Use of COMSOL to Design a Model for Neural Probe Thermal Studies

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Abstract

Neural probes have both scientific and therapeutic applications within neuroscience.[1] The incorporation of optical sources into neural probes enhances their temporal resolution and target specificity.[2] One issue with the inclusion of a light source onto the probe tip is that the source may cause unwanted heating. This problem may be addressed with the addition of active cooling at the probe tip and surrounding tissues. As the complexity of the design increases, there is a greater need for a computer model that can readily be used to model design variations. In this project, a model will be developed and tested in the COMSOL Multiphysics environment that will eventually take into account the effects of blood perfusion, thermal diffusion in the neural tissue, injected fluid flow and vascular uptake on the temperature profile of the affected area. The resulting model will be a design tool capable for use in developing novel neural probes that include light and heat sources and active cooling. Figure 1 shows the result of a 2D axisymmetric model of the neural probe with a heat source along its shank, utilizing the Bioheat model including blood perfusion. As part of this model development, we are also building a physical test platform that utilizes an Agar gel with similar mechanical and electrical properties as neural tissue. A specialized probe needs to designed that will incorporate an ohmic heater at its tip. Figure 2 shows a model of the probe with the ohmic heater developed in the AC/DC module. COMSOL is being used to optimize the heater pattern for these probes in order to better match the thermal behavior expected from an optical neural probe. The result of the electrical model will be coupled to the thermal model illustrated in Figure 1 by using the power output from the ohmic heater as a function of shank position as the source in the model shown in Figure 1.

Reference

1. K. Wise et al., “Microelectrodes, microelectronics, and implantable neural microsystems,” Proceedings of the IEEE, vol. 96, no. 7, July 2008, pp. 1184-1202.
2. I.-J. Cho et al., “A 16-site neural probe integrated with a waveguide for optical stimulation,” in Proc. IEEE 23rd International Conference on Micro Electro Mechanical Systems (MEMS): Wanchai, Hong Kong, 24-28 Jan 2010.

Figures used in the abstract

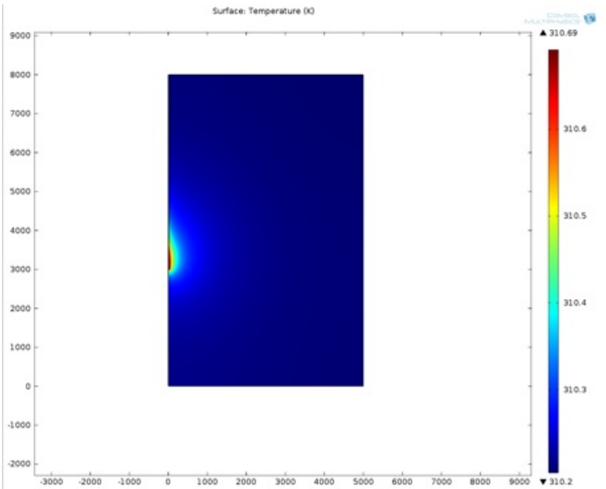

Figure 1: 2-D axisymmetric bioheat model of a probe in neural tissue. The probe is represented by a cylinder with the same cross-sectional area as the actual neural probe.

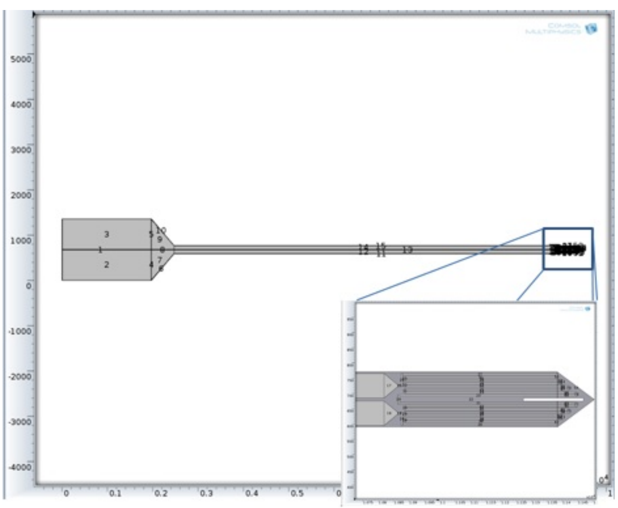

Figure 2: Geometry for Ohmic heating probe model which utilizes the AC/DC module. The model will provide the power output as a function of shank position which will be used as the source in the thermal model shown in Figure 1.