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

PROPOSITION DE STAGE 2022/2023

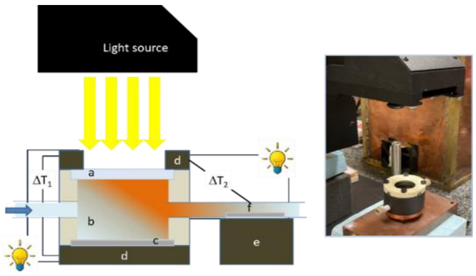
THERMOELECTRIC ENERGY CONVERSION IN COMPLEX FLUIDS (INTERNSHIP 1/2)

1. 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 two on-going research projects to understand and exploit the heat-to-electricity conversion mechanisms in such complex fluids. (**Please consult Internship 2/2 for the second proposition**)

1) <u>Co-generation of heat & electricity using *nanofluids* (liquid suspensions of nanometer-sized additives) via hybrid solar-thermal collectors</u>. 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 currently being tested at SPHYNX. For the nanofluids, we use maghemite (iron oxide, collaboration with Sorbonne U) nanoparticles in aqueous media known for their long-term stability, moderately elevated heat absorption capacity and improved thermoelectric efficiency[2,3]. The internship has for its short-term goal to benchmark the prototype feasibility 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 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.. (The candidate must apply for PhD scholarship).



Hybrid solar-thermoelectric cell developed via INO/SPHYNX collaboration

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 some 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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<u>REFERENCES:</u>

[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).