INSTITUT D'ÉLECTRONIQUE ET DES SYSTÈMES

INTERNSHIP : STUDY OF A THERMOELECTRIC GENERATOR BASED ON N-TYPE ORGANIC MATERIAL ON A FLEXIBLE SUBSTRATE FOR IOT APPLICATIONS

Level : M2

Location : Laboratoire IES (UMR 5214 UM/CNRS), 860 rue Saint Priest, 34000 Montpellier

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The amount of energy already available around us is astonishing. Although there are a few exceptions, in most situations, we already have enough energy to run an IoT device properly. In [1], it is stated that the energy density available with a solar cell is 10µW/cm2 (indoor) to 15mW/cm2 (outdoor), while an energy density of 40µW/cm2 is possible from a thermoelectric sensor in contact with the human body. Thermoelectric generator (TEG) technology [2] holds great promise for powering IoT devices at very low power levels. A TEG can be implemented in a "uni-leg" or "double-leg" topology. A "double leg" is more efficient, but requires the use of two semiconductor materials with opposite doping (n-type and p-type) for each cell. In a "uni-leg" topology [3], the idea is to build a device based on cascaded cells alternating metal and semiconductor. The parameters required for both elements are high electrical conductivity combined with low thermal conductivity. In addition, the Seebeck coefficient, which indicates the property of a material to generate a voltage difference when subjected to a temperature gradient, needs to be as high as possible. Finally, the figure of merit ZT = $(\alpha 2\sigma/k)T$ where α is the Seebeck coefficient, σ the electrical conductivity, k the thermal conductivity and T the average temperature, must be maximized for an energy recovery application. Currently, most TEGs are fabricated on rigid substrates with non-durable materials, but we can find some work in the literature involving the use of doped polymers such as PEDOT:PSS [4]. It is reported in [5] that the ZT of a commonly used inorganic material (p-PbTe) is between 0.19 and 1.67 at 300K and 800K respectively. For organic materials, the best value achieved is ZT=0.3 obtained at room temperature [6].

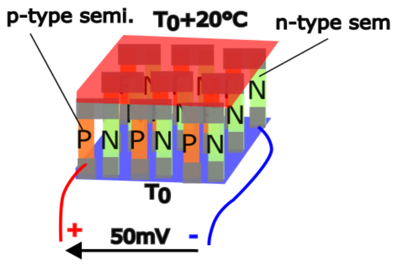

Fig 3. Thermoelectric generator basic principle

Objective

The aim of this internship is to design a flexible TEG using an organic material based on small pi-conjugated molecules with N-type behavior. We propose here to first design a uni-leg TEG based on the organic material studied in the ANR Pi-CANTHERM project, and a metal (aluminum (Al), silver (Ag)). We will first characterize the ZT that can be achieved with this material. Then, a planar design of a TEG based on multiple cells will be realized. The expected result is to demonstrate that we can generate several µW for a temperature gradient of 20°C.

Following the internship

The M2 internship can be followed by an 18-month engineer contract (University of Montpellier) as part of the ANR Pi-CANTHERM project.

Required skills

- Instrumentation
- Electronics
- Modeling and data processing
- An experience in clean room fabrication technique is appreciated

[1] K. S. Adu-Manu, N. Adam, C. Tapparello, H. Ayatollahi, and W. Heinzelman, ‘Energy-Harvesting Wireless Sensor Networks (EH-WSNs): A Review’, ACM Trans. Sen. Netw., vol. 14, no. 2, pp. 1–50, May 2018, doi: 10.1145/3183338.
[2] H. Jouhara et al., ‘Thermoelectric generator (TEG) technologies and applications’, International Journal of Thermofluids, vol. 9, p. 100063, Feb. 2021, doi: 10.1016/j.ijft.2021.100063.
[3] C. Yang et al., ‘Transparent flexible thermoelectric material based on non-toxic earth-abundant p-type copper iodide thin film’, Nat Commun, vol. 8, no. 1, Art. no. 1, Jul. 2017, doi: 10.1038/ncomms16076.
[4] S. Lin et al., ‘Flexible thermoelectric generator with high Seebeck coefficients made from polymer composites and heat-sink fabrics’, Commun Mater, vol. 3, no. 1, Art. no. 1, Jul. 2022, doi: 10.1038/s43246-022-00263-1.
[5] G. J. Snyder and A. H. Snyder, ‘Figure of merit ZT of a thermoelectric device defined from materials properties’, Energy Environ. Sci., vol. 10, no. 11, pp. 2280–2283, 2017, doi: 10.1039/C7EE02007D.
[6] J. Liu et al., ‘N-type organic thermoelectrics: demonstration of ZT > 0.3’, Nat Commun, vol. 11, no. 1, p. 5694, Dec. 2020, doi: 10.1038/s41467-020-19537-8.