Simulation of Cascaded Thermoelectric Devices for Cryogenic Medical Treatment

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Abstract

Cooling brain tissue to around 20°C has been shown to reversibly suppress the synaptic activities of that tissue thus allowing surgeons to identify the functional role of the brain site being cooled. Such process will help the surgical team to effectively map the brain and identify the boundaries of diseased tissues. Also, there is a need to ablate the cancerous tissue and minimize the damage to the healthy ones and cryosurgery has the potential of providing such requirement. This work involves numerical simulation to develop a micro cooling probe with tip diameter of 1mm and tip temperature ranging from 4°C to -70°C.

With a tip temperature of 4°C, tissue temperature of 20°C can be achieved and thus brain mapping process can be carried out. Alternatively with a tip temperature of -70°C, the diseased tissues can be destroyed through freezing.
The objective of this project is to develop a micro cooling probe utilizing a cascade of thermoelectric coolers (TEC). Utilizing the TEC eliminates the need to use cryogenic liquid as a cooler for the cryoprobe. Moreover Using Thermoelectric cooling systems offers advantages over conventional method for cooling the cryoprobe, including compact in size, light in weight, and easily switching between cooling and heating modes.

TEC is a solid state device which converts electric current to thermal gradient. Thermoelectric cooling system is composed of a cooling section, cascade of thermoelectric modules, heat sink and coolers (As shown in Figure 1). In this project thermoelectric cooler are used to absorb heat from a tissue and pump it to the heat sink.

Using COMSOL Multiphysics®, a model was setup to simulate the thermal performance of a Bismuth Telluride P type junction and results were validated against published work. The modelling was then extended to simulate a multiple of n and p type junctions forming thermoelectric modules. The simulation was then carried out using a cascade of thermoelectric modules to achieve a cold end temperature of -70°C. Figures 2-3 show the predicted temperature distribution through single stage, two-stage and thee-stage peltier modules. Table 1 summarizes the results in terms of the current, voltage input and the predicted cold end temperature. Results showed that the use of a cascade of three peltier devices can generate the target cooling temperature of -70°C. This work highlights the potential of using COMSOL Multiphysics® software to simulate the heat transfer of complicated and advanced cooling devices.

Reference

B.J.Huang et.al, A design method of thermoelectric cooler, International Journal of Refrigration,23,208-218(2000)

Figures used in the abstract

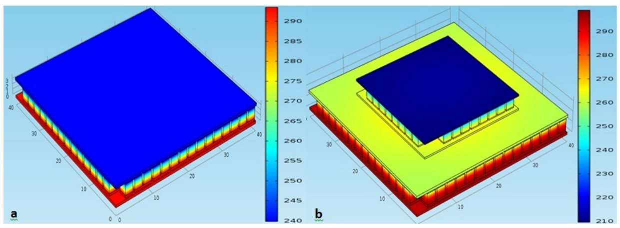

Figure 1: Temperature distribution in (a) Single stage Thermoelectric module (b) 2-stage thermoelectric modules.

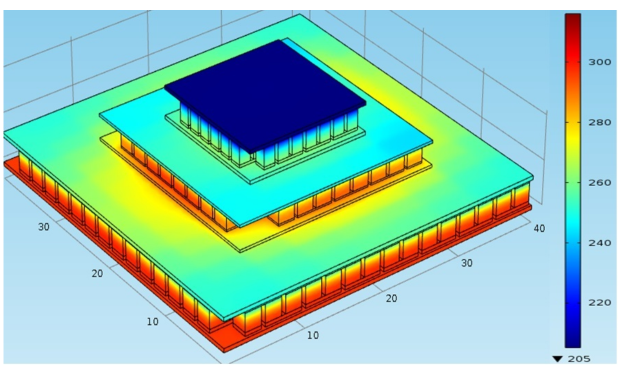

Figure 2: Temperature distribution in 3-stage thermoelectric modules.