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Flagella-like Beating Motions of Chains formed by Active Brownian Particles

Daiki NISHIGUCHI, and Masaki SANO
Department of Physics, The University of Tokyo

Asymmetrical colloidal particles (called "Janus particles") made by coating hemispheres of polystyrene beads with gold exhibit self-propelling motions under AC electric field. This propelling mechanism is theoretically understood only for a low frequency regime [1].

Under high frequency AC field (>30kHz), it is experimentally reported that the Janus particles also self-propel but their direction is reversed compared with the case of the low frequency regime [2]. The most distinctive feature of the two frequency regimes is the profiles of the induced charge on the Janus particles. Though the induced electric dipole on the gold hemisphere can follow the AC field, the dipole on the polystyrene hemisphere cannot follow it and delays. This means that the electric quadrupole is induced on the whole Janus particle.

In the high frequency regime, the quadrupole-quadrupole interaction results in attractive forces between particles (Fig.1). This causes particles to be connected with each other and they form some interesting complexes such as doublets, triplets, and chains.

Here we focused on the chains, especially the chains with their front particles stuck to the substrate. Janus chains do not propel straightforwardly but they wriggle and curve. When their front particles are fixed, they exhibit flagella-like beating motions (Fig.2). As the intensity of the applied AC electric field increases, the propelling force of each particle becomes stronger and this results in higher beating frequency. In order to elucidate the mechanism of beating motions, we observed chains under various conditions and evaluated how these wriggling or beating motions depend on the properties of the applied AC electric field.

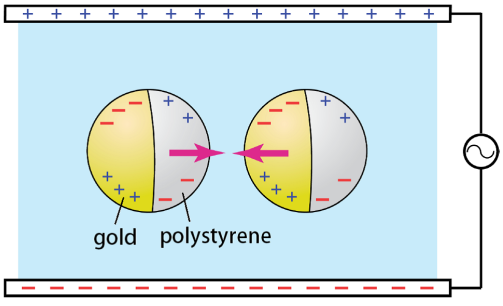

Figure 1: Attractive interaction in the high frequency regime.

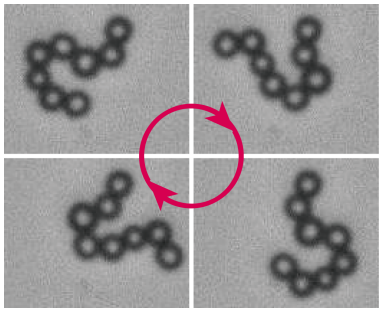

Figure 2: One cycle of the beating motion.

[1] Sumit Gangwal, Olivier J. Cayre, Martin Z. Bazant, and Orlin D. Velev. PRL (2008)
[2] Ryo Suzuki, Hong-Ren Jiang, and Masaki Sano. arXiv (2011)