Proceedings of the 8th World Congress on Recent Advances in Nanotechnology (RAN'23)
Lisbon, Portugal – March 23 – 25, 2023
Paper No. ICNNFC 158
DOI: 10.11159/icnnfc23.158

Fabrication and Characterization of Encapsulated CNT-Sb_2Te_3 Thermoelectrical Hybrid Structures

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Extended Abstract

Thermoelectrics (TE) is a perspective approach to improve the energy efficiency of different processes by waste heat capturing and conversion to useful energy. A device that produces usable electrical power from the temperature difference is called a thermoelectric generator (TEG). Generally, TEGs are composed of p-type and n-type semiconductor pairs to provide more charge carriers and lower travel paths for the same input energy. Nowadays, most of the commercially available TEGs have rigid rectangular shapes, which significantly limit the range of their potential applications. For example, waste heat capturing from curved heated surfaces, as well as the development of self-powered wearable electronics operating at the temperature difference between the human body and the surrounding environment [1]. Such applications require the development of efficient flexible TE materials.

Common approach for the development of such materials is joining together a polymer matrix and inorganic micro- or nanostructured TE filler. Conventional flexible TE nanocomposites are based on electrically conductive polymers mixed with different thermoelectric fillers, in particular, carbon nanotubes (CNTs) or nanostructured inorganic materials known as the best for near-room temperature TE applications – bismuth and antimony chalcogenides (Bi_2Se_3, Bi_2Te_3, Sb_2Te_3). However, a significant drawback of conductive polymer-based TE nanocomposites is poor stability of the polymer matrix in air, as well as its toxicity and relatively high cost.

Widely available non-toxic, nonconductive polymers as, for example, polyvinyl alcohol (PVA) and polydimethylsiloxane (PDMS or silicone) may become a green alternative to the conductive polymer matrices [2]. However, for the development of an effective TE nanocomposite based on non-conductive polymer, advanced TE fillers are required to establish an effective network throughout the polymer matrix. Previously, it has been shown that direct deposition of bismuth or antimony chalcogenides on pre-fabricated CNT scaffolds results in a formation of flexible n-type CNT-Bi_2Se_3 or p-type CNT-Sb_2Te_3 hybrid networks, exhibiting Seebeck coefficients comparable with the values reported for bulk Bi_2Se_3 or Sb_2Te_3 [3]. Recently, an approach of the application of CNT-Bi_2Se_3 and CNT-Sb_2Te_3 hybrid networks for the fabrication of n-type and p-type PVA-based TE composites and the development of flexible TEG has been demonstrated [4]. However, the thermoelectric efficiency of these composites was low due to the high resistance of the nanocomposites. Later, it was found that the encapsulation of CNT-Bi_2Se_3 hybrid networks in PVA instead of mixing with it results in much higher TE efficiency due to the preservation of interconnections between the CNTs and Bi_2Se_3, established during the synthesis of CNT-Bi_2Se_3 hybrid networks [5].

In this work, the encapsulation approach is used for the fabrication of p-type flexible TE composites based on CNT-Sb_2Te_3 hybrid networks. Sb_2Te_3 was synthesized on pre-deposited onto glass substrates p-type MWCNT networks via a catalyst-free vapour-solid deposition technique [5]. The obtained hybrid networks were encapsulated in PDMS polymer matrices and lifted off the glass substrates. Structural and morphological analysis of the hybrid networks was performed using electron microscopy and energy dispersive X-ray methods. Thermoelectrical performance of the CNT-Sb_2Te_3 hybrid networks before and after encapsulation were measured under ambient conditions by a laboratory-made setup. The PDMS-encapsulated CNT-Sb2Te3 hybrid networks were found suitable for the further development of flexible TEGs.

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