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Influence of low temperatures on dielectric properties of human red blood cells

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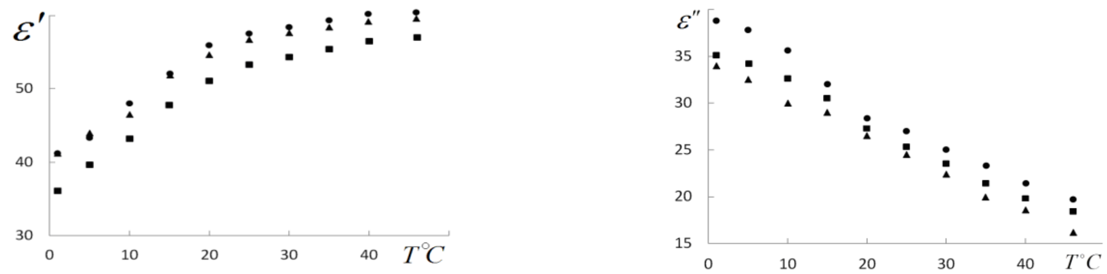
Suspensions of red blood cells (RBC) and their membranes (RBC ghosts) a heterogeneous media characterized by dielectric permittivity $\varepsilon = \varepsilon' - i\varepsilon''$, where ε' is the relative permittivity, $\varepsilon''/\varepsilon' = \tan(\delta)$ is the tangent of dielectric losses [1], and demonstrate Maxwell-Wagner type of frequency dependence $\varepsilon(\omega)$ described by the Havriliak-Negami formula [2]

$$\varepsilon(\omega) = \varepsilon_\infty + \frac{\varepsilon_0 - \varepsilon_\infty}{(1+(i\omega\tau)^{1-a})^b} \text{ ,(1)}$$

where ε_0 and ε_∞ are the limiting values of ε' for frequencies well below and above the relaxation frequency, τ is the relaxation time. When $a \in [0,1[, \mathrm{b} = 0$ or $a = 0, b \in]0,1]$ (1) gives the Cole-Cole or Cole-Davidson formula, respectively.

Dielectric properties of RBC suspensions are usually studied by the broadband dielectric spectroscopy at a fixed room or physiological temperatures, while actually the measured values ε' and ε'' are temperature dependent, and both $\varepsilon(\omega)$ (1), $\varepsilon(\mathrm{T})$ curves measured on healthy volunteers and patients with cancer (Fig.1) exhibit distinct differences, that is used for early diagnostics [3].

Here the dielectric properties ε', ε'' of diluted aqueous RBC suspensions at the temperatures are studied based on the data on the influence of low temperatures on the proteins [4], thickness and density of the hydration shells [1], changes in viscosity of the membrane and hemoglobin solution inside the cell influences rheological properties the RBC as a complex multilayered physical structure and lead to variations in their mechanical relaxation [5].



a b

Fig. 1. Experimental curves ε′(T) (a) and ε″(T) (b) for the RBC suspensions of healthy donors (■), patients with breast cancer (▲) and lung cancer (●).

The layered model of the RBC including its internal contents (i), cytoskeleton (ii), membrane (iii), glycocalyx (iv), and hydration shells (v) with different temperature dependent structure and physical parameters has been developed. Theoretical curves $\varepsilon(\omega)$, $\varepsilon(\mathrm{T})$ have been computed and validated on the measurement data. New diagnostic important indexes are obtained.

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