Chin. Phys. B Vol. 26, No. 8 (2017) 088203

Anisotropic transport of microalgae *Chlorella vulgaris* in microfluidic channel*

Nur Izzati Ishak[1,†], S V Muniandy[1,2], Vengadesh Periasamy[3], Fong-Lee Ng[4], and Siew-Moi Phang[4]

[1] *Plasma Technology Research Center, Department of Physics, University of Malaya, Kuala Lumpur 50603, Malaysia*
[2] *Center for Theoretical Physics, Department of Physics, University of Malaya, Kuala Lumpur 50603, Malaysia*
[3] *Low Dimensional Materials Research Center, Department of Physics, University of Malaya, Kuala Lumpur 50603, Malaysia*
[4] *Institute of Ocean and Earth Sciences, University of Malaya, Kuala Lumpur 50603, Malaysia*

(Received 6 March 2017; revised manuscript received 12 April 2017; published online 10 July 2017)

In this work, we study the regional dependence of transport behavior of microalgae *Chlorella vulgaris* inside microfluidic channel on applied fluid flow rate. The microalgae are treated as spherical naturally buoyant particles. Deviation from the normal diffusion or Brownian transport is characterized based on the scaling behavior of the mean square displacement (MSD) of the particle trajectories by resolving the displacements in the streamwise (flow) and perpendicular directions. The channel is divided into three different flow regions, namely center region of the channel and two near-wall boundaries and the particle motions are analyzed at different flow rates. We use the scaled Brownian motion to model the transitional characteristics in the scaling behavior of the MSDs. We find that there exist anisotropic anomalous transports in all the three flow regions with mixed sub-diffusive, normal and super-diffusive behavior in both longitudinal and transverse directions.

Keywords: Brownian motion, anomalous transport, scaled Brownian motion, microfluidic, *Chlorella vulgaris*

PACS: 82.70.–y, 05.40.–a, 83.80.Hj, 47.15.G– **DOI:** 10.1088/1674-1056/26/8/088203

1. Introduction

Transport phenomena are diverse, depending on the particle characteristics, flow properties, media, and geometries of the systems. Hard microscopic spherical particles immersed in Newtonian fluid typically move in random motion due to elastic collisions with the surrounding fluid particles. This erratic motion can be modelled as random walk with properties similar to Gaussian process and the diffusion characteristics follow Fick's law of normal diffusion, resulting in the mean square displacement (MSD) varying linearly with time lag.[1] Transport behaviors of particles of soft-particles for example from biomaterials tend to deviate from the standard normal diffusion, mainly due to complex interaction of particle elasticity, shape factor, and surface interaction, fluid hydrodynamic forces,[2] and the confinement geometries.[3–6]

Behaviors of particles in the open domain, i.e., away from the solid boundaries and subjected to the shear flow have been widely studied.[7–10] Numerical studies by Yu *et al.*[11] on the flow of pipe revealed that the large particle can affect instability of the flow such that the particles trigger the turbulence transition of the flow. Under the shear flow, the MSD of passive Brownian spherical particles along the streamwise direction exhibits anomalous scaling proportional to cubic power of time.[7,12] Recent numerical study on the behavior of Brownian self-driven particles at low Reynolds number in a Poiseuille flow shows that the MSD along the flow direction in short time follows the quartic time scaling behavior, whereas in longer time it always follows the quadratic time scaling behavior.[13] The surface of confinement wall greatly influences the transport behavior of particles, and even at the center of the channel, particles exhibit the sub-diffusive behavior.[14] In addition, complex multibody hydrodynamic interaction of the volumetric particles suspension induces the anomalous diffusive behavior in the direction normal to the wall, showing dependence on the distance from the particles to the wall.[15] Under an extreme confined geometry, the system exhibits the anomalous sub-diffusion known as single file diffusion (SFD), where the particles are lined-up in sequence, and incapable of passing through each other. Thus, their sequence remains unchanged over time.[16] Transient anomalous sub-diffusion, where the system exhibits the sub-diffusion behavior on a short time scale and normal diffusion in longer time is observed when the particles transported encounter obstructions.[17,18] Meanwhile, super-diffusive process is observed as the particles are transported in the crowded cellular environment.[19,20]

Particles' motion dispersed in hard-sphere fluid is strongly influenced by the direct hydrodynamic interaction and extra friction due to distortion of pairwise distribution function of multicomponent dispersion.[21–24] The medium complexity for example highly viscous medium or crowded medium could induce anomalous transport behavior. This allows self-diffusion of the non-interacting hard sphere parti-

*Project supported by the Science Fund from the Ministry of Higher Education of Malaysia under the Fundamental Research Grant Scheme (Grant No. FRGS: FP057-2014A) and the Fund from the University of Malaya Research Grant (Grant No. UMRG: RP020A-14AFR).

†Corresponding author. E-mail: izzati_91_ishak@siswa.um.edu.my

 http://iopscience.iop.org/cpb http://cpb.iphy.ac.cn