CEA Saclay –Service de Physique de l'Etat Condensé (SPEC)
Laboratoire *SPHYNX* (http://iramis.cea.fr/spec/SPHYNX/)

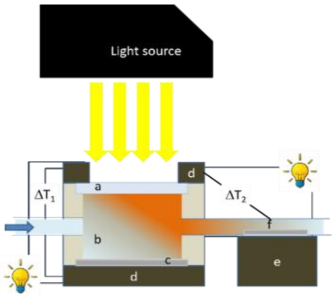
PROPOSITION DE STAGE 2023/2024

THERMOELECTRIC ENERGY CONVERSION IN COMPLEX FLUIDS
COGENERATION OF HEAT AND ELECTRICITY USING NANOFLUIDS

Thermoelectricity, a materials' capability to convert heat in to electric energy has been known to exist in liquids for many decades. Unlike in solids, this conversion process liquids take several forms including the ***thermogalvanic*** reactions between the redox ions and the electrodes, the ***thermodiffusion*** of charged species and the temperature dependent formation of electrical double layer at the electrodes. The observed values of Seebeck coefficient ($Se = -\Delta V/\Delta T$, the ratio between the induced voltage (ΔV) and the applied temperature difference (ΔT)) are generally above 1 mV/K, an order of magnitude higher than those found in the solid counterpart.

At SPHYNX, we have an on-going research project to understand and exploit the heat-to-electricity conversion mechanisms in such complex fluids, namely, the co-generation of heat & electricity using *nanofluids* (liquid suspensions of nanometer-sized additives) via hybrid solar-thermal collectors.

In this project, we combine the sun-light absorption and the thermo-electrodiffusion of nano-additives to simultaneously produce heat and electricity from the solar radiation[1]. A prototype device has been built (see figure) by our partner laboratory (National Optical Institute, INO, Firenze, Italy) and the first demonstration of the electric potential and the power generation from sun-light has recently been achieved at SPHYNX. For nanofluids, aqueous ferrofluids (collaboration with Sorbonne U) will be first used, that are known for their long-term stability, an elevated heat absorption capacity and improved thermoelectric efficiency[2,3]. However, other nanoparticles (carbon-based and inorganic ones) are also considered exploring varying optical absorption ranges. The internship has for its short-term goal to benchmark the prototype feasibility in more *realistic* conditions by determining the extractable magnitude of heat generation, thermal gradient and the power-output as a function of the irradiation power and nanoparticle concentration. Upon its successful completion, the internship will be converted into a PhD thesis research project (funding not secured), investigating the underlying laws of physics behind the solar radiation absorption (heat) and the thermoelectric potential and power generation and other associated phenomena in various types of nanofluids, as well as the development of larger and more evolved devices identifying the impact of cell geometry (including that of thermal insulator), fluid-flow patterns, etc..



Hybrid solar-thermoelectric cell developed by INO & SPHYNX. Imange not available due to the on-going patent application.

Our long-term goal is to deepen the understanding of the bespoke compound thermoelectric phenomena in liquid media, and to demonstrate the application potential of complex thermoelectric liquids based on affordable, abundant and safe materials for thermal energy harvesting as an energy efficiency tool.

The ideal candidate will have strong background in Physics (thermodynamics) with basic theoretical/practical notion of Chemistry (CPGE in MP/PC/BCPST or Undergraduate double-major in Physics & Chemistry, and Energy/Electrochemistry/Chemistry courses in Master 1&2). No numerical skills are necessary for these positions, however, basic data analysis skills are required. Hands on experience in the laboratory environment (glovebox handling, electronic hardware manipulation, etc.) is a plus.

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REFERENCES:
[1] Z. Liu *et al.*, "Enhancement of solar energy collection with magnetic nanofluids," *Therm. Sci. & Eng. Prog.*, **8**, 130 (2018).
[2] E. Sani, *et al.*, "Multifunctional Magnetic Nanocolloids for Hybrid Solar-Thermoelectric Energy Harvesting," Nanomaterials, 11(4), 1031; https://doi.org/10.3390/nano11041031 (2021).
[3] T. Salez *et al.*, "Magnetic enhancement of Seebeck coefficient in ferrofluids," *Nanoscale Adv.*, **1**, 2979 (2019).