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Thermodynamic model of dielectric relaxation of micro/nanoparticle: effect of temperature jump

L. V. Batyuk[1], N. N. Kizilova[2], A. N. Borodkina[1]

[1]Kharkov National Medical University, 4 Nauki Ave., Kharkiv, 61022, Ukraine
e-mail: liliya-batyuk@ukr.net
e-mail: ania_b@ukr.net
[2] Warsaw University of Technology, Pl. Politechniki 1, Poland, 00661, Warsaw
e-mail: n.kizilova@gmail.com

The research of nanobiotechnology and development for nanoscale devices nanomedicine-related products are extremely intensive and worldwide are still increasing. Biological fluids are suspensions of micoparticles (MP) like human blood where a three major types of micoparticles: WBCs, RBCs, and MLPs. The nanoparticles (nanodiamonds (ND)) are used for different sort of drug delivery, cancer treatment and other medical applications [1-3]. In accordance with the frequency dependence, dielectric properties of each type of this MP/NP are characterized by relaxation time constant. The region of dielectric relaxation 9.2 HHz is most interesting for obtaining unique information on structural changes in solutions of polar liquids with variations in temperature and composition [4]. The physical phenomena at the micro/nano scale in MW fields is described by the enhanced irreversible thermodynamics (EIT) that introduces the Helmholtz free energy $\Im$ as a function of its parameters X,Y, their fluxes $J_{X,Y}$, and their time and space derivatives in the form $\Im = \Im(X, \mathrm{Y}, J_{X,Y}, \nabla J_{X,Y}, \dot{J}_{X,Y}$, where dot corresponds to the time derivative. Therefore, the classical physical laws like Fourier heat, Darcy mass transfer, and other laws possess the generalized form [5]: $\tau \dot{J}_X + J_X = -k\nabla X + \lambda \nabla^2 X + f(X)$ (1), where τ is the relaxation time ($\tau = 0$ in slow varying fields), λ is the scale related parameter ($\lambda = 0$ at macro scale), k is the transfer parameter. In the complex MP+NP suspensions in MW fields a series of novel coupled transfer phenomena appeared due to (1). In this study the coupled heat J_T and mass J_ρ transfer phenomena are studied. Thus, to determine the restructuring of polar liquids by the change in the activation entropy, it is necessary to have information about the temperature dependences of the dielectric permittivity spectra in the relaxation region, from which the value of τ can be determined.

Using the values of the complex dielectric permittivity, we can relaxation time τ, which are related to the change in activation entropy which has been determined for temperature range between 0° and 10°C. 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 dielectric permittivity of blood samples of healthy individuals and blood samples of the patients who underwent chemo- and x-ray therapy of tumors (before and after the treatment). Some important correlations are found and discussed. Suggested that the temperature jumps is induced permeation of water in the cells. A local decrease in temperature by 1-2 degrees blocks the permeability of the cell membrane [5]. It is shown the hydrated shells of the MP and NP are influenced by the particle geometry, curvature of the interfaces, relaxation phenomena in the MW fields, and ambient temperature.

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