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Optical Bio-Microrheology

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Rheology is the study of dynamic elastic and viscous properties (jointly known as the dynamic viscoelastic property) of materials or systems. In contrast with the conventional (macro-) rheology, often applied to study the average viscoelastic property of bulk materials on the order of a cubic centimeter (i.e, ~ 1cc) without any spatial resolution, microrheology refers to the study with micron- or sub-micron- spatial resolution, frequency response in the range of 0.01 Hz to a few hundred Hz, and requiring only an extremely small amount of sample on the order of a micro-liter. In this paper, we present the development and the applications of several optical microrheological methods, both active and passive, to characterize the dynamic viscoelastic properties of a few selected biological samples, including bio-fluid to living cells.

In active optical microrheology, we focus on the experimental method based of jumping optical tweezers, in conjunction with the Kelvin solid model, to characterize the viscoelastic property of individual red blood cells in terms of the Young’s modulus and viscosity; we have demonstrated that this approach provides a simple and yet powerful platform to quantify the change in viscoelasticity of individual red blood cells in response to different physical and chemical stimuli. As a specific example of the potential biomedical applications of this technique, we measured and compared the Young’s modulus and viscosity of individual human red blood cells (RBCs) without vs. with different chemical treatments to study the contribution of different constituents of human RBCs to their elasticity and viscosity.

In passive optical microrheology, we applied video particle tracking (DVPT) to measure and compare (1) the intracellular dynamic viscoelasticity of normal HeLa cells vs. HeLa cells infected by Enterohemorrhagic *E. coli* (EHEC), (2) the intracellular stiffness at different stages of Epithelial–mesenchymal transition (EMT), (3) dynamic viscoelasticity of synovial fluid (SF) samples from patients with three common types of arthritis, namely, OsteoArthritis (OA), Rheumatoid Arthritis (RA), and Gouty Arthritis (GA).

In each example, the biomedical implications and potential applications are discussed. The viscoelastic properties of bio-fluid and living cells are often correlated to their pathobiology and physiological functions; a change in their viscoelasticity often occurs in response to chemical and/or physical stimulation. Hence, the investigation of viscoelastic properties of bio-fluid and living cells may serve as complementary diagnostic biomarkers.