and CZTS solar cells using different thermoelectric hybridization strategies », Energy, 131, 230-238 (2017) [4] T. Park et al., « Photothermally Activated Pyroelectric Polymer Films for Harvesting of Solar Heat with a Hybrid Energy Cell Structure », ACS Nano, 9, 12, 11830-11839, (2015) [5] Y. J. Kim et al., « High-Performance Monolithic Photovoltaic—Thermoelectric Hybrid Power Generator Using an Exothermic Reactive Interlayer », ACS Appl. Energy Mater., 2, 4, 2381-2386 (2019) [6] Draine, B.T., & Flatau, P.J., "Discrete dipole approximation for scattering calculations", J. Opt. Soc. Am. A, 11, 1491-1499 (1994) [7] Baldwin, C.L., Bigelow, N.W., & Masiello, D.J., "Thermal Signatures of Plasmonic Fano Interferences: Toward the Achievement of Nanolocalized Temperature Manipulation", J. Phys. Chem. Lett., 5, 8, 1347–1354 (2014) Acknowledgment: this work was partly supported by the French RENATECH network.



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