Boosting Thermoelectric Power Factor of Carbon Nanotube Networks with Excluded Volume by Co-embedded Microparticles

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Abstract

This study aims to enhance the thermoelectric performance of carbon nanotube (CNT)-polymer composites by incorporating silica microparticles to create an excluded volume. The power factor of CNT networks, which has been limited by inefficient tunneling transport and low conducting channel density, is the focus of improvement. Single-walled CNTs, silica microparticles, and polydimethylsiloxane (PDMS) are the main materials used. Experimental methods involve synthesizing CNT-PDMS composites with varying silica content, characterizing them using scanning electron microscopy and Raman spectroscopy, and measuring electrical conductivity, Seebeck coefficient, and thermal conductivity. The power factor, determined by the electrical conductivity and Seebeck coefficient, serves as the evaluation metric. Results demonstrate a significant power factor enhancement of over six fold by incorporating silica microparticles. The excluded volume effect induced improved connectivity and alignment of CNTs, enhancing tunneling transport and increasing the geometric factor. Sample compression further boosts the power factor by over two fold through improved CNT alignment. Mechanical bending tests reveal excellent mechanical stability of the CNT-PDMS composite, rendering it promising for wearable thermoelectric devices. Thermal conductivity remains relatively flat with increasing silica content, primarily due to the dominance of phononic contribution over electronic contribution. In conclusion, this research successfully demonstrates the efficacy of silica microparticles in enhancing the power factor of CNT-PDMS composites. The simultaneous increase in electrical conductivity and Seebeck coefficient, along with exceptional mechanical stability, makes these composites suitable for thermoelectric energy conversion. Future optimization efforts should focus on improving the overall figure of merit.

Biography of Presenter

Dr. Je-Hyeong Bahk is an assistant professor jointly at the Dept. of Mechanical and Materials Engineering and the Dept. of Electrical Engineering and Computer Science, University of Cincinnati (UC), OH. Dr. Bahk is currently the director of the thermoelectric energy conversion lab (https://sites.google.com/site/jhbahk) at UC. Before joining UC, he was a postdoctoral research associate at the Birck Nanotechnology Center, Purdue University, IN. Dr. Bahk has participated in numerous research projects on design and fabrication of efficient nanotechnology-based thermoelectric materials and devices since his Ph.D study at University of California, Santa Barbara. He also developed several online simulation tools at nanoHUB.org for thermoelectric devices and materials simulation. (https://sites.google.com/site/jhbahk/simulation-tools)