

Nano thermo-hydrodynamics models for quantitative estimations of the cell membrane fluidity: a review

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The cells are the smallest units of the live matter, and their interaction with other cells and environment are determined by the cellular membranes. The latter possess mechanical, thermal and electric properties, which values strongly depend on the state of the cells (healthy, influenced, stresses, diseased). That is why the mathematical models of the cellular membrane and their physical properties are essential for the medical diagnostics purposes [1]. The mechanical properties of the cells and their membranes are represented by their density, elasticity and fluidity. While the density can be easily measured; the elasticity can be estimated by the rheometry and micro/nano indentometry; but the measurements of fluidity needs more complex mathematical models and governing equations for the heat transfer [2]. The most relevant model of the heat transfer at the micro and nano scales is based on the Navier-Stokes equations for the incompressive fluid (water as the main components of the cells and their membranes) combined by the heat transfer equation in the Guyer-Krumhansl form [3]

$$\tau \frac{\partial^2 T}{\partial t^2} + \frac{\partial T}{\partial t} + \rho_b c_b w_b (T - T)_b = k \left(\nabla^2 T + a \frac{\partial}{\partial t} \nabla^2 T \right) + q_m + q_e, \quad (1)$$

where T is the temperature, τ is the relaxation time, a is the diffusivity, k is the thermal conductivity, q_m and q_e are the metabolic and externally stimulated sources of heat, the subscript b related to the blood flow in the tissues provided the cells in the perfused tissue or bioreactor are considered.

The system of the Navier-Stokes equations together with the heat equation in the form (1) has been solved by the finite difference method with iterations over time.

- [1] Gad-el-Hak M. The MEMS Handbook. Second ed. CRC Press, New York. – 2006.
- [2] Yang Y., Liu J. Nano thermo-hydrodynamics method for investigating cell membrane fluidity. // Front. Energy Power Eng. China. – 2008, – 2(2). – pp. 121-128.
- [3] Nóbrega S. , Coelho P. J. A parametric study of thermal therapy of skin tissue. // J. Thermal Biol. – 2017. – 63(2). – pp. 92-103.