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DESIGN AND REALIZATION A NEW THERMOELECTRIC SENSOR, APPLICATION

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The present paper deals with design and realization of a New thermoelectric sensor adapted to conceive a circuit breaker, using the thermoelectric effects (Joule, Peltier and Seebeck). The sensor includes two printed circuits. The first is constituted of two resistive tracks of constantan, it is the transmitting circuit. The second, a planar thermoelectric circuit acting as a receiver, is constituted of many plated differential thermocouples. The transmitting circuit is placed on the top surface of the receiver circuit so that the resistive tracks are placed on the levels of thermoelectric junctions. The measuring method consists to passing electrical currents through the resistive tracks in order to generate temperature gradients between junction points of the bimetallic circuit. Then the resulting temperature differences between junction points is directly converted into a proportional Seebeck voltage. As an application, the sensor is adapted to realize a differential circuit-breaker with a low difference current.

Keywords: Thermoelectric effects; Circuit-breaker; Thermoelectric sensor

1. INTRODUCTION

The Seebeck effect was implemented for a long time to conceive and realize a great diversity of sensors, the measurement of physical size is a difference in temperature between two points. The essential advantage of the thermoelectric sensors is to be differential and to

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detect with precision the equality between two temperatures. The industrial applications of the Seebeck effect are numerous and relate to the measurement of the temperature differences. For an example, a thermopile is the sensitive element for the thermocouples and many sensors [1, 2]. The problems arising from the use of the traditional thermoelectric circuits are to solve the practical problems posed by the welding of many bimetallic contacts. The fabricating method of bimetallic circuits consists to deposit by electrolytic way a metal layer of high conductivity on a metal support of low conductivity [3, 5, 6]. In a previous work [4], we described and characterized a new thermoelectric sensor in the shape of printed circuit, adapted to low fluid flow measurement. The object of this work is studied experimental of the coupling between two constantan resistive tracks crossed by an electrical current and other bimetallic circuit used as a thermal gradients detector. The two circuits are placed one on the top of the other thus constituting a new sensor based on the thermoelectric effects. As an application, a differential circuit-breaker was realized, it is characterized by its speed, its low difference of current, its easy fabricating process, and low in cost.

2. DESCRIPTION

The sensitive element is the thermoelectric sensor, includes two printed circuits. The fabrication of this circuits used the printed circuit technology. The first circuit (or transmitting circuit) is composed of two constantan resistive tracks as shown in Figure 1. The electric resistance R of constantan, with low temperature coefficient, is intended to be traversed by an electrical current I. To realize this circuit, we dispose of a constantan sheet of thickness 25 µm on Kapton support of thickness 25 µm. The second circuit as shown in Figure 2 is a thermoelectric track comprising a continuous ribbon of constantan of thickness 25 µm available on Kapton of thickness 25 µm. The ribbon is covered uniformly with an electrolytic copper deposit of high conductivity of thickness 5 µm. Using the photoengraving techniques, the circuit is engraved with iron perchloride following the form and the dimensions desired. The ammonium dysulfateperoxyde attacks mainly copper and leaves intact the constantan sheet, is used to reveal the shape of the electrodes as shown in Figure 3. An example of masks

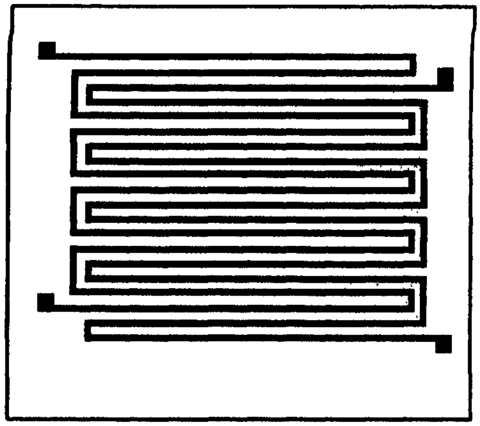

FIGURE 1 Resistive constantan tracks.

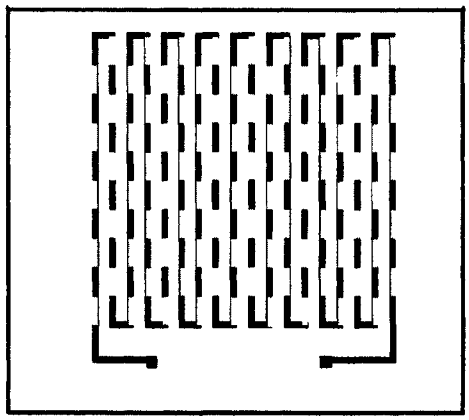

FIGURE 2 Bimetallic circuit with plated electrodes.

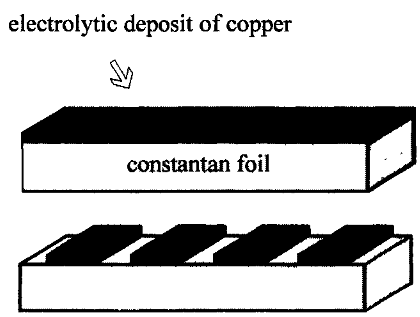

FIGURE 3 Thermoelectric chain.

shown in Figure 4 is used for the fabricating processes. The thermoelectric track shown in Figure 2 is comprised by many plated differential thermocouples interconnected in series. The temperature gradients between the thermoelectric junctions are detected by this track and directly converted into a proportional change in the Seebeck voltage [4, 5]. The thermoelectric track realized of width 0.2 mm, length 1000 mm, and distance between two consecutive junctions 3 mm.

The resistive tracks of the transmitting circuit are placed on the top of the junction points of the receiver circuit (or thermopile) as shown in Figure 5. The disposition of the two circuits one on the top surface of the other, offers a thermal symmetry, and minimizes the offset voltage introduced by the inaccuracy of alignment of the two circuits. When the resistive tracks are crossed by an electrical current I, locally

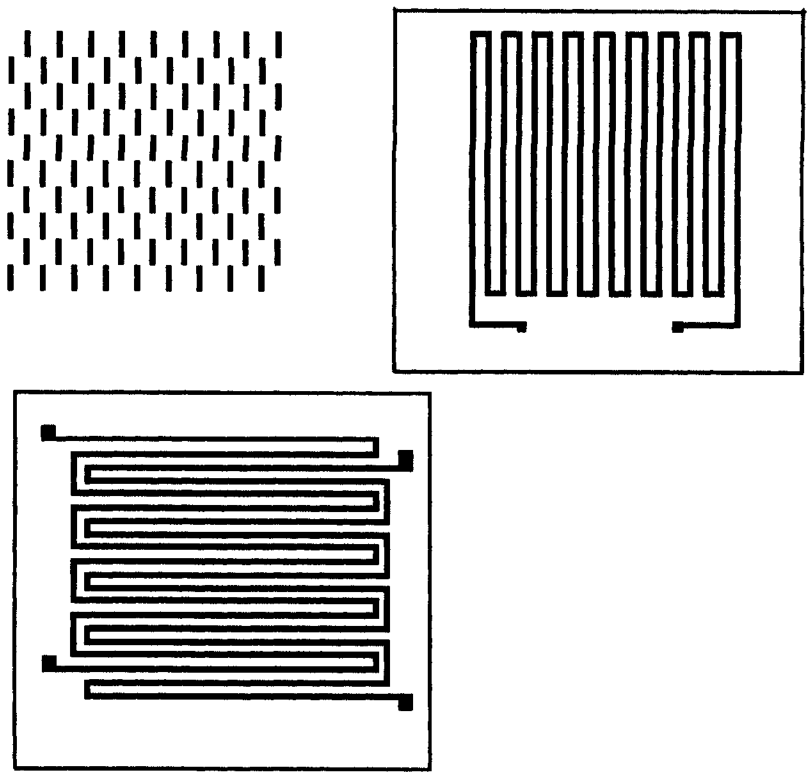

FIGURE 4 Example of used mask.

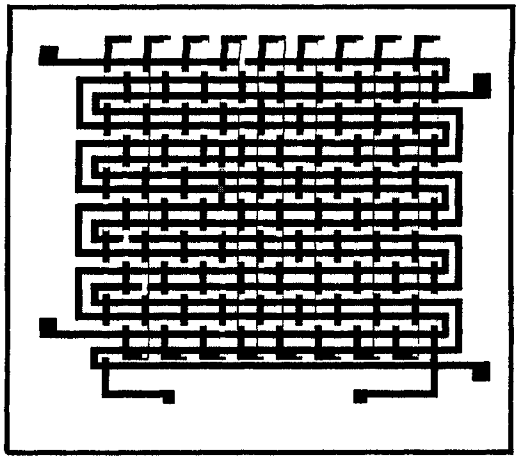

FIGURE 5 Used sensor constituted with two circuits.

the power dissipated by a section of resistance dR is proportional to the electrical current square: $dP = dR \cdot I^2$. The temperature of this section rises proportionately at the dissipated power dP, $T = T_{\text{ambiant}} + R_{th} \cdot dP$, R_{th} is the local thermal resistance. The tracks, when they crossed by an electrical current, create variations in temperature on the levels of the junction points. The detector circuit is charged to measure the temperature difference between the junction points and delivers a proportional voltage to this difference. When the electrical currents crossed the tracks are the same, the voltage generated by the bimetallic circuit is zero. When the electrical currents are different, the Joule powers released by the tracks are different and the temperature variations are created between the junctions points. The voltage delivered by the thermopile is proportional to the power difference dP, and $\Delta V = a \cdot \Delta P$, with a is a coefficient dependent of thermoelectric capacity, electric conductivity of copper–constantan pair, and their dimensions.

3. EXPERIMENTAL RESULTS

The object of this work is to present a whole of results which make it possible to design and produce a new sensor based on the coupling between resistive and thermoelectric tracks. In order to realize the sensor, the transmitting circuit is placed on the top surface of the bimetallic circuit (copper–constantan) as shown in Figure 5 so that the resistive tracks are placed on the top junction points as shown in Figure 6. The device is easily fixed on the top surface of the dissipated heat sink as shown in Figure 7.

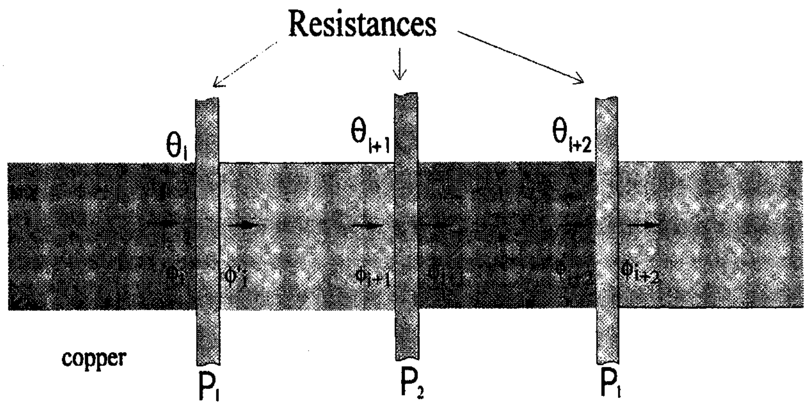

FIGURE 6 Section of the sensor.

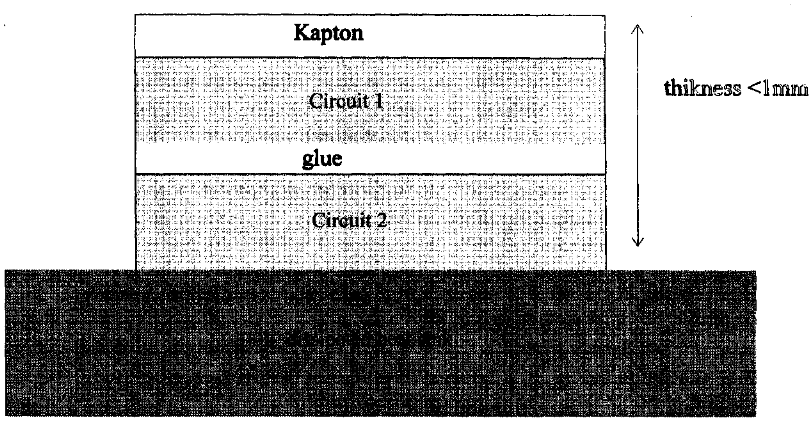

FIGURE 7 The sensor on the dissipated heat sink.

3.1. Measurement of Thermal Gradients Induced by an Electrical Current

Only one of the two resistive tracks is crossed by an DC current. The track creates, by Joule effect, a difference in temperature between the junction points of the thermopile. The voltage variation delivered by the thermopile as a function of the electrical current square is shown in Figure 8. It is noted that this variations is quite proportional to the Joule power present at the level of the junction points.

3.2. Differential Mode Measurement

The resistive tracks, resistance R_1 and R_2, are placed in the circuit as shown in Figure 9. The electrical currents I_1 and I_2 crossing the tracks create variations in temperature on the levels of the junction points. The thermopile delivers a voltage representative of the variation in temperature between the junction points. A round a given current value crossing one of the tracks, we proceed to a variation of the current with

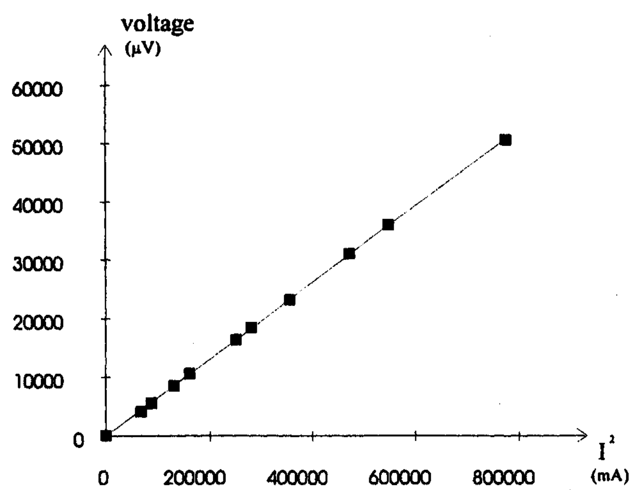

FIGURE 8 Variation of the output voltage against the current square.

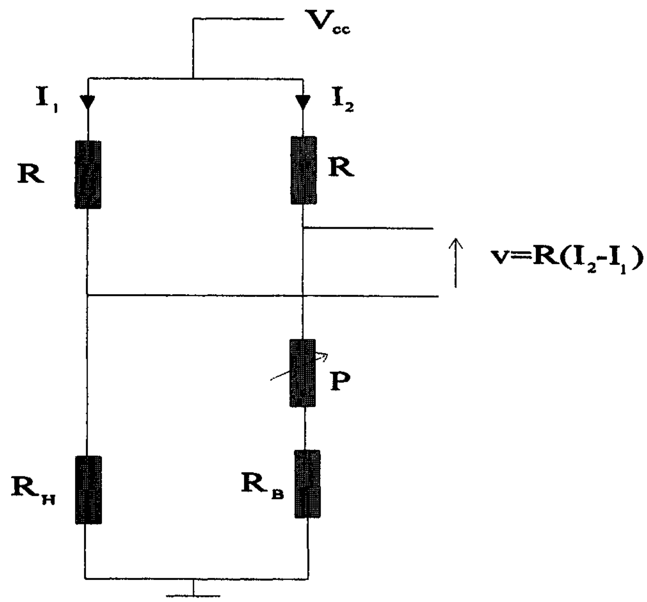

FIGURE 9 Differential mode circuitry.

a variable resistance P. The experimental results enable us to trace for each value of current, the voltage variation delivered by the thermopile against the variation between the two electrical currents crossing the two resistive tracks and this variation is shown in Figure 10. It is noted there is shift of voltage (offset) when the two electrical are equal ($\Delta I = 0$). This defect is introduced by the inaccuracies of alignment of the two circuits one on the top of the other, and by the defect of fabricating circuits. We note, if the current is high the shift of voltage is high.

3.3. Common Mode Measurement

To achieve an industrial device, it is necessary to correct this shift of voltage. For that, the resistive tracks are connected in series (Fig. 11), and crossing by an electrical current in order to have a maximal shift of voltage. The current variation is adjusted with the variable resistance R_v in order to have Seebeck voltage in zero.

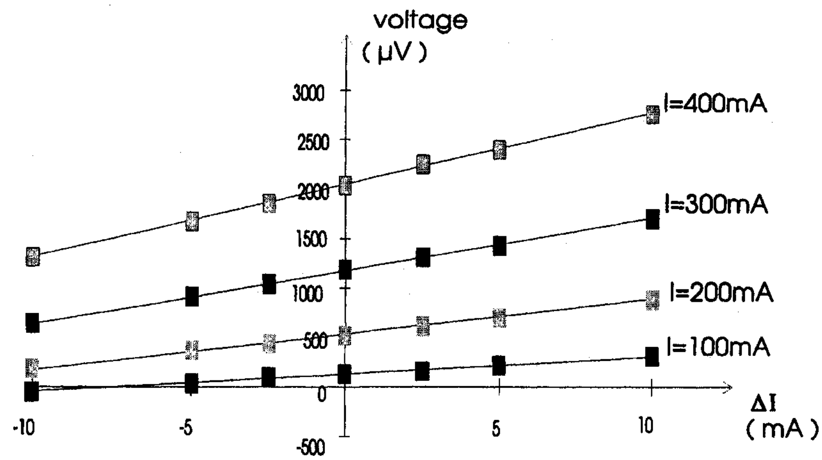

FIGURE 10 Variation of the output voltage against the difference of the current.

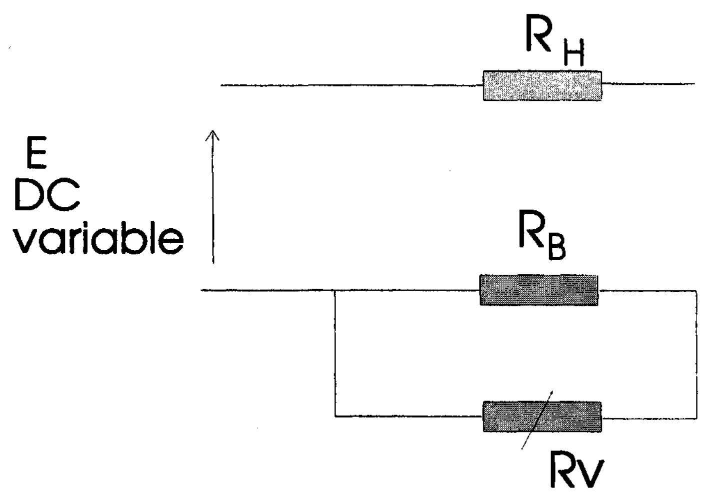

FIGURE 11 Common mode circuitry.

4. APPLICATION: DIFFERENTIAL CIRCUIT-BREAKER

The corrected device in inserted in the circuit as shown in Figure 12. When the currents crossing resistance tracks is the same, the voltage

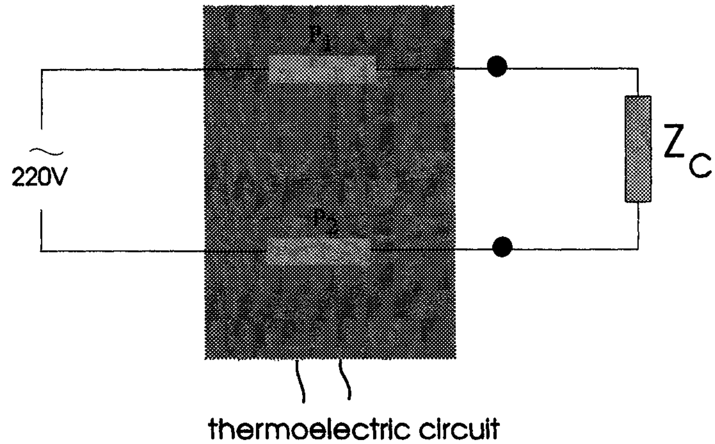

FIGURE 12 Differential circuit-breaker circuitry.

delivered by the thermopile is zero. If there is a low difference between values of currents, the sensor delivers a representative voltage of this difference. This voltage value is amplified with an amplifier of precision instrumentation, and the output of this amplifier is compared to an adjustable reference voltage. This reference fixes the difference of current accepted by the load (the minimal difference of current is the order 3 mA).

5. CONCLUSION

The experimental studies of thermal gradients generated by two tracks placed on the top junction points of the bimetallic circuit, permitted us to conceive and a new thermoelectric sensor. This sensor is adapted to realize a differential circuit-breaker with low difference of current. Such sensor can be adapted for an other application, is gas flow measurement.

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