Thermoelectric Generators With Double Cooling And Novel Thermoelectric Materials

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INTRODUCTION:

Recent developments (1) in thermal metamaterial that enhance the response of thermoelectric generators (TEG) have revived the interest in TEG research. Comsol Multiphysics offers the unique opportunity to model TEGs with various cooling systems (air, water, etc) and developing practical prototypes for commercial use. Our project models the Seebeck and Thomson effects for a TEG with a dual cooling system (forced air and circulating water)and heat sink for a variety of common and novel thermoelectric materials that display high thermoelectric properties at various temperatures. Experimental data has been acquired under different hot face temperature values and cooling conditions. Depending on the load, currents as high as 1.0 A can be sustained by a 5.6cmx5.6cm Bismuth Telluride commercial TEG (tegpro.com) with a dual water and air cooling system and a maximum temperature of 300 degrees C on the hot face. The Comsol model was developed based on the examples included in Comsol database of applications. Other configurations are being studied such as the replacement of Cu as the contact material with novel high conductivity materials. Two under-graduate students participated in this study. Both students value Comsol as an important asset to their successful internship applications and plan on developing more projects in Comsol. For temperatures below 550K, nanostructured BiSbTe shows the best thermoelectric performance of the group tested.

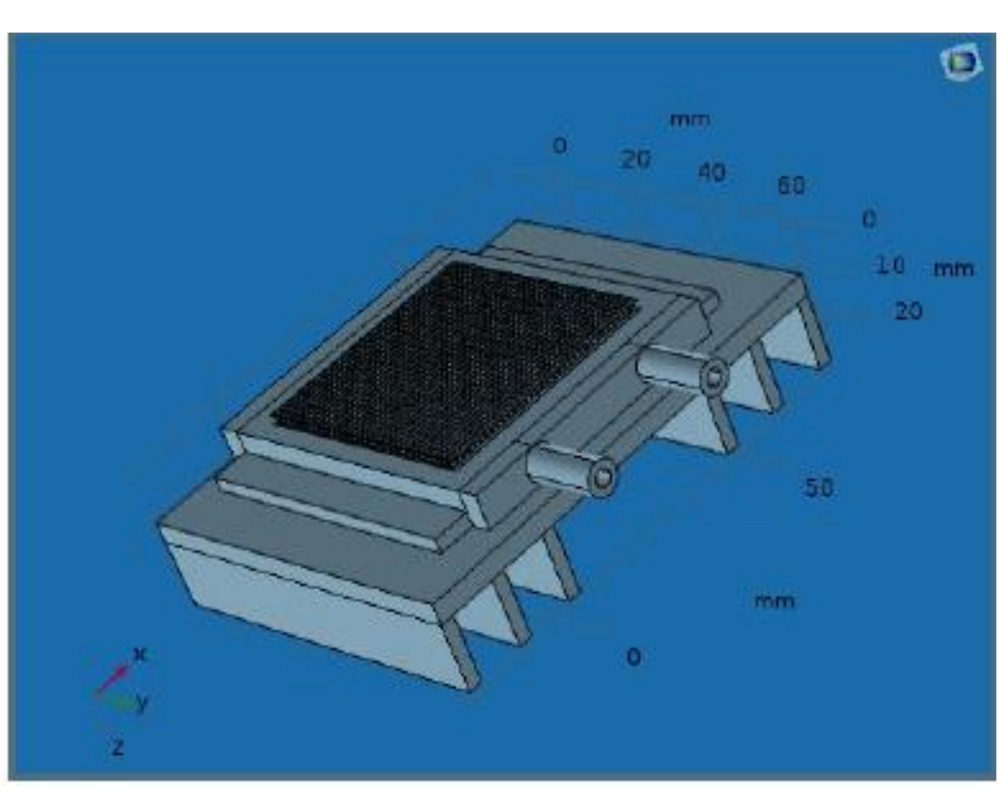

Fig. 1: Thermoelectric generator with dual cooling system (air and circulating water) and a heatsink

COMPUTATIONAL METHODS:

The stationary study model used Heat Transfer in Solids coupled with Laminar Flow. It is based on the models offered by Comsol Multiphysics in the applications database. It solves for electric potentials and temperature distribution for a variety of temperature values and thermoelectric materials using custom meshing and linear discretization.

RESULTS:

The first data set obtained is the electric potential generated as a function of the hot surface temperature for four thermo-electric materials, Bi_2Te_3, PbTe, Spark Plasma Sintered SPS Cu_2Te and nanostructured BiSbTe. The test model is composed of just a set of three semiconductor pairs connected in series, with no external cooling. The cold

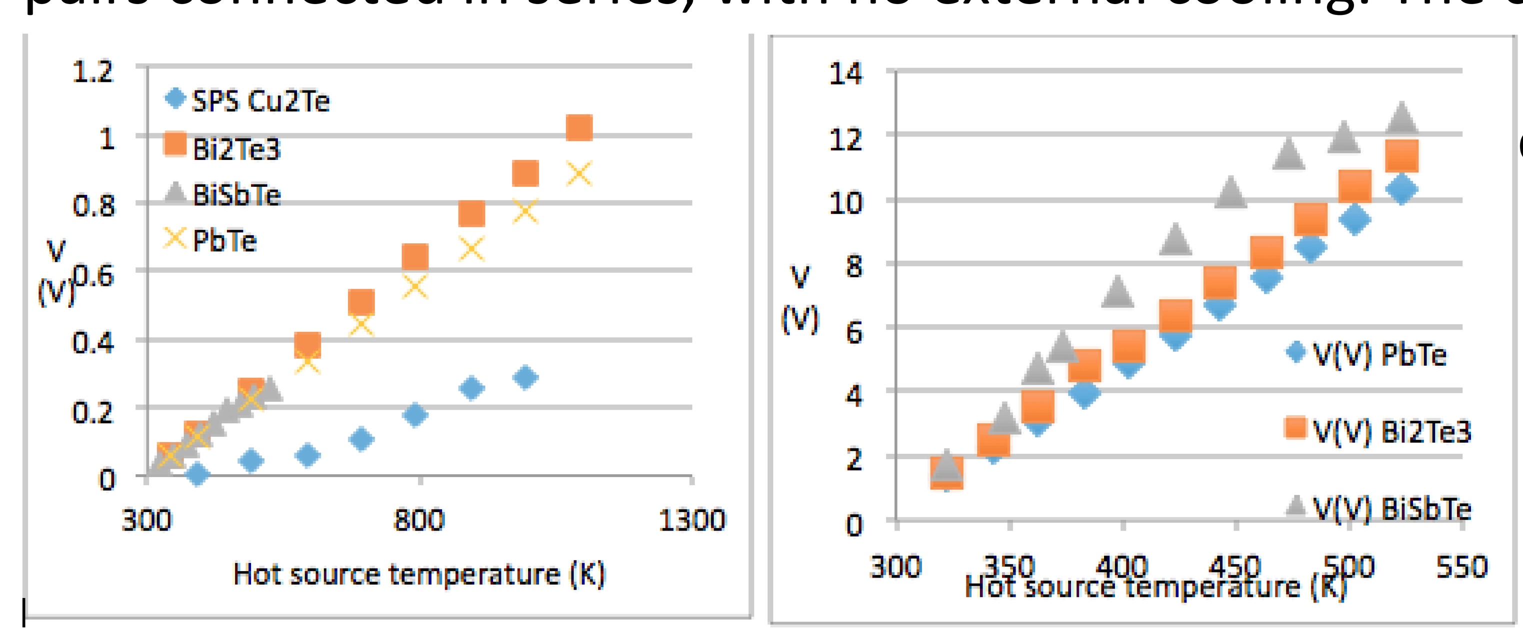

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Fig. 2a left Comparison of thermoelectric performance in the absence of cooling.

Fig. 2b right Comparison of thermoelectric performance in the absence of cooling.

Fig. 2a (left) shows that below 550K the thermoelectric performance of BiSbTe is slightly lower than Bi2Te3 in the absence of cooling. However, in Fig. 2b (right) we see that when cooling is added, BiSbTe generates an electric potential up to 23% higher than Bi2Te3. The overall performance of SPS Cu2Te well below the three materials in Fig.2a. More testing needs to be done on Cu2Te as the physical constant values at various temperatures become available. All models developed are currently being integrated in the various courses of the Engineering Physics curriculum.

CONCLUSIONS: Comsol Multiphysics played a significant role in spurring interest and ideas for an undergraduate materials science laboratory that combines fabrication, characterization and modeling. Nanostructured BiSbTe proves to be a superior novel thermoelectric under complete cooling conditions. The computer simulations demanded material properties research which in turn spurred fabrication and characterization ideas for the new materials science laboratory at Ramapo College.

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