Complex Fluids & Microfluidics Workshop 2008 (CFMW08)

Melbourne, Australia
1–2 September 2008

The inaugural Complex Fluids & Microfluidics Workshop was held in Melbourne, Australia at the beginning of September 2008. The workshop constituted an informal gathering of researchers working in complex fluids and microfluidics with the primary purpose of providing a forum for cross-fertilization of ideas on current advances and future directions in these areas. In addition, the workshop, whose programme comprised of eight plenary lectures and two panel discussion sessions to allow for the exchange of ideas amongst delegates and panel members on perspectives on future directions in both subject areas, was also aimed at providing graduate students with the opportunity to meet and listen to eight of the most prominent experts in complex fluids and microfluidics. The informal and small group setting of the workshop also provided ample opportunities for networking and discussion.

The workshop was well-attended, with over 80 participants from over 25 institutions across the world, including those as far away as China, France, Japan, Singapore, Sweden, Switzerland, Russia, Taiwan, UK and USA, as well as several researchers from industry. About half of the participants consisted of graduate students, whose registration fee was waived, made possible by kind support from the Australian Research Council Nanotechnology Network. Other sponsors of the workshop include the Monash Institute of Nanosciences, Materials & Manufacturing, the Australian Society of Rheology, the Commonwealth Scientific & Research Organisation and the Institute for Platform Technologies at RMIT University.

Following a short welcome from Professor Tam Sridhar, the Dean of Engineering at Monash University, Professor John Brady (California Institute of Technology, USA) delivered the first plenary lecture on the microrheology and microdiffusivity associated with single particle motion in colloids. Due to the disturbance in the surrounding microstructure surrounding the particle as it is pulled through the medium, a nonlinear response results in the form of an osmotic or reactive entropic force which arises to resist the particle motion. An analytical model was constructed and Brownian dynamics simulations were carried out, both of which were employed to extract information on the effective viscosity of the colloidal dispersion. This is in contrast to the inference of elastic or viscous moduli of the dispersion from measurements of the fluctuating thermal motion associated with the linear, near-equilibrium response of passive probe particles. A discussion was then provided on how the microviscosity obtained relates to conventional macroscopic rheological measurements.

This was followed by an in-depth discussion on three-dimensional foam rheology associated with random soap froth by Dr Andrew Kraynik (Sandia National Laboratories, USA). Through simulations carried out with the Surface Evolver software, Dr Kraynik showed how the foam structure and packing can be predicted, including the intermittent topological transition cascade that arises in the foam structure, and how their shear modulus and yield stress can be calculated. The simulation results showed remarkable agreement with the seminal experimental results by Matzke (1946) and the shear modulus measurements of Princen & Kiss (1986).

An excellent tutorial on the rheology of entangled, highly branched flexible polymers was presented by Professor Gary Leal (University of California, Santa Barbara, USA). The concept of the tube model used to describe the linear and nonlinear behaviour of linear chain polymers was systematically extended to branched polymers, from star polymers with single branch points to multiple branches and subsequently branched polymers with multiple branch points. Conceptual issues arising in recent attempts to describe asymmetric branched polymers, with arms of differing lengths, were also elucidated in the lecture.

These fundamental concepts conveniently set up a logical framework for the subsequent lecture by Professor Eric Shaqfeh (Stanford University, USA) on the non-equilibrium dynamics associated with a single stained DNA strand in dilute and concentrated solutions. Beginning with a discussion of how the use of video fluorescence microscopy to visualize DNA chains has revolutionized the field of polymer solution rheology, Professor Shaqfeh reviewed the state of research in single DNA dynamics studies in shear flow for isolated molecules in solution, before going on to discuss a new application of single molecule microscopy involving DNA dynamics in highly entangled solutions. In order to understand the physical principles behind these measurements, the conformational dynamics were examined via molecular simulations employing a slip-link method, using multiple nonlinear, worm-like chains with different degrees of polymer entan-

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Figure 1 (left): A subset of the participants of the Complex Fluid & Microfluidics Workshop 2008.

Figure 2: The keynote speakers and organisers during lunch.

glement and molecular weights. The simulations demonstrate that the stretching in the chain length with increasing degree of entanglement, is responsible for a nonlinear shear stress plateau. Due to molecular individualism that occur in the polymer chain dynamics, it was also shown that mean-field approximations are insufficient to describe the chain dynamics, at least those arising under experimental conditions. Finally, Professor Shaqfeh described the tumbling dynamics of the DNA through the power spectral density of fluctuations in the chain length.

Professor Justin Cooper-White (University of Queensland, Australia) offered a vibrant discussion on the elastic instabilities associated with the flow of dilute and semi-dilute polyethylene oxide solutions in a microfluidic slit contraction. This began with a review of earlier work in which the flow instability regimes from pseudo-Newtonian behaviour to steady viscoelastic flow, the onset of inertial-elastic instabilities and finally the appearance and growth of vortical structures, were characterised as a function of the Reynolds and Wissenberg numbers. Interestingly, geometric changes downstream of the contraction were observed to suppress the inertial-elastic instabilities upstream. The contraction length was also observed to play an important role in the fluid's viscoelastic response.

The other three speakers presented topics of a slightly different nature, adding to the flavour of the broad scope of the workshop, which was designed with a view that a variety of motifs from polymeric liquids, colloidal suspensions, physiological/biological fluids and granular materials (under the general umbrella of complex fluid systems), to fluid actuation, micro-mixing, separation, bioparticle sorting and DNA manipulation (under the general micro/nanofluidics theme), would be covered.

Professor Sriram Ramaswamy (Indian Institute of Science, Bangalore, India) brought to the table a discussion on the active hydrodynamics of colloidal particles as a framework to describe the statistical mechanics of the motion arising from collections of self-propelled living matter such as shoals of fish or filamental bacteria. This was extended to describe the instability associated with a thin-film suspension of these self-driven particles, which arises due to the coupling between the active stresses and the particle orientation with respect to the film interface.

Professor Nadine Aubry (Carnegie Mellon University, USA) described her work on electrokinetically-driven microfluidic phenomena, in particular that involving the influence of the electric-field on a single and a collection of particles suspended in a fluid medium. Electrostatic interactions between particles were observed to give rise to particle chains due to the induced dipoles arising as a consequence of the applied electric field. Experiments and numerical simulations were also presented to show how particles at the interface of two immiscible liquids assemble onto two-dimensional lattices under the application of a transverse electric field due to the combination of capillary and electrostatic interactions. Finally, instabilities at the interface of two stratified miscible fluids in a microchannel, invoked through the application of an electric field, were discussed, with particular reference to its potential for driving efficient micro-mixing.

Numerical and asymptotic models to describe the fluid-structure interactions of biological interfaces within a physiological system were presented by Professor Oliver Jensen (University of Nottingham, UK). These were constructed to describe, for example, the squeezing and spreading of the interstitial fluid between a deformable cell and the endothelial lining of capillaries and the respiratory tract. Adhesion forces arising from the intermolecular bonds cell receptors and their ligands on the wall were modelled through springs, whose torsion provide resistance to bond tilting and breakage as the cell peels (as described by a quasi-steady travelling wave) and rolls along the wall. Cell sliding motion was also discussed through the analogue of two parallel plates whose sliding friction arises again due to the adhesion forces modelled by the springs.

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As the last session of each day, a discussion forum was organized in which all the speakers who spoke during the day faced the audience and answered questions on their topics. Both the discussion sessions were lively and extended, and gave an opportunity for the speakers to carefully address issues raised by the members of the audience. Points that were discussed included the limitations of the tube model in describing deviations from equilibrium dynamics of entangled polymeric systems and the role of molecular individualism in these systems; the treatment of free volume effects due to the increased number of chain ends in branched polymers; the effect of the electric field in altering the contact angle of particles in small scale flows, and the possible effect of oscillatory electric fields; the treatment of viscous stresses and polydispersity in the modelling of foam rheology; the importance of hydrodynamic interactions in the description of the microrheology of colloidal suspensions; the role of fluorescent tags in altering the dynamics of the stained polymer; the motivations behind the use of polyethylene oxide solutions for the characterization of viscoelastic flow in microfabricated contraction geometries; the influence that the penetrability of cells to liquids would have on the deformability of biological interfaces; and the applicability of concepts from active particle hydrodynamics on a large scale such as to flocks of birds. These broad ranging discussions added significantly to the pedagogic value of the workshop to students and researchers alike.

Feedback from the participants was certainly very positive. In general, the participants found the workshop to be extremely beneflcial in terms of stimulating further developments in these research areas as well as facilitating new collaborative networks. Given the encouraging response, we certainly hope that successive workshops along similar themes will be held.

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