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Abstract of the Ph.D. Thesis

Motion at the Nanoscale in Polymer Solutions with Application to Biophysical Problems

All living organisms, irrespective of the level of biological complexity, are from the point of view of physical chemistry dynamic, far-from-equilibrium systems. The recent rapid development of biochemistry and molecular biology revealed in detail the chemical structure of these systems – both in terms of constitution and function of different molecular species, as well as biochemical pathways connecting them into functional items. A new arising challenge is to capture the dynamics, grounding the intricate regulation and synchronization mechanisms in the basis of thermodynamics. This, however, cannot be achieved without an accurate description of passive and active matter transport at molecular and mesoscopic level. In case of complex systems, whose transport properties are strongly length-scale-dependent, it is not trivial. The hereby presented Thesis is an experiment-based contribution to elucidation of this issue.

Convenient model complex systems used throughout the Thesis are aqueous polymer solutions, where the crucial length scales are clearly defined. Moreover, such solutions are of high interest *per se* due to broad industrial applications and recent dynamic development of polymer sciences. Within this experimental framework, a few related problems are investigated and discussed. The main theses are as follows:

1. Diffusion is an activated process. In case of complex liquids, activation energy for diffusion depends on the probe size and structure of the liquid; this relationship is equivalent to the viscosity scaling and can be utilized to assess interactions in complex systems;
2. At short time scales, the rate of response of the polymer mesh to mechanical disturbances determines the effective viscosity of the solution. Due to a depletion-layer-like effect, oscillators overrunning the polymer relaxation experience viscosity reduced by orders of magnitude compared to the steady state value;
3. Viscosity scaling is crucial for active transport. Model motor protein, kinesin, comes to a stall upon a moderate increase of activation energy for diffusion of its domains. Such behaviour confirms a mechanism of the protein's processive motion which implies ubiquitous exploitation of Brownian diffusion in natural molecular machines.

The text is divided into five chapters. Chapter 1 gives a comprehensive introduction to the topic and presents the current state of knowledge on transport properties of complex liquids. Chapter 2 provides background on the experimental techniques utilized in the presented studies: fluorescence correlation spectroscopy (FCS), rheometry, dynamic light scattering (DLS), quartz tuning fork oscillation decay and total internal reflection fluorescence (TIRF) microscopy. In Chapter 3, technical details on all the performed experiments are given. Chapter 4 contains experimental results along with their discussion, grouped according to the three main theses listed above. Finally, Chapter 5 gives a brief overview of the obtained results and final conclusions.