N-type thermoelectric fabrics based on vapor grown carbon nanofibers

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 (VGCFNs) can fill the current lack of simple pathways towards the direct production of n-type TE materials.

Methodology
Aqueous dispersions of commercial VGCFNs, pyrograf III PR 24 LHT XT, purchased from Applied Science, Inc. (Cedarville, OH, USA), grown by chemical vapor deposition (CVD) at 1100 °C, and then heat-treated at 1500 °C, 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).

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).

Impact/Conclusions
The negative thermoelectric power of this type of VGCFNs, 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 VGCFN. 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 VGCFNs 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.