Near-Wall Dynamics of Suspended Colloidal Particles in Shear and Electroosmotic Flow

Minami Yoda (minami@gatech.edu)

G. W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology

Manipulating colloidal particles of radii $a = O(0.1\ \mu\text{m}–1\ \mu\text{m})$ suspended in an aqueous electrolyte solution and flowing through a microchannel near the channel walls is of interest in microfluidics because such particles can be used to "preconcentrate" target analytes, which are usually detected and transduced by surface-mounted sensors and actuators. The flow itself can also affect the dynamics of these suspended particles via wall-normal "lift" forces. Lift forces have been reported in Poiseuille flow driven by a pressure gradient $\Delta p/L$, as well as in electroosmotic (EO) flow driven by a voltage gradient (electric field) of magnitude $|E|$.

Total internal reflection fluorescence microscopy (TIRFM) is used to visualize dilute (bulk volume fractions < 0.5%) suspensions of colloidal (radius $a \approx 250–500$ nm) fluorescent polystyrene particles within about 1 μm of the wall in combined Poiseuille and EO flows through ~34 μm deep fused-silica and PDMS-silica channels. In this near-wall region, parabolic laminar Poiseuille flow is essentially simple shear flow with shear rate $\dot{\gamma}$. In combined Poiseuille and EO "co-flow," the particles are strongly repelled from the wall, with a force that appears to be much greater than the sum of the lift forces observed in EO, or Poiseuille flow, alone. Moreover, the force appears to scale with $|E|$ and $\dot{\gamma}^{1/2}$, suggesting that these forces are neither "dielectrophoretic-like," nor electroviscous, in nature.

More surprising, in combined Poiseuille and EO "counterflow," the particles are attracted to the wall, even though both have a negative surface charge, and assemble into concentrated streamwise "bands" above a minimum $|E|$, and in most cases, a minimum $\dot{\gamma}$. These bands, which appear to exist only within a few μm of the wall, are roughly periodic in the cross-stream direction, although there is no external forcing along this direction. To our knowledge, there is no theoretical explanation for why these particles would form such structures. Experimental observations of these band characteristics are therefore presented for a variety of particle sizes, concentrations and zeta-potentials. Preliminary high-speed visualizations over the entire channel depth suggest that the bands form once the near-wall particle concentration exceeds a threshold value, and that the band formation may be associated with a convective instability.

Biographical Sketch

Minami Yoda received her degrees from Caltech and Stanford, and was a researcher at TU Berlin and TU Delft. She is a Professor in the Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. Dr. Yoda is Vice-Chair of the American Physical Society (APS) Division of Fluid Dynamics and an Associate Editor for the Springer journal *Experiments in Fluids*. She is a Fellow of the APS and the American Society of Mechanical Engineers (ASME).