Australian Society of Rheology

2012 Rheology Lecture Series

In 2012 the Australian Society of Rheology (ASR) is presenting a lecture series which is open to anyone interested in the flow and deformation of matter. The next lecture in the series is at RMIT University (City campus).

DATE: Tuesday, 24th January, 2012

TIME: 5:30-6:00 pm: Refreshments (nibbles and drink)
6:00-7:00 pm: Presentation

SPEAKER: **Professor Gareth H. McKinley (MIT, USA)**
Hatsopoulos Microfluids Laboratory, Dept of Mechanical Engineering,
Massachusetts Institute of Technology (MIT), Cambridge, MA 02139, USA

VENUE: Research Lounge, RMIT University

Research Lounge, Access via 5th Floor, Building 8, City Campus, RMIT University, Melbourne, Vic 3000 (opposite Swanston Library)

Transport and Parking

The City campus is located diagonally opposite Melbourne Central Station. Most Melbourne trams travel along Swanston St. While car parking is not available on the city campus, numerous private car parks offer parking facilities in, or close to the city.

1. Professor Gareth H. McKinley (MIT, USA) (with Randy H. Ewoldt, Christopher Dimitriou)

Title: Rheological Fingerprinting of Complex Fluids and Soft Solids

Abstract: Viscoelastic materials, such as many biomaterials and non-Newtonian fluids, typically experience mechanical loading which evokes a nonlinear rheological response. Such complex materials can provide novel functionality in biological and engineered systems. However, standard rheological characterization techniques are often insufficient to appropriately describe nonlinear viscoelasticity. We introduce a complete, low-dimensional language and framework (or *ontology*) for characterizing nonlinear viscoelasticity using large amplitude oscillatory shearing (LAOS) deformations.

For many material systems the common practice of reporting only "viscoelastic moduli" as calculated by commercial rheometers (typically the first harmonic Fourier coefficients) is insufficient and/or misleading in describing nonlinear material phenomena. The mathematical structure of the nonlinear response is fully captured by higher Fourier harmonics, but these coefficients lack a clear physical interpretation. We build on the earlier geometrical interpretation of Cho et al. (2005) that decomposes a nonlinear stress response into elastic and viscous stress contributions using symmetry arguments. We then use Chebyshev polynomials as orthonormal basis functions to further decompose these stresses into harmonic components having physical interpretations. This framework naturally generates alternative measures of viscoelastic moduli, all of which reduce to G' & G" in the linear regime, but offer different physical insight into the nonlinear response. The results can be represented in the 2D space of frequency and strain-amplitude first discussed by Pipkin and generate a unique '*rheological fingerprint*' of a viscoelastic material. We use this Chebyshev decomposition to propose physically meaningful material measures and clearly-defined concepts such as strain-stiffening/softening

and shear-thickening/thinning which can be used in conjunction with graphical representations of the strain, strain-rate, and stress as the coordinate axes ('Lissajous-Bowditch' curves). The new ontology and associated software package (MITlaos) is general enough to be applied to any viscoelastic material, ranging from purely elastic to purely viscous. In general, LAOS fingerprinting is invaluable for both quantifying and describing the nonlinear rheological response of a wide range of materials including biopolymer gels, regenerative polymer networks, entangled melts and micellar solutions as well as extracting model parameters for nonlinear constitutive models. To illustrate the approach we examine the nonlinear rheological response of various soft materials including pedal mucus gel from terrestrial gastropods, wormlike micelle solutions, hydrogels and emulsion-based oilfield drilling fluid. These latter examples motivate our ongoing work on extending this ontology to quantitative description of elasto-visco-plastic materials and yielding transitions via large amplitude controlled stress deformations.