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THERMOCOUPLE-BASED DISTRIBUTED TEMPERATURE SENSOR

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ABSTRACT

In this study, we developed a thermocouple-based distributed temperature sensor. This sensor consists of two thermocouple wires attached to plastic plates with spacers and a sheet of aluminum foil. Only when the pressure is applied to the sensor, the voltage is induced by the temperature difference between the pressure applied point and output point. Utilizing a T-type thermocouple, we fabricated a thermocouple-based distributed temperature sensor with a dimensions of 35 x 1 x 0.05 cm. When the pressure was applied to a location 11.7 cm, 17.5 cm or 23.3 cm from the sensor edge, essentially the same voltages were generated according to the temperature difference. The sensitivity was 0.04 mV/ °C and the relationship between the temperature difference and the induced voltage was approximately linear.

KEYWORDS: Temperature Sensor, Thermocouple, Distributed Sensor

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Original Article

INTRODUCTION

Temperature sensing is critical in many applications. Many sensors such as pressure, force, flow, level, and position require temperature information to insure accuracy. Therefore, temperature monitoring should be performed in order to use these sensors for accurate measurements. In addition, knowledge of temperature can be used to prevent damage to expensive systems. Moreover, the measurements of body temperature can help detect illness and monitor whether treatment is working. Thus, many researchers have been interested in developing different types of temperature sensors for a variety of applications[1]-[3].

Distributed sensing technology is attractive because a single cable can potentially replace several individual sensors, dramatically simplifying sensor installation and readout. A fiber-optic cable is mainly used to develop distributed sensing technology[4]-[5]. However, fiber-optic distribution sensors are expensive and can not be used to conduct distributed measurements within centimeter ranges. Specifically, a fiber-optic temperature sensor can not produce accurate measurements in the precise location of many vibrations and mechanical shocks. Thermocouples have the widest temperature range of all sensor technologies, from -200 to 2315 °C, and can be used in various environments. Their inherently simple design allows them to withstand high levels of mechanical shock and vibration[6]. Recently, automobile researchers have expressed considerable interest in distributed temperature measurements in centimeter ranges to monitor driver mental states[7]-[8]. In this study, a distributed temperature sensor based on a thermocouple for the measurement of temperatures within centimeter ranges is investigated. This sensor consists of two thermocouple wires attached to plastic plates with spacers and a sheet of aluminum foil.

THEORY

A thermocouple is an electrical device consisting of two different conductors forming electrical junctions at differing temperatures. A thermocouple produces temperature-dependent voltage as a result of the Seebeck effect, which is a phenomenon observed when measuring electrical voltage induced by a thermal gradient. Based on the assumption that one end of two connected conductors(A and B) is at temperature T_1 and the opposite end is at temperature T_2 (Figure 1), each conductor produces a themovoltage $V_A = S_A(T_2 - T_1) = S_A\Delta T$ and $V_B = S_B\Delta T$, where S_A and S_B are the respective Seebeck coefficients of conductors A and B. Therefore, the measured voltage difference between two conductors is:

$$V_{AB} = V_A - V_B = S_A\Delta T - S_B\Delta T = S_{AB}\Delta T \quad (1)$$

where $S_{AB} = S_A - S_B$ is the effective Seebeck coefficient of the conductor pair. S_A and S_B are intrinsic material properties of the conductors, whereas S_{AB} is an effective Seebeck coefficient that describes the performance of a composite device.

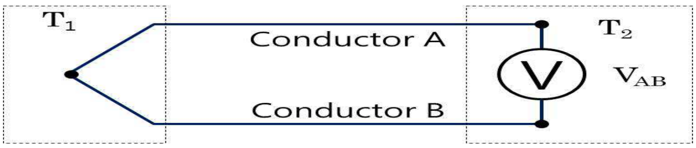

Figure 1: Simple Thermocouple Device

Many types of thermocouples exist. The most common types of thermocouples are types B, E, J, K, N, R, T, C, and P. Before a thermocouple for measuring temperature difference is employed, the limitations of available types should be considered. A type T thermocouple consisting a copper wire and constantan has the highest measurement sensitivity among thermocouple types. Thus, we used a type T thermocouple to produce a thermocouple-based distributed temperature sensor.

The methods section is usually the second-longest section in the abstract. It should contain enough information to enable the reader to understand what was done, and important questions to which the methods section should provide brief answers.

SENSOR FABRICATION

A thermocouple based distributed sensor(Figure 2) was fabricated using a T type thermocouple. The sensor was composed of a constant and a copper wire, as well as two thin plastic plates with spacers and a sheet of aluminum foil. First, two wires were attached to the two plastic plates with spacers using an epoxy. A sheet of aluminum foil was attached to the spacers of one plastic plate. Finally, two plastic plates were bonded. The thermocouple-based distributed temperature sensor with dimensions of 35 x 1 x 0.05 cm was produced.

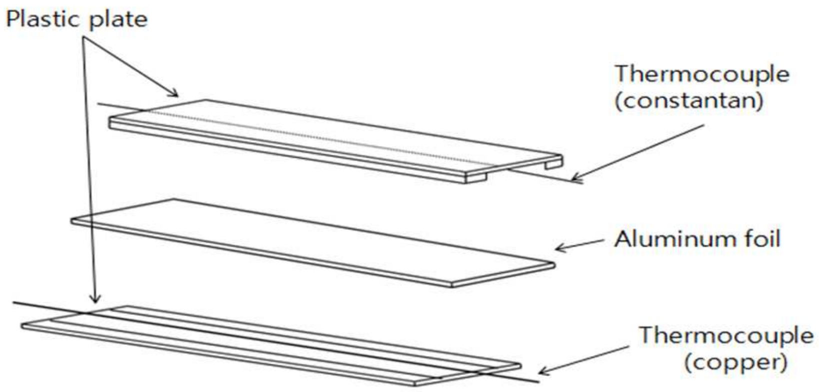

Figure 2: Thermocouple-Based Temperature Sensor

When no external perturbation occurred, the two wires of the thermocouple were not contacted and thus, a voltage was not generated. Only when the pressure was applied to a location of the distributed temperature sensor, two wires were contacted through aluminum foil. Therefore, generation voltages were measured according to the temperature difference between two ends of the thermocouple.

EXPERIMENTS AND RESULTS

The thermocouple-based distributed temperature sensor was evaluated experimentally. The experiment setup as shown in Figure 3 consisted of a hot plate for controlling temperature, temperature sensor and temperature reader for measuring temperature, as well as a thermocouple-based distributed temperature sensor and voltage meter. The voltage generated at the output end of the thermocouple was measured as the temperature on the hot plate changed when the pressure was applied to a location of the distributed temperature sensor.

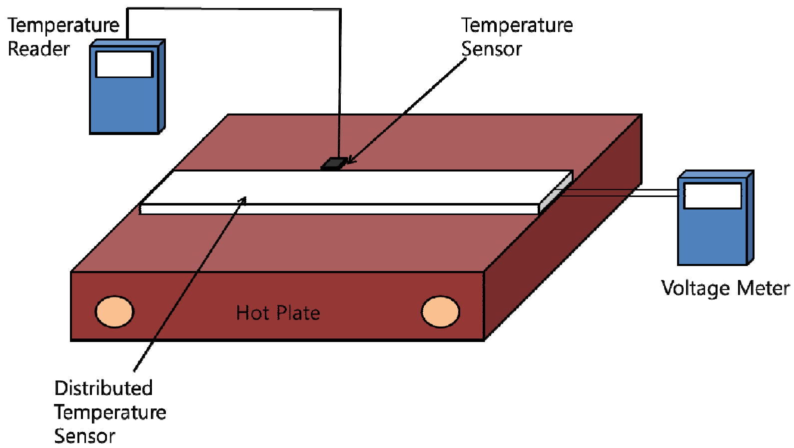

Figure 3: Experimental Setup

Figure 4 shows generated voltages measured according to the temperature difference between the contact point and the output end of two wires. The dashed line represents the measured voltages when two wires were contacted directly. The dotted line represents the measured voltages when two wires were contacted through the aluminum (Al) foil. The generated voltages when using Al foil were a somewhat higher than that generated when not using Al foil. The higher voltage generation when using Al foil occurred because of the two junctions induced by the two wires and Al foil.

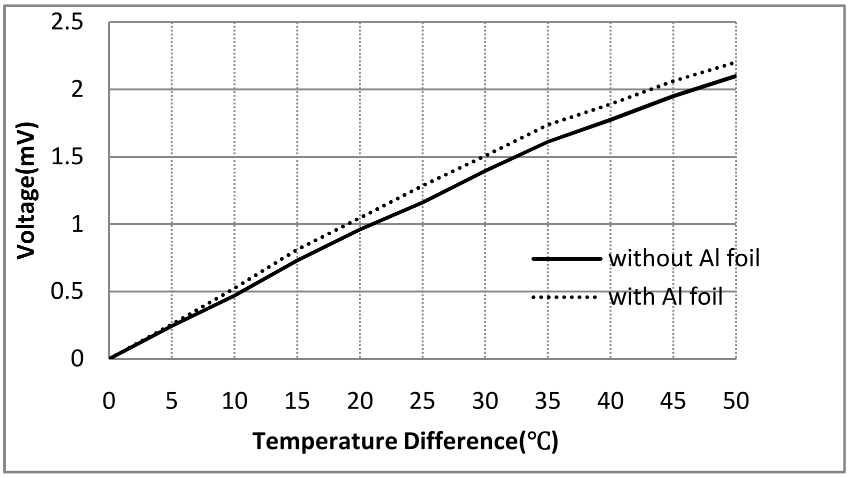

Figure 4: Output Voltages with and without Al Foil

Figure 5 shows output voltages measured based on the temperature difference when the contact areas of two wires and Al foil were 1, 3, and 5 cm^2. The solid, long dashed and dotted line show the voltages measured by the voltage meter when the contact areas were 1, 3, and 5 cm^2, respectively. The results reveal that the amplitude of the generation voltage did not depend on the contact area.

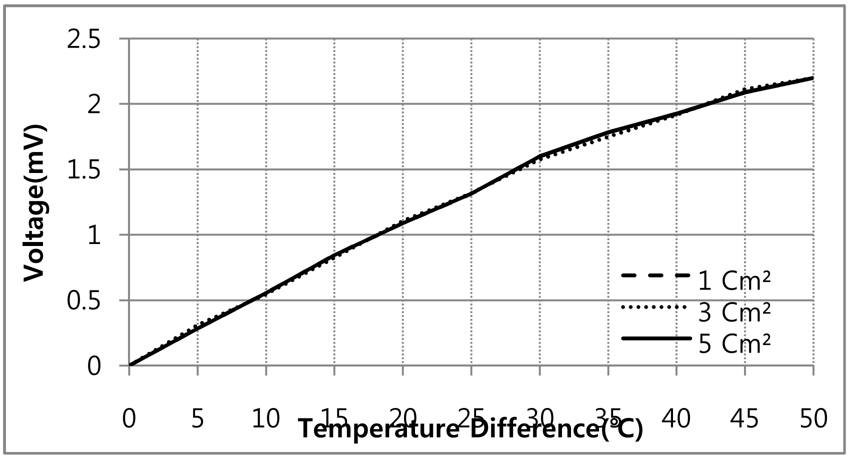

Figure 5: Output Voltages Based on Contacted Areas

Figure 6 shows output voltages measured based on the temperature difference when the contact locations of two wires were at 11.7, 17.5, or 23.3 cm from the output end. The solid, long dashed and dotted line represent the measurement voltages when the respective contact locations were 11.7, 17.5, and 23.3 cm from the output end. Three lines indicate that essentially the same voltages were generated based on temperature difference. The sensitivity was 0.04 mV/ °C and the relationship between the temperature difference and induced voltage was approximately linear

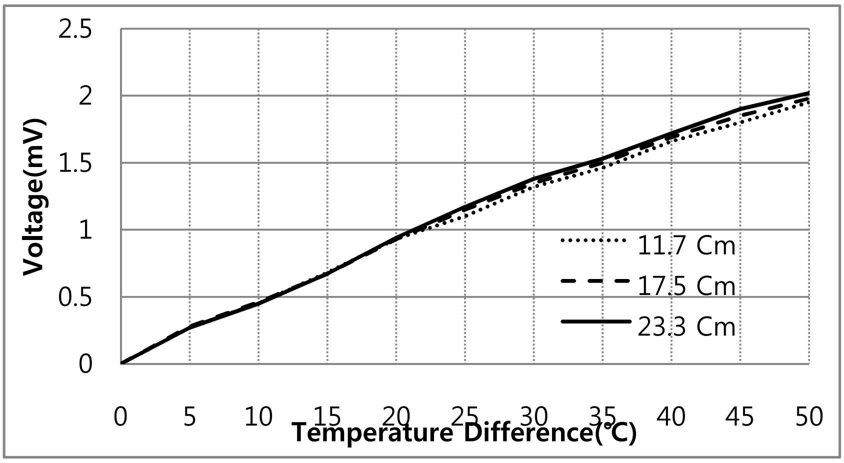

Figure 6: Output Voltages Based on Contacted Locations

The thermocouple based distributed temperature sensor was analyzed experimentally. The sensor was configured using two wires of thermocouple bonded to the two plastic plates with spacers. The output voltage was induced by a temperature gradient only when the pressure was applied to the distributed sensor. The amplitude of the voltage was independent of the pressure-applied location. The sensitivity was 0.04 mV/ °C and the relationship between the temperature difference and induced voltage was approximately linear.

SUMMARY

A thermocouple based distributed temperature sensor was investigated. This sensor consisted of two wires of thermocouple bonded to two plastic plates with spacers. The output voltage of the distributed temperature sensor was induced by a temperature gradient only when the pressure was applied to the distributed sensor. The sensitivity was 0.04 mV/ °C and the relationship between the temperature difference and induced voltage was approximately linear. The research results show that this thermocouple-based distributed sensor can be used to measure the skin temperature of a driver when this sensor is installed on a car steering wheel. Moreover, this sensor can be used as a thermal-switch.

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