THERMODYNAMIC APPROACH TO DIELECTRIC PARAMETERS OF HUMAN BLOOD: APPLICATION TO EARLY MEDICAL DIAGNOSTICS OF TUMORS

Batyuk L.[1], Kizilova N.[2,3*]

[1]Kharkiv National Medical University, Kharkiv, Ukraine
[2]Warsaw University of Technology, Warsaw, Poland
[3]Vilnius Gediminas Technical University, Vilnius, Lithuania
[*]n.kizilova@gmail.com

ABSTRACT

Rheological properties of blood is widely used for clinical diagnostics (blood viscosity, blood plasma viscosity, electrophoretic mobility of red blood cells (RBC), RBC aggregation rate and blood sedimentation rate) while dielectric properties of the blood samples have been seldom studied due to the lack of fast technologies and equipment. Viscous, elastic, thermal and electric properties of the native and washed RBC can be used for nonspecific diagnostics, while dielectric constant $\varepsilon = \varepsilon^{/} + i\varepsilon^{//}$ and its temperature dependence $\varepsilon(T)$ can be used for early diagnostics of diabetes [1] and oncology [2]. Thermodynamics consideration of dielectric properties of human blood in application to the patients with diabetes has been done in [1] for the thermodynamic model with one temperature which is applicable for the dilute suspensions only. Moreover, the dielectric properties of blood plasma may also be affected by disease and more complex model of the multiphase fluid must be used for theoretical consideration and derivation of diagnostic parameters.

In this paper human blood is considered as a concentrated suspension of aggregating particles suspended in the complex fluid containing the microparticles (MP) with additional degrees of freedom. It is well known in many severe diseases like tumor the blood plasma is rich of products of tissue degeneration and necrosis, and those particles are able to rotate, orient and deform, that can be described by additional internal variables.

It is assumed the specific entropy S of the concentrated suspension is composed of the quasi-regular part characterized by the thermodynamic temperatures T_T^s and T_T^f of the solid (RBC) and fluid (blood plasma) phases, and the so-called fluctuating temperatures T_F^s and T_F^f correspondent to chaotic behaviour of the RBC in the concentrate suspension and the MP in the blood plasma. Usually the MPs possess positive electric charge which decreases natural negative surface charge of the RBCs, that enforce RBCs to rapprochement and aggregation. Then $S = H(S_T^s + S_F^s) + (1-H)(S_T^f + S_F^f)$, where H is the RBC concentration. For the specific entropies the following assumptions have been accepted: $S_{T,F}^{s,f} = S_{T,F}^{s,f}(U_{T,F}^{s,f}, \left|e_{ik}^{s,f}\right|, \left|P^{s,f}\right|, \lambda_{T,F}^{s,f})$, where $e_{ik}^{s,f}$ are tensors of microdeformations of the RBC and MP accordingly, $\vec{P}^{s,f}$ are polarization vectors, $\lambda_{T,F}^{s,f}$ are the internal parameters responsible for the RBC and MP orientation in the external field [3]. Phenomenological equations, linear approximation state equations and relaxation equations have been found. Phenomenological and state coefficients as function of frequency of the external field have been estimated. Theoretical results have been compared to the measurement data of the $\varepsilon^{/}(T)$ and $\varepsilon^{//}(T)$ curves measured on 30 blood samples of healthy individuals and 30 blood samples of the patients who underwent chemo- and x-ray therapy of tumors (before and after the treatment).

The state coefficients of the model, displacement currents associated to rotation polarization and entropy production as functions of external temperature and frequency ω of the external field have been compared to the experimental curves measured and computed for the healthy and oncologic blood samples. Some important correlations are found and discussed. Based on the comparison of the thermodynamic model and experimental data two novel indexes for early medical diagnostics of tumor growth have been proposed.

REFERENCES

[1] F. Farsaci, S. Ficarra, A. Russo, A. Galtieri and E. Tellone, Dielectric properties of human diabetic blood: Thermodynamic characterization and new prospective for alternative diagnostic techniques, J. Advanced Dielectrics, vol. 5, 1550021, 2015.

[2] L. Batyuk, Influence of cancer disease on dielectric characteristics of structural-functional state of erythrocyte membranes, ScienceRise, vol.12, pp.11-17, 2015.

[3] F. Farsaci and P. Rogolino, An alternative dielectric model for low and high frequencies: A non-equilibrium thermodynamic approach, J. Non-Equilib. Thermodyn., vol. 37, pp.27-41, 2012.