

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

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**Introduction:** Deep Brain Stimulation (DBS) is an emerging intervention for treating Parkinson's Disease(PD). Finite Element Model(FEM) of the DBS electrode is performed. A comparative study of the current density distribution on the electrode surface and the tissue temperature distribution of unipolar, monopolar and quadripolar electrode configurations are done using COMSOL.

**Results:** The electrical distribution for the three DBS lead is obtained as shown in Figure 4.

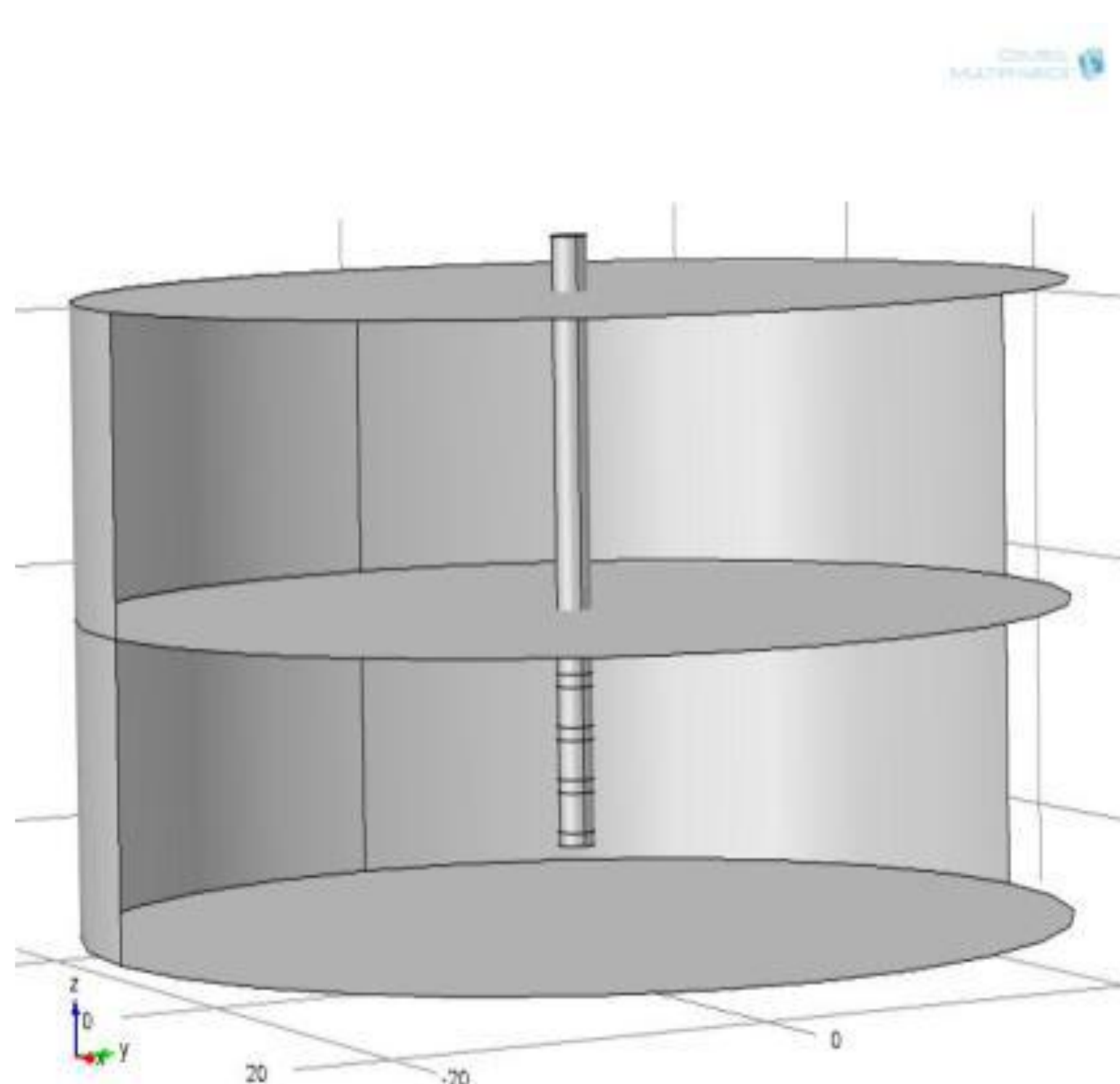


Figure 1 Cylindrical Model of Gray and White Matter

Tissue	Electrical Conductivity (S/cm)	Thermal Conductivity (W/m*K)	Heat Capacity (J/Kg*K)	Relative Permittivity
Grey matter	0.9854	0.57	3650	52
White matter	0.8243	0.52	3650	46
Polyamide	1e-12	18	840	-
Platinum	8.9e6	71.6	113	-

Table 1. Material Properties

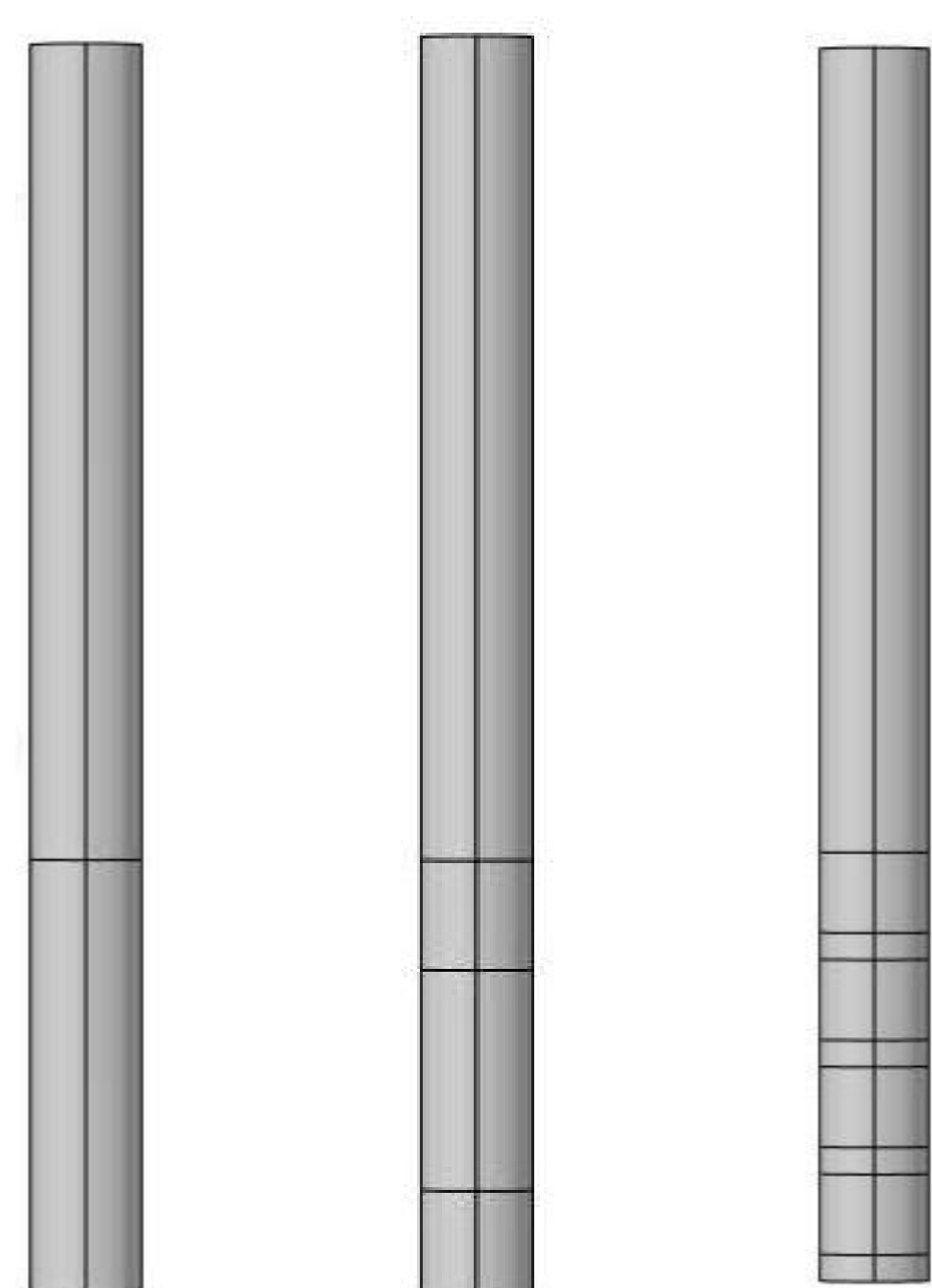


Figure 2 Electrode Configuration

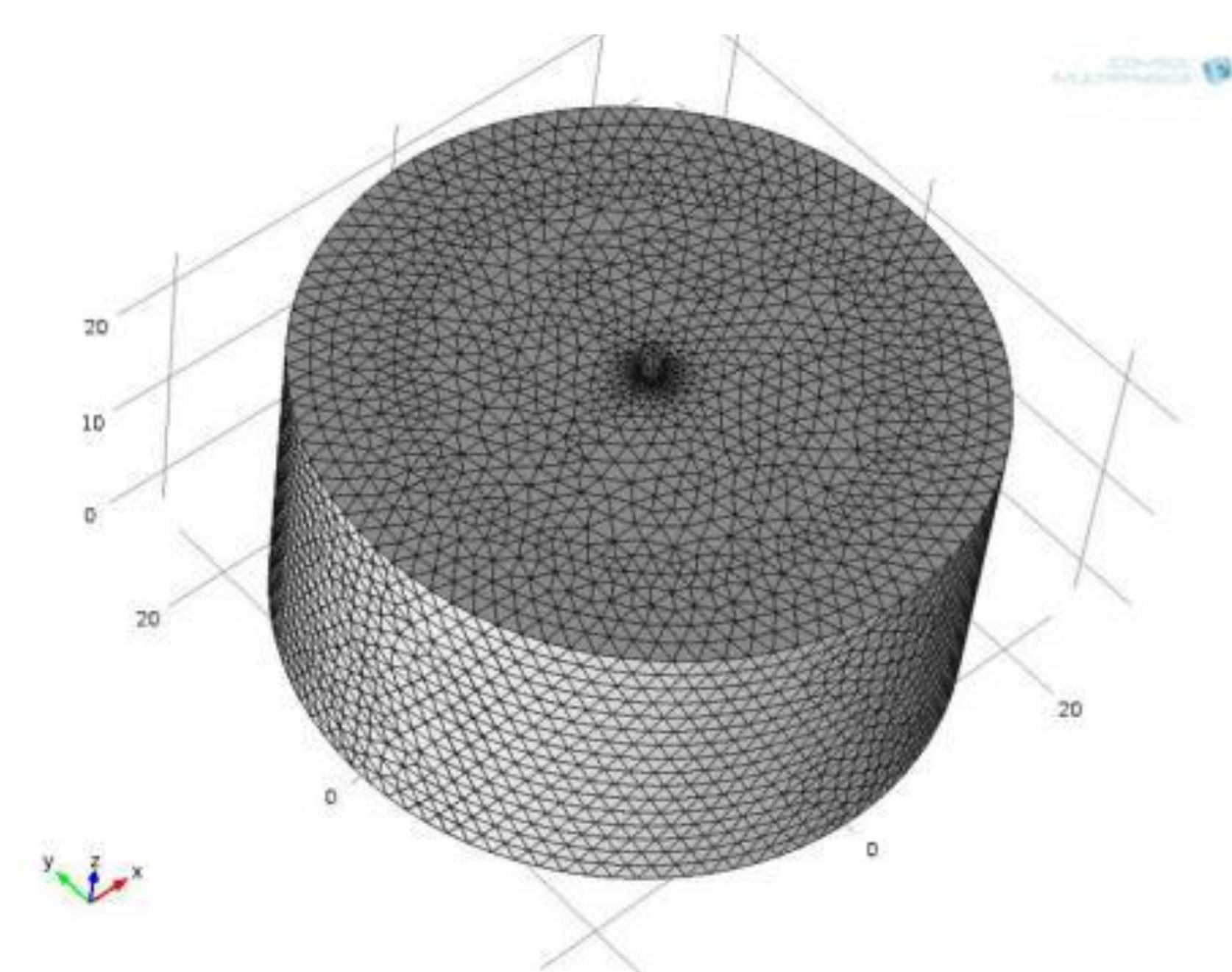


Figure 3. Meshed Geometry

**Computational Methods:** The governing equation[2] for the Bio heat transfer is given by the Pennes heat conduction equation (1) as shown below. Table 2 gives the parameter definition and values.

$$\rho C_p (\delta T / \delta t) = \nabla \cdot (k \nabla T) - \rho_b \omega_b C_b (T_b - T_b) + Q_m + \sigma |\nabla V|^2 \dots \dots \dots (1)$$

Variable	Sym	Value	Units
Brain Tissue Density	$\rho$	1040	kg <sup>3</sup>
Specific Heat of the Brain Tissue	$C_p$	3650	J Kg <sup>-1</sup> °C <sup>-1</sup>
Body Core Temperature	$T_b$	36.7	°C
Electrical Conductivity	$\sigma$	0.15-0.35	Sm <sup>-1</sup>

Variable	Sym	Value	Units
Blood Density	$\rho_b$	1000	Kg/m <sup>3</sup>
Heat Capacity of the Blood	$C_b$	3600	J Kg <sup>-1</sup> °C <sup>-1</sup>
Thermal Conductivity of the Brain Tissue	$k$	0.45-0.6	Wm <sup>-1</sup> °C <sup>-1</sup>
Blood Perfusion	$\Omega_b$	0.004-0.012	ml S <sup>-1</sup> ml <sup>-1</sup>

Table 2. Parameters of Bio-Heat Module

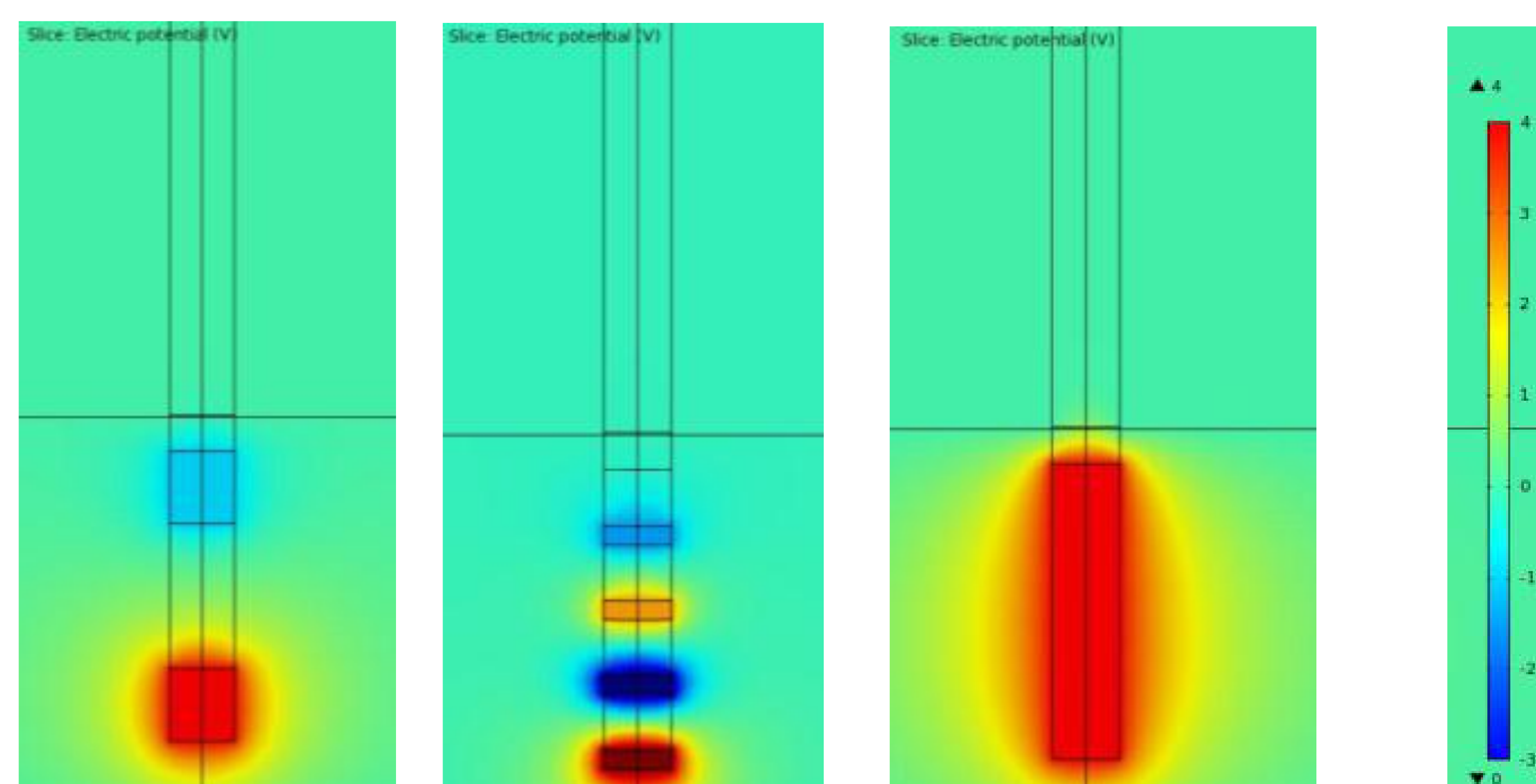


Figure 4. Spatial Distribution of Electric Potential In monopolar, bipolar and quadripolar electrode configuration

Maximum temperature of 37.158° C is seen at the surface of quadripolar electrode configuration as shown In Figure 5.

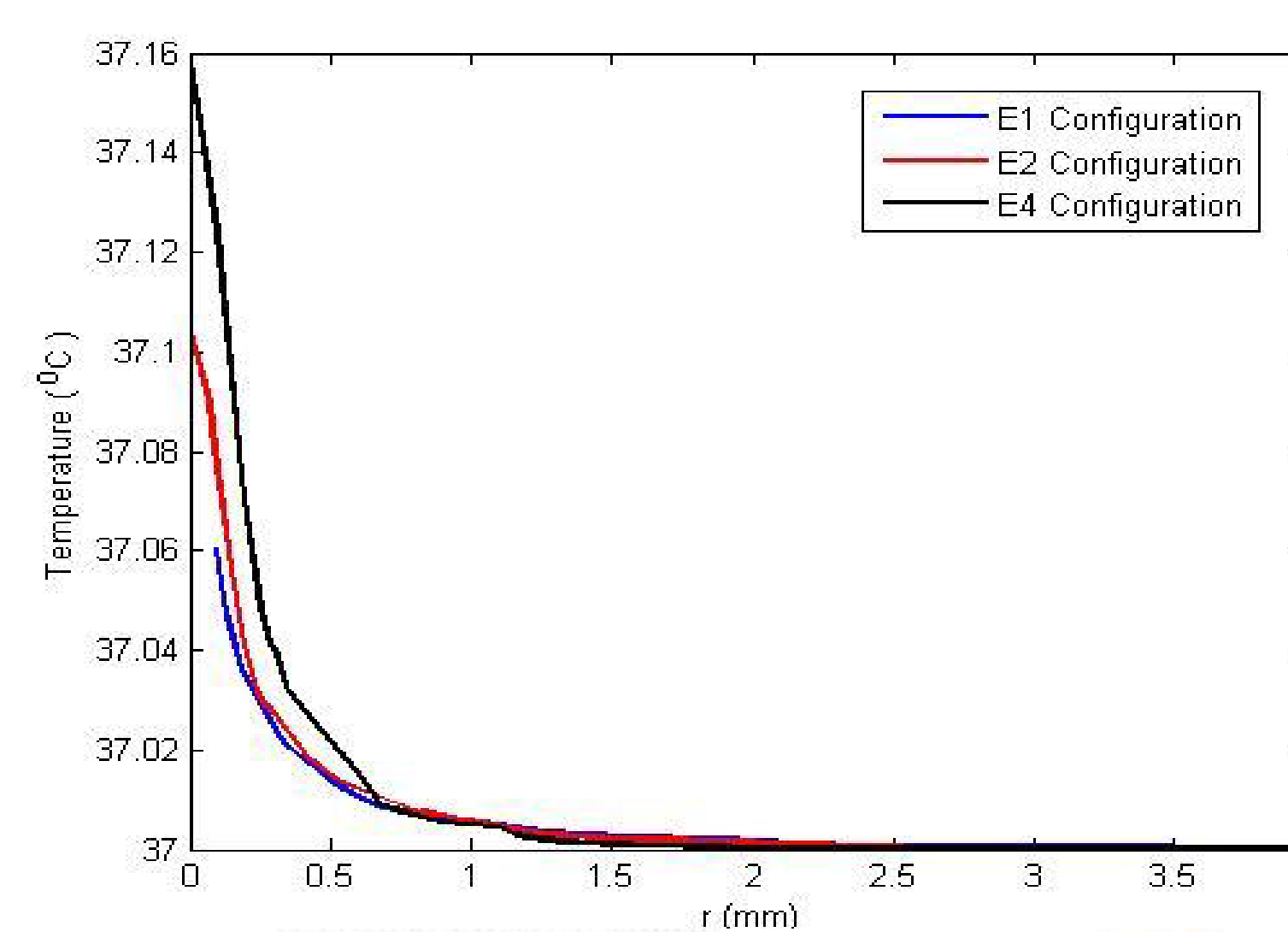


Figure 5. The temperature distribution vs. arc length

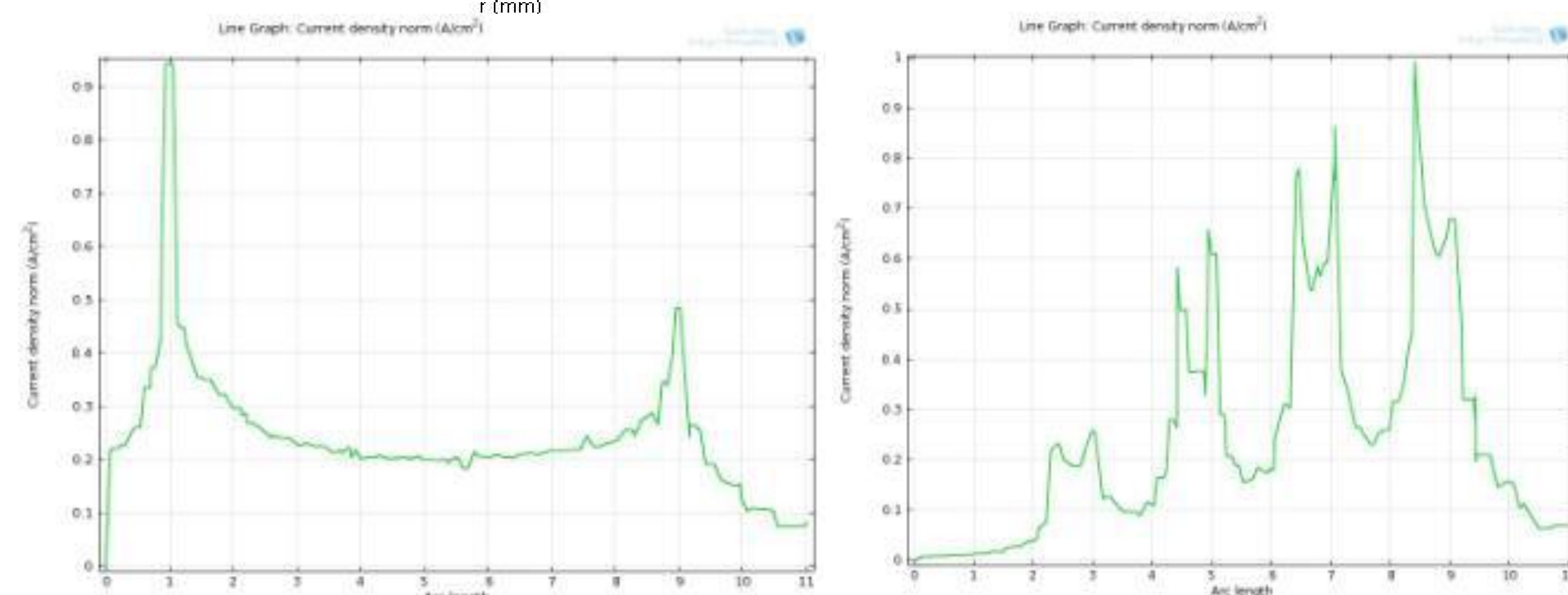
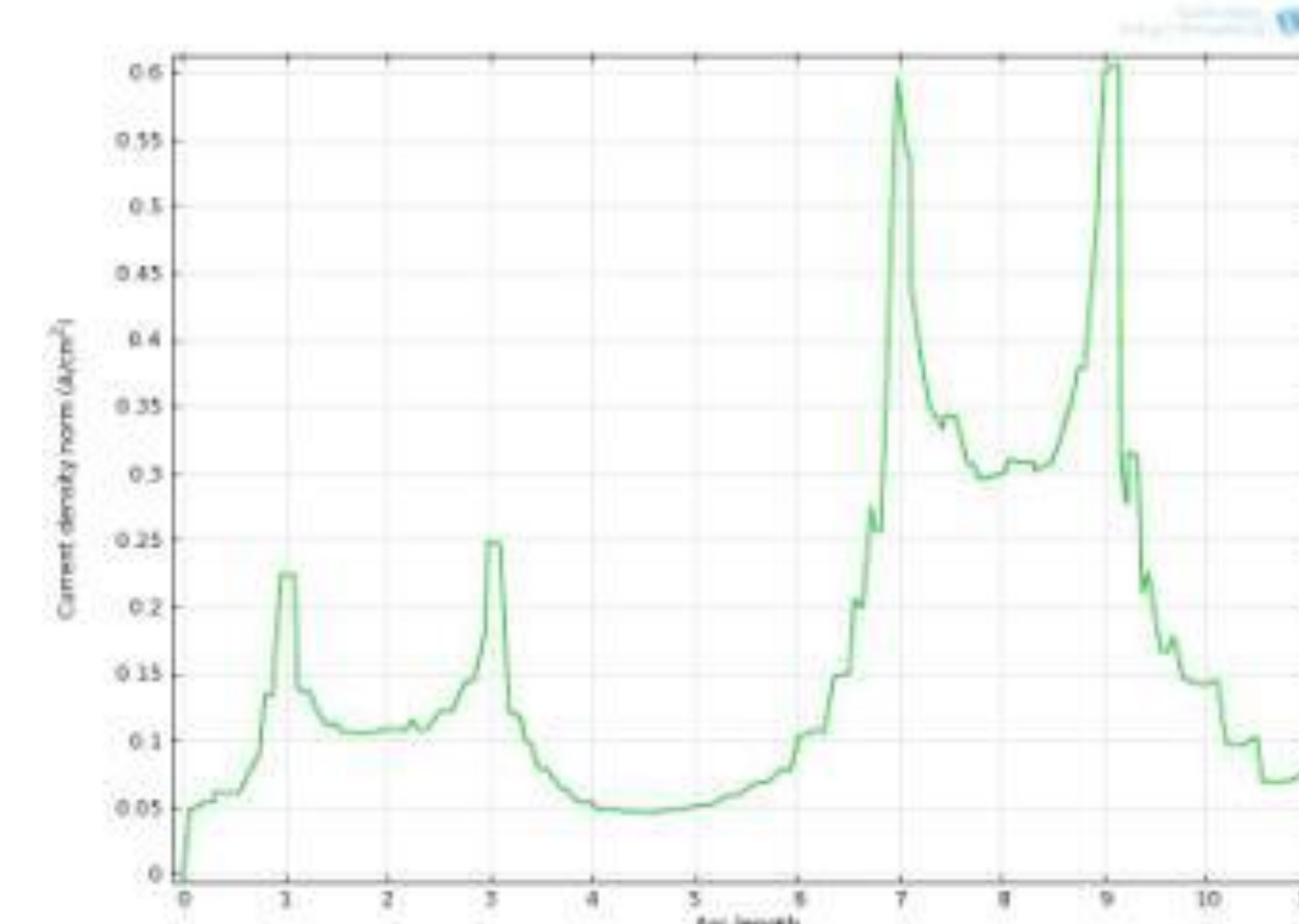


Figure 6. Current Density distribution on the electrode surface



**Conclusions:** Simulation gives a platform for the DBS safety ranges to be maintained based on thermal considerations. The future work focuses on the optimized electrode design involving the tissue inhomogeneity and blood perfusion parameters.

**References:**

- [1] Warren M. Grill , Xuefeng F. Wei , High Efficiency Electrodes for Deep Brain Stimulation, Conf Proc IEEE Eng Med Biol Soc. 2009 ; 2009: 3298–3301.
- [2] X.G.Li , H.von Holst, J.Ho and S.Kleiven, 3-D Finite Element Modeling of Brain Edema: Initial Studies on Intracranial Pressure Using Comsol Multiphysics, Excerpt from the Proceedings of the COMSOL Conference 2009 Milan.