Thermoelectric Generators With Air/water Cooling And Novel Metamaterial Components

D. Buna, D. Tafone, L. Hohxa
School of Theoretical and Applied Science, Ramapo College of NJ, United States

INTRODUCTION The work presented here is a model of a thermoelectric generator (TEG) with water and heat sink cooling. We compare the common Bismuth Telluride and Lead telluride with Spark Plasma Sintered Cu_2Te and nanostructured BiSbTe. The work is part of the development of an undergraduate laboratory for materials science.

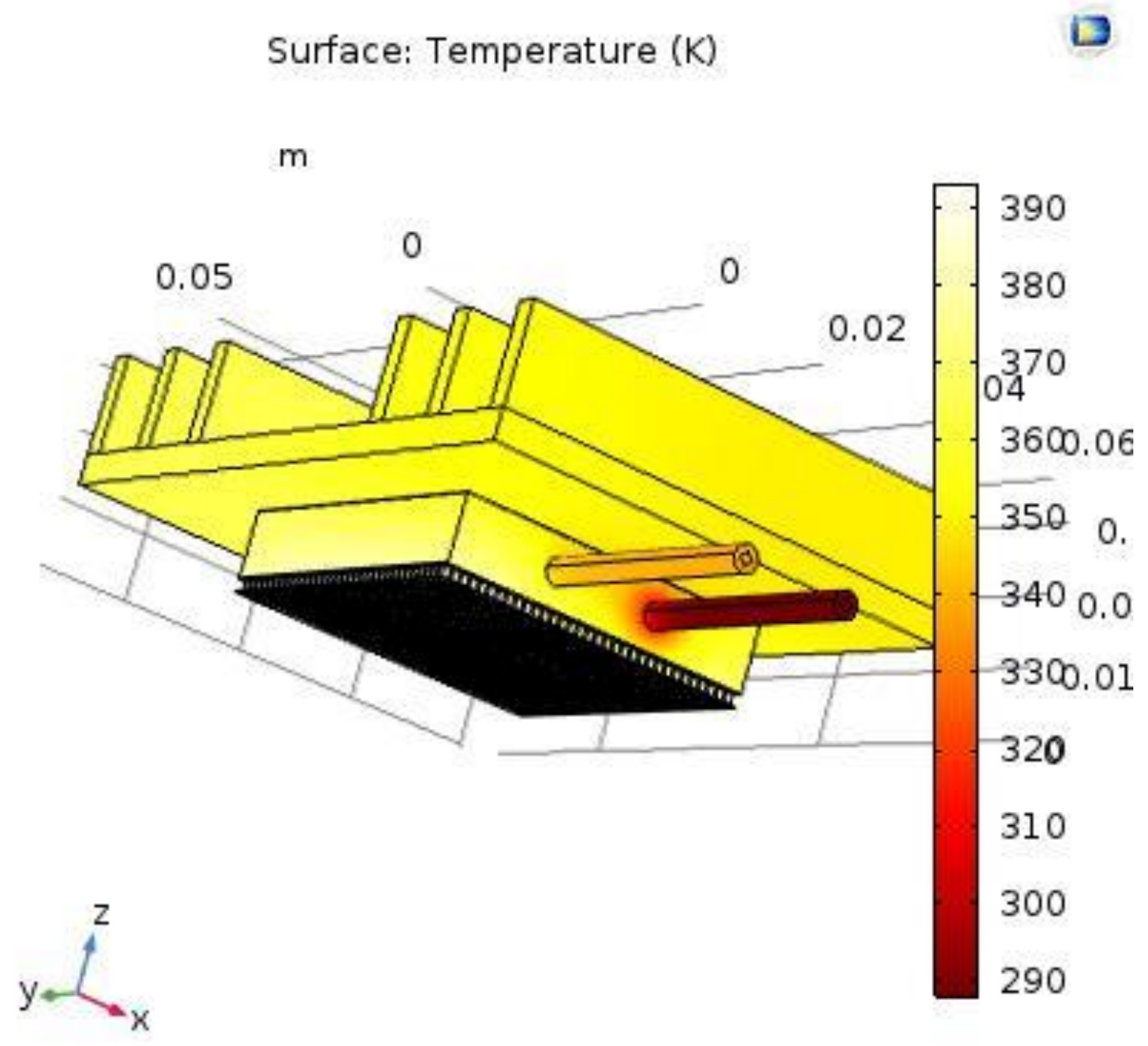

Figure 1 TEG with water cooling and heat sink

COMPUTATIONAL METHODS: The Heat transfer module and laminar flow interfaces were used. The model was solved in stationary state in two distinct set-ups. In the first setup the TEG only model had the cold face maintained at 20^0C and a parametric sweep over temperature as well as a material sweep was performed. In the second set-up, a water cooler and a heat sink were added. The cooling water inlet is maintained at 17^0C.

MODEL:

The TEG model consists of an array of pairs of 1x1x1.5mm thermoelectric rectangular legs connected in series. The legs are connected via rectangular block electrical contacts (aluminum or copper) and the entire system is sandwiched between two thin rectangular sheets (alumina or graphite sheets). The empty spaces are air-filled and the whole TEG is insulated with a thin layer of silicone. The TEG is cooled via a rectangular water cooler with a cylindrical inlet and outlet placed on the cold face as well as a heatsink placed on top of the water cooler. Four different thermoelectric materials were tested: Spark Plasma Sintered Cu_2Te, nanostructured BiSbTe, Bi_2Te_3 and PbTe. Their physical constants and fabrication methods were researched in literature. Each set of constants used in the simulation was measured at the hot temperature value used in the model.

RESULTS

The electrical conductivity sigma, thermal conductivity K and Seebeck coefficient of the materials tested are below:

T(K)	sigma(10^{+5}S/m)	K(W/mK)	S(10^{-6}V/K)
298.15	1.25	1.13	185
323.15	1.1	1.08	195
348.15	0.95	1	205
373.15	0.88	0.95	210
398.15	0.75	0.955	213
423.15	0.65	1	216
448.15	0.6	1.07	220
473.15	0.57	1.1	215
498.15	0.53	1.2	210
523.15	0.5	1.27	205

Table 1 Physical constants for nanostructured BiSbTe

T(K)	sigma(10^{+5}S/m)	K(W/mK)	S(10^{-6}V/K)
300	4	2	25
400	3.6	1.9	30
500	2.3	1.65	35
600	1.5	1.25	38
700	1.6	1.75	50
800	1.5	1.54	65
900	1.45	1.9	80
1000	1.4	1.7	90

Table 2 Physical constants for SPS Cu2Te

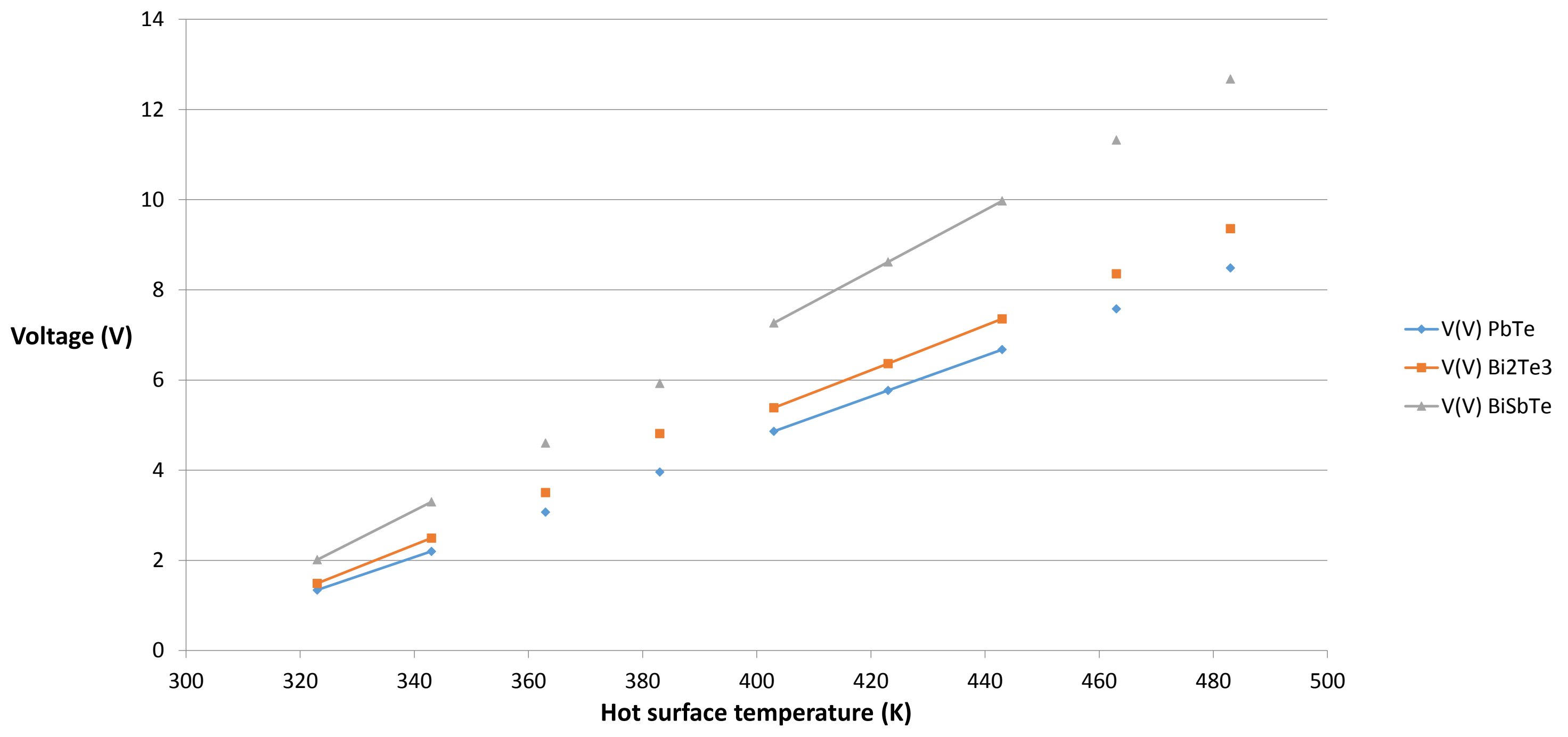

Figure 2 Electric potential for a double-cooled 32x32 array of thermoelectric materials in vacuum

CONCLUSIONS: Nanostructured BiSbTe performs the best of the materials tested with and without insulation and no external cooling. More results need to be collected with double cooling as the model is modified to handle experimental cooling data.

REFERENCES:

Bed Poudel ad et al, High-Thermoelectric Performance of Nanostructured Bismuth Antimony Telluride Bulk Alloys, *Science*, **Vol 320**, 634-638 (2008)
Ying He ad et al, High thermoelectric performance in copper telluride, *NPG Asia Materials*, **Vol 7**, 1-7 (2015)
Comsol Multiphysics applications database.