Proceedings of the 2nd International Conference on Fluid Flow, Heat and Mass Transfer
Ottawa, Ontario, Canada, April 30 – May 1, 2015

Our Creeping Future: Stokes Flow Enabling Tomorow's Materials

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Mother Nature leverages structure-property relations to make superior materials tailored to her needs. For instance the high damage-tolerance of bones results from its complex nano-scale heterogeneities in stiffness. The exceptional resilience of resilin, a protein that enables high-frequency wing movements in insects, can be attributed to structural features in its molecule. These recent findings promise new materials that are far superior to the existing, and ultimately the capability to tailor a material to a specific need. However, thus far our means to control microstructure are extremely limited at the molecular scale. Nanomaterials, e.g., nanoparticles, remedy this limitation. They can be used as the building blocks of larger matter. Bulk properties of such matter depend on the organization of the constituent nanoparticles. Thus, developing scalable methods to organize nanomaterials hold the key to the future of materials.

Taking a second inspiration from nature, we find self-assembly to be the most efficient of means for manipulating small matter; it can be used to quickly fabricate materials of 'real-world' sizes. Self-assembly is easily realizable in a liquid bath. Thus, understanding the mechanics of self-assembly takes us back to the century-old Stokes Flow; motion of particles of negligible inertia in a fluid. We will discuss how this ancient understanding is used to engineer the next generation of materials; how a self-assembly process can be designed and controlled in order to produce a desired microstructure in a larger material. Specifically, we will discuss (1) the organization of magnetic nanoparticles into microstructure of desired morphology in a polymer composite, and (2) the organization of magnetically labeled cells with the intent to generate an artificial tissue of desired architecture.