# THE STUDY ON SEEBECK EFFECT OF TEXTILE THERMOCOUPLE MANUFACTURED BY EMBROIDERY TECHNIQUE

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## ABSTRACT

Textile thermocouples, designed with conductive yarns by embroidery, was developed for measuring of temperature. Electromotive force (emf) of them was measured in the temperature range between 20°C and 40°C. The emf of embroidered thermocouple linearly was increased and experimentally measured Seebeck coefficient was 21.96μV/°C. It was considered that the embroidered thermocouple might be a candidate of temperature sensors with more setretchable and durable properties than metal embedded textile products.

**Key Words:** Conductive yarns, Seebeck coefficient, Textile sensor, Embroidered thermocouple

## 1. INTRODUCTION

Recently, as the wearable device industry grows up, textile sensors have been studied variously in the field of monitoring human body signals such as pulse rate, respiration rate and body temperature. Until now, most of textile products embedded with semiconductor or metal/carbon based small sensors are known for having some problems such as uncomfortable fit, low stretchability and poor durability.

Many researchers have tried to replace electronic components with textile elements. Seebeck effect of fabric and yarns was evaluated, e.g., making thermocouple using etched and non-etched Nickel-Coated Carbon Fiber [1] and carbon fabric [2]. Benny M., et al. also reported the Seebeck coefficient of 22 types of thermocouples using combinations of five conductive yarns and three metal wires [3]. However, these are shown too hard to integrate onto the textile fabrics due to stiffness. In order to solve these problems, embroidery technique was applied to obtain better stretchability and durability.

## 2. MATERIALS

In our experiment, four conductive yarns with different line resistance were used for measuring Seebeck coefficient. The specifications of conductive yarns were shown in Table 1. Each line resistances data was obtained directly measured with digital multimeter Fluke 175.

**Table 1.** Specifications of conductive yarns

| Item | Company* | Materials | Line resistance (Ω_20cm) | Linear Density | Yarn Type |
|---|---|---|---|---|---|
| Ag1 | Qingdao | Ag-plated PA | $1.05 \times 10^2 \Omega$ | 70D | Filament |

| | | | | | |
|---|---|---|---|---|---|
| Ag2 | Imbut | Ag-coated PA | 2.3x10Ω | 210D | Textured |
| Ag3 | AMANN | Ag-coated PA<br>Co-Twisted with PET | 9.2x10Ω | 81D | Twisted |
| Cu | Beijing | Cu-plated PA | $1.34\text{x}10^{4}\Omega$ | 70D | Filament |

*Qingdao: Qingdao Tianyin Textile Technology Co., .Ltd, AMANN: Amann & Soehne GmnH & Co., Beijing: Beijing Landingji Engineering Tech Co., Ltd.

## 3. EXPERIMENT

### 3.1 Fabrication of embroidery thermocouples

Technical embroidery machine from ZSK Stickmaschinen GmbH (Germany) was used to make embroidered thermocouple using F-head at speed of 250rpm, needle sizes of 65/9Nm and 90/14Nm.

### 3.2 Seebeck coefficient Measurement

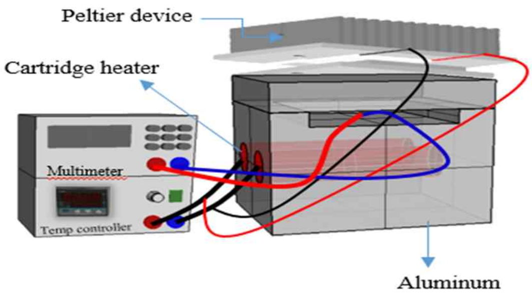


**Fig 1.** Illustration of the emf measurement set- up. * The Junction of embroidered thermocouple was placed on the Teflon-coated aluminum chamber.

The emf of as-made thermocouples were measured with test equipment in **Fig. 1**. The test equipment consisted of keithley 2182A Nanovoltmeter, and thermostat including cartridge heater, RTD sensor, peltier cooling device and a PID type controller. The change of the emf value according to the increase in temperature was measured at an interval of 5°C within a range of 20°C to 40°C under the constant condition of 20°C and relative humidity 50%. Seebeck coefficient was calculated from the slope of the emf curve within the range of temperature.

### 3.3 Durability test

For durability test, the textile thermocouple stayed at 35°C and higher relative humidity environment 70% for 48 hours and measured emf compared to initial one.

### 3.4 Stretchability test

Stretchability of embroidered thermocouple was evaluated under the same experimental conditions. After 100 times of repeated stretchability test with specially designed bending system, the value of Seebeck coefficient compared to initial one.

## 3. RESULT AND DISCUSSION

All four yarns showed linear changes of emf in the measuring range of temperature, and the availability possibility of use as a textile thermometer. The pair of Ag2 and Cu yarns, was selected to be the best combination of thermocouple due to the biggest differences in Seebeck coefficient. End connection with two yarns by knotted or embroidered technique was shown little difference. Fig. 2(a) shows that the longer thermocouple leg length, the higher emf is generated in the case of knotted thermocouple. Fig. 2(b) shows the difference in performance of the thermocouple according to variation of manufacturing method. The Seebeck coefficient of the embroidered one was 21.96μV/°C and difference from knotted thermocouple was only 4%.

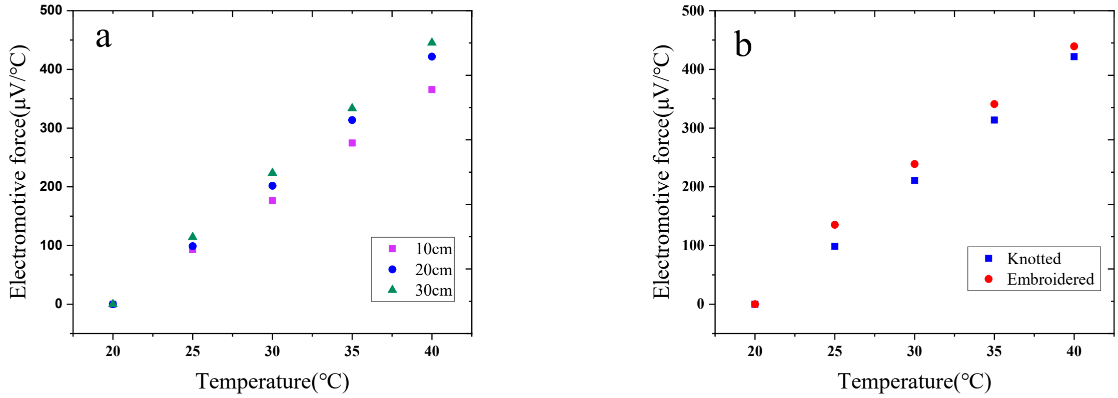


**Fig 2.** Temperature-emf relationships of knotted thermocouple with different leg length 10cm, 20cm and 30cm(a) and manufacturing type of textile thermocouple(b).

## 4. CONCLUSION

In this study, we used four conductive yarns to confirm Seebeck effect of the textile thermocouples made from them. From the experimental results, Seebeck coefficient of the embroidered thermocouple was 21.96μV/°C. It was considered that the embroidered thermocouple might be a candidate of temperature sensors with more setretchable and durable properties than metal embedded textile products.

## 5. REFERENCES

1. Gilbert D. M., Izabela C. W., Carla H., & Lieva V. Seebeck Coefficient of Thermocouples from Nickel-Coated Carbon Fibers: Theory and Experiment, *MDPI. Materials*, 2018, Vol.1, No.6, 922.
2. Veluswamy P., Shota S., Mani N., Masaru S., Kenji M., Yasuhiro H., & Hiroya I. Seebeck Coefficient of Flexible Carbon Fabric for Wearable Thermoelectric Device, *IEICE TRANS. ELECTRON.*, Vol.E101-C, No.5, 343-346
3. Benny M., Gilbert D.M., Lieva V. L, & Carla H. Textile yarn thermocouples for use in fabrics, *Journal of Engineered Fibers and Fabrics*, 2019, Vol.14, 1-7.