# LABORATORY EQUIPMENT AND TECHNIQUE

## ON THE CONTRIBUTION TO ELECTROLYTICAL FORMATION OF THERMOPILES

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Electrolytical formation of thermopiles has been recently adopted in the construction of heat flow meters end in microcalorymetry. The influence on the thermopile sensitivity of etching before electrolytical plating and of the coil shape are discussed. Due to the application of etching before plating and of optimum shaping, an increase of sensitivity by up to 50%, as compared with thermopiles obtained by usual electrolytical methods, is reported to be possible.

The electrolytical method of thermopile formation has been applied for many years in making heat flow meters [1], [6]. Recently this method drew the attention of constructors of microcalorimeters [2], [7] as it enables thermopiles to be made without soldering every individual thermopair. Fitting the ends of wires of two different materials, before soldering them, was the most troublesome operation when using previous methods. Moreover, the amount of manual operations increase considerably with the number of thermoelements of a thermopile.

On the other hand, when using the electrolytical method for making, for example, copper-constantan thermopiles, the copper wires are replaced by the constantan ones covered with a layer of copper. Thus individual fitting and soldering becomes unnecessary and the majority of other operations can be easily automatized. Therefore the contribution of manual operations to preparing a 1000 pair thermopile is not much greater than that necessary for a 100 pair one. The possibility of reducing the dimensions of thermopiles is a second advantage of the electrolytical method. However, electrolytically formed thermopiles show a relatively small sensitivity of a single thermoelectric couple, the sensitivity of a constantan-copper plated constantan wire thermoelement is one half of that of a copper-constantan thermoelement.

Some effords have been undertaken to increase considerably the sensitivity of a single thermoelement electrolytically formed. These are reported below.

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Let as consider, at first, one of the possible ways of obtaining rapidly a thermopile of 100 thermoelements by using the electrolytical method. We make, accordingly, a coil of 100 turns of constantan wire and dip it into molten parafffin in such a manner that only one half of each turn is immersed. After the paraffin hardens a 10-percent aqueous solu-

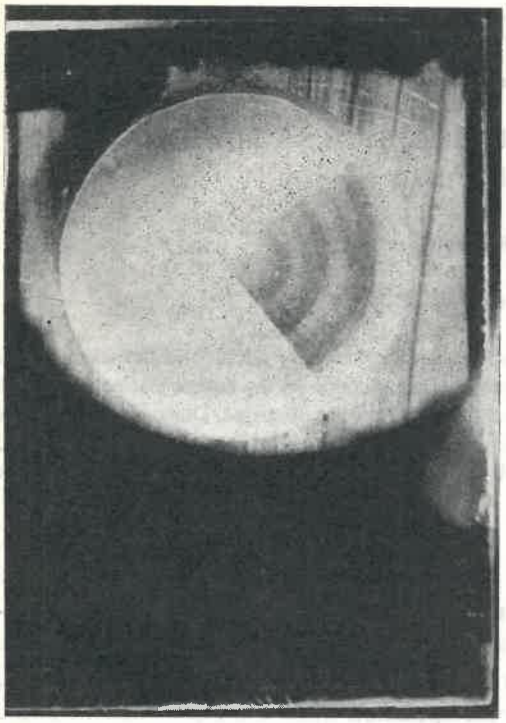

Fig. 1

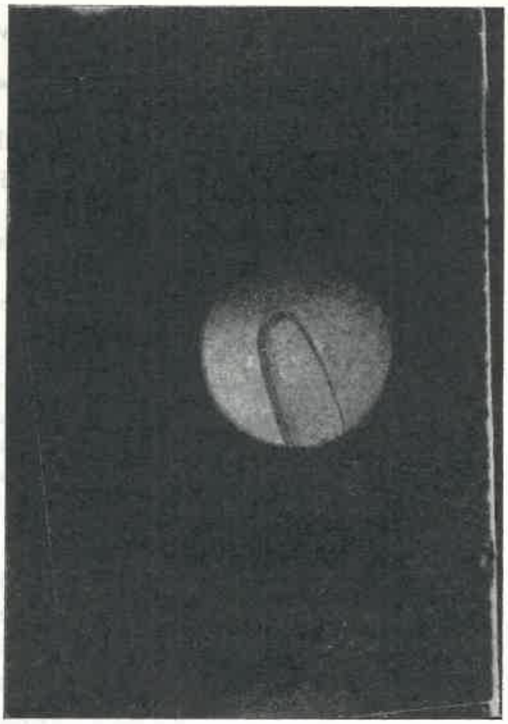

Fig. 2

Fig. 1. A heat-flow-meter made in the Cracow Technical University by the autor [1] by using a thermopile of circular turns. The pile of 800 electrolytically formed thermopairs is rolled into an Archimedes spiral, and sealed with duracryl resin. Applications: in buildings trade and refrigation industry to measurements of heat flux of order of 1 W/m² flowing through protective walls. The copper covered part of the thermopile is lighter than that of constantan only. Twofold magnification

Fig. 2. Single turn of a thermopile, of elliptical cross-section. The etched part, to be covered with copper, can be seen. 10-fold magnification

tion of $CuSO_4$ is pured into the vessel containing the coil, and a copper electrode is placed over the coil in the solution. Both ends of the coil are connected to the negative pole of accumulator. The copper anode is formed in such a way as to enable a uniformly covering with copper layers of all the halves of the turns protruding from the paraffin. Electrolysis should last a dozen or so minutes with a current intensity of 15 milliamperes. When the paraffin is removed from the coil, the thermopile is ready for use (Fig. 1).

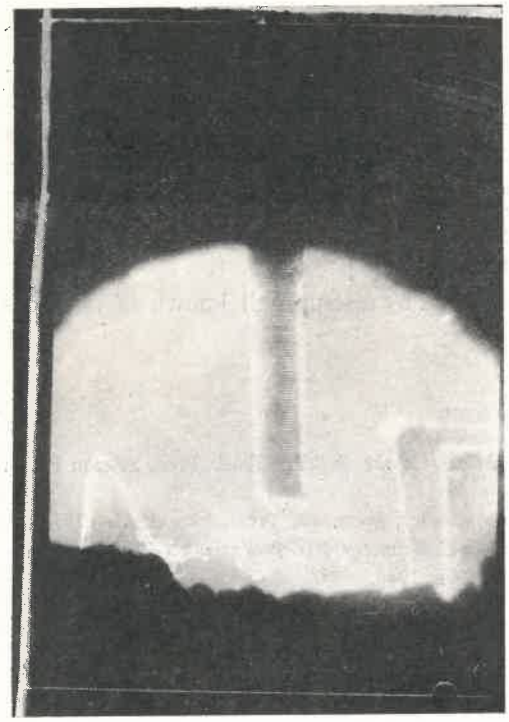

Fig. 3

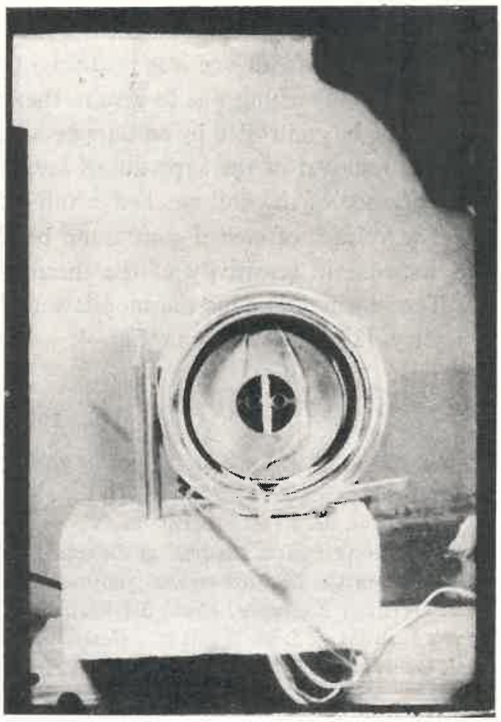

Fig. 4

Fig. 3. Part of a ready thermopile of 600 thermoelements. Constantan wire is wound on a polivinylochloride core. After etching in 10% solution of nitric acid and depositing the copper layer, the whole element is sealed wich duracryl resin. Length of the thermopile 10 cm, thickness of the constantan wire −0.1 mm, density of the winding 6 turns per millimeter of thermopile length

Fig. 4. Device for determination of sensitivity of the elliptical cross-section thermopile. Thick-walled copper pipe shown of external diameter $d_1 = 60$ mm, internal diameter $d_2 = 20$ mm weight 2 kg. Inside the pipe the set of thermopile "*s*" to be examined is inserted, stuck to a thin-walled copper tube "*t*" of the 5 mm diameter and 2 g weight, containing a heater. Current of power $10^{-6}$ W supplying the heater inside "*t*" give rise to *ca* 0.8 scale division deflection of a galvanometer connected to the thermopile of sensitivity of $10^{-9}$ A/scale div. Thick-walled copper pipe inserted into a vacuum flask, in order to minimize the influence of ambient temperature fluctuations. Two thermopiles were coupled in a push-pull arrangement, in a single pipe 2. A completed thermopile and copper tube with heater of shown on the lefes side of the photograph (threefold size reduction)

In order to improve the electrolytical method of preparing thermopiles, the optimal form of the single turn, and the optimal thickness of the copper layer have been searched. An elliptical form are the turns has been proven to be better than a circular one, because, for the same ohmic resistance, the distance between cold and warm joints becomes greater. The optimal thickness of the copper layer appeared to be one reducing the ohmic resistance of the thermopile to about 50 percent of the initial resistance of the constantan coil. This is evident, because such an optimally thick copper layer short-circuits that section of the constantan wire on which it is deposited, and using more copper is useless.

A treatment that especially improved the sensitivity of the thermopiles, was etching the constantan coil (with one side protected by paraffin) before electroplating it with copper. The aim of the etching was to give to the turns a profile presented in Fig. 2. The degree of etching can be controlled by an ohmmeter, as the resistance of the coil gradually increases with the removal of the superfluous layer of constantan. The etching was stopped when the resistance of the coil reached a value 50% greater than the initial one.

The volume of etched constantan being replaced with copper resulted in a *c.* 50 per cent increase in sensitivity of the thermopile [4], [5], [6].

The sensitivity of the thermopile was determined by a setup well known in microcalorimetry [2], [3], shown in Fig. 4.

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