NANOTECHNOLOGIES

UTAustin Portugal

N-type thermoelectric fabrics based on vapor grown carbon nanofibers

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Background

Conductive fillers like carbon nanotubes (CNTs) are extensively investigated to fabricate thermoelectric (TE) materials. Nevertheless, most as-produced CNTs have positive Seebeck Coefficients due to oxygen doping (Figure 1). It is for this reason that similar carbon nanostructures like vapor grown carbon nanofibers (VGCNFs) can fill the current lack of simple pathways towards the direct production of n-type TE materials.

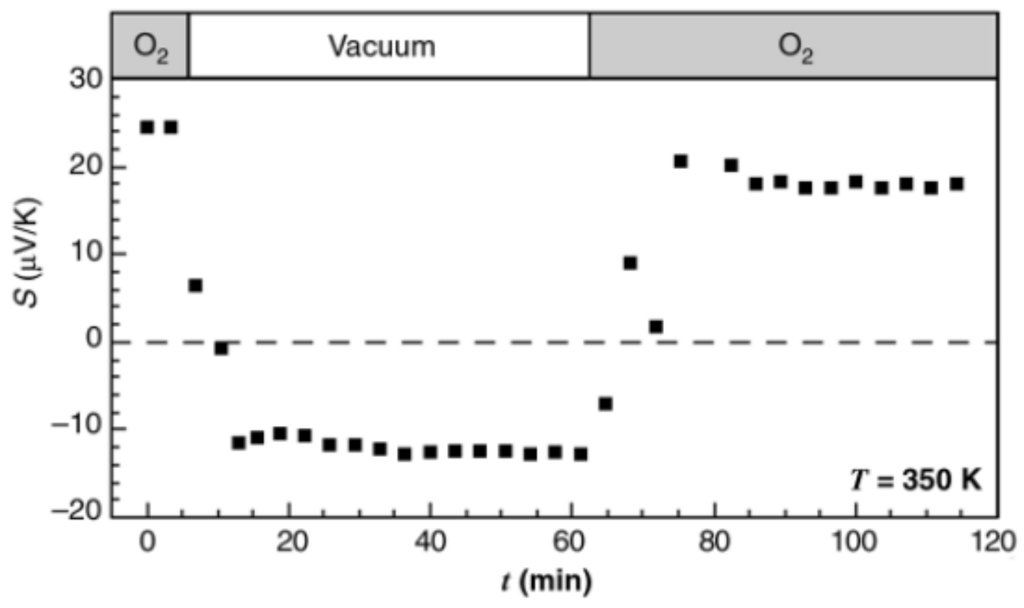
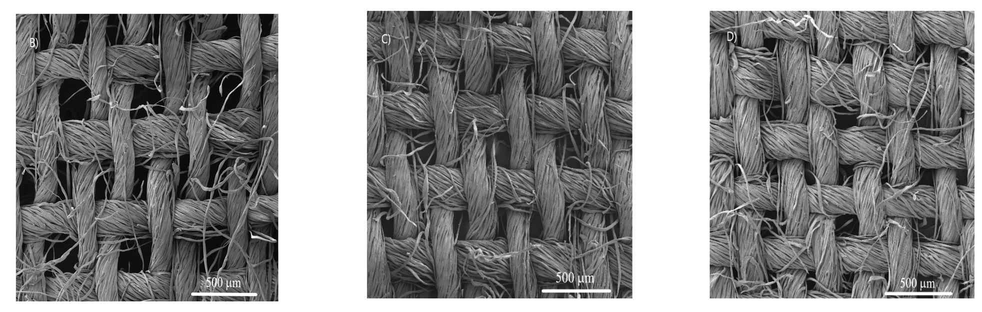
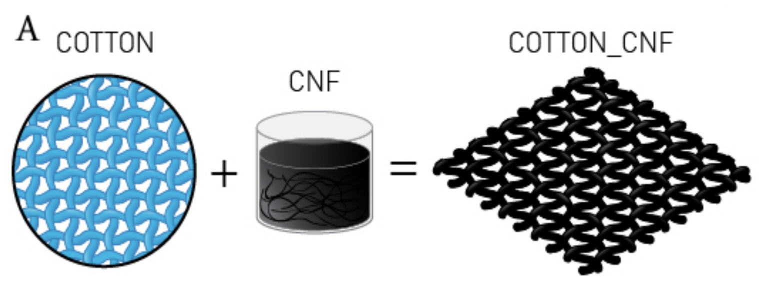


Figure 1. Sensitivity to environmental conditions of thermoelectric power *S* for SWCNTs at *T*=350 K. In vacuum, *S* is *n*-type, whereas in an oxygen environment, *S* is *p*-type, with a larger magnitude. Many previous transport measurements have found that as-prepared nanotubes are strongly *p*-type, with no proper theoretical explanation given. [A. Zettl, Science 287 (5459) 2000]

Methodology

Aqueous dispersions of commercial VGCNFs, *pyrograf III PR 24 LHT XT,* purchased from *Applied Science, Inc. (Cedarville, OH, USA)*, grown by chemical vapor deposition (CVD) at 1100 ºC, and then heat-treated at 1500 ºC, were used for coating common cotton woven fabrics with different linear densities by a simple dipping-drying process (Figure 2A). The main aim was to analyze their electrical conductivity (σ), and thermoelectric power (TEP) or Seebeck coefficient (α).



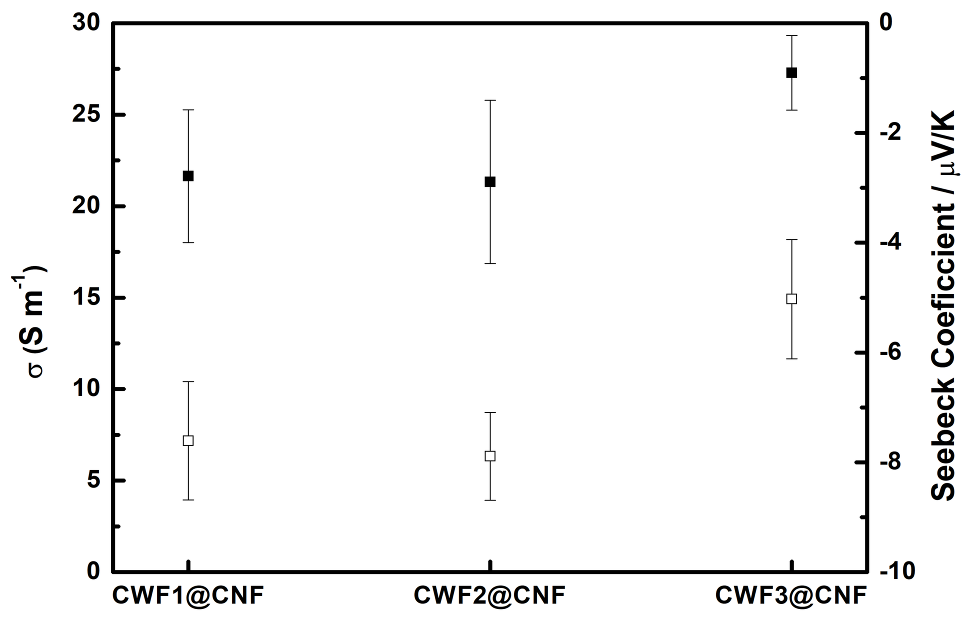


Sample Name	Cotton Fabric Linear Density (Tex)	VGCNF Type	VGCNF aqueous dispersion	
CWF1@CNF	14.9 x 20.2	PR 24LHT XT	5 mg/ml SDBS	3.2 mg/ml VGCNF
CWF2@CNF	16.3 x 19.1			
CWF3@CNF	16.7 x 19.7			

Figure 2. (A) Dip-coating processing. (B, C, D) SEM images of pristine cotton woven fabrics CWF1, CWF2 and CWF3 with different linear densities. (Table) Dip-coated fabric sample type.

Results

The dip-coated fabrics show that the morphology of the coated CNF layer depends strongly on the type of cotton fabric used (Figures 3A, 3B, 3C). Samples CWF1@CNF and CWF2@CNF showed values of *σ*, and α around 21 S m^{-1} and -8 μV K^{-1}, whereas samples CWF3@CNF achieved a slightly higher σ of 27 S m^{-1}, and the lowest α of -5 μV K^{-1}, related with the different morphology of their coated CNF layer observed in SEM micrographs (Figure 3C).



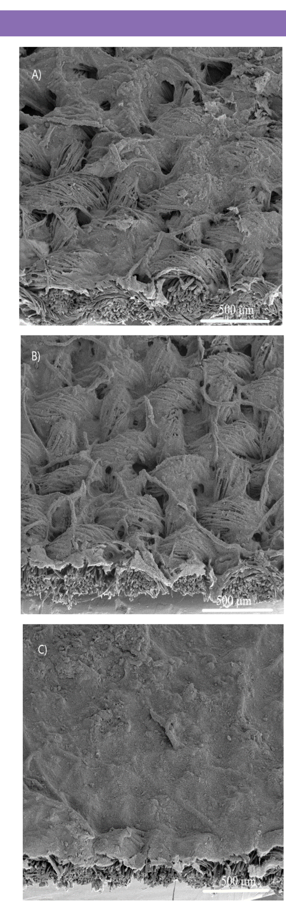


Figure 3. (A, B, C) SEM images of dip-coated fabrics CWF1, CWF2 and CWF3. In-plane electrical conductivity (solid symbols), and negative TEP (open symbols) of dip-coated fabrics at room temperature.

Impact/Conclusions

The negative thermoelectric power of this type of VGCNFs, produced by CVD at 1100 °C, with a post heat treatment of 1500 °C, means that the majority of their charge carriers are electrons, in contrast with most as-produced CNT that show positive α due to their immediate oxygen doping after synthesis. We attribute this negative α to the double wall structure surrounding the hollow tube of the VGCNF. The n-type contribution caused by the highly graphitic character of the inner shells must counteract the lower p-type contribution caused by the highly disordered and thinner outer shell, and as consequence the sum of both contributions are negative at the end [1]. The results show that commercial and as-received VGCNFs can be used for fabricating n-type TE flexible fabrics by common and simple methodologies, without requiring deoxygenation pre-treatments and/or further specific additives during their processing.

[1] A.J. Paleo, E.M.F. Vieira, K. Wan, O. Bondarchuk, M.F. Cerqueira, L.M. Goncalves, E. Bilotti, P. Alpuim, A.M. Rocha, Carbon, 150, 408-416 (2019).

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FCT Fundação para a Ciência e a Tecnologia
TEXAS The University of Texas at Austin
2C2T Centro de Ciência e Tecnologia Têxtil
UMINHO CMEMS Center for Microelectromechanical Systems
INL International Iberian Nanotechnology Laboratory
SEMS
Queen Mary University of London