BSR Mid-Winter Meeting Timetable and Abstracts
Rheology of Active, Evolving and Responsive Systems
12th and 13th December 2022

I1	Monday 10.10-10.50	Dr Charley Schaefer (York)	Flow-Induced Self-Assembly of Native Silk Protein
C1	Monday 10.50-11.15	Dr Manlio Tassieri (Glasgow)	Machine learning opens a doorway for microrheology with optical tweezers in living systems
I2	Monday 11.20-12.00	Dr Anders Aufderhorst-Roberts (Durham)	Molecular and Mesoscale Mechanics of Folded Protein Hydrogels
C2	Monday 12.00-12.25	Dr Leandro Rizzi (Viçosa, Brazil)	Heterogeneities and non-markovian walks in the microrheological response of gels
C3	Monday 12.25-12.50	Dr Carl Reynolds (Birmingham)	Structure and rheology of electrode slurries and implications for battery manufacture
C4	Monday 12.50-13.15	Frankie Haywood (Bristol)	A new HPHT rheometer for measuring the viscosity of volatile-bearing magmas.
C5	Monday 14.00-14.25	Dr Paul Grassia (Strathclyde)	Three Bubbles Good, Two Bubbles Better
C6	Monday 14.25-14.50	Dr Patrick Ilg (Reading)	Simulating the Flow of Ferrofluids with Multiparticle Collision Dynamics
C7	Monday 14.50-15.15	Joshua Cummings (Strathclyde)	Numerical Investigation of Non-Newtonian Fluid Flows in a Multi-Inlet Sudden Expansion
I3	Monday 15.30-16.10	Dr Kirsty Wan (Exeter)	Controllable self-propulsion at low-Reynolds number
C8	Monday 16.10-16.35	Dr Becky Hudson (Swansea)	Characterising the evolving rheological properties of gelling materials using chirp protocols on a stress controlled rheometer
C9	Monday 16.35-17.00	Elton Lima Correia (Oklahoma, USA)	2D glass transition of Janus particle-laden interface
	Monday 17.00		Close
	Tuesday 10.00		Re-Opens
I4	Tuesday 10.05-10.45	Dr Davide Michieletto (Edinburgh)	Topologically Active Polymers
C10	Tuesday 10.45-11.10	Dr Prachi Thareja (Gandhinagar, India)	k-carrageenan hydrogels for 3D printing and water remediation
I5	Tuesday 11.30-12.10	Prof Alan Smith (Huddersfield)	Rheo-Dissolution: Simultaneous Measurement of Rheology and Drug Release
C11	Tuesday 12.10-12.35	Dr Francesco Del Giudice (Swansea)	Space-time Evolution of Microfluidic Crystals from dilute viscoelastic suspensions
C12	Tuesday 12.35-13.00	Dr Abarasi Hart (Sheffield)	Effect of Polyvinylidene Fluoride Molecular Weight on Rheology and Microstructure of Slurry of LiNi0.8Mn0.1Co0.1O2 and Carbon Black
I6	Tuesday 13.30-14.10	Prof Stephen Wilson (Strathclyde)	BSR Annual Award winner, 2022
I7	Tuesday 14.10-14.45	Dr Joseph Cousins (Strathclyde)	Vernon Harrison Prize winner, Mathematical modelling and analysis of industrial manufacturing of liquid crystal displays
	14.45		close

	Abstracts	
	presenter	**title**
I1	Dr Charley Schaefer	Flow-Induced Self-Assembly of Native Silk Protein
	Silk fibres have an out-of-equilibrium semi-crystalline structure that emerges in response to shear and extensional flow. This process of natural silk spinning requires orders of magnitude less energy input than for the industrial spinning of synthetic polymer fibres. To understand how this class of polymers responds to strong flow, we developed a coarse-grained (quasi-)single-chain model that describes the intermolecular reversible crosslinks in an effective environment. Through simulations, and supported by analytical approximations, we found that the stochastic opening and closing of reversible crosslinks leads to the emergence of highly disperse dynamical chain conformations. We found that the fraction of highly stretched chain segments, which are needed to nucleate crystals, is finely controlled and optimised by both the molecular design of the polymer and by the flow rate.	
I2	Dr Anders Aufderhorst-Roberts	Molecular and Mesoscale Mechanics of Folded Protein Hydrogels
	In nature, folded globular proteins carry out a wide variety of functions that arise from their ability to undergo conformational change under mechanical strain. This precise mechano-responsiveness makes them attractive candidates as soft responsive materials, for example by chemically crosslinking them into hydrogel networks. However, it is unclear to what extent their mechanical properties have structural, as opposed to molecular origins. To address this, we probe hydrogels of the muscle-derived protein $I27_5$, using a multimodal linear and nonlinear rheology approach to examine their viscoelasticity, reversibility, and fracture. In the linear viscoelastic regime, we show that the hydrogels consistently exhibit power-law viscoelasticity with a power law exponent $\beta = 0.3$. This is consistent with a fractal meso-structure, with calculated fractal dimension d_f ~2.5. Probing the hydrogels at high strains, in the nonlinear viscoelastic regime, we observe simultaneous strain stiffening and energy dissipation, indicating alignment and unfolding of the folded proteins on the molecular scale. Remarkably, this behaviour is highly reversible, as the value of β, d_f and the viscoelastic moduli return to their equilibrium value, even after multiple cycles of deformation. Analysis of repeated loading curves reveals a gradual accumulation of stress in the hydrogel after each deformation cycle, which likely contributes to an eventual fracture at high strain. Together, these findings highlight a previously unrevealed diversity of viscoelastic properties that have structural, rather than molecular, origins. These considerations may be key to controlling the viscoelasticity of folded protein hydrogels as well as for their envisaged applications as biomaterials.	
I3	Dr Kirsty Wan	Controllable self-propulsion at low-Reynolds number
	Many small aquatic organisms self-propel using flexible appendages called cilia, arranged in diverse topologies and configurations. Whenever multiple cilia exist in close proximity they will invariably interact, leading to the emergence of many types of local and global coordination patterns. Adjacent cilia can communicate physically through the fluid, but they can also do so via elastic or cytoskeletal linkages through the cell or tissue surface. In this talk we will consider the strategies and consequences of distinct modes of ciliary coordination and propulsion in diverse organisms ranging from single-celled eukaryotes (protists), to the ciliated larvae of marine invertebrates. We will also discuss how ciliary arrays select different modes of synchrony or metachrony, and the implications of this for controlled navigation.	

I4	Dr Davide Michieletto	Topologically Active Polymers
	Polymer physics successfully describes most of the polymeric materials that we encounter everyday. In spite of this, it heavily relies on the assumption that polymers do not change topology (or architecture) in time or that, if they do alter their morphology, they do so in equilibrium. This assumption spectacularly fails for DNA in vivo, which is constantly topologically re-arranged by ATP-consuming proteins within the cell nucleus. Inspired by this, we study study entangled systems of DNA which can selectively alter their topology and architecture in time and may expend energy to do so. Solutions of topologically active DNA can display unconventional viscoelastic behaviours which I will discuss in this talk.	
I5	Prof Alan Smith	Rheo-Dissolution: Simultaneous Measurement of Rheology and Drug Release
	Drug delivery systems that undergo sol-gel transitions *in situ* can be used to increase drug retention time at the desired physiological site of action and control drug release. The rheological behaviour of polymers used in such formulations, when exposed to physiological conditions, can therefore have a great impact upon drug release rates and ultimately affect the efficacy of the drug. Rheological measurements of gelation and drug release from such systems, are usually performed separately, which is not particularly representative of the realistic scenario. This is due to difficulties associated with changing the chemical environment to simulate initial contact with physiological fluids during rheological measurements using existing methods. Controlling the chemical environment is critical for formulations that have rapid sol-gel transitions mediated by changes in pH or presence of ionic crosslinkers in physiological fluids. Here, we have developed a 3D printed rheo-dissolution cell (consisting of a fine mesh and a 55 ml flow though reservoir) which can replace the lower plate of rheometer and allows samples to make contact with simulated physiological fluids during rheological measurements. In addition, the flow though system provides the option to change the physiological solution the formulation is exposed to as rheological measurements are in process. Furthermore, the physiological fluid can be sampled during the rheological measurements, allowing quantification of drug release from the *in situ* gel formulation. This technique provides an insight to the impact changes in rheological behaviour have on the release of drugs in real-time and could be utilised in early stages of the development process when designing *in situ* gelling drug delivery systems. The wider application of this system is the ability to test any polymer, for many different industrial applications, where there may be a need for rapid or slow gelation while monitoring molecules that are taken up or released from the sample in real time.	
I6	Prof Stephen Wilson BSR Annual Award Winner	BSR ANNUAL AWARD LECTURE 2022
	By employing a judicious combination of analytical (often asymptotic) and numerical methods it is sometimes possible perform detailed analyses of paradigm problems which are able to bring greater understanding of both the underlying physics and/or the industrial applications of practically important situations. In this talk I will describe a number of such investigations arising in the study of liquid crystals, thixotropic fluids, and thin-film flow (notably rivulet flow) of non-Newtonian fluids (see, for example, references [1]-[7]). In particular, this talk describes various aspects of joint work with a number of colleagues, notably Dr Brian Duffy, Prof. Nigel Mottram, and Dr David Pritchard, and former PhD students Fatemah Al Mukahal, Judit Quintains Carou, Andrew Croudace, Catriona McArdle, and Yazariah Yatim, all of whom I thank for their unique and invaluable contributions.	

	[1] Yatim, Y.M., Wilson, S.K., Duffy, B.R. "Unsteady gravity-driven slender rivulets of a power-law fluid" J. Non-Newt. Fluid Mech. 165 1423 (2010) [2] McArdle, C.R., Pritchard, D., Wilson, S.K. "The Stokes boundary layer for a thixotropic or antithixotropic fluid" J. Non-Newt. Fluid Mech. 185-186 18 (2012) [3] Pritchard, D., Duffy, B.R., Wilson, S.K. "Shallow flows of generalised Newtonian fluids on an inclined plane" J. Eng. Math. 94 115 (2015) [4] Pritchard, D., Wilson, S.K., McArdle, C.R. "Flow of a thixotropic or antithixotropic fluid in a slowly varying channel: the weakly advective regime" J. Non-Newt. Fluid Mech. 238 140 (2016) [5] Al Mukahal, F.H.H., Duffy, B.R., Wilson, S.K. "Rivulet flow of generalized Newtonian fluids" Phys. Rev. Fluids 3 083302 (2018) [6] Pritchard, D., Croudace, A.I., Wilson, S.K. "Thixotropic pumping in a cylindrical pipe" Phys. Rev. Fluids 5 013303 (2020) [7] Cousins, J.R.L., Duffy, B.R., Wilson, S.K., Mottram, N.J. "Young and Young-Laplace equations for a static ridge of nematic liquid crystal, and transitions between equilibrium states" Proc. Roy. Soc. Lond. A 478 (2259) 20210849 (2022)	
I7	Dr Joseph Cousins Vernon Harrison Prize winner	Mathematical modelling and analysis of industrial manufacturing of liquid crystal displays
	Liquid crystal displays (LCDs) are now ubiquitous in every aspect of modern life. Televisions, computer monitors, mobile phones and tablets are now used for hours every day by most of the world's population. Each of these LCDs makes use of the optoelectrical properties of a thin layer of nematic liquid crystal (nematic), which is now widely manufactured using the One Drop Filling (ODF) method. In the ODF method, nematic is dispensed onto a lower substrate in the form of droplets, which are allowed to equilibrate and then an upper substrate is lowered towards the droplet-laden lower substrate, squeezing the droplets together to form the thin layer of nematic. Although the efficiency and speed of the ODF method have significantly improved LCD manufacturing, the method involves large nematic flow speeds, which may cause transient flow-driven distortion of the nematic molecules at the substrates from their required orientation. This may then lead to permanent or semipermanent flow-driven misalignment of the orientation of the molecules in crucial substrate alignment layers, which may, in turn, degrade the optical properties of the final display. Indeed, flow-driven misalignment of the orientation of the molecules in the alignment layers may be the cause of unwanted optical effects that can occur in the ODF method known as "ODF mura". Motivated by a need for further understanding of flow-driven misalignment of the orientation of the molecules in the substrate alignment layers, we formulate and analyse mathematical models for various aspects of the nematic fluid dynamics in the ODF method.	
C1	Manlio Tassieri (Glasgow)	Machine learning opens a doorway for microrheology with optical tweezers in living systems
	It has been argued [Tassieri, Soft Matter, 2015, 11, 5792] that linear microrheology with optical tweezers (MOT) of living systems "is not an option", because of the wide gap between the observation time required to collect statistically valid data and the mutational times of the organisms under study. Here, we have taken a first step towards a possible solution of this problem by exploiting modern machine learning (ML) methods to reduce the duration of MOT measurements from several tens of minutes down to one second. This has been achieved by focusing on the analysis of computer simulated trajectories of an optically trapped particle suspended into a set of Newtonian fluids having viscosity values spanning three orders of magnitude, i.e. from 10^{-3} to 1 Pa·s. When the particle trajectory is analysed by means of conventional statistical mechanics principles, we explicate for the first time in literature the relationship between the required duration of MOT experiments (T_m) and the fluids relative	

	viscosity (η_r) to achieve an uncertainty as low as 1%; i.e., $T_m \cong 17\eta_r^3$ minutes. This has led to a further evidence explaining why conventional MOT measurements commonly underestimate the materials' viscoelastic properties, especially in the case of high viscous fluids or soft-solids such as gels and cells. Finally, we have developed a ML algorithm to determine the viscosity of Newtonian fluids that uses feature extraction on raw trajectories acquired at a kHz and for a duration of only one second, yet capable of returning viscosity values carrying an error as low as ~0.3% at best; hence the opening of a doorway for MOT in living systems.	
C2	Leandro Rizzi (Brazil)	Heterogeneities and non-markovian walks in the microrheological response of gels
	I will present a simple and self-consistent approach based on microrheology [1] that allows one to obtain the mechanical response of viscoelastic materials during their gelation transition. By considering a non-markovian Langevin equation, I obtain general expressions for the mean-squared displacement and the time-dependent diffusion coefficient that take into account the heterogeneities of the gel. I will show that these quantities can be directly related to the memory kernels and the response function and provide estimates for the complex shear modulus and the complex viscosity of the material. The approach is validated by applying it to describe experimental data on chemically cross-linked polyacrylamide through its sol-gel transition. [1] L. G. Rizzi. Journal of Rheology 64 (2020) 969. DOI: http://doi.org/10.1122/8.0000034	
C3	Carl Reynolds (Birmingham)	Structure and rheology of electrode slurries and implications for battery manufacture
	Slurry casting is the most common method of electrode manufacture, and with heavy investment into current manufacturing lines, it will be for some time. It is vital to optimise these lines for best performance and allow rapid adoption of novel, more sustainable, drop-in technologies. In slurry casting, active materials are mixed into a slurry and coated onto a current collector which is then dried, calendared, and assembled into a cell. Currently, these stages are optimised by trial and error and there is a need for advanced metrology and process understanding to enable in-line control, rapid optimisation, and reduction of wastage in time and materials. The rheological properties of the slurry are key in the suite of metrology for process control during electrode manufacture, as they offer important insights into the slurry structure and are vital to the microstructure of the final coating. High slurry viscosity creates excess pressure and limits coating speed, elasticity causes instabilities leading to coating defects and high flow causes slumping leading to thin, poorly structured coatings. However, due to differing solvent systems and components, and the complex nature of the many competing interactions, finding the source of these detrimental rheological properties can be difficult. We discuss the rheology of industrial formulations, the underlying structure that gives rise to these flow properties and how rheological methods, including shear and extension, can be used for process control.	
C4	Frankie Haywood (Bristol)	A new HPHT rheometer for measuring the viscosity of volatile-bearing magmas.
	Magma rheology exerts a primary control on a wide range of volcanic processes, from the extraction of magma in the deep earth, during its transport towards the surface, and finally the way it is extruded at the surface as a gentle effusive flow or a violent explosive eruption. Throughout this journey, the magma experiences significant changes in pressure and temperature, that affect the viscosity of the melt, but also the role of crystal and volatile	

	phases (especially H2O) in the bulk rheology. It is clear that reliable measurements of the viscosity of volatile-bearing magmatic magmas at these high pressures and high temperatures (HPHT) are needed to constrain models and predict transport and eruptive behaviour. However, current viscosity measurements of high temperature materials are often limited to anhydrous, ambient pressure conditions as a consequence of the difficulty posed in adding a pressurised chamber to a rheometer. Here, we introduce a new HPHT rheometer capable of achieving pressures and temperatures up to 250 MPa and 1200C and measuring viscosities in the range 100Pas-30,000Pas. The rheometer has a concentric cylinder configuration which is able to achieve HPHT conditions due to a magnetic coupling which links an internal spindle to an external rheometer head. The HPHT rheometer produces viscosity measurements with an uncertainty of ±5%, the technical features and challenges that contribute to this uncertainty will be presented.	
C5	Paul Grassia (Strathclyde)	Three Bubbles Good, Two Bubbles Better
	The flow of just three bubbles along a channel captures many of the features of foam flow in porous media. Here a situation is considered in which bubbles are arranged in a staircase fashion zig-zagging across a channel (two bubbles attaching to one channel wall, but just a single bubble attaching to the other). The resulting topological asymmetry also implies asymmetry in the drag forces associated with foam film motion. When the system is driven fast enough, the imbalance in drag can cause the staircase structure to break. Bubbles then exchange neighbours during a so called T1 topological transformation. Previous work [1,2] has shown that the three-bubble system is sufficiently complex that it admits different ``flavours'' of T1 transformation, variously called T1c, T1u, T1l, and so on. Which flavour of T1 is selected depends on bubble sizes relative to channel size and also upon imposed driving pressure. All that previous work however focussed solely on the first T1 that the three-bubble system encountered [1,2]. The present contribution therefore examines the entire sequence of T1 transformations that a three-bubble system can undergo. It is revealed that that the daughter states produced after the first T1 tend themselves to be unstable, meaning they are short-lived intermediates which break again via additional T1 transformations. Eventually the three bubble system reaches a stable final configuration that can then simply flow along. However, like the T1 transformations that produced them, these final configurations themselves come in different flavours. Which flavour is selected depends on bubble size relative to channel size and upon imposed driving pressure. A feature common to all the final configurations however is topological symmetry: in the final flowing structure, equal numbers foam films attach to either channel wall. One configuration which seems to be particularly favoured is a state in which just two bubbles stacked across the width of the channel continue flowing along, with a third bubble left behind altogether. This two-bubble configuration is found to have high mobility: not just higher mobility than the original parent three-bubble configuration, but also higher than any other competitor final configuration. [1] Torres-Ulloa C, Grassia P. 2022 Viscous froth model applied to the motion of two-dimensional bubbles in a channel: Three-bubble case. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 478, 20210801. doi: 10.1098/rspa.2021.0642 [2] Torres-Ulloa C, Grassia P. 2022 Viscous froth model applied to the dynamic simulation of two-dimensional bubbles in a channel: Three-bubble case. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 478, 20220487. doi: 10.1098/rspa.2022.0487	
C6	Patrick Ilg (Reading)	Simulating the Flow of Ferrofluids with Multiparticle Collision Dynamics
	Ferrofluid flow is fascinating since their fluid properties can conveniently be manipulated by external magnetic fields. Novel applications in micro- and nanofluidics as well as in biomedicine have renewed the interest in the flow of colloidal magnetic nanoparticles with a focus on small-scale behaviour. Traditional flow simulations of ferrofluids, however, often use	

simplified constitutive models and do not include fluctuations that are relevant at small scales. Here, we address these challenges by proposing a hybrid scheme that combines the multi-particle collision dynamics method for modelling hydrodynamics with Brownian Dynamics simulations of a reliable kinetic model describing the microstructure, magnetization dynamics and resulting stresses. Since both multi-particle collision dynamics and Brownian Dynamics are mesoscopic methods that naturally include fluctuations, this hybrid scheme presents a promising alternative to more traditional approaches, also because of the flexibility to model different geometries and modifying the constitutive model. The scheme was tested in several ways. Poiseuille flow was simulated for various model parameters and effective viscosities were determined from the resulting flow profiles. The effective, field-dependent viscosities are found to be in very good agreement with theoretical predictions. We also study Stokes' second flow problem for ferrofluids. For weak amplitudes and low frequencies of the oscillating plate, we find that the velocity profiles are well described by the result for Newtonian fluids at the corresponding, field-dependent viscosity. We also illustrate the new method for the benchmark problem of flow around a square cylinder. Interestingly, we observe that the length scale of the recirculation region is increased, whereas the drag coefficient is decreased in ferrofluids when an external magnetic field is applied compared with the field-free case at the same effective Reynolds number.

C7	Joshua Cummings (Strathclyde)	Numerical Investigation of Non-Newtonian Fluid Flows in a Multi-Inlet Sudden Expansion

A numerical investigation of the flow of non-Newtonian fluids through a two-dimensional planar sudden expansion, with three horizontal inlets of equal width is conducted using an in-house finite volume solver [1]. We first investigate flows of inelastic non-Newtonian fluids described by the power-law model for a range of multi-inlet configurations, highlighting the importance of the spacing ratio between the inlets and its influence on the resulting flow [2]. The spacing ratio between the inlets was found to be responsible for the formation of internal vortices, which lead to vortex interactions that affect the critical conditions causing the flow to become asymmetric and later time dependent. The study is then expanded to consider viscoelastic fluids of constant viscosity described by the upper-convected Maxwell (UCM) model. Initially, creeping flow conditions (i.e Reynolds number, Re, tending to zero) are considered to investigate the effects of elasticity, neglecting the influence of inertia, where vortex-stabilising effects due to elasticity have been observed. This is in agreement with observations of other studies that employ single-inlet planar sudden expansion configurations [3, 4]. Intermediate vortices at the sections between the inlets are not observed for creeping-flow conditions, however interesting interactions are observed for varying Weissenberg numbers (Wi). To account for inertial effects and investigate further the influence of vortex interactions, numerical simulations are performed at constant elasticity number (El = Wi/Re), which is representative of realistic experimental conditions.

[1] A. Afonso, P. J. Oliveira, F. T. Pinho, and M. A. Alves, "The log-conformation tensor approach in the finite-volume method framework," JNNFM, vol. 157, no. 1-2, pp. 55–65, 2009.

[2] C. G. Carson, R. J. Poole, K. Zografos, and M. S. Oliveira, "Multiple inlet sudden expansion flow of power-law fluids," JNNFM, submitted, 2022.

[3] R. J. Poole, M. A. Alves, P. J. Oliveira, and F. T. Pinho, "Plane sudden expansion flows of viscoelastic liquids," JNNFM, vol. 146, no. 1-3, pp. 79–91, 2007.

[4] G. N. Rocha, R. J. Poole, and P. J. Oliveira, "Bifurcation phenomena in viscoelastic flows through a symmetric 1:4 expansion," JNNFM, vol. 141, no. 1, pp. 1–17, 2007.

C8	Dan Curtis (Swansea)	Characterising the evolving rheological properties of gelling materials using chirp protocols on a stress controlled rheometer
	Frequency modulated (chirp) waveforms have previously been used for the rapid characterisation of viscoelastic materials using strain-controlled protocols (e.g. Geri et al., 2018). However, stress-controlled rheometric protocols are often more appropriate for strain sensitive or gelling materials. Here, we establish a stress-based chirp protocol (σ-OWCh) for the study of such materials. Experiments conducted on a single head rheometer under stress-controlled conditions suffer from an inherent strain offset which, for conventional rheometric protocols, can be removed using a baseline correction. Removing the strain offset using a baseline correction is not straightforward in chirp based rheometry. Therefore, we propose seeking the complex viscosity, $\eta^*(\omega)$, as an intermediate parameter for the complex modulus, $G^*(\omega)$, to overcome this problem. The σ-OWCh protocol is then demonstrated in the study of biopolymer gelation.	
C9	Elton Lima Correia (Oklahoma)	2D glass transition of Janus particle-laden interface
	Janus particles at fluid interfaces are still a growing field of research. The increase in binding energy, when compared to homogenous colloidal particles, and their dual characteristic open up new possibilities for novel applications. In many such applications, interfacial materials become subjected to deformations that produce compression/expansion and shear stresses. Therefore, it is important to understand the impact that the Janus character brings to interfaces. In this work, we study the microstructure of two-dimensional (2D) Janus particle monolayers formed at the air-water interface and examine the interfacial shear viscoelasticity with an interface rheometer that was adapted for in situ surface pressure control via compressions on a Langmuir trough. We extend concepts from bulk rheology to interfacial rheology as a tool to understand the viscoelastic behavior of the monolayer. Finally, by calculating the time relaxation spectrum from the measured 2D dynamic moduli, we conclude that a glass transition is taking place by analogy.	
C10	Prachi Thareja (Gandhinagar, India)	k-carrageenan hydrogels for 3D printing and water remediation
	κ-carrageenan is one of the seaweed-derived polysaccharides that is commonly used in the food additive and pharmaceutical industry. We report the gelation of 0.25-2 % w/v κ-carrageenan with salts by rheology, FTIR, and SEM. A synergistic increase in storage modulus was obtained with the mixed salt of KCl and $CaCl_2$. We then assess the printability of these hydrogel inks based on a simple extrusion process. The two extrudable pre-gel inks are further characterized using rheological measurements to mimic the printing process. The 3D printing of the two optimized inks is conducted using an Allvei 3 3D printer. Live/dead assay for human lung cancer cells seeded on the printed scaffolds was conducted, and cell viability > 95 % was observed. κ-carrageenan hydrogel beads containing TiO_2 nanoparticles are prepared by a simple injection technique, the beads are then crosslinked in a mixed salt solution of KCl and $CaCl_2$ to increase their strength. The rheological analysis of hydrogel discs prepared in a similar manner is conducted to approximate the elastic properties of the beads. It is observed that the crosslinking of discs using mixed salt leads to a synergistic increase in modulus. κ-carrageenan/TiO_2 beads crosslinked by mixed salt have higher storage modulus, higher adsorption capacity, and stability as compared to beads crosslinked by single salt. The κ-carrageenan/TiO_2 beads can degrade up to 78% of 5 ppm Methylene Blue in 210 minutes. These biopolymer beads can be regenerated by UV irradiation and reused. The beads	

	are further tested as column packing in a syringe for the adsorption of single and multicomponent dye systems.	
C11	Francesco Del Giudice	Space-time Evolution of Microfluidic Crystals from dilute viscoelastic suspensions
	Suspensions are generally considered to be diluted when they stop obeying the Einstein-Stokes relation, valid for non-interacting hard spheres. Experimental results from past works showed that this is generally true when the bulk particle concentration is less than around 5% in volume. We here show that rigid spherical particles confined in a microfluidic device with characteristic lateral side 5 times larger than the particle diameter display strong hydrodynamic interactions even at bulk concentrations as small as 0.25% in volume. By using a viscoelastic liquid as suspending medium, we observe the formation single-line microfluidic crystals, specifically strings of equally-spaced particles, generated by the viscoelasticity-mediated hydrodynamic interactions under pipe shear flow. The spacing between the particles is mainly controlled by geometrical parameters, and by the type of viscoelastic suspending liquid. The microfluidic crystal is formed because of a space-time evolution of particle distances while flowing in a straight channel, resulting from the hydrodynamic interactions between consecutive particles mediated by the fluid viscoelasticity.	
C12	Abarasi Hart (Sheffield)	Effect of Polyvinylidene Fluoride Molecular Weight on Rheology and Microstructure of Slurry of LiNi0.8Mn0.1Co0.1O2 and Carbon Black
	One of the critical unit operations in the manufacturing of Li-ion batteries is slurry processing. Electrode slurries are complex colloidal systems and highly viscoelastic, and their rheology varies greatly with polyvinylidene fluoride (PVDF) molecular weight (MW), resulting in coatings of varying microstructure. This study examined the influence of PVDF MW (180 kg.mol-1, 275 kg.mol-1, 530 kg.mol-1, 534 kg.mol-1, 600 kg.mol-1, and 1300 kg.mol-1) on the flow behaviour, yield stress, particle-polymer interactions and electrode film microstructure due to network of particles of LiNi0.8Mn0.1Co0.1O2 (NMC811) and carbon black (CB) bridge by polymer with electrode slurry comprising of NMC811, CB, PVDF and N-methyl-2-pyrrolidone (NMP). The slurries rheological behaviour was modelled using the Herschel-Bulkley equation. With increasing PVDF MW, there is a significant increase in the viscosity of the liquid phase (i.e., PVDF dissolved NMP), which was fitted with the empirical Mark–Houwink equation. Based on yield stresses and flow behaviour indexes, PVDF180 and PVDF275 electrode slurries tend towards Newtonian behaviour, PVDF530 and PVDF534 are highly shear-thinning, PVDF600 is moderately shear-thinning and PVDF1300 approximates Bingham plastic flow characteristics. CB particles form a percolated particle network based on bridging flocculation in PVDF-NMP solutions, causing a high yield stress that is higher than the corresponding electrode slurry. In addition, PVDF MW has a significant impact on the integrity of the internal network structures formed between NMC811 and CB particles with the most adsorbed PVDF MW showing the greatest structural breakdown and shear-thinning behaviour. Microstructurally, Scanning Electron Microscope (SEM) revealed cracks on the CB-PVDF layer and sedimentation of NMC811 particles in cathode films prepared with PVDF180 and PVDF275 slurries. Electrode films fabricated with PVDF530, PVDF534, PVDF600 and PVDF1300 have NMC811 particles dispersed and embedded within the percolated particle network of the CB particles bound together by PVDF.	