SWIMMER-MICRORHEOLOGY

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Microrheology is one of the most useful techniques to measure rheological properties of soft matter and various biological materials including cells. There are two different methods; passive microrheology and active microrheology.In the passive microrheology, both local and bulk mechanical properties of a medium can be extracted from a Brownian motion of a probe particle [1]. In this method, the generalized Stokes-Einstein relation (GSER) is used to analyze thermal diffusive motions. In the active microrheology, on the other hand, the probe is actively pulled through the fluid, with the aim of driving the medium out-of-equilibrium and measuring mechanical responses [2]. Within the linear response theory, the generalized Stokes relation (GSR) is employed to obtain the frequency-dependent complex shear modulus.

We propose a new type of active microrheology using a microswimmer. Microswimmers are tiny machines that swim in a fluid like sperm cells or motile bacteria, and are expected to be applied to microfluidics or microsystems. As one of the simplest microswimmers, we consider Najafi-Golestanian's three-sphere swimmer model [3], where three in-line spheres are linked by two arms of varying length (see Fig.1). Recently such a swimmer has been experimentally realized. We investigate its motion in a general viscoelastic medium, and obtain a relation which connects the average swimming velocity and the frequency-dependent complex shear viscosity of the surrounding viscoelastic medium [4]. We show explicitly that the absence of the time-reversal symmetry of the swimmer motion leads to the real part of the viscosity, whereas the absence of the structural symmetry of the swimmer is reflected in the imaginary part of the viscosity. Hence we call it as ``swimmer- microrheology''. Our result also indicates that the Purcell's scallop theorem, which states that time-reversible body motion cannot be used for locomotion in a Newtonian fluid, breaks down for a three-sphere swimmer in viscoelastic media if the structural symmetry is violated.

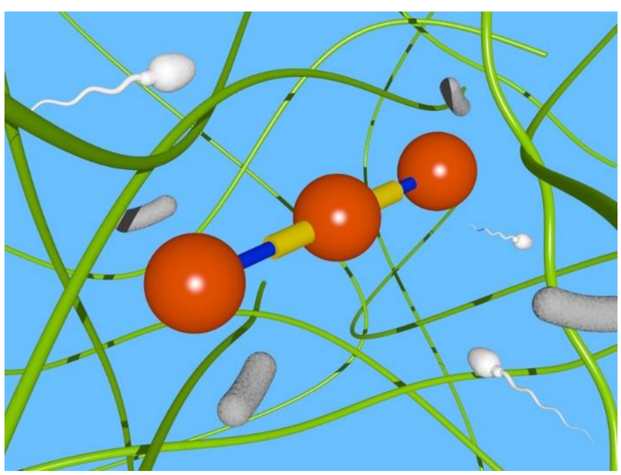

Fig.1: Three-sphere swimmer in a viscoelastic fluid.

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