

Monolithic Nanothermocouples

S. Blanco Alvarez ^a, F. Chaltin ^a, X.D.A. Baumans ^a, S. Melinte ^c, R.B.G. Kramer ^b, A.V. Silhanek ^a

^a Experimental Physics of Nanostructured Materials, Q-MAT, CESAM, Université de Liège,
B-4000 Sart Tilman, Belgium

^b Université catholique de Louvain, Institute of Information and Communication Technologies,
Electronics and Applied Mathematics (ICTM), Institut de la Matière Condensée et des Nanosciences
(IMCN), 1348 Louvain-la-Neuve, Belgium

^c Institut Néel CNRS & Université Grenoble Alpes, F-38042 Grenoble Cedex 9, France

e-mail: s.blanco@uliege.be

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Thermocouples are the oldest and simplest illustration of thermoelectric properties of material. Their basic operation principle is based on joining elements with different Seebeck coefficient to create an open circuit voltage difference between the two ends of the junction when is heated to a temperature above the surrounding temperature. Cheap and reliable, they are used in a variety of applications including differential thermometry [1], infrared thermal sensors [2] and energy harvesting of wasted heat [3].

As thermal sensor, their precision is limited spatially by the size of the interface between the two materials and temporally by the mass of the junction. To improve both aspects, their size were reduced to nanoscale dimension, giving rise to thermal imaging techniques such as scanning thermal microscopy (SThM) [1].

However, fabricating devices to this scale is not trivial and require numerous steps and a great precision. In order to simplify this process, Szakmany *et al.* [4] introduced a novel thermocouple system made of a single metal. Exploiting the scattering interaction between electrons and the boundaries of the material, they were able to change the Seebeck coefficient of a Nickel by reducing the width of the Ni thin film. The resulting device proved to be a good implementation of infrared thermal sensor.

This monolithic thermocouple device is of great interest because of its simplicity. From a practical point of view, it only requires one lithography step and one deposition, making it cheap and easy to implement. From a more fundamental point of view, the system also possesses the great quality of its simplicity in exploring the different parameters governing the system (material, size, geometry, etc.).

In our study, we created on-chip platforms for calibrating single-metal thermocouples and we test them for two different metals: Ni and Pt. The difference in electronic properties of Ni and Pt allowed us to study the interplay between the thermocouple width and the electron mean free path of the material, the fundamental driving mechanism of this system. In addition, we studied the evolution of the Seebeck coefficient at different operating temperature, from room temperature to 4K, giving us insight on the role played by phonons in the system.

A better understanding of the underlying mechanism associated to single-metal thermocouples could lead to the ability to fine tune the Seebeck coefficient of a material, potentially improving the efficiency of thermoelectric devices as wasted heat harvesters.

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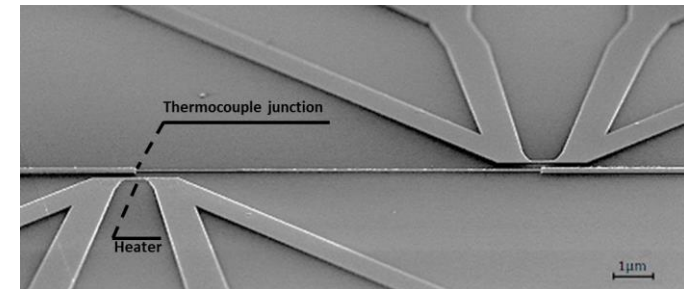


Figure 1. Tilted view of the Pt thermocouple with two heating devices added to measure heat conduction

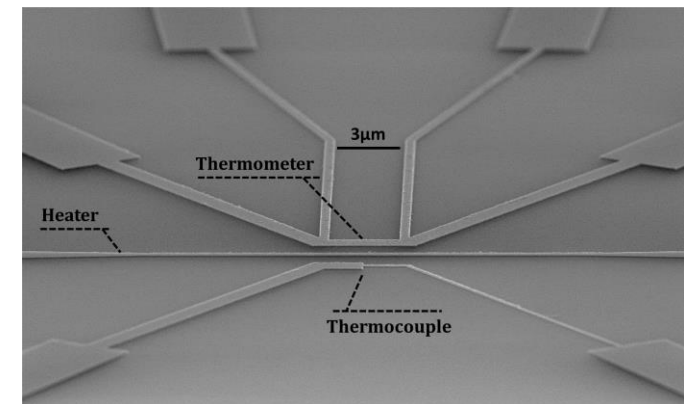


Figure 2. From top to bottom, tilted view of a calibrated Pt thermometer, Pt central heater line and Pt thermocouple used to study the temperature dependence of the thermocouple.