Journal of Fiber Bioengineering & Informatics 5:2 (2012) 163–168
http://www.jfbi.org | doi:10.3993/jfbi06201205

Thermal Properties of Cotton Fabric Coated with Polypyrrole

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Abstract

Polypyrrole was chemically synthesized by in situ polymerization in the presence of surfactant dopant on cotton denim fabric. Shape and size of the particles are characterized by SEM micrographs. Electrical and thermal conductivity of fabric samples were measured and it was found that electrical conductivity can be increased by increasing the concentration of polypyrrole, but there is no significant relation between electrical and thermal conductivities.

Keywords: Polypyrrole; Cotton Fabric; Thermal Conductivity

1 Introduction

Several works have been devoted to the coating of fibres or fibrous materials with Conducting Electroactive Polymers (CEP). All these works involve a vapour-phase treatment of oxidant-containing carriers with the monomers [1]. Polymers with conjugated π-electron backbones can be oxidized or reduced more easily and are more reversible than conventional polymers. Dopants, which act as charge transfer agents, affect this oxidation or reduction process and render these polymers conductive.

The ultimate goal of electrically conductive polymer research is to combine the process ability of polymers with the electronic properties of metal or semi-conductors [2]. Unfortunately, most of these conductive polymers are intractable and cannot be processed into useful articles. This is particularly true for polypyrrole (PPy) and polyaniline (PANi), which are preferred for their high conductivity and stability under environmental conditions [3, 4].

In the mid-1970s, the first polymer capable of conducting electricity was discovered in a new form of polyacetylene. The announcement of this discovery quickly reverberated around scientific community, and the intensity of the search for others magnified dramatically [5, 6, 7].

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Among the first commercial products incorporating conductive polymers there was Contex, a line of conductive textile products originally manufactured by Milliken [8], starting around 1990, and now produced by Eeonyx Corp., under the trade name of EeonTex^{TM}.

There has been little attention devoted to the determination of the thermal conductivity properties of polypyrrole. Kanazawa et al. [9] reported a thermal conductivity value of 3.77 [$Wm^{-1}\cdot K^{-1}$] for a copolymer of pyrrole and N-methylpyrrole. No information was given regarding the measurement technique or temperature at which the test was made.

For metals the Wiedemann-Franz law states that the ratio of thermal to electrical conductivity is proportional to temperature. The proportionality constant is the Lorenz number and it is a constant for a wide range of metals. This behavior may be explained by applying Fermi Dirac statistics to the "free" electrons in the material [10, 11]. Hence, it can be shown that the ratio of the electronic component of thermal conductivity λ [$Wm^{-1}\cdot K^{-1}$] to electrical conductivity σ [$S\cdot m^{-1}$] is given by Eq. (1).

$$\lambda/\sigma = (\pi^2/3)(k/e)^2T \tag{1}$$

where k is the Boltzmann constant [JK^{-1}], e the charge on an electron [C] and T the absolute temperature [K], the Lorenz number for metals is given by $(\pi^2/3)(k/e)^2$ and is equal to 2.45×10^{-8} [$W\cdot\Omega\cdot K^{-2}$].

In this study PPy was chemically polymerized in different concentrations on cotton denim fabric by surfactant dopant. Cotton fibre surface was characterized by SEM. Volume and surface electrical conductivity of fabric samples was measured together with thermal conductivity.

2 Methodology

Cotton denim fabric was desized and washed thoroughly for complete removal of finishing additives. Construction of the fabric sample is mentioned in Table 1.

Table 1: Description of the fabric sample

Description	
Warp Yarn	Cotton Dyed, Tex 49.25
Weft Yarn	Cotton, Tex 49.0
Weave	Twill 3/1 Z
gram per sq. meter (GSM)	248

2.1 Sample Preparation

PPy was chemically synthesized in different concentrations on cotton denim fabric by in situ polymerization in the presence of surfactant dopant. Five different aqueous emulsions of Pyrrole (Sigma) with concentrations 1% to 5% were prepared by adding Dodecyl benzenesulphonate (DBSA) (Sigma) 0.05 M in each solution.

Five samples of fabric were immersed completely in each emulsion for 5 hours. Each sample was then taken out from emulsion and immersed in 0.1M $FeCl_3$ (Sigma) for further 10 hours in order