Available online at www.sciencedirect.com
SCIENCE DIRECT®

Synthetic Metals 150 (2005) 139–143

SYNTHETIC METALS

www.elsevier.com/locate/synmet

Development of a cooling fabric from conducting polymer coated fibres: Proof of concept

Eric Hu, Akif Kaynak *, Yuncang Li

School of Engineering and Technology, Deakin University, Victoria 3217, Australia

Received 16 December 2004; accepted 28 January 2005
Available online 17 March 2005

Abstract

It is supposed that there should be a thermal electric effect if a dc current is applied across two dissimilar conducting polymers, similar to so called "Peltier effect" in metals or semiconductors. However, this hypothesis has not been tested on conducting polymers and using these materials to make cooling fabrics has never been attempted before. Polypyrrole coated fabrics were used to test the hypothesis in this preliminary study. Seebeck and the Peltier effects were proven to exist. However, thermoelectricity effect between two conducting polymer coated fabric samples was only about 10 μV/°C. Cooling effect by conductive polymer powder was achieved but performance was unsteady due to electrical degradation of the conducting polymer. Nevertheless, the concept was demonstrated and the development of a cooling fabric is possible.

Keywords: Cooling effect; Peltier effect; Conducting polymers; Textiles

1. Introduction

The clothing industry has been involved in research on textile materials that offered greater comfort and functionality. A cooling effect would be one of the most desired attributes of clothing. New fabric technologies have recently introduced garments that provide a cooling effect without relying on external cooling sources. A portable cooling system is often incorporated into a garment and includes a heat transfer medium to absorb heat from the body. Typically, these materials can be grouped into three general categories: granular materials, phase change materials and water-retaining fibre-based materials. These systems can be further classified as circulating or passive [1]. The former includes a fluid circulating through tubes stitched into the garment and upon contact the fluid removes the body heat. This set up requires a power supply, a pump, and a heat sink to absorb the heat from the circulating liquid. The latter use special materials incorporated into the garment to absorb heat from the body through contact and do not require interaction of the wearer. Both of these systems are generally bulky and not suitable for lightweight applications. Moreover, additional weight causes additional metabolic heat generation due to extra work done by the wearer.

Conducting polymers have attracted a great deal of research interest due to wide-ranging modulation of their electrical properties and responsiveness to external stimuli such as temperature and chemicals [2–4]. But chemically or electrochemically synthesized conducting polymer films have poor mechanical properties, which hinder their practical applications. This limitation is overcome by allowing the polymerisation to take place on textile surfaces to produce conductive fabrics with excellent mechanical properties [5–7]. Potential of such fabrics in heating applications have been reported [8–10]. Furthermore, novel fibres that act as a semiconductor (n- or p-type material) [11,12] could be produced by coating the surface of fibres with conducting polymers. Using these conductive fibres, new fabrics could be produced, that will demonstrate the so called "Peltier effect" and

* Corresponding author. Tel.: +61 3 5227 2909; fax: +61 3 5227 2539.
E-mail address: akaynak@deakin.edu.au (A. Kaynak).

0379-6779/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.synthmet.2005.01.018

achieve the cooling effect like the traditional semi-conductor cooler. This paper presents the preliminary investigations on the proposed cooling fabric by working on the Peltier effect.

2. Experimental and results

2.1. The Seebeck effect

In the world of thermoelectric technology, there are three thermoelectric effects, the Seebeck effect, Peltier effect and Thomson effect. The Seebeck effect occurs between junctions of any two members of the thermoelectric series. In the presence of a temperature difference between the junctions a small current flows around the circuit. The Peltier effect occurs whenever electrical current flows through two dissimilar conductors; depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. The Peltier effect is the reverse of the Seebeck effect and a typical junction phenomenon.

Experimentally, it is easier to prove the Seebeck effect than Peltier effect as the applied temperature is controlled in the former and the resulting potential difference is measured. If the Seeback effect exists in the conductive fabric, the Peltier effect should also be observed. So, experiments to prove the existence of the Seeback effect on conductive fabrics were followed by the Peltier effect tests.

In order to prove the existence of Seebeck effect in conducting polymer coated fabrics, a simple experimental bench rig was set up. Two different fabrics (A and B) were connected as shown in Fig. 1. Conductive fabric A was prepared by immersing the textile in an aqueous solution containing 2.4 mg/ml pyrrole and 14 mg/ml Ferric chloride. The reaction was conducted at 4 °C for 4 h. Then, the conductive fabric is rinsed with water and dried at 80 °C for 6 h. Conductive fabric B was prepared by oxidizing the fabric by immersing into a 10 g/l ferric chloride solution followed by exposure to monomer (pyrrole) vapour to obtain a semiconducting coating of polypyrrole on the fabric. A temperature difference is applied to the two junctions of conductive fabrics A and B. The potential difference was measured by a Fluke 189/FVF multimeter.

Table 1
Results showing the existence of Seebeck effect

Sample	ΔT (°C)	ΔV (mV)	R (Ω)
1	55	0.022	5300
2	55	0.058	587

ΔT: the temperature difference between hot and cold side; ΔV: the thermoelectricity produced at ΔT; R: the resistance of fabric.

The low temperature plate (ice water, about 5 °C) was connected to the positive and the high temperature (hot water) to the negative terminal of the voltmeter (Fig. 1). The thermoelectricity was observed and the result is shown in Table 1. If the cold and the hot sides are reversed, thermoelectricity will be negative.

The thermoelectricity was also observed in conductive polymer fabric (part A) in contact with aluminium as part B. The result are shown in Fig. 2 with further data in Table 2.

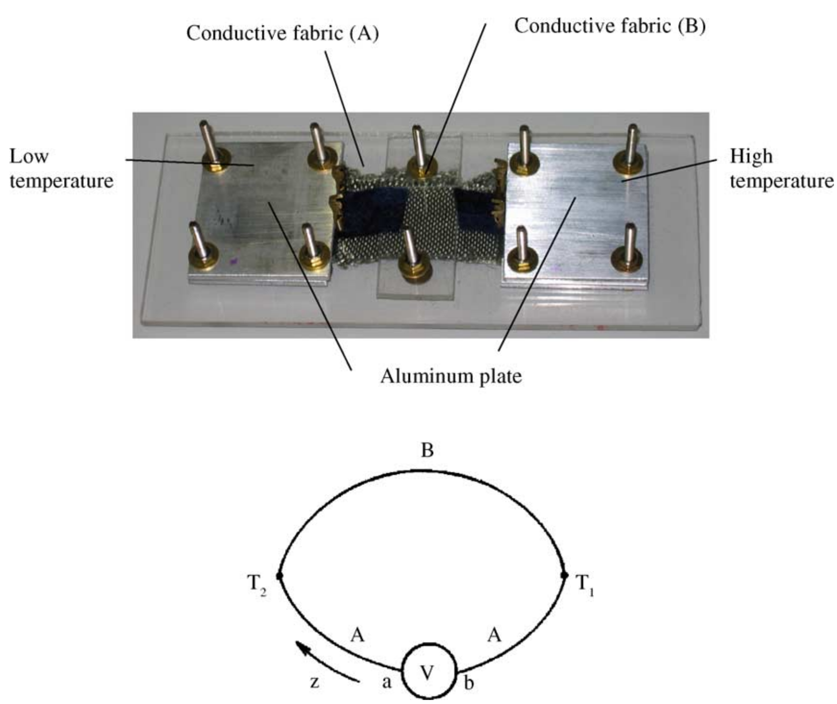

Fig. 1. Experimental set-up for testing Seeback effect.