Polymer-SWCNT composites for recovering waste heat into electrical energy

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Singlewalled carbon nanotubes (SWCNTs), consisting of rolled graphene sheets with fullerene end caps, are not only used to incorporate the function of electrical conductivity into insulation polymers but also to create thermoelectric materials which are able to recover waste heat into electric energy. The thermoelectric (TE) effect (also called Seebeck effect) is evidenced as an electrical potential (voltage ΔU) induced by a temperature difference (ΔT) between the two sides of a material. High Seebeck coefficient, high electrical conductivity and low thermal conductivity are favourable for a high TE efficiency of a material. The advantages of polymer based thermoelectric materials are not only their cost efficiency, but also the ease of processing, flexibility, low density, and intrinsic low thermal conductivity.

SWCNTs of the type TUBALL™ from OCSiAl were employed to construct an electrical conducting network in a polypropylene (PP) matrix by melt processing in a twin-screw compounder. For these SWCNTs a very low electrical percolation threshold of ~ 0.1 wt% was found [1]. The effect of SWCNT content on electrical conductivity and Seebeck coefficient (S) was studied. In addition, the addition of copper oxide (CuO) powder, a nontoxic compound with high S value, together with CNTs was shown to enhance the S of the composites [2]. Furthermore, the addition of an ionic liquid (IL) as processing additive during mixing improved the electrical conductivity of the composites and simultaneously increased S [3]. The maximum S value reached was 63.8 μV/K, resulting in a power factor of 0.26 $\mu W/(m \cdot K^2)$.

With the aim to demonstrate the applicability of melt mixing to fabricate thermoelectric generator (TEG), an easy and cheap route to switch p-type into n-type composites was developed since for an TEG both types are needed. At the investigated SWCNT concentrations (0.8 wt% and 2 wt%) and a fixed CuO content of 5 wt%, the polyethylene glycol (PEG) addition converted p-type composites (positive S value) into n-type (negative S). To construct the demonstrator, two composites were selected: p-type PP/SWCNT composite (with S up to 45 μV/K), and n-type composite (with S up to -56 μV/K) using PEG. The two prototypes with 4 and 49 thermocouples of these p- and n-type composites delivered output voltages of 21 mV and 110 mV, respectively, at a temperature gradient of 70 K (Fig. 1).

References

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Figures

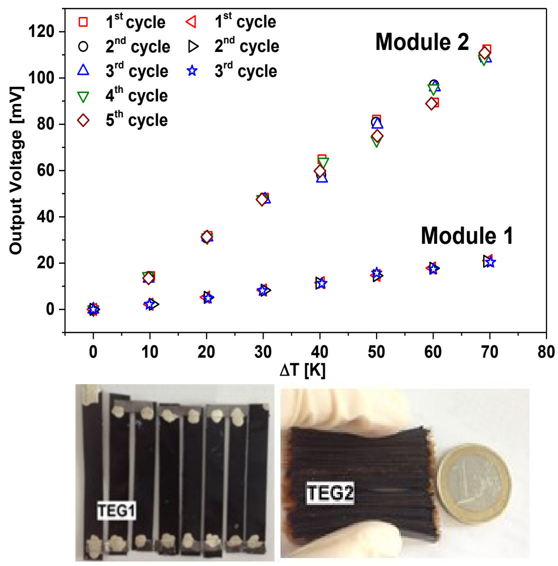

Figure 1. Thermo-electric output voltage versus ΔT for two prototype thermoelectric generators (TEG1 and TEG2) [4]