Multiphysics Modeling and Analysis of DBS Electrodes: Application to Parkinson's Disease

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Abstract

Introduction: Parkinson's disease is one of the neural disorders that has become progressive and affects millions of people in the world. Deep brain Stimulation (DBS) is a surgical technique that delivers high frequency electrical pulses to the target area in the thalamus. DBS helps Parkinson's disease patients by regulating brain signals from thalamus and eliminates tremor.

This paper deals with the design and development of various electrode configurations based on the realistic architecture of Medtronic leads (3387) [1]. Finite element analysis (FEA) is used to study the thermal effects of DBS on temperature increase in the brain. The distribution of DBS-induced temperature changes are analyzed based on the electrode lead configurations, physical properties of the electrode, and various tissue properties [2].

Bio-heat transfer model is developed for DBS using Bioheat transfer physics, and implementing the Penne's model in COMSOL Multiphysics®. COMSOL is used to model a cylindrical DBS electrode of radius 0.635 mm, contacts lengths of 1.5 mm, separated by 1.5 mm as shown in Figure 1. The geometry of brain tissue was chosen to be a cylinder of radius 50mm and height 150mm as shown in Figure 2. The temperature at outer boundaries of brain tissue is fixed at 370 C for thermal boundary conditions [3].

Results: The results obtained from the design predict that the clinical DBS protocol may induce a temperature increase up to 0.50C-0.70C in the surrounding brain tissue which depends on the stimulation/tissue parameters. When using various electrode configurations, an increased temperature rate is observed with the three electrode configuration. It gives a maximum temperature increase of 37.740C.

Conclusion: The spatial temperature distribution obtained from our results helps to determine the thermal characteristics of DBS. Also the result provides a platform about the DBS safety ranges to be maintained, based on thermal considerations. Temperature increase above 400 C - 410 C in the brain will result in hyperthermia and in our study we did not observe any temperature increase above 400 C [4]. Hence this study gives an insight about the temperature range that must be maintained during DBS.

Key Words: Deep Brain Stimulation, Parkinson's disease, Finite element analysis, COMSOL

Reference

References:
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[3] Mattias Åström, “Modelling, Simulation, And Visualization of Deep Brain Stimulation,”
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Figures used in the abstract

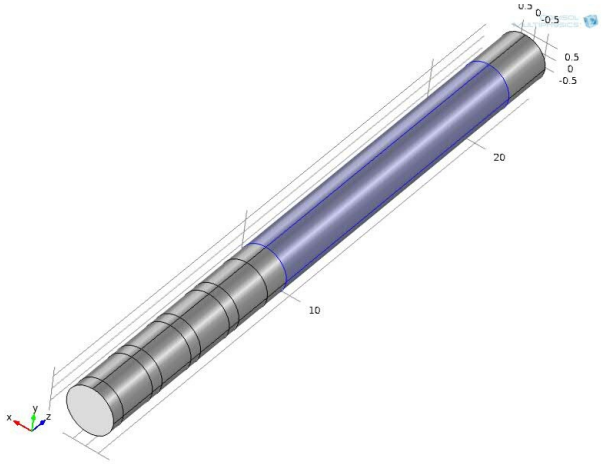

Figure 1: Model of the DBS electrode

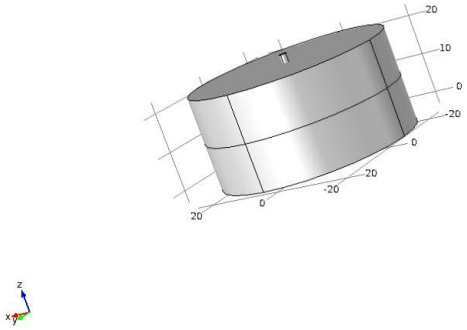

Figure 2: Model of brain tissue.