Design of a low power wearable thermoelectric generator

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Problem Statement

A possible solution to the low battery life problem is a self-powered system that can harvest energy from some non-depleting source and convert it into power. The human body too is a source of energy. The temperature differential between the body and its surroundings may be utilized to generate power using thermoelectricity principles and use it to power electronic medical implants such as heart pacemakers and other similar medical and communication devices.

Abstract

This project simulates a wearable thermoelectric generator to power medical implants by harvesting heat from the human body. A simple model and COMSOL simulations were used to design and validate a single-couple prototype using Bismuth Telluride and copper. Subsequently, a multi-couple model with 154 couples was developed, achieving a power output of 1.4 mW, sufficient to power most medical implants that use batteries. This offers a long-lasting and sustainable alternative to traditional battery-powered implants.

Model

A multiphysics model for a unit couple is developed and is shown in Figure 1. The unit couple TEG module consists of a P-type and a N-type Bismuth Telluride leg having a cross-sectional area of 0.6 mm x 0.6 mm and a leg height of 1.38 mm. The connection Coppers plate of the top surface palate has a cross-sectional area of 1.6 mm x 0.6 mm and a height of 0.3 mm and the two bottom plates have cross-section area 0.8 and 0.6 with height 0.3. The TEG legs are connected electrically in series and thermally in parallel. The top planar surface is defined as the TEG cold side at 298 K and the bottom is defined as the hot side at 310 K. One end of the TEG is defined as terminal and the other as ground. Connection between the two legs is made through copper. The flow of heat from the hot side to the cold side via the semi-conductors P-N blocks represents the thermoelectric generator (TEG). A multi-couple model is constructed by connecting 154 unit couples in series. The dimensions of the entire module are 22.6 mm x 13.6 mm x 2.03 mm and is shown in Figure 2.

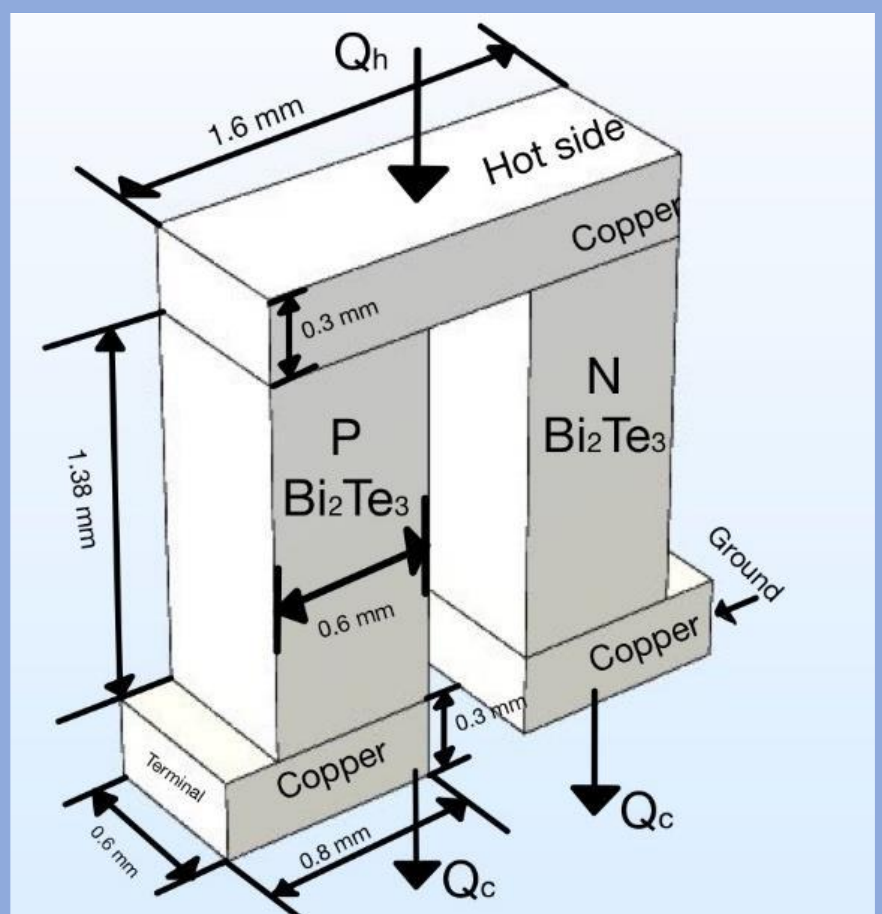

Figure 1: Schematic of unit couple

Table 1 Power requirements of common implantable medical devices [2]

Implanted Device.	Applications	Typical Power Requirement
Cardiac pacemaker	Conduction disorders	30–100 μW
Cardiac defibrillator	Ventricular tachycardia	30–100 μW (Idle)
Neurological stimulator	Essential tremor	30 μW to several mW
Drug pump	Spasticity	100 μW–2 mW
Cochlear implant	Auditory assistance	Up to 10 mW
Glucose monitor	Diabetes care	>10 μW

Simulation Results

Results for the multi-couple thermoelectric generator from COMSOL simulations for voltage, current and power are presented in Table 2.

Table 2 COMSOL results for the multi-couple model

Voltage (V)	Current (A)	Power (W)
0.13795	0.010144	0.001399365

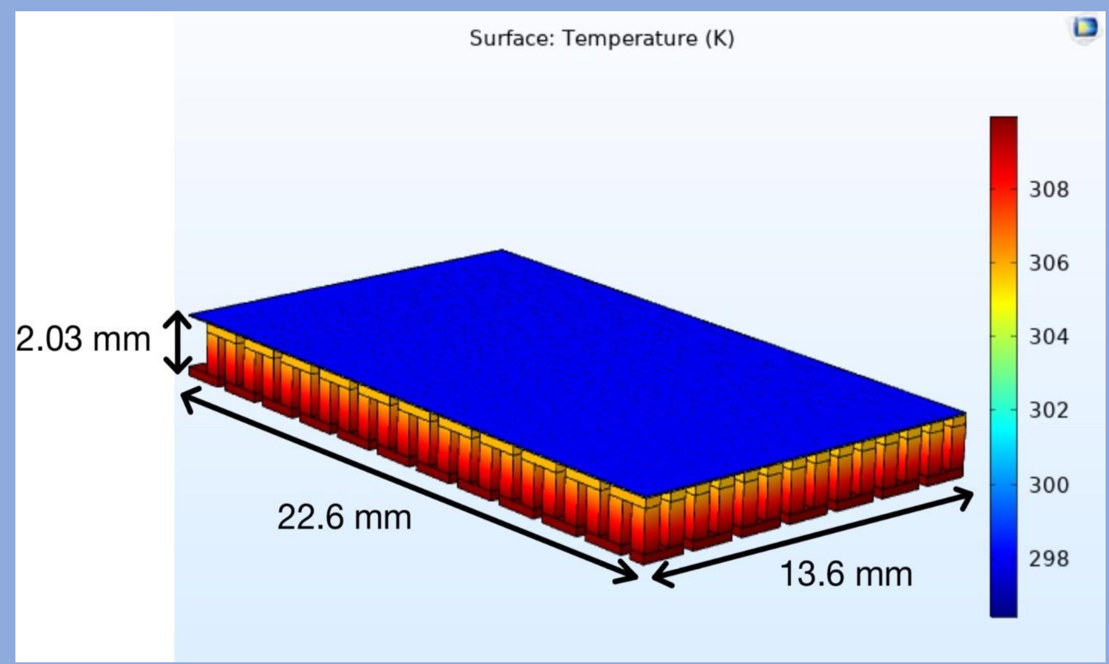

Figure 2 Multi-couple TEG temperature distribution

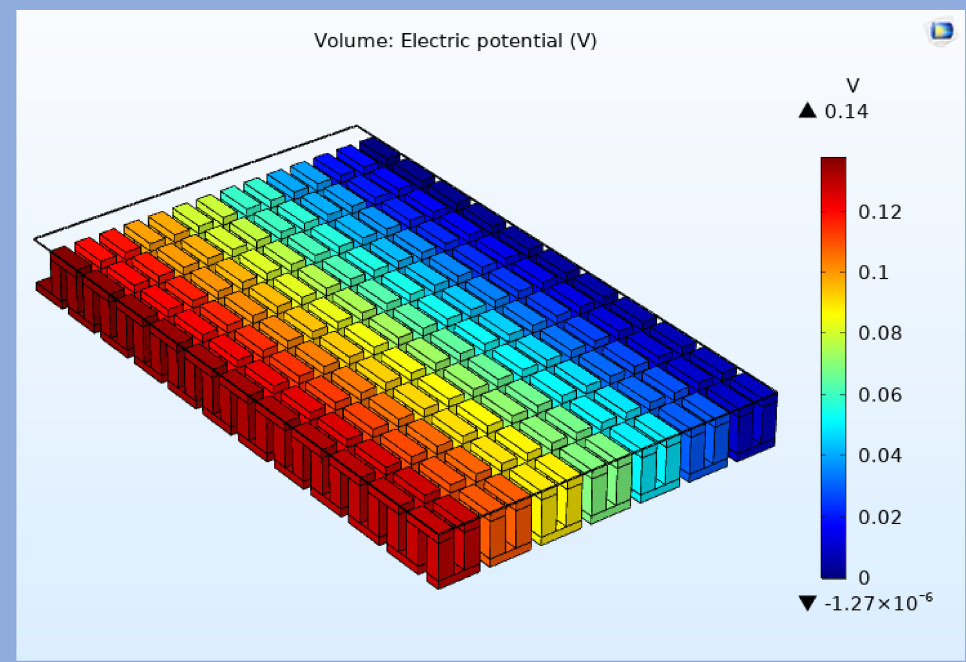

Figure 3 Multi-couple TEG electric potential

Effect of Load Resistance Variation

The following Figures show the effect of variation of load resistance on voltage, current, power and efficiency of a multi-couple TEG module.

Figure 4 Voltage vs load resistance for multi-couple TEG

Figure 5 Current vs load resistance for multi-couple TEG

Figure 6 Power vs load resistance for multi-couple TEG

Figure 7 Thermal efficiency vs load resistance for multi-couple TEG

Conclusions

- In this project, a low power wearable type thermoelectric generator is designed and simulated using COMSOL Multiphysics software.
- Multi-couple model having 154 couples with overall dimensions of 13.6 mm x 22.6 mm x 2.03 mm is developed and simulated.
- The COMSOL simulations show that the multi-couple model produces a voltage of 0.13795 V, a current of 0.010144 A and a power output of 0.001399365 W (≈1.4 mW) sufficient to power most of the medical implants for which the TEG was designed.

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