Control of heat flow through a thermoelectric material

Keywords

Thermoelectric material, heat flow, thermal conduction, electrical shunt

Background

The manipulation of heat flow through solid-state materials has opened up a field of research towards various applications, new ones such as camouflage, promising ones with concentrators for energy recovery, or even counterintuitive ones by reversing the direction of flow using devices integrating thermal metamaterials [1]. The geometry and properties of the materials used are usually fixed and determine the function of the device. This work focuses on the integration of thermoelectric materials into systems to modulate functionality.

Thermoelectric materials are almost exclusively used as energy converters. They allow conversion between temperature differences and potential differences. The conversion is reversible and results in a temperature difference when a current is passed through the material. Cooling (Peltier effect) and recovery of electrical energy (Seebeck effect) from lost thermal energy are two current applications of this phenomenon. The figure of merit of the thermoelectric material (zT), which describes the efficiency of the transformation, depends on three physical parameters for a given temperature T: the electrical conductivity, the thermal conductivity and the Seebeck coefficient.

Objectives

The proposed work aims to investigate the use of thermoelectric materials to manipulate (modulate, stop, direct...) a heat flow. The thermoelectric element with variable thermal conductivity will be integrated into the heat guide to allow the flow to be modified locally.

Figure 1 highlights the management of a heat flow by directing it to the left channel. The thermal conductivity of the Peltier module is increased in this channel while it is minimised in the channel on the right. This heat transfer has the advantage of being flexible in directing the flow to the other branch and is easy to implement. Such a system can be used for intelligent cooling of multilayer solid state devices. Theoretical studies show that the thermal conductivity of a thermoelectric material can be modified by adding an external static or dynamic electrical impedance condition to the electrical connection, but without experimental confirmation [2].

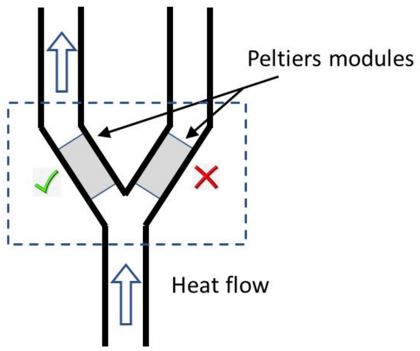

FIG 1: Solid-state heat flow guidance: a Peltier module supplemented with an external impedance condition either passes (left) or stops (right) the heat flow.

Work flow

The different steps foreseen for this thesis are the following:

- Study and bibliographical survey on the management of heat flow, the means implemented to modulate it and the applications.

- Modelling and instrumentation of a thermoelectric leg to validate the concept of variable thermal conductivity.

- Study of the influence of different physical parameters and the effect of different types and architectures of electrical shunts (inverse problem).

- Design, simulation and implementation of a complete and optimised solid state heat flow control demonstrator. The control parameter(s) will gradually become static and then dynamic in order to enrich the range of possible functionalities of the device.

[1] I. Peralta et al., Advanced Engineering Materials 22(2) (2020) 1901034.
[2] A. Massaguer Colomer *et al*., Applied Energy 154 (2015) 709–717.

Candidate profile

This PhD thesis is aimed at a motivated and curious graduate of an engineering school or a Master 2 research degree, with a good knowledge in the following fields: electronics, numerical modelling and simulation of physical systems. A good level of French and English would be appreciated.

The candidate will have to show autonomy and creativity in the development of the devices.

Conditions of the contrat

The thesis will take place at the GREMAN laboratory (UMR CNRS 7347) at the IUT of Blois (41), France. Travel to the GREMAN site in Tours is expected.

Start of thesis: 01/10/2023

Funding over 36 months (grant from the University of Tours).

Laboratory website: http://greman.univ-tours.fr/

Superposition and contact

CV and cover letter to be sent to

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