Optimization of Flexible Thermoelectric Materials using Multi-Walled Carbon Nanotubes

Miguel A. S. Almeida¹, Ana L. Pires¹, and André M. Pereira¹

¹IFIMUP- Institute of Physics for Advanced Materials, Nanotechnology and Photonics, Departamento de Física e Astronomia da Faculdade de Ciências da Universidade do Porto, Rua Campo Alegre, 687, 4169-007 Porto, Portugal

up201706001@edu.fc.up.pt

Introduction

Society’s dependence on energy is increasing considerably, raising the need to capture sustainable energy. Thermoelectric generators (TEGs) are devices based on the Seebeck effect and have the ability to convert waste heat into electrical power for powering devices, for instance in remote locations. These devices are characterized by the figure-of-merit, $ZT = \frac{\alpha^2 T}{k}$, or by the power factor, $PF = \sigma S^2$ ($\sigma$, electrical conductivity; $k$, thermal conductivity; $S$, Seebeck coefficient) [1]. Flexible TEGs are usually made by using simple printing methods and printable inks. These inks are a mixture of inorganic material and organic material, composed by microparticles of thermoelectric material, and the organic material polymer to give the desire flexibility depending on the final application [2]. One of the techniques used to increase the performance of these devices is the mixture of nanoparticles with the microparticles of the TE material. In the presented work we used multi walled carbon nanotubes (MWCNTs) due to their poor thermal conductivity, high electrical conductivity and filtering effect.

Preparation method

- Bi$_2$Te$_3$ powder
- MWCNT powder
- Polyvinyl alcohol (PVA)
- Bi$_2$Te$_3$ + MWCNT Film
- Bi$_2$Te$_3$ + MWCNT pellet
- Stencil printing technique

Characterization methods

The TE material can be characterized by its own ZT or PF, which indicates the efficiency of material on the conversion of thermal energy in electrical energy. In this study, it was used the PF to compare the different compositions of TE material. To determine the PF value was used a homemade setup to measure the Seebeck coefficient, a four-point probe measurement to the resistivity and an indicator to the film’s thickness.

Experimental results

- Electrical conductivity
- Seebeck coefficient
- Power Factor

Experimental results

Five samples were pressed before being printed on the PET substrate. In order to understand the influence of pressing on the final results, an unpressed sample was developed, where it was found that a better results were obtained.

Conclusions

- Computer simulations in COMSOL Multiphysics show that it is possible to maintain the Seebeck coefficient of the TE material if contact between the grains is present, even when applying to a matrix with poor properties.
- Experimental results show a decrease in TE properties with the application of MWCNT, however, the unpressed sample has better properties than the others. These results indicate a possible agglomeration of the MWCNTs and an increase in the distance between Bi$_2$Te$_3$ grains, a phenomenon that must be avoided.
- Future work
  - In order to verify the filtering effect and improve results, dispersion techniques such as ultrasonicator should be used.
  - Composites/Mixture of TE powders unveil to be simple method and with high potential be applied to a thermoelectric device.

References:
[1] Freer, Robert et al. Journal of Materials Chemistry C 8 (2020);

Acknowledgements:
This work was financially supported by Fundação para a Ciência e a Tecnologia (FCT)/MEC and FEDER under Program PT2020 through the project NORTE-01-0145-FEDER-022096 from FEDER, and funding through the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No. 863307 (Ref. H2020-FETOPEN-2018-2019-2020-01).