

Non-equilibrium transport of colloidal soft matter: from anomalous transport to self-propelled dynamics

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1. INTRODUCTION

Gradients of thermodynamic variables such as temperature, chemical potential, and osmotic pressure cause migration of molecules and small particles in fluids. Recently, novel methods to utilize phoretic properties (electro-, thermo-, and diffusiophoresis) are proposed for transporting and screening particles such as DNA molecules and colloids in lab on-chip. Several nontrivial transport properties of colloidal soft matter in non-equilibrium conditions have been found and studied in these efforts. Among them, it is a challenging problem to understand and control the colloidal migration driven by a surface hydrodynamic flow which is induced by the interaction between a colloidal surface and surrounding solute or charges, because the scaling of transport coefficients against particle size for such cases is different from the Einstein- Stokes relation[1]. We also encounter even richer non-equilibrium transport properties of colloids when an asymmetry is introduced to each colloidal particle. We prepared asymmetric colloidal particles, so called Janus particle, which exhibit self-propelled motion even in the uniform and symmetric external field owing to the surface flow induced by the asymmetry of the particle itself. We found a way to promote self-organized collective motions of Janus particles by controlling the interaction between Janus particles. When the interaction becomes attractive, Janus particles self-organize a chain structure which spontaneously deforms its shape to exhibit snaking and spiraling motion. This provides an example of self-propelled deformable micro-swimmer[2,3]. In the presentation, we will explain an example of nontrivial transport phenomena of colloids in the external fields, afterwards we demonstrate a rich variety of the transport phenomena of Janus particles and their collective dynamics as micro-swimmers.

2. TRANSPORT IN TEMPERATURE GRADIENT

In thermophoresis, the speed and direction of migration along a temperature gradient are characterized by Soret coefficient, which is generally material-dependent. Diffusiophoresis is a similar phenomenon where colloid particles move along a gradient of solute molecules. In the presentation, we report experimental and theoretical studies on a phoretic motion of colloidal particles in a polymer solution under a temperature gradient. We find that a Soret coefficient of a colloid is sensitive to the polymer (PEG) concentration; as increasing the amount of polymer, the Soret coefficient reverses its sign and its magnitude outweighs by far its intrinsic value at the highest polymer concentration studied. The dependence of the Soret coefficient on the polymer is experimentally determined and is corroborated by our hydrodynamic calculations[1].

REFERENCES

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