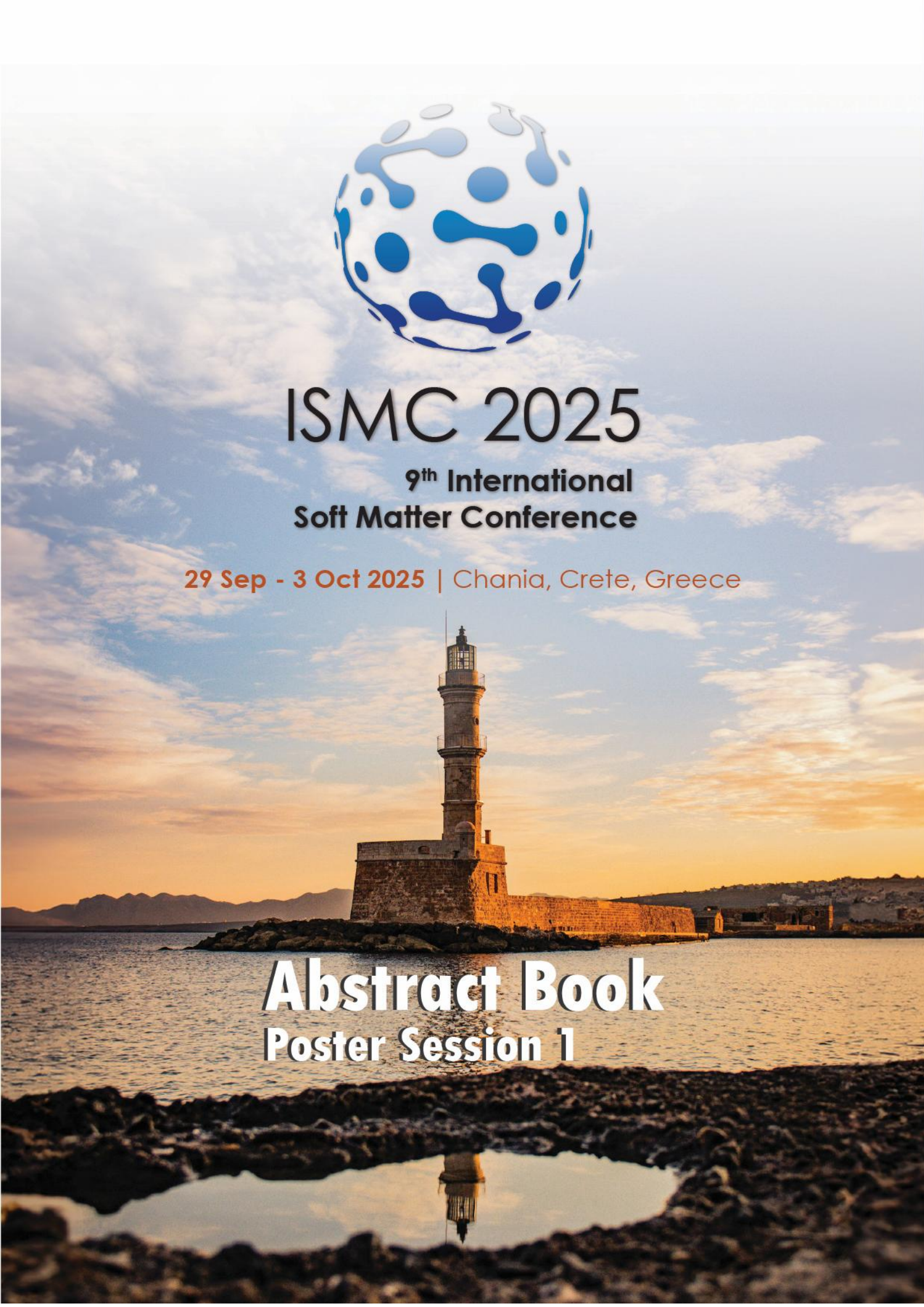

ISMC 2025

9th International Soft Matter Conference

29 Sep - 3 Oct 2025 | Chania, Crete, Greece

Abstract Book

Poster Session 1

POSTER SESSION 1

(Monday 29/09 - Tuesday 30/09)

A. Active matter

P.1

Propulsion of a Chiral Swimmer in a Weakly Viscoelastic Fluid

Ruby Shakya, P. S. Burada

Department of Physics, Indian Institute of Technology Kharagpur, Kharagpur 721302, India

Presenting author's e-mail: rubyshakya1407@kgpian.iitkgp.ac.in

We study the propulsion of a chiral swimmer [1] utilizing perturbation expansion up to second order in the Deborah number De in a weakly viscoelastic fluid, which is modeled as a second-order fluid [2]. We get analytical formulas for the swimming velocity, rotation rate, power dissipation, and efficiency by using the generalized reciprocity theorem [2]. The swimmer's characteristics include the normal stress ratio parameter b, which controls the viscoelastic response, and slip coefficients β, which categorize it as a pusher, puller, or neutral swimmer.

Our results reveal that, at the leading order in viscoelasticity, pushers experience enhanced propulsion and rotation, whereas pullers are hindered, and neutral squirmers maintain their velocity but exhibit reduced rotation. At second order, swimming speed decreases universally, whereas rotation is further amplified for pushers and pullers. Additionally, we find that increasing swimmer chirality consistently reduces power dissipation and enhances efficiency for all swimmer types, and that stronger viscoelastic effects amplify energetic costs for pushers while benefiting pullers. With possible uses in biomedical and microfluidic technology, these discoveries shed light on the hydrodynamics of synthetic and biological chiral micro-swimmers in complex fluids.

Keywords: Chiral swimmer, viscoelastic fluid, Stokes flow, Deborah number.

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P.2

Emergent dynamics of active elastic microbeams

Martinet Quentin [1], *Li Yuting* [1], *Aubret Antoine* [2], *Hannezo Edouard* [1], *Palacci Jérémie* [1]

[1] *ISTA Institute of Science and Technology Austria, Klosterneuburg, Austria* [2] *LOMA CNRS, Bordeaux, France*

Presenting author's e-mail: quentin.martinet@ist.ac.at

The engineering of machines at microscale is a challenge, owing to difficult assembly and reconfigurability at this size. We previously demonstrated a novel approach, templated assembly, which exploits optical forces and the activity of the colloids to create autonomous, mobile, stable reprogrammable [1] and self-positioning [2] metamachines, or machines made of machines.

Those metamachines however lack the ability to reconfigure and adapt their shape to their environment. It would be desirable to achieve machines with more sophisticated mechanical or dynamical response, such as responsive and flexible parts to go through a constriction. In a step in that direction, we investigate the static and dynamical properties of an active elastic beam: a micromachine made of 20-50 active colloids [3].

We first study the mechanical properties of the active beam, seen as a material, and estimate the Young modulus of the active beam through a micro tensile test with optical tweezers. This mechanical property is also independently validated with the persistence length measurements. We show the importance of the coupling of the individual active colloids with the hydrodynamic flow on the persistence of the motion of these active beams. We furthermore observe a complex dynamics of the microbeams clamped on one hand with optical tweezer. We show that the dynamics arise from the coupling between motion and hydrodynamic alignment and describe our experiments with an analytical model of an elastic beam driven by an active particle. The model notably unveils the emergence of self-oscillations in this internal driven material.

Keywords: Active solid, Emergent oscillations, Elasticity

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P.3

Tuning the run and tumble dynamics of active lipid vesicles

V. Willems[1], M. Lytte[2], E. Joseph[1], N. Martin[1], S. Deville[3,4], J.C. Baret[1,4], B. Sprinkle[2], L. Alvarez[1]

[1]Univ. Bordeaux, CNRS, CRPP, UMR 5031, F-33600 Pessac, France
[2]Applied Math and Statistics, Colorado School of Mines, 1500 Illinois St, Golden, CO 80401
[3]Institut Universitaire de France, 1 rue Descartes, 75231 Paris Cedex 05, France
[4]Institut Lumière Matière, UMR 5306, Université Lyon 1, France

Presenting author's e-mail: vivien.willems@u-bordeaux.fr

The creation of bioinspired microswimmers with adaptive motility presents significant potential to design advanced synthetic cells and active biomimetic systems. Active colloids are broadly used as model systems to design biomimetic microsimmers [1], yet their rigid and solid architecture limits their adaptability and functionality. Thus, giant unilamellar vesicles (GUVs), mimicking the properties of cell membranes [2], present an interesting route for the development of new soft artificial microswimmers.

Here we present reconfigurable active phase-separated Janus vesicles actuated with AC electric fields [3], with navigation patterns achieved through reversible membrane mixing processes that are influenced by environmental temperature and lipid membrane composition. Our Janus-like GUVs, fabricated from a ternary lipid mixture exhibiting liquid-liquid phase separation [4], exhibit self- propelled motion via induced charge electroosmosis when placed between parallel electrodes [5]. Interestingly, the fluid nature of the vesicle membrane allows the formation of asymmetry-symmetry transient states resulting in run-and-tumble events not observed in solid Janus particles. The tumble events lead to an enhanced reorientation of the vesicles motion, decoupled from thermal rotational diffusivity. We investigate how membrane fluidity and lipid phase miscibility influence the frequency of tumble events. By adjusting the lipid composition and using temperature as an external trigger, we modulate membrane fluidity and phase separation. Thus, we can a priori and in-situ program the occurrence of tumble events [6]. Our findings demonstrate the potential of synthetic cell membranes as architectures to replicate the intricate motility reminiscent of cells, providing an important step toward creating next-generation microswimmers.

Keywords: active matter, soft microswimmers, AC-electric field, Janus vesicles, phase-separation

Acknowledgements: V. W. and L. A. are thankful to Prof. M. Angelova, and Prof. H. Kellay for fruitful discussions. L.A. and V.W. acknowledge IdEx Bordeaux (France) for financial support. J.-C Baret acknowledges the support of the `Fondation Simone et Cino Del Duca' and of the Univ. Bordeaux (RRI Frontiers of Life). L.A. and V.W. thank Dr. N. Martin and Dr. E. Ducrot for access to confocal microscopy, Dr. J.P Chapel for help with DLS measurements.

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P.4

Dynamic Patterns formed in Extensible Chains due to Follower Activity

Sattwik Sadhu [1], Nitin Kriplani [1] and Raghunath Chelakkot [1]

[1]Department of Physics, Indian Institute of Technology Bombay, Powai, Mumbai-400076, Maharashtra, India

Presenting author's e-mail: 204120001@iitb.ac.in

Follower activity leads to a wide range of conformational and dynamical states in active semiflexible chains [1-2]. Such patterns are caused by the coupling between chain geometry and the activity. We study the emergence of such patterns in a flexible chain of active particles connected by elastic bonds, where the monopolar activity is directed along the local tangent of the chain [3]. The particle at one of the ends is either passive or driven in a fixed direction. In the overdamped and noiseless limit, we observed a range of dynamical steady states depending on the number of particles, bond stiffness, activity, and the definition of 'local tangent'. For example, with the second-order tangent definition, our model shows a helical and a wave-like dynamical state depending on the ratio of the external drive to the internal activity. However, switching to the first-order tangent definition gives qualitatively different states.

To understand the conformational and dynamical states in such chains without bending rigidity, we first study a more simplified system by removing the external drive and the excluded volume interaction. We consider a three-bead (N=3) system with a first-order tangent definition, which exhibits a circular trajectory in both underdamped and overdamped limits. Our analytical study explains the existence and the steady-state properties of closed trajectories in such systems. For systems with larger N, we observe various complex steady-state trajectories which are either bound or unbound in space. Such trajectories range from simple circles and waves to complex trochoids, and supercoiled structures. We found that these states also depend on whether the system is underdamped or overdamped. We have done numerical quantifications of the conformational and dynamical properties of such chains. Our analytical study provides the limiting behavior of such systems in the limit of large N.

Keywords: Bead-Spring model, Follower activity, Steady state properties

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P.5

Confinement Effects on Algal Motility in Freestanding Soap Films

A. Jarosik[1], A. Eremin[1]

[1] Department of Nonlinear Phenomena, Institute of Physics, Otto von Guericke University, Magdeburg 39106, Germany

Presenting author's e-mail: alexey.eremin@ovgu.de

We explore the dynamics of swimming algae *Chlamydomonas reinhardtii* in soap films, presenting a novel experimental setup to investigate micro-swimmer behaviour in quasi-2D environments. Using advanced methods to evaluate film thickness and swimmer trajectories, we identified three distinct swimming modes: a standard mode characterised by run-and-tumble behaviour, a circular mode, and mixed forms. The soap films, with their radially or elliptically varying thickness, create unique hydrodynamic conditions that significantly influence swimmer dynamics.

Our findings reveal that algae exhibit altered behaviour depending on the film's thickness, with cells unable to penetrate regions below a critical threshold. In these quasi-2D films, the gravitaxis commonly observed in three-dimensional environments is suppressed, causing algae to adopt circular swimming patterns across the film. Quantitative analysis of radial orientation and swimming speed further highlights notable changes in velocity linked to film thickness gradients.

These results enhance our understanding of micro-swimmer dynamics in constrained geometries, offering valuable insights into the behaviour of active matter under reduced dimensionality. This work contributes to the broader field of biophysical research, providing a framework for future studies on the interplay between hydrodynamics and swimmer behaviour in minimal environments.

Keywords: active matter, microswimmers, 2D fluids

Acknowledgements: This study was supported by DFG with projects ER 467/14-1

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P.6

Dynamics of a Chiral Active Granular Particle

Shubham Sharma [1], *Deepak Kumar* [2]

[1]*Department of Physics, IIT Delhi*
[2]*Department of Physics, IIT Delhi*

Presenting author's e-mail: phz218072@iitd.ac.in

Externally driven granular matter constitutes a useful system for studying the physics of active matter. Usually, self-propulsion is induced in individual grains by incorporating a suitable asymmetry in shape or some dynamical aspect, such as the frictional interaction. In this work, we introduce a simple model of grain, where the chiral activity emerges through a sequence of spontaneous symmetry breaking in the particle's kinetics. As a result, the system shows a distinct statistical response, including a non-Gaussian velocity distribution with multiple peaks, a broad power-law curvature distribution, and a bounded chirality probability along with a phase transition from passive achiral to active chiral state as a function of vibration amplitude. Our study establishes this as a model experimental system to study the non-equilibrium statistical mechanics of chiral active systems and can inspire novel locomotion strategies in robotics.

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P.7

Strong Confinement Effect on Sheared Puller-type Microswimmer Suspensions

Haruki Hayano [1], *Akira Furukawa* [2]

[1]*Department of Applied Physics, The University of Tokyo, Tokyo, Japan*
[2]*Institute of Industrial Science, The University of Tokyo, Tokyo, Japan*

Presenting author's e-mail: hayano@iis.u-tokyo.ac.jp

Active suspensions of microswimmers, such as bacteria swimming in a solvent, exhibit unique and anomalous properties that are absent in passive systems. While extensive simulation studies have focused on pusher-type swimmers like *E. coli* and *Bacillus subtilis*, which generate extensile flow fields, investigations of puller-type swimmers, such as *Chlamydomonas reinhardtii*, remain relatively limited.

In this study, we employ direct hydrodynamic simulations with model swimmers designed to mimic *Chlamydomonas reinhardtii* (Fig. 1) [1] to explore the behavior of sheared puller-type microswimmer suspensions. Puller-type swimmers create contractile flow fields along their swimming directions, leading to hydrodynamic interactions that preferentially align them vertically. Our simulations reveal that this alignment, along with the resultant orientational order of swimming motion, is especially pronounced near boundary walls where local swimmer density is enhanced. This near-wall effect predominantly determines the overall swimming dynamics and the rheological properties of suspensions. Moreover, our model suspensions exhibit a pronounced confinement effect. As the confinement height decreases, we observe a reversal in swimming direction and a crossover from viscosity enhancement to viscosity reduction. This is controlled by the interplay between the confinement size and the intrinsic trajectory radius of the swimmers under shear flow. In the extreme case of quasi-2D confinement, hydrodynamic interactions produce a remarkable collective motion among the swimmers.

Our findings reveal that puller-type microswimmers display anomalous rheological and collective behaviors that not only distinguish them from passive systems but also set them apart from pusher-type microswimmers [2].

Keywords: Microswimmer, Rheology, Hydrodynamic simulation

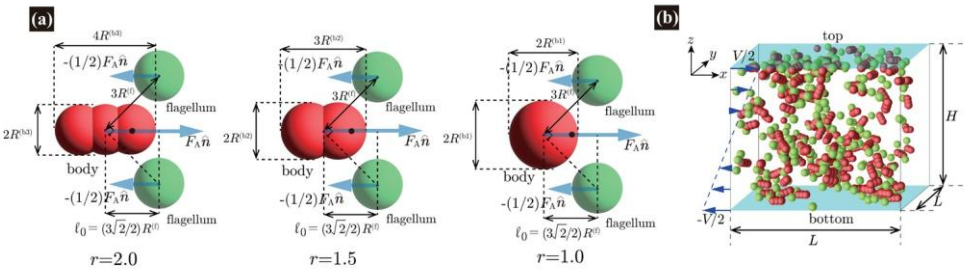

Figure 1. *(a) puller-type model swimmers (b) simulation system*

Acknowledgements: This work was supported by JSPS KAKENHI (Grants No.20H05619) and JSPS Core-to-Core Program "Advanced core-to-core network for the physics of self-organizing active matter" (Grants No. JPJSCCA20230002) and JST SPRING (Grants No. JPMJSP2108).

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P.8

Directed transport of active particles in an oscillating Channel

Rahul Sinha [1], *Ankit Gupta* [1] *and P.S. Burada* [1]

[1]*Department of Physics, IIT Kharagpur, Kharagpur, India*

Presenting author's e-mail: rahulsinha@kgpian.iitkgp.ac.in

We study the directed transport of non-interacting active particles confined in a 3D corrugated oscillating channel. Here, the oscillatory boundary influences particle movement along the channel direction. We vary the oscillatory frequency, amplitude, and diffusivity to examine their impact on the mean velocity($\langle v \rangle$) and effective diffusion (D_{eff}) of the particles. We find that the oscillatory channel induces directed transport, which is optimum at intermediate frequencies. This resonance effect [3] is due to the matching of the diffusive time scale with the time scale associated with the channel oscillations. These findings are corroborated by the semi-analytical results based on the Ficks-Jacob approximation [1,2] in the low frequency (adiabatic regime) regime. Here, the activity of the particles favors the directed transport, showing enhanced $\langle v \rangle$ and D_{eff}. Interestingly, D_{eff} decays when the translational and rotational diffusion constants in some regimes increase, supporting enhanced directed transport. These findings have significant implications for microfluidic device design and pumping the fluids and particles on the micro and nanoscale.

Keywords: Active Particles, Ficks-Jacob approximation.

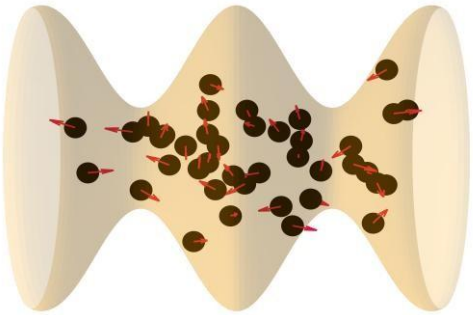

Figure *Snapshot of active particles confined in static corrugated channel.*

Acknowledgements: This work has been supported by the Indian Institute of Technology Kharagpur.

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P.9

Shaping Phase Behavior in Active Rod Systems: Swarming, Flocking, Active Turbulence, and Jamming

Yogesh Shelke[1], Anpuj Nair S[1], and Hanumantha Rao Vutukuri[1]

[1]Active Soft Matter and Bio-inspired Materials Lab, Faculty of Science and Technology, MESA+ Institute, University of Twente, 7500 AE Enschede, The Netherlands

Presenting author's e-mail: h.r.vutukuri@utwente.nl

Active soft matter systems continue to captivate researchers due to their relevance to biological and synthetic systems alike. Understanding and controlling emergent behaviors in these systems is essential for designing reconfigurable synthetic materials, advancing micro-robotics, and exploring collective cell migration. Among various synthetic active systems, self-propelled rods are currently a subject of great interest in active soft matter physics, serving as a minimal model due to their ability to mimic and provide deeper insights into biological phenomena such as bacterial swarms and biopolymers like microtubule assemblies.

In equilibrium systems, the shape anisotropy of individual building blocks is known to play a crucial role in creating exotic structures and controlling phase behavior. However, whether and how this shape anisotropy influences internally driven, out-of-equilibrium synthetic systems remains elusive. Here, we present combined experimental and simulation studies using colloidal self- propelled rods to elucidate when and how shape-induced alignment, aspect ratio, steric interactions, hydrodynamic interactions, and density fluctuations drive self-organization in active matter, drawing inspiration from the rich collective dynamics observed in bacterial systems such as *E. coli*.

We demonstrate that, as particle concentration increases, the system undergoes a distinct sequence of transitions, from run-and-tumble motion to swarming, active turbulence, formation of large clusters, and ultimately jamming [2]. By systematically varying rod aspect ratio and particle density, we construct a comprehensive state diagram mapping these distinct collective phases. We further characterize the spatiotemporal evolution of these states through analyses of velocity correlations and giant number fluctuations.

Our findings highlight how particle anisotropy, hydrodynamics, and density govern emergent structures, providing novel pathways to design and control collective behaviors in synthetic active materials and establishing clear parallels with biological phenomena, such as bacterial swarming and biofilm formation.

Keywords: Self-propelled rods, Active Turbulence, Flocking, Active Matter, Self-organization

Acknowledgements: We gratefully acknowledge the Netherlands Organization for Scientific Research (NWO) for funding through the NWO-M1 and XS grants.

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P.10

Collective flow patterns in 2D self propelled particle systems with constant average propelling velocity

Yonglun Jiang [1,2], Juliane U. Klamser [2], and Ludovic Berthier [3]

[1]Department of Physics, Chengdu University of Technology, Chengdu, China
[2]Laboratoire Charles Coulomb (L2C), Universit´e de Montpellier and CNRS (UMR 5221), Montpellier, France
[3]Laboratoire Gulliver, CNRS (UMR 7083), ESPCI Paris PSL, Paris, France

Presenting author's e-mail: yonglun.jiang@cdut.edu.cn

We study an overdamped model of self-propelled disks in two dimensions, with fixed propelling directions and a fixed average propelling velocity. An analogy between this active matter model and disordered solids under simple shear can be made[1]. The model can efficiently avoid dynamical arrest, and we find robust active mesoscale flows in the steady state. Such collective flow patterns lead to chaotic advection and transport over large length scales reminiscent of the active turbulence phenomenon observed in many other active systems. We further characterize the flow pattern through measurements of kinetic energy spectrum and spatial velocity correlations. We show that the characteristics of these flow patterns strongly depend on the driving velocity, and are distinct from active turbulent flows reported in other types of active systems.

Keywords: active turbulence, mesoscale flows, dense active matter systems

Acknowledgements: The work was supported by a grant from the Simons Foundation (#454933, L. B.)

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P.11

Self-Propulsion Trajectories of Active Particles Under an External Magnetic Field

Megha Varma [1], *Jatin Bhumarkar* [1], *Snigdha Thakur* [2], *and Venkateshwar Rao Dugyala**[1]

[1] *Soft Matter and Active Matter Lab, Department of Chemical Engineering, Indian Institute of Science Education and Research Bhopal, Bhopal, 462 066 Madhya Pradesh, India*

[2] *Department of Physics, Indian Institute of Science Education and Research Bhopal, Bhopal, 462 066 Madhya Pradesh, India*

Presenting author's e-mail: megha20@iiserb.ac.in

The study of the self-propulsion behavior of active particles and predicting their trajectories is essential for achieving desired paths by using external stimuli. This phenomenon is important in various applications such as drug delivery, transportation, water remediation, etc. In this regard, anisotropic magnetic micro-swimmers, platinum-coated hematite@silica cube particles (HM@SiO_2- Pt) with varying magnetic strengths have been used to study the effect of the geomagnetic field on their trajectories, using hydrogen peroxide as a fuel medium. Notably, these particles exhibit three different types of self-propulsion trajectories based on their magnetic strength: random, meandering, and straight, with their corresponding Mean Squared Displacements (MSD). The experimental and simulation studies revealed the competition between the rotational diffusivity (D_R) of the particle and the critical magnetic frequency (ω_c) in determining the self-propulsion trajectories. Rotational diffusivity tries to randomize the direction of self-propulsion, while critical magnetic frequency aligns the particles in the direction of the geomagnetic field by quenching the rotational diffusivity. The nature of these trajectories is characterised by the ratio of rotational diffusion time (τ_R) and magnetic relaxation time (τ_M), which are inversely related to D_R and ω_c of the particles, respectively. When $\tau_R/\tau_M << 1$, the particle follows a random trajectory, for $\tau_R/\tau_M \approx 1$, the particle exhibits meandering-like trajectories. While a particle with $\tau_R/\tau_M >> 1$, the trajectory becomes straight. In addition, the complex patterns are achieved by adjusting the orientation of the external magnetic field.

Keywords: Magnetic particles, Particle trajectories, Meandering trajectories

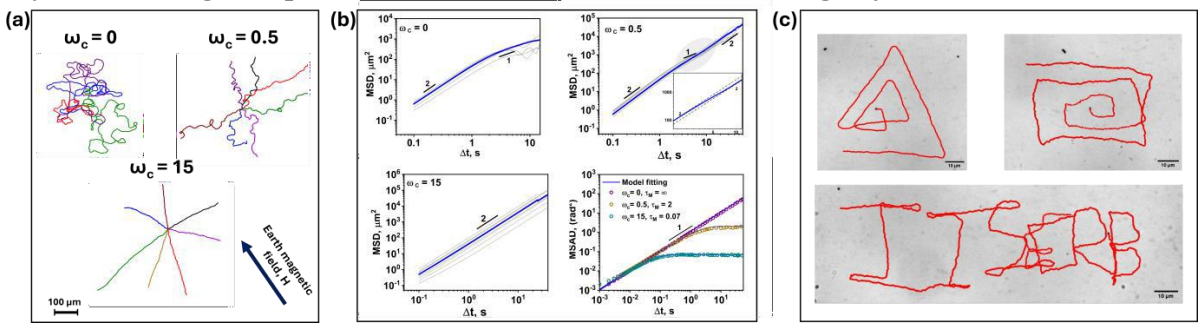

Figure 1. *(a) Self-propulsion trajectories of HM@SiO_2–Pt cube particles under 0.5 wt.% H_2O_2 with different magnetic strengths (b) Mean squared displacement and Mean squared angular displacement of corresponding particle trajectories (c) Experimentally controlled pattern drawings of spiral triangle, rectangle, and word IISERB.*

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P.12

Emergence of rotating clusters in active Brownian particles with visual perception

Radha Madhab Chandra , Alan Biju John , A.V Anil Kumar

School of Physical Sciences, National Institute of Science Education and Research, HBNI, Jatni, Bhubaneshwar 752050, India

Presenting author's e-mail: r adhamadhab.chandra@niser.ac.in

The formation of collective organization in active systems results from a balance of repulsive, attractive, and alignment interactions. It has been shown that a change in activity of individual components from the visual perception of the immediate neighbors induces group formation in various geometries[1]. We have investigated the group formation and subsequent dynamics of these intelligent active Brownian particles (iABPs) with visual perception using Langevin dynamics simulations. We observe the emergence of rotating clusters of these active particles when the visual perception of these particles are in the mid range. We found that these rotating clusters are the largest aggregates as revealed by the cluster size distributions and mean cluster sizes. We have also found that the persistent motion[2] of active particles with visual perception is intimately correlated with these emerging structures by analyzing the persistent probability as well as orientational correlation function. For rotating clusters, the persistence probability is quickly decaying and the orientational correlation function shows oscillatory behaviour.

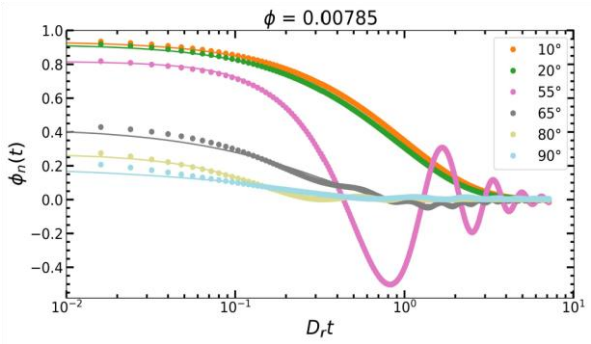

Figure 1. *Autocorrelation function for different vision angles*

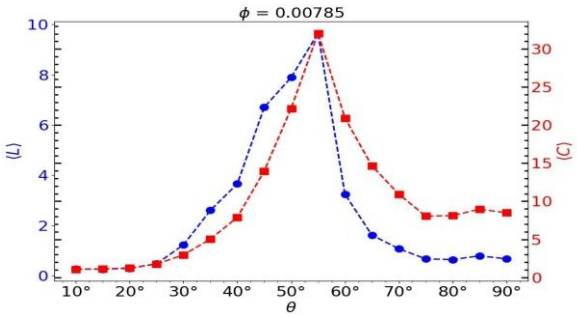

Figure 2. *Average clustersize and angular momentum for different vision angles*

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P.13

Aerotactic response and magnetic control of a magnetotactic bacterium (MSR-1)

Changsong WU[1], Xavier BENOIT GONIN[1], Thierry DARNIGE[1], Carine DOUARCHE[2], Daniel MIDTVEDT[3], Giovanni VOLPE[3], Rodrigo SOTO[4], Eric CLEMENT[1]

[1]PMMH, CNRS, ESPCI Paris, Sorbonne Université, 75005, Paris, France
[2]FAST, CNRS University Paris-Saclay, Orsay, France
[3]Physics Department, University of Gothenburg, Sweden
[4]Department of Physics, University of Chili, Santiago, Chile

Presenting author's e-mail:changsong.wu@espci.psl.eu

MSR-1 (magnetospirillum gryphiswaldense) are magnetotactic bacteria that can be grown in the lab [1]. They display two essential features also present in the wild: micro-aerotaxis and magnetotaxis, both properties intimately related to the MSR-1 ecological niche taking place at low O_2 concentration [2]. This condition is optimal for the synthesis of organelles (the magnetosomes) which are responsible for a biased motility under the earth magnetic field [3]. The interplay between micro-aerotaxis and magnetotaxis remains a subtle and still unraveled issue that needs to be fully modeled [4]. To clarify this question, we built a microfluidic chip where the environment in terms of oxygen level, oxygen gradients and magnetic field can be fully controlled around the niche oxygen concentration. This device allows to study the collective organization of MSR-1 populations in various conditions. In parallel, we designed and solved a simple theoretical model suited to reproduce the aerotactic response switches around the low O_2 niche concentration. Moreover, we built an Artificial Intelligence 3D Lagrangian tracking device suited to monitor under bright field MSR-1 trajectories. This technique solves difficulties about weak signal and deleterious action of green fluorescent protein excitation. We extract the statistical features of the motility under magnetic field via very long-time 3D tracking of the bacterium.

Keywords : Magnetotactic bacteria, microaerotaxis, 3D-Lagrangian tracking

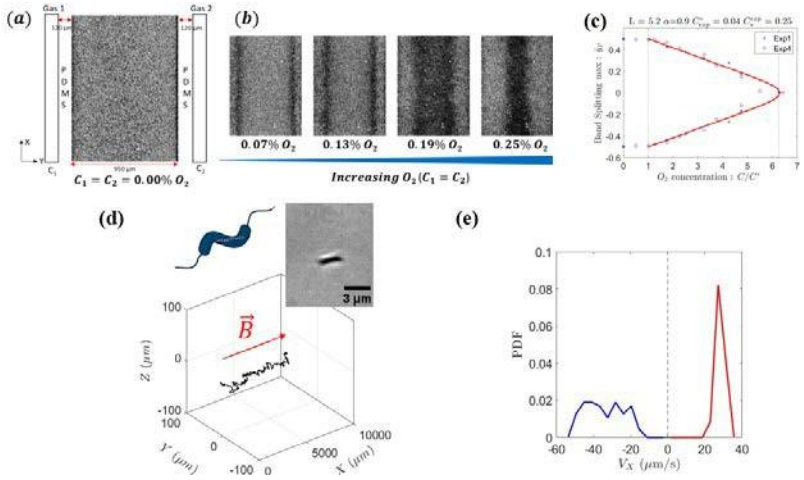

***Figure 1**. (a) Aerotactic band formation (darker region) of an MSR-1 population around the O_2 niche concentration in a PDMS microfluidic chip. O_2 concentrations are fixed at the channel edges via two gas channels mixing O_2 and N_2. (b) Increasing O_2 edge concentrations displays a transition from wall accumulation to split band and central band formation. (c) Band maxima positions as a function of the oxygen edge concentration with analytical prediction (in red). (d) 3D tracking during 350s of a "North-Seeker" MSR-1 under magnetic field. (e) Swimming velocities distribution.*

Acknowledgements: Grant ANR-21-CE30-"BAGMAG"

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P.14

Resonances in odd viscoelastic materials

Julius Kiln [1], *Alexander Mietke* [1]

[1]*Rudolf Peierls Centre for Theoretical Physics, Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom*

Presenting author's e-mail: julius.kiln@physics.ox.ac.uk

Active matter describes materials that are powered by microscopic sources of energy. This energy injection can lead to a wide variety of phenomena and unconventional material properties, including odd elasticity and odd viscosity [1,2]. Odd elasticity has been observed in two-dimensional living chiral systems made of starfish embryos [3]. Odd viscosity was experimentally identified in fluids made of spinning colloids [4]. Despite some analytical examination of these systems, a widely applicable method for solving force balance equations for odd materials on finite domains was so far not available.

The Papkovich-Neuber (PN) ansatz [5,6], introduced almost a hundred years ago, has proved an invaluable method for solving the force balance equation of a Stokes fluid and of a passive linearly elastic solid. This ansatz postulates an explicit solution in terms of harmonic scalar and vector fields, reducing the task of finding a solution to finding those harmonic fields, which is typically straightforward in separable coordinate systems. We generalise this idea and find an ansatz for odd solids and fluids that reduces to the known PN solutions in the limit of vanishing odd material parameters. Altogether, this provides a new and versatile method for finding analytical solutions to this class of problems. Using this result, we construct the displacement field for an odd elastic material in circular domain under both displacement and stress boundary conditions. Further extending this method to write displacement and flow solutions of an odd viscoelastic material explicitly, we study the relaxation response to initial deformations and to oscillatory boundary conditions, finding resonances at certain forcing frequencies even in an overdamped system. Finally, based on these new PN solutions, we propose rheological protocols for measuring odd material properties.

Keywords: Active Solids, Odd Elasticity, Odd Viscosity, Odd Rheology, Biophysics

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P.15

Spatiotemporal Organization of Active Matter Suspensions in Viscoelastic Medium: A Dissipative Particle Dynamics (DPD) Study

Simran Kapoor [1], Venkata Sathish Akella [1]

[1]*Soft Matter Lab, Department of Physics, Indian Institute of Technology Jammu, Jammu & Kashmir, India - 181221.*

Presenting author's e-mail: 2021rph2027@iitjammu.ac.in

Microorganisms often navigate viscoelastic media to enhance their functionality[1]. For instance, motile organisms such as sperm migrate through the viscoelastic medium of cervical mucus to fertilize the egg. While comprehending the behavior of active suspensions in open systems is essential and fundamental, most biological systems are often under geometrical confinement, whether soft or rigid. Recently, Liu et al.[2] observed E. coli bacteria, suspended in a drop of viscoelastic medium, self organize into a periodically oscillating vortex —whose frequency can be regulated by changing the viscoelasticity of the suspending fluid. In the present study, we report a two-dimensional minimalistic computational model to reproduce and gain further insight into the above-mentioned experimental study. We employ Dissipative Particle Dynamics (DPD), a mesoscopic and particle-based methodology, to model the active particle suspension in a viscoelastic medium that captures all the experimental observations. All the respective constituents are modeled as DPD particles; however, the polymers are linear chains of DPD particles with FENE spring potential between neighboring particles. In addition, the active particles have a self-propulsion force characterized by an appropriate P´eclet number. The simulation results are in agreement with the reported findings in the literature, namely, on varying the polymer concentrations within the fluid, the self-organization of active particles within the drop transitions from rotation of the drop to the oscillatory vortex. Finally, we presented a phase diagram for the drop dynamics as a function of the P´eclet number (Pe) and packing fraction Φ_a of active particles, as well as the dependence of the domain size on the drop dynamics. Our results offer insight into the influence of viscoelasticity on the spatiotemporal organization of bacterial active matter.

Keywords: Active particles, viscoelastic fluid, spatiotemporal organization, polymers, DPD.

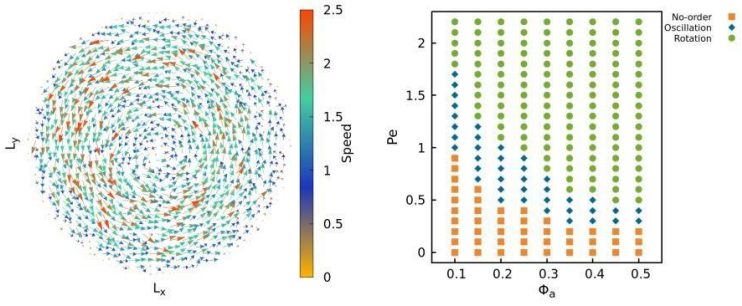

Figure 1. *(Left)* Corresponding velocity flow field of rotating drop of active particle suspension. (Right) *Phase diagram for the suspension drop as* P´eclet *number (Pe) and number fraction of active particles* Φ_a *is varied at a constant concentration of polymers.*

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P.16

Collective dynamics of intelligent active Brownian particles with visual perception and velocity alignment in 3D: spheres, rods,and worms

Zhaoxuan Liu [1], Marjolein Dijkstra [2]

[1] Soft Condensed Matter & Biophysics Group, Debye Institute for Nanomaterial Science, Utrecht University, The Netherlands
[2] Soft Condensed Matter & Biophysics Group, Debye Institute for Nanomaterial Science, Utrecht University, The Netherlands

Zhaoxuan Liu's e-mail: z.liu4@uu.nl

Many living systems, such as birds and fish, exhibit collective behaviors like flocking and swarming. recently, an experimental system of active colloidal particles has been developed, where the motility of each particle is adjusted based on its visual detection of surrounding particles. These particles with visual-perception-dependent motility exhibit group formation and cohesion. Inspired by these behaviors, we investigate intelligent active Brownian particles (iABPs) equipped with visual perception and velocity alignment in three dimensions using computer simulations. The visual-perception-based self-steering describes the tendency of iABPs to move toward the center of mass of particles within their visual cones, while velocity alignment encourages alignment with neighboring particles. We examine how the behavior varies with the visual cone angle θ, self-propulsion speed (Péclet number pe), and the interaction strengths of velocity alignment (Ω_a) and visual-based self-steering (Ω_v). our findings show that spherical iABPs form dense clusters, worm-like clusters, milling behaviors, and dilute-gas phases, consistent with 2d studies. By reducing the simulation box size, we observe additional structures like band-like clusters and dense baitball formations. Additionally, rod-like iABPs form band-like, worm-like, radiating, and helical structures, while iABP worms exhibit band-like, streamlined, micellar-like and entangled structures. many of these patterns resemble collective behaviors in nature, such as ant milling, fish baitballs, and worm clusters. Advances in synthetic techniques could enable nanorobots with similar capabilities, offering insights into multicellular systems through active matter.

Keywords: Intelligent particle, active matter, collective behavior, self-propulsion.

P.17

Collecting Particles in Confined Spaces by Active Filamentous Matter

Rosa Sinaasappel [1], Kokkoorakunnel Ramankutty Prathyusha [2], Harry Tuazon [2], Elham Mirzahossein [1], Pierre illien [3], Saad Bhamla [2], and Antoine Deblais [1]

[1]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, 1098XH Amsterdam, The Netherlands.
[2] School of Chemical and Biomolecular Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA.
[3] Sorbonne Université, CNRS, Physicochimie des Electrolytes et Nanosystèmes Interfaciaux (PHENIX), Paris, France.

Presenting author's e-mail: a.deblais@uva.nl

The potential of compliant and adaptable active matter for particle transport presents a promising avenue for the development of efficient, autonomous systems. However, achieving optimal task efficiency often depends on external control mechanisms, which can limit the autonomy of such systems. In this study, we draw inspiration from *Tubifex tubifex* and *Lumbriculus variegatus*, centimeter-sized worms that exhibit an extraordinary ability to aggregate dispersed particles within confined environments. By observing their natural behaviors, we identify a simple, yet effective particle collection strategy driven by flexibility and activity. Using these biological insights, we develop larger-scale robotic systems and simulations that replicate the particle aggregation dynamics of living worms. Our results reveal that coupling between activity and flexibility governs the efficiency of particle clustering, and this principle applies universally across biological, robotic, and simulated filaments. These findings open new avenues for designing autonomous soft systems by tuning structural parameters such as topology and bending stiffness to optimize collection strategies.

Keywords: Active matter, Active polymer, Aggregation, Fragmentation, Emergence.

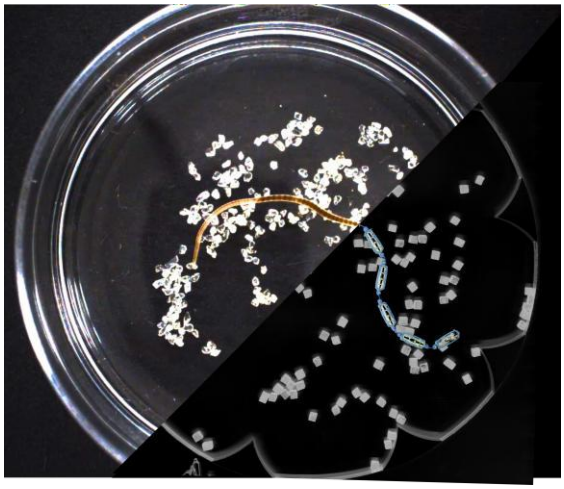

Figure 1. *Collecting particles with active filamentous matter. (Top) A California blackworm (Lumbriculus variegatus) in a petri dish with sand particles. Over time, the worm gathers the sand into larger clusters. (Bottom) A robotic filament composed of connected "Hexbug" bots moves within a circular arena, interacting with passive (Styrofoam) particles. The robotic filament collects particles into clusters, mimicking the behavior of the living worm.*

Reference

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P.18

Transition of Bacterial Turbulence from Two to Three Dimensions

Da Wei[1], Yaochen Yang[2,3], Xuefeng Wei[2,4], Ramin Golestanian[5,6], Ming Li[1], Fanlong Meng[2,3,4], and Yi Peng[1,3]

[1]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
[2]CAS Key Laboratory for Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China
[3]School of Physical Sciences, University of Chinese Academy of Sciences, 19A Yuquan Road, Beijing 100049, China
[4]Wenzhou Institute, University of Chinese Academy of Sciences, Wenzhou, Zhejiang 325000, China
[5]Max Planck Institute for Dynamics and Self-Organization (MPIDS), D-37077 Göttingen, Germany
[6]Rudolf Peierls centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, United Kingdom

Bacterial turbulence—chaotic flow emerging from dense suspensions of swimming bacteria—offers a striking example of low-Reynolds-number turbulence driven by internal activity rather than inertia. While it shares visual similarities with classical turbulence, its underlying physics is fundamentally different and remains poorly understood, especially across dimensions. In this study, we experimentally probe the dimensional dependence of bacterial turbulence by imaging flow fields in chambers with variable heights, bridging quasi-2D to 3D geometries. We identify three distinct regimes of turbulent structure, separated by two critical confinement heights. These regimes arise from the interplay between bacterial body length, emergent vortex size, and vertical confinement. Our analysis of the kinetic energy spectra reveals universal scaling laws in both quasi-2D and 3D regimes. Remarkably, these scaling behaviors remain robust across changes in bacterial activity, morphology, and confinement. Transitions between scaling exponents occur in two discrete steps as the system crosses the critical heights. To explain these findings, we develop a continuum hydrodynamic model incorporating image systems to account for boundary-induced flows. The model successfully captures the observed spectral transitions and structural features. Together, our results offer a unified framework for understanding how dimensionality controls self-organization and energy transfer in active turbulent systems.

P.19

Rolling at right angles: the dynamics of superparamagnetic active rollers

Eavan Fitzgerald [1], Cécile Clavaud [2], Debasish Das [3], and Scott R. Waitukaitis [1]

[1]Institute of Science and Technology Austria
[2]Université de Rennes
[3]Strathclyde University

Presenting author's e-mail: eavan.fitzgerald@ist.ac.at

Quincke rotation occurs when a dielectric particle in a weakly conducting fluid rotates spontaneously in response to an external DC electric field **E**. Above a threshold value $\mathbf{E_C}$, surface friction drives rolling in the plane orthogonal to **E,** at a constant speed set by the field. Although single rollers typically perform quasi-linear random walks, emergent collective motion in sufficiently dense colloidal suspensions lead to the formation of vortexes, density bands, directed flows *etc* [1], subject to the geometry of the confining region.

In our system, we introduce an additional degree of freedom using superparamagnetic colloids and observe markedly different dynamics. With no magnetic field **B**, rollers execute tight circular trajectories or even orbits. These are more unstable at higher **E** fields, as periods of circular motion may be interspersed with short "walks". Introducing a homogeneous in-plane **B** alongside the electric field linearises the circular motion, as the rollers' induced magnetic moment aligns with **B**, thereby fixing the Quincke rotation axis. Coherent linear trajectories perpendicular to the magnetic field lines are executed, which is consistent with other work [2].

However, as we increase the applied **B** field beyond 200G, we see the appearance of an anomalous linear mode of active rollers travelling parallel to the magnetic field axis. In numerical simulations, we have implemented a model of anisotropic magnetic susceptibility to account for the stabilisation of the magnetic dipole, thereby facilitating the emergence of this secondary linear mode. Our simulations show the magnetic dipole moment tumbling in the plane orthogonal to the plane of motion as the roller successfully replicates the quasi-stable trajectories observed in experiments. We have strengthened our proposed stabilising mechanism with a simple analytic model which identifies a set of secondary energetic minima corresponding to the tumbling mode seen in simulations.

Keywords: active rollers, anisotropy, magnetic susceptibility, Quincke effect

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P.20

Field-driven reversible networks from colloidal rods

José Fojo[1] , Rodolfo Subert[3], Laura Rodríguez-Arco[2,4], Modesto T. López-López[2,4] ,Marjolein Dijkstra[3] ,Carla Fernández-Rico[5] and Laura Àlvarez[1]

[1]CNRS, Univ. Bordeaux, CRPP, UMR5031, 33600 Pessac, France
[2]Universidad de Granada, Departamento de Física Aplicada, Campus de Fuentenueva,E-18071 Granada, Spain.
[3]Soft Condensed Matter & Biophysics, Debye Institute for Nanomaterials Science, Utrecht University, The Netherlands
[4]Instituto de Investigación Biosanitaria Ibs., E-18014 Granada, Spain
Department of Materials, ETH Zürich, 8093 Zurich, Switzerland.

Presenting author's e-mail: jose.fojo-vazquez@u-bordeaux.fr

Highly interconnected percolated networks are interesting structures for materials with enhanced transport and mechanical properties [1]. While percolated networks of anisotropic particles have been explored at the nanoscale [2], achieving highly interconnected structures at the microscale remains challenging. In this work, we explore the controlled assembly of rod-like polymer colloids under external fields [3] leading to reversible 2D-network patterns [4]. By varying voltage and frequency, we modulate the pore size and thickness of the network. We find that field-driven attractive interactions enable percolation at lower area fractions than predicted for non-interacting rods. Monte Carlo simulations incorporating dipolar interactions and electrostatic boundary conditions confirm the field-induced transition from isotropic to aligned rod configurations, supporting the emergence of percolated networks. This work presents a simple and robust approach for assembling reconfigurable colloidal networks with controlled connectivity, offering new strategies for designing adaptive soft materials.

Keywords: Colloidal rods, Electric fields, Percolation, Self-assembly.

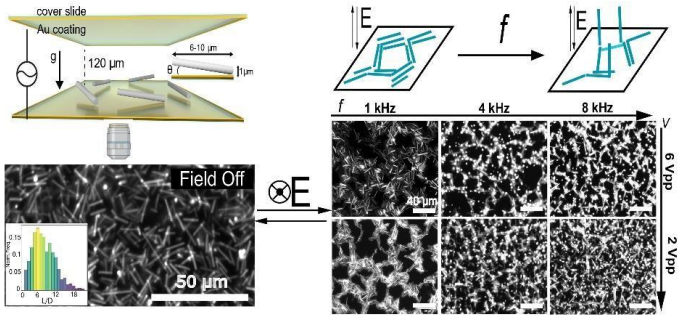

Figure 1. *Tunable network formation in colloidal rods via electric field manipulation*

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P.21

Cooperation and collective motion in binary mixture of active colloids

L. Alvarez[1] E. Sesé-Sansa[2], D. Levis[3,4] I. Pagonabarraga[3,4], L. Isa[5]

[1]*Univ. Bordeaux, CNRS, CRPP, UMR 5031, F-33600 Pessac, France*
[2] *CECAM, École Polytechnique Fédérale de Lausanne (EPFL) Switzerland*
[3]*Departament de Física de la Matèria Condensada, Universitat de Barcelona, Spain*
[4]*UBICS University of Barcelona Institute of Complex Systems, Barcelona, Spain*
[5]Laboratory for Soft Materials and Interfaces,5 Department of Materials, ETH Zurich, 8093 Zurich, Switzerland

Presenting author's e-mail: laura.alvarez-frances@u-bordeaux.fr

The complex interactions driving collective motion in nature result in fascinating out-of-equilibrium self-organization processes. Cells of the same and/or different species coordinate their movement to enhance environmental exploration, achieving efficient navigation and maximizing survival through emergent cooperative and competitive behaviors. Group dynamics are often explored with dense suspensions of active colloids as synthetic model systems. While significant progress has been made in understanding collective behavior in single-species systems [1,2,3], active mixtures of different motilities remain largely unexplored. Here, we present a system of active colloids that exhibit flocking and spatial segregation driven by external electric fields, with particles having distinct motilities and independently tunable interactions [4]. We experimentally and numerically report on the formation of highly dynamic polar clusters of both species of particles, with alignment occurring regardless of their propulsion speed. In dense binary mixtures, effective segregation emerges, with the dynamics of fast and slow particles influenced by interspecies interactions. In addition, including gravity in these interacting systems while changing the particle interaction via frequency leads to interesting chiral collective behavior [5]. These results highlight synergistic effects in the self-organization of active mixtures, offering insight into designing systems with advanced group dynamics.

Keywords: active matter, collective behavior, non-reciprocal, cooperative motion

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P.22

Clustering of Active Particles in Tunable Colloidal Environments

Abhimanyu Nowbagh[1], Venkata M.S.G. Tanuku[2], Thomas Palberg[2], and Ivo Buttinoni[1]

[1]Institute of Experimental Colloidal Physics, Heinrich-Heine University, 40225 Düsseldorf
[2]Institute of Physics, Johannes-Gutenberg University, 55128 Mainz

Presenting author's e-mail: abhimanyu.nowbagh@hhu.de

Active colloids are microscopic particles which propel through aqueous media by converting the externally available energy into directed motion. Using non equilibrium thermodynamics to understand biological systems: interactions of active colloids with crowded systems, and emergent phenomena of ensembles of active particles, remain an important and open question.

In this work, we investigate the dynamics of active particles in crowded environments subjected to alternating-current (AC) electric fields. The AC electric field is used to control: i) the velocity of active particles and ii) the inter-particle interaction between passive colloids. As we increase electric field strength, the velocity of active particles increases and the inter-particle interaction between passive colloids becomes stronger. We study the behaviour of active particles as a function of: i) the frequency of the applied AC electric field, ii) the area fraction of the passive crowd, iii) the active to passive particle number ratio, and iv) the velocity of the active particles.

Our experimental findings show that the active particles reorient faster with an increasing electric field strength. With an increase in the active to passive particle ratio, we show that cluster formation is non-monotonically sensitive to the passive crowd density.

Keywords: Colloids; Active-Passive Interaction; Cluster Formation; Non-Equilibrium Statistical Mechanics

P.23

Multifunctional metal oxide membrane for simultaneous oil- water separation and contaminant degradation

Santhra Krishnan P[1], Sriharitha Rowthu[2], Sreeram K. Kalpathy[1]

[1] Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai - 600036, India
[2] Department of Materials Engineering Indian Institute of Technology Gandhinagar, Gandhinagar - 382055, Gujarat, India

Presenting author's e-mail: mm21d009@smail.iitm.ac.in

The problem of oil-water separation has tremendous economic value in contributing towards "waste to wealth" conversion by facilitating the recovery of oil and water for recycled uses. Besides, photocatalytic degradation of toxic dyes and oily contaminants is a crucial step in water purification and is directly linked to environmental remediation. Multifunctional membranes from transition metal oxide (TMO) materials utilize the synergy between super wettability effects and photocatalytic degradation, as a one-pot solution for treatment of oily wastewater.

Nickel titanate (NTO) synthesized via a polymer precursor-based sol-gel route using Styrene Acrylonitrile (SAN), has been known to possess multiple band gap values (2.25–3.47 eV) allowing efficient absorption of both visible and UV spectral regions of the solar spectrum [1]. In the present work, photocatalysis experiments performed using NTO nano powders as catalysts showed 76.2% degradation efficiency of methylene blue dye in water, which is comparable to that of TiO_2 (81%), the most commonly used photocatalytic material. It is further planned to fabricate multipurpose membranes of these nano powders for combined oil-water separation and photocatalytic purification applications. The fabrication will be done through a colloidal lithography route to achieve microscale topographic texturing [2]. For this purpose, specific textures present in superhydrophobic species like Lotus leaves and Periwinkle petals were replicated onto polydimethylsiloxane (PDMS) moulds. The resulting PDMS moulds showed enhanced hydrophobicity (contact angles in the range 130° - 145°), attributed to the surface roughness, governed by Wenzel's and Cassie-Baxter's theories. It is planned to cast NTO-binder mixtures onto these PDMS templates followed by subsequent sintering at a suitable temperature to fabricate porous membranes. These findings and the proposed work highlight the potential of NTO-based materials for simultaneous separation and degradation for the treatment of oil-contaminated water, compared to currently known solutions for this problem.

Keywords: Photocatalysis, Colloidal Lithography, Replica Modelling, Porous membranes, Oil-water separation.

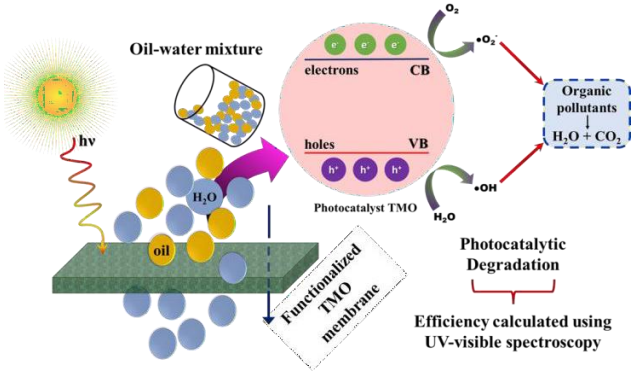

Figure 1. *Proposed photocatalytic TMO membranes for oil-water separation*

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P.24

Pairwise interaction between a pair of pushers at fluid-fluid interface

Rishish Mishra [1], Harinadha Gidituri [2], and Harish Pothukuchi [1]

[1]Department of Mechanical Engineering, Indian Institute of Technology, Jammu, India
[2]Department of Chemical Engineering, Birla Institute of Technology and Science, Pilani, Hyderabad Campus, India

Presenting author's e-mail: 2020rme2088@iitjammu.ac.in

Microorganisms such as bacteria are often found at the fluid-fluid interfaces. Physico-chemical interactions between the cells lead to the formation of biofilms at the interface. During the initial stages of biofilm formation, the hydrodynamic interaction between these microswimmers and the interface plays a crucial role in determining the fate of the biofilm. In such a context, understanding the hydrodynamic interaction between a pair of microswimmers is paramount and it unravels the process causing the inception of collective behavior. In this study, we use a squirmer model to look into the pairwise interaction between a pair of pusher-type microswimmers at the interface, as the majority of the bacteria exhibit pusher-type flow characteristics. We consider microswimmers with varying squirmer parameters (β) that are neutrally trapped at the interface, under different viscosity contrasts (λ) between the .two fluids. The steady-state orientation angle (ϕ) between the microswimmer and interface is largely dependent upon the β and λ. The Reynolds (Re) and Capillary (Ca) numbers are kept very small.

We have studied three different interactive configurations between the microswimmers. In the first configuration, a leader-follower pair swims in line at a steady separation (h). In the second, two microswimmers swim parallel in the same direction. Finally, the third involves anti-parallel swimmers facing each other, separated by an offset distance. The hydrodynamic interaction between the swimmers is presented in terms of trajectories, inter-particle angles θ, steady state distance (h), and the flow field distribution. The results indicate that while the interaction between the swimmers is mainly governed by their dipole strength, the viscosity contrast plays a key role in determining the effective distance they travel.

Keywords: Pairwise-interactions, Squirmer, Microswimmer, Interface

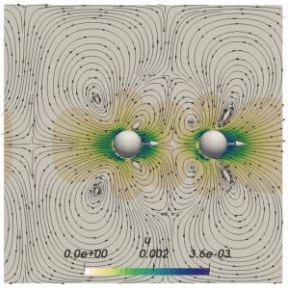

Figure 1. *Flow field distribution of leader and follower microswimmers with velocity contours in the background.*

P.25

Non-equilibrium dynamics and emergent phases in an active colloidal ice

Renaud Baillou [1], *Pietro Tierno* [1]

[1] *Departament de Física de la Matèria Condensada, Universitat de Barcelona, Av. Diagonal 647, 08028 Barcelona, Spain*

Presenting author's email: rbaillou@ub.edu

Artificial Colloidal Ice (ACI) is a soft-matter based model system for geometric frustration made of paramagnetic colloidal particles confined in double-well potentials at a one-to-one filling ratio. The interactions between the colloidal particles can be tuned via the application of an external magnetic field and typically these interactions are isotropically repulsive, inducing the formation of a triangular lattice of particles in absence of substrate. However, imposing a square arrangement of the double wells may lead to competing interactions and geometric frustration set in [1].

Motivated by recent experimental advances in both magnetic active matter and colloidal ice (see figure 1), we perform numerical simulations to explore the phenomena emerging when activity is introduced into the colloidal particles composing an ACI.

We show that a directed self-propulsion towards a localized target introduces an anisotropic active component that competes with the isotropic magnetic repulsion. This interplay enables continuous control of an anisotropic phase with regions adopting the previously observed plasma-like [2] or ice-like [3] states depending on their orientation.

Keywords: Colloidal Ice - Active Matter - Anisotropy

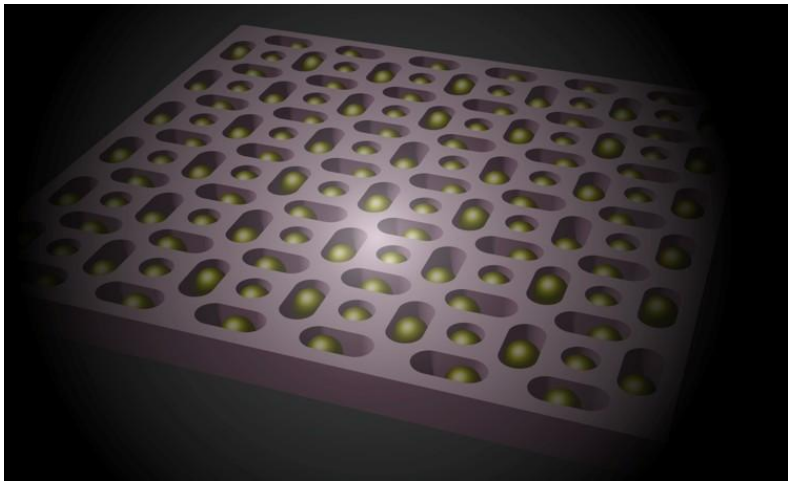

Figure 1. *Illustration of square artificial colloidal ice composed of phototactic paramagnetic particles confined into elongated grooved holes, supplemented with central paramagnetic inclusions that induce magnetic hills. Particles repel each other under a perpendicular magnetic field and become localized on one side of each well when the magnetic field increases. A gradient of light actively drives the phototactic particles towards the center.*

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P.26

Collapse transition of attractive tangentially-driven active polymers

Baptiste Parage[1], *Sara Jabbari-Farouji* [1]

[1]*Institute of Physics, University of Amsterdam, Science Park 904, 1098XH Amsterdam, The Netherlands.*

Presenting author's e-mail: b.m.m.parage@uva.nl

Active polymer-like systems are ubiquitous in nature and span all length scales, from chromosomal DNA driven by molecular motors to filamentous microscopic and macroscopic organisms such as bacteria and worms. While the physics underlying fully repulsive chains (*i.e.*, the good-solvent limit) is by now well established [1], comparatively little attention has been devoted to the role of attractive interactions, relevant for poor-quality solvents, on conformational and dynamical properties. We address this question by performing single-chain Brownian dynamics simulations of 3D flexible tangentially-driven active polymers [2] with tunable intra-chain attraction.

For passive (*e.g.*, molecular) polymers, increasing the monomer-monomer attraction strength results in a collapse transition, characterized by a significant reduction in both the chain's radius of gyration and its orientational relaxation time. In striking contrast, for attractive tangentially-driven active polymers with sufficiently high activity levels, we observe a collapse of the conformation without significant change on the orientational relaxation time. That is, the relaxation time becomes essentially independent of the attraction strength, despite a substantial reduction in polymer size. The relaxation mechanism of active polymers is systematically identified as an intermittent swellingshrinkage process of the chain over time (see ***Figure 1***). Furthermore, the dependence of the scaling exponent ν on the attraction strength is largely mitigated by activity.

Keywords: active matter - active polymer – collapse transition

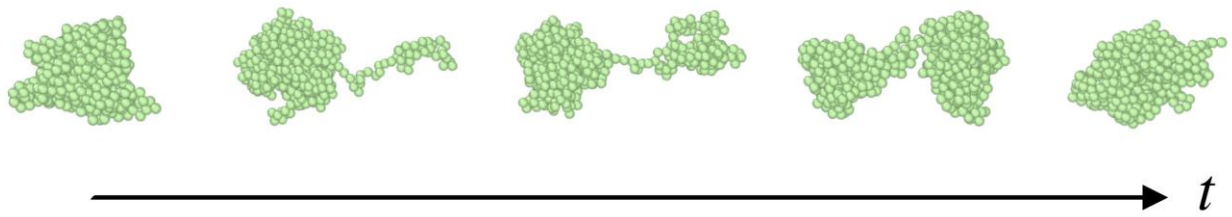

Figure 1. *Swelling-shrinkage process of a tangentially-driven active polymer with 'strong' attractive interactions.*

References

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G. Glasses, Granular, Jamming

P.27

Emergent mechanics of a random network of elastic ribbons

Mizuki Ono [1], Hirofumi Wada [1]

[1] Department of Physical Sciences, Ritsumeikan University, Shiga, Japan

Presenting author's e-mail: rp0108ei@ed.ritsumei.ac.jp

A shredded cabbage salad or shredded paper may form large aggregates when slightly compressed (typically by its own weight) (Fig.1). Similarly, a bundle of human hairs may swell due to their random intrinsic curvatures to form a characteristic shape like ponytail [1]. These structures are the typical examples of the disordered packing of randomly bent slender elements with transient frictional contacts. While an emergent mechanics of a randomly packed solid elements such as spheres and rods has been extensively studied recently [2,3], how a randomly packed bendy slender elements, such as paper strips, can form a disordered stable network with stiffness at low volume fraction, is largely unexplored.

Here we study experimentally the emergent shape and bulk mechanics of a random network of orientationally disordered slender elements. In our experiment, fresh uniform elastic strips of fixed length cut from a flat paper are prepared in an acrylic cylinder, which is subjected to cyclic compression tests (Fig.1). The resulting force responses suggest that most of the plastic deformations (crease formations) occur at the first compression cycle. The subsequent cycles then reveal how the transient contact geometry, friction and elasticity may affect the overall mechanical responses of the network. Fixing the volume fraction at the specific value 0.011, we change the lengths of the strip systematically and find that the elasticity and self-supporting structure of the packing emerges at a critical length that scales linearly with the radius of the cylinder. Visualization of the three- dimensional configurations of the samples at various compression level revealed by the computer assisted tomography is used for estimating the average coordination number and tangling behavior of randomly creased strips (Fig.2).

Keywords: friction, contact, elasticity, geometry

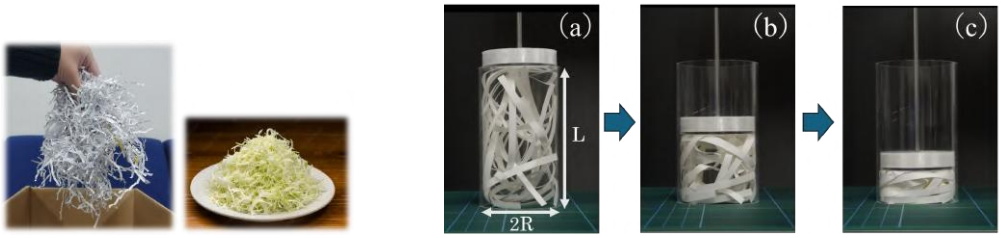

Figure 1. *(Left) Photos of shredded cabbage salad and shredded paper. (Right) Compression experiment (R=27.5 mm, L=15 cm). (a) 0% compression (b) 50% compression (c) 80% compression.*

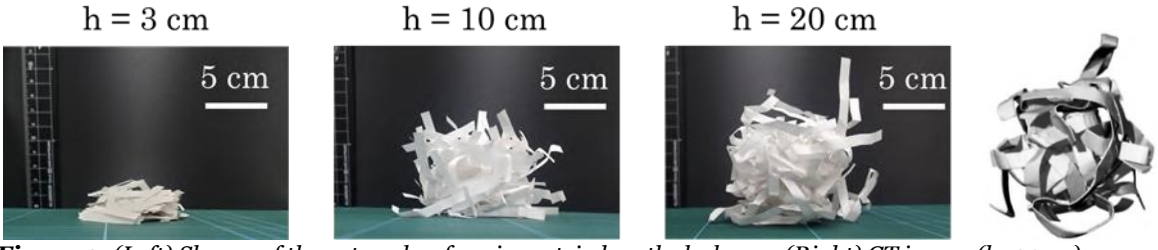

Figure 2. *(Left) Shapes of the networks of various strip lengths h shown. (Right) CT image (h=20cm).*

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P.28

Rheology of Curved Rods and Applications in Biological Systems

Holly Bridge[1] , Tyler Shendruk[1] , Christopher Ness[2], Gavin Melaugh[1]

[1]School of Physics and Astronomy, University of Edinburgh, EH9 3FD, United Kingdom

[2] School of Engineering, University of Edinburgh, Edinburgh EH9 3JL, United Kingdom

Presenting author's e-mail: h.bridge-1@sms.ed.ac.uk

Dense suspensions are a broad class of out-of-equilibrium systems that often display interesting macroscopic behaviour under flow. The rich physics observed for suspensions of spheres can be expanded to particles of more complex geometries. This work applies concepts from dry granular physics to model the rheology of suspensions of curved rods. The curvature-dependent jamming volume fraction, ϕ_J, is investigated in both monodisperse and polydisperse systems, whereby mixtures of morphologies provide insight into blood flow blockages that occur in sickle cell anemia patients. We try to understand such mechanisms of jamming by quantifying structural properties such as co-ordinate number, alignment and interlocking.

Keywords: Rod-like rheology, polydispersity, jamming transitions, orientational order

P.29

Contact charging with levitated particles: widening the scope with two new charge measurement techniques

Markus Felber [1], *Galien Grosjean* [1] *and Scott R. Waitukaitis* [1]

[1]*Institute of Science and Technology Austria*

Presenting author's e-mail: markus.felber@ista.ac.at

If two electrically neutral materials are brought into contact, an exchange of charge can occur. This effect is called tribocharging and has been known for over 2500 years [1]. Even though this phenomenon affects a wide range of fields - including soft matter systems e.g. charge build-up in granular matter or charging between polymers – we still have a poor understanding of the fundamental processes at play. In our group we use a powerful technique, acoustic levitation, to study tribocharging between a spherical particle and a plate. Contacts are done by switching off the acoustic field for a brief moment, letting the sphere bounce once and recapturing it again by switching the field back on. The charge is then obtained by tracking the position of the sphere with a high speed camera as it reacts to an external electric field. With this, we can perform a large number of contacts between the sphere and the plate whilst resolving the charge exchange of each individual charging event. While this setup has proven to work very well, it does come with some significant limitations: The amount of data to process for each measurement is very high. This leads to computation times of minutes to obtain one charge value, limiting us in the number of bounces we can realistically observe. Additionally, charge can only be measured after each bounce – the transfer process itself cannot be recorded.

To overcome these issues, we are going to implement two new charge measurement techniques. To address the long processing times, an event based sensor (EVS) will replace the optical camera. EVS cameras record only pixel changes in intensity, minimizing the data rate and therefore rendering them ideal for efficient position tracking. This allows us to significantly speed up the analysis process, potentially even achieving real-time measurements.
To obtain information about the charging dynamics during the contact itself, a more continuous measurement is needed. For this, a capacitive system will be deployed. The charged sphere induces image charges in the plate which are measured as a potential. Using a suitable electrometer, frequencies up to 2 MHz can be achieved, allowing us to observe the charge exchange during contact on a timescale of microseconds [2]. Implementing these new techniques will enable us to dive into a number of unresolved topics, such as the saturation charge after a very large number of contacts, charging under the presence of external electric fields or metal-polymer charging for different material combinations.

Keywords: charge exchange, same material, granular media

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P.30

Effect of Ultrasound on the Shear Thickening Transition of Corn Starch Suspension

Aoxuan WANG [1], Fabrice Toussaint [2], and Thomas Gibaud [1]

[1] Laboratoire de Physique, ENS-Lyon, CNRS, Lyon, Rhône 69007, France;
[2] HOLCIM INNOVATION CENTER, HOLCIM, Saint Quentin Fallav, Sélectionner un état 38291, France
Presenting author's e-mail: aoxuan.wang@ens-lyon.fr

Shear thickening — a phenomenon where the viscosity of a suspension increases drastically under shear—is a critical challenge in industrial processes, including petroleum extraction and transport, pharmaceutical manufacturing, and 3D printing of construction materials. Addressing this challenge requires innovative, controllable, lightweight, and universally applicable strategies to regulate shear thickening transitions effectively. High-power ultrasound, as a high-frequency mechanical wave, offers a promising unconventional approach by dynamically altering particle distribution and interactions within the suspension.

In this work, we developed an integrated rheology-ultrasound setup, capable of applying controlled ultrasound with amplitudes around 0.1 - 4 micron during rheological measurements. Using this system, we studied the impact of ultrasound on shear thickening behaviour in corn starch suspensions across a range of volume fractions. The results reveal that high-power ultrasound significantly mitigates shear thickening, and can even completely dethicken it at high amplitudes, as shown in Fig. 1.

Keywords: Ultrasound; Shear thickening transition; Corn starch; jamming system.

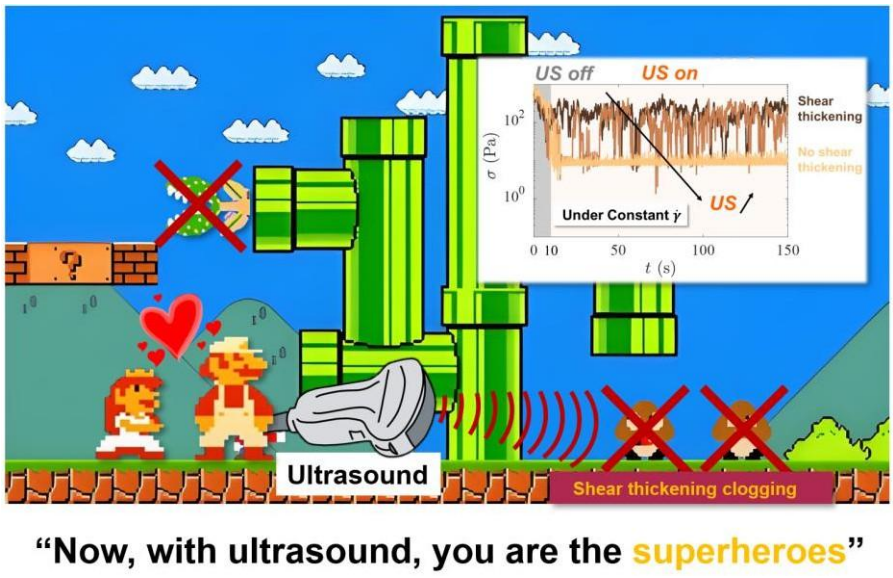

Figure 1. *Effect of ultrasound on the shear thickening transition of corn starch.*

P.31

Programming torsional buckling in soft meta-shells

A.Ghorbani[1], M. Mirzaali[2], T. Roebroek[1], C. Coulais[3], D. Bonn[3], E. v/d Linden[1], M. Habibi[1]

[1]Laboratory of Physics and Physical Chemistry of Foods, Wageningen University, 6708 WG, Wageningen, The Netherlands

[2]Department of Biomechanical Engineering, Delft University of Technology, 2628 CD, Delft, The Netherlands

[3]Institute of Physics, University of Amsterdam, 1098 XH, Amsterdam, The Netherlands

Presenting author's e-mail: mehdihabibi@gmail.com

When we twist a thin cylindrical shell, it will buckle. This instability, called torsional buckling and can lead to systemic failure in diverse engineering or natural phenomena. Via rational design of meta shell structure, we show that we can program and even prevent this instability due to programming the local instabilities, which circumvent the global torsional instability even under very large deformations. This is done by using the auxetic properties of a holey cylindrical elastic shell. When the principal axes of the designed meta-structure are relatively aligned with that of the compressive component of the applied stress during twisting, the meta-shell shrinks radially via local buckling of thin hinges. The shrinkage leads to the stacking of unit cells along the compressive component of the applied stress. Besides that this structure provides a platform for the programmability of the Poynting effect and normal force induced by torsion in our system. Finally, we highlight the potential of tailoring anisotropies and programming instabilities in meta shells, with diverse applications. For example, we demonstrate a soft torsional compressor through a torsion release mechanism for generating pulsatile flows, transport of yield stress fluids, or even locomotion in complex fluids.

Reference:

A. Ghorbani, M. Mirzaali, T. Roebroek, C. Coulais, D. Bonn, E. v/d Linden, **M. Habibi**, Suppressing torsional buckling in auxetic meta-shells, *Nature Communications* 15 (1), 6999, 8, 2024.

P.32

Supercritical density fluctuations and structural heterogeneity in supercooled water-glycerol microdroplets

Iason Andronis[1], *Foivos Perakis*[1]
[1]*Department of Physics, Stockholm University, Stockholm, Sweden*

Presenting author's e-mail: iason.andronis@fysik.su.se

Recent experiments and theoretical studies strongly suggest that water undergoes a liquid-liquid phase transition (LLPT) in the supercooled regime. However, how this behavior influences aqueous solutions remains an open question. In this study [1], we combine femtosecond small- and wide-angle X-ray scattering (SAXS/WAXS) with molecular dynamics (MD) simulations to investigate supercooled glycerol–water microdroplets at dilute conditions (χ_g = 3.2% glycerol mole fraction) over a wide temperature range (229.3–295 K). To access the deep supercool regime, we utilize rapid evaporative cooling of microdroplets. We find that, both the isothermal compressibility (κ_T) and correlation length (ξ) of the solution increase anomalously upon cooling, following a power-law behavior, and the addition of glycerol suppresses these density fluctuations and shifts the κ_T-maximum of water from ~230 K to ~223 K. While this shift suggests the system remains in the supercritical regime, structural markers, such as the local order and the existence (and temperature crossover) of High-density-liquid (HDL) / Low-density-liquid (LDL) populations, remain similar to pure water. This indicates that the hypothesized framework of a second critical point in water, extends to dilute aqueous solutions, with glycerol modifying the temperature response of the system. We therefore suggest that, by modulating collective fluctuations, glycerol contributes to cryoprotection, potentially delaying nucleation and ice formation. This work provides a framework for designing optimized cryoprotectant mixtures and could inform future developments in cryopreservation, especially for complex biological systems where avoiding ice nucleation is critical.

Keywords: supercooled water, glycerol, cryoprotectants, LLCP, Widom line

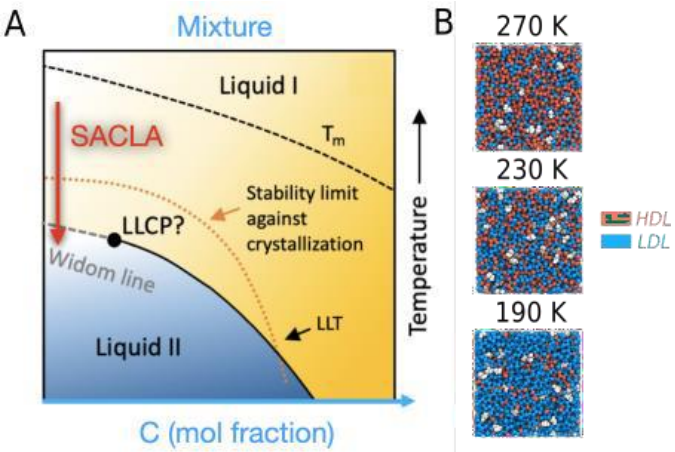

Figure 1. A) *Schematic representation of the Temperature – concentration phase diagram of the solution. The downward red arrow indicates the range of temperatures that were probed in this study.* ***B)*** *Snapshots of the MD simulation box of the solution, with colored water molecules, according to their local structure (LDL, HDL).*

References

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B. Biological and living matter

P.33

Density-Dependent State Transitions and Active Flow in an Actomyosin System

Tomoka Kashiwabara [1], *and Yusuke T. Maeda* [1]

[1]*Dept. of Chemical Engineering, Kyoto Univ., Kyoto, Japan*

Presenting author's e-mail: kashiwabara.tomoka.32e@st.kyoto-u.ac.jp

The collective dynamics of the cytoskeletal system contribute to biological functions such as cytokinesis, organelle positioning, and intracellular transport. In reconstituted systems using cytoplasmic extracts obtained from cells, the force generated by myosin motors and the polymerization rate of actin filaments are crucial parameters for the contraction of the actin-myosin (actomyosin) cytoskeletal system [1, 2]. However, to understand the contraction mechanisms of the cytoskeletal system in a high-protein-density, viscous intracellular environment, the relationship between whole protein density and contraction dynamics must be further explored [3].

In this study, we manipulated protein density by preparing solutions with different volume fractions ϕ of cytoplasmic extract and visualized the bulk dynamics with tracer particles in solution (Fig. 1a). At an intermediate volume fraction ϕ =40%, the movement of tracer particles driven by the cytoskeletal system was limited, but with increasing ϕ, longer-range movement emerged (Fig. 1b, top). At ϕ =60%, the speed of tracer particle movement repeatedly increased and decreased over a period of approximately 150 seconds. At ϕ =80%, the particle speed gradually decayed over time (Fig. 1b, bottom). These results suggest that the amount of protein affects the cytoskeletal system's cross-linking state and contractile strength, altering tracer dynamics. Furthermore, we examined the state transition of the diffusion speed using the equation: $v = \Delta r(\tau) / \tau$, where

$\Delta \mathbf{r}(\tau)$ is the displacement of a tracer particle over a time duration τ (Fig. 1c). The results showed that v was suppressed at low to moderate protein concentrations but then, at higher concentrations, exceeded thermal motion in low-viscosity solutions without cytoplasmic extract.

Keywords: self-organization; cytoskeleton; molecular motor

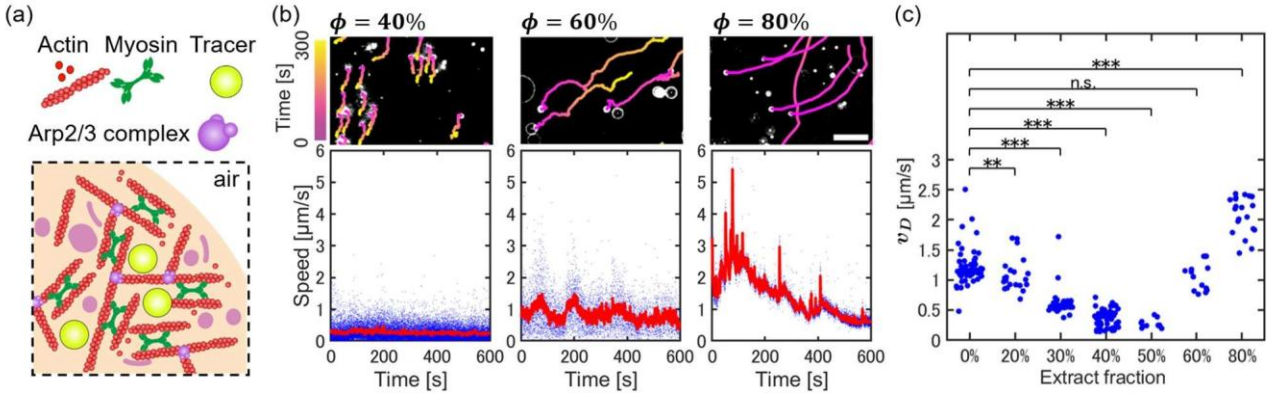

Figure 1 (a) Schematics of bulk actomyosin extract containing actin, myosin, tracer particles, Arp2/3, and associated proteins. (b) Advective flow observed via tracer particles in bulk actomyosin extract at various protein mass fractions. (Top) Microscopic image of tracer particles overlaid with their trajectory curve. Scale bar: 50 μm. (Bottom) Time evolution of tracer particle speed (blue). The red line represents the mean speed averaged over the particle population at each time point. (c) Diffusion speed v of tracer particles at various mass fractions of protein. τ = 1 sec.

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P.34

Multi-scale self-organization of active cytoskeletal prototissue

Lukas J. Neumann[1,2] *and Andreas R. Bausch*[1,2]

[1]*Chair for Cellular Biophysics, Center for Functional Protein Assemblies, Department of Bioscience, Technical University of Munich, Technical University of Munich School of Natural Sciences, Garching 85748, Germany*
[2]*Center for Organoid Systems, Technical University of Munich, Garching 85748, Germany*

Presenting author's e-mail: lukas.neumann@tum.de

Morphogenetic self-organization in biological tissues emerges from adhesion-mediated interactions and active viscoelastic remodeling of the cytoskeleton. Mechanotransduction coordinates collective migration and deformation, translating mechanical signals across cellular and tissue scales. Simple biological bottom-up systems have recently been used to study the adhesive properties of prototissue and cytoskeletal remodeling in protocells. However, multi-scale self-organization in synthetic active matter systems, modeling prototissue adhesion, remodeling and active deformation remain scarce. Here, we introduce a phospholipid vesicle-based cytoskeletal prototissue to investigate selforganization in minimal morphogenesis. This system consists of two distinct active components: (i) slow cytoskeletal vesicles encapsulating actin, α-actinin, and myosin II, forming an active actin cortex, and (ii) fast, highly deformable vesicles encapsulating an active microtubule fluid. We characterize the multi-scale self-organization of this soft active matter system, revealing how the interplay between adhesion, cytoskeletal remodeling, and active deformation drives tissue-scale structure formation and symmetry breaking. Our findings bridge concepts from active matter physics, tissue mechanics, and synthetic biology, demonstrating how minimal ingredients—adhesive interactions, cytoskeletal activity, and deformability—synergistically drive emergent organization in non-living protocellular systems.

Keywords: Prototissue, Active Soft Matter, Cytoskeleton

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P.35

Coarse-grained simulations of peptide *LGE1*$_{1"80}$

Agaya Johnson[1], *Anton Polyansky*[2], *Pedro A. Sanchez*[1],
Bojan Zagrovic[2], *Sofia Kantorovich*[1]

[1]*Computational and Soft Matter Physics, University of Vienna, Kollingasse 14-16, 1090 Vienna*
[2]*Department of Structural and Computational Biology, Campus-Vienna-Bio Centre 5, 1030, Vienna*

Presenting author's email: agaya.johnson@univie.ac.at

Biomolecular condensates, such as P-bodies, nucleoli, and stress granules, play a crucial role in cellular regulation, including transcription, RNA metabolism, and ribosome biogenesis. Understanding their formation and organization is essential for uncovering the molecular basis of diseases like neurodegenerative disorders, cancer, and diabetes [1]. However, due to their structural heterogeneity and fast dynamics, capturing their organization requires a coarse-grained (CG) modeling approach that bridges atomistic details with mesoscale properties [2,3].

In this work, we develop a coarse-grained model based on atomistic potentials to study the formation of condensates of LGE1$_{!"\#\$}$, a protein of interest in biomolecular phase separation and shown in Fig.1. Our approach aims at a **patchy model**, where interactions are coarse-grained in a way that preserves essential binding patterns while reducing computational complexity. We employ **cluster analysis** as a criterion to derive effective interactions, ensuring that the CG model retains key features of the self-assembly and phase separation observed in atomistic simulations.

By leveraging CG modeling, we extend simulations to longer timescales and larger system sizes, enabling us to explore whether biomolecular condensates form through **phase separation, self-assembly, or aggregation**. Our approach provides insights into the structural transitions of LGE1$_{!"\#\$}$ within condensates and the fundamental mechanisms governing these transitions. This work contributes to the development of predictive models for biomolecular organization in crowded cellular environments.

Keywords: self-assembly, coarse-graining, phase separation

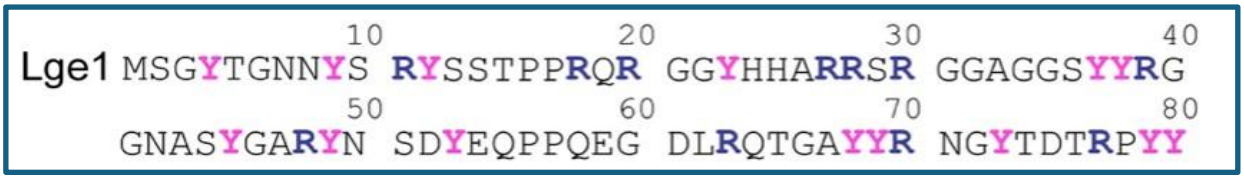

Figure 1. LGE1 1-80 protein used for coarse-graining.

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P.36

Bacterial sedimentation: Effects of activity?

Hyorin Nam[1], *Eleonora Secchi* [2], *Jan Vermant* [1]

[1]*Laboratory for Soft Materials, Department of Materials, ETH Zürich, Switzerland*
[2]*Department of Civil, Environmental and Geomatic Engineering, ETH Zürich, Switzerland*

Presenting author's email: hyorin.nam@mat.ethz.ch

Swimming bacteria, the most well-known and extensively studied form of living active matter,exhibit a remarkable property: they are self-propelled organisms that move without any external fuel. This activity presents a challenging problem in the theoretical understanding of the complex dynamical behaviors within the realm of statistical physics of soft matter.

The sedimentation process in active matter suspension has become a focal point due to the pervasive presence of swimming microorganisms in natural and industrial processes. Some studies have explored simulations of squirmer sedimentation [1] and experimentally examined the behavior of dilute artificial swimmer suspensions [2], but in-depth research on live bacterial sedimentation has yet been carried out. Apart from the result that the presence of swimming bacteria significantly slows the sedimentation front of passive particles [3], we investigated that motile bacterial suspensions which, surprisingly, exhibit a much higher settling velocity compared to non-motile (passive) bacterial suspensions, displaying vortex-shaped instability during sedimentation (Figure 1). We must acknowledge that both suspensions have a volume fraction of ~ 0.00057, which should be in a dilute regime. In the present research, we will focus on studying the origins of this instability and its link to the high settling velocity, particularly in relation to the dilute limit and the excluded volume of swimming bacteria.

Prior to this phase, Vibrio anguillarum was selected based on the criteria that they produce minimum extracellular polymeric substance which leads to biofilm, possess exceptionally high speed (~ 50 $\mu m/s$), and have constant growth kinetics over an extended duration. Preliminary image analysis has been conducted to extract parameters that describe the properties of the selected bacteria such as run-reverse-flick swimming pattern, the distribution of angle change, swim speed, and reorientation time.

Keywords: Active matter, Bacterial sedimentation, Motility, Dilute limit

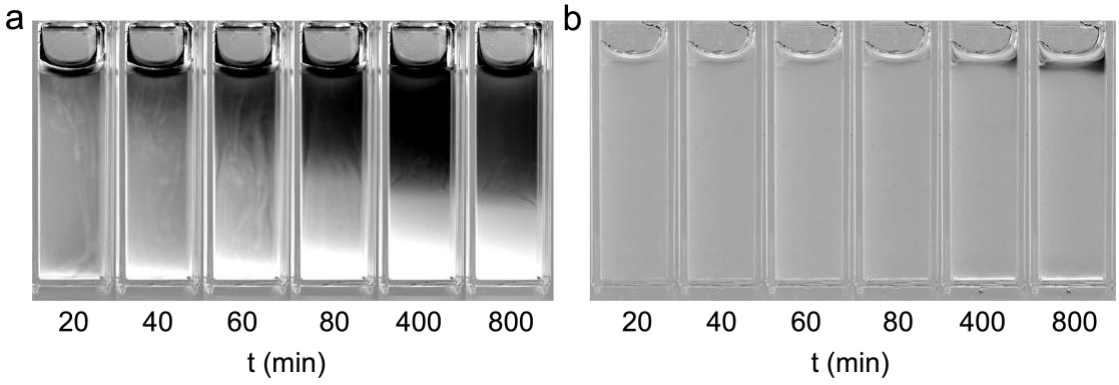

Figure 1. *Bacterial sedimentation of (a) motile and (b) non-motile Vibrio anguillarum.*

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P.37

A 3D bioprinted breast cancer model for drug screening

Ioanna Zorba [1], Varvara Platania [2], Maria Chatzinikolaidou [2,3]

[1]Department of Biology, University of Crete, Heraklion, Greece
[2]Department of Materials Science and Engineering, University of Crete, Heraklion, Greece
[3] Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Heraklion, Greece

Presenting author's e-mail: joanzorb23@gmail.com

Breast cancer is a very heterogenous disease, varying in aggressiveness and prognosis, and one of the most common malignancies worldwide [1]. As the disease progresses, tumors exhibit distinct mechanical and morphological characteristics that correlate to their aggressiveness [1]. At a cellular level, drug sensitivity and the migratory capacity of the cancer cells changes, hindering the treatment. 2D cell culture models are commonly used to study drug responses on breast cancer cells, but with results that often do not reflect preclinical and clinical outcomes [2]. 3D bioprinting offers a promising alternative that enables more complex in vitro drug testing, taking into consideration the cell-cell interactions in a 3D environment mimicking the microenvironment of cancerous tissue, as well as the dynamic interactions of the cells with their environment itself.

In this study, a novel bioink was developed to replicate the biochemical and mechanical properties of the breast cancer microenvironment, which plays a key role to the progression of the disease [1]. The bioink consists of 7.5% poly(ethylene glycol) diacrylate, a synthetic, photocurable, biologically inert polymer with tunable mechanical properties, 7% gelatin that mimics the high collagen content in the breast cancer extracellular matrix [1], and 2% alginate, a natural polysaccharide offering stability to the material via ionic crosslinking.

The developed bioink showed adequate printability, stability, and mechanical properties, with Young's modulus values of 160□30 kPa, comparable to those of breast tumors. Degradation experiments showed a mass loss of 10% over 28 days. Ongoing studies assess the ability of the highly metastatic murine breast cancer 4T1 cells to proliferate and migrate from the bioprinted constructs to a surrounded healthy breast tissue analogue, as well as validate anti-cancer drug effects on the proliferation and migration of the embedded cells within the bioink.

Keywords: Breast Cancer, Tissue Engineering, 3D bioprinting, in vitro model

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Microbial navigation and ecology in flow networks

Ran Tao[1], Georgios Gounaris[1], Eleni Katifori[1], Arnold Mathijssen[1]

[1]Physics Department, University of Pennsylvania

Presenting author's e-mail: rtao21@sas.upenn.edu

Bacteria often thrive in flow networks, including branched microchannels, vascular systems, tissues, foams, and porous media. Instead of being advected downstream, microbes can swim upstream to reach nutrient sources and colonize favorable habitats. Here, we study experimentally and theoretically how bacteria navigate in these structured environments and actively construct niches surrounded by flows. First, we nanofabricated microfluidic networks with branching and looping architectures. Subsequently, we inoculated these devices with E. coli bacteria and mapped out their dynamics using single cell tracking. We reveal that bacteria accumulate in specific areas of the network, governed by the currents in the surrounding network segments. By tuning these currents using flow network theory, we can control the bacterial motion and guide their population dynamics. Finally, we explore the ecology of multiple bacterial species in these flow networks and reveal how different architectures affect microbial coexistence, cooperation, and competition. Hence, we achieve programmable control for various functions, including species-specific depletion and accumulation, species sorting, structured community biofilm formation, and biomedical contamination prevention.

Keywords: Bacteria, Flow Networks, Ecology

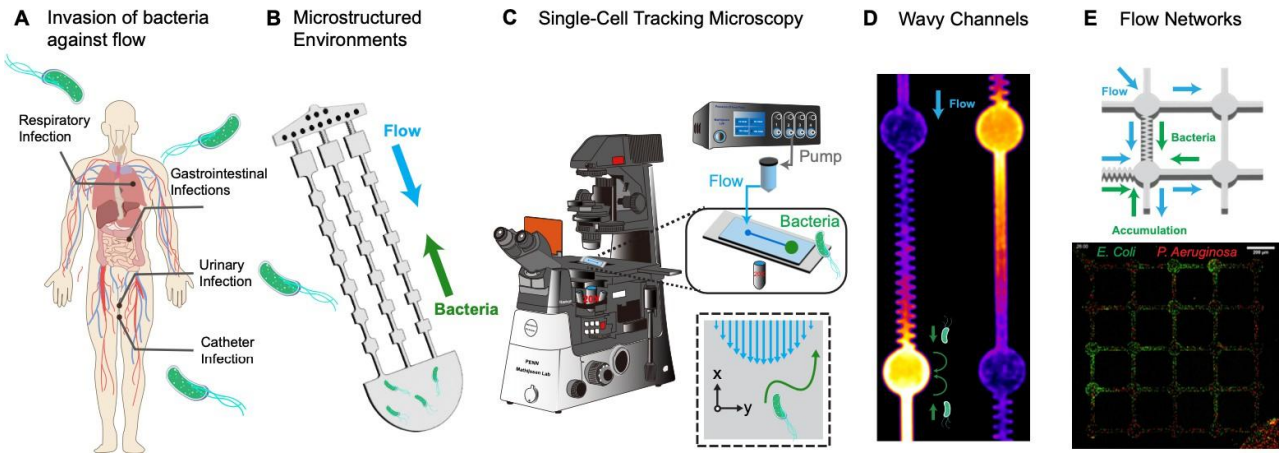

Figure 1. *(a) Bacteria can invade the human body by moving against fluid flows, leading to infections in the respiratory, gastrointestinal, and urinary tracts, as well as catheter-associated infections. (b) A microstructured environment mimics biomedical devices or bodily tracts exposed to bacterial invasion. In this setup, bacteria (green) are introduced in the bottom reservoir (gray) and migrate upstream against the flow (blue). (c) These microfluidic devices are studied using single cell tracking microscopy under well-controlled flow conditions to analyze bacterial behavior at the microscale. (d) Prevent of upstream migration with wavy channels. (e) Flow networks and multi- species ecology. P. Aeruginosa spreads out while E. Coli accumulates in specific nodes.*

P.39

Tuning the binding selectivity in molecular recognition, targeting and activation

Jure Dobnikar [1]

[1] *Institute of Physics, Chinese Academy of Sciences, Beijing, China*

Presenting author's e-mail: jd489@cam.ac.uk

A prerequisite for functioning of vital biological processes is the ability to recognize specific conditions or situations and respond when (and only when) it is needed. This is particularly obvious in the processes involved in the immune response where failure to respond to an attack can be lifethreatening, but so can a wrong response (autoimmune disorder). On a molecular level this means that living systems must be able to respond to the presence of specific molecules in an on-off manner, *e.g.*, triggering a sharp response when external ligands are presented above a certain threshold density, but no response when they are not.
As demonstrated by Martinez-Veracoechea and Frenkel studying binding of ligand-decorated probes to receptor-decorated surfaces [1], probes with ligands that form very strong bonds cannot be selective, while those with multiple ligands each forming a weak bond can exploit the combinatorial entropy of binding to "super-selectively" distinguish between "target" and "non-target" surfaces. Here, I will present our theory of optimal multivalent binding for targeting cells with arbitrary receptor composition [2], which we further applied to design a new method for detecting microbial genome [3]. Moreover, we showed that the multivalent binding theory also underlies the activation of immune system response and can regulate the onset of autoimmune disorders [4].
In our recent study [5], we explored how tuning the inter–receptor attraction can enhance or suppress cellular response to external agents. In the presence of multivalent ligand–coated particles, the cells that operate close to critical conditions can switch receptor-clustering on or off in an almost stepwise fashion by small changes (less than k_BT) of the inter–receptor attraction. This in turn provides a precise control over binding of multivalent external agents to their membranes. Based on our results, it is tempting to speculate that the immune system may tune the receptor attraction to activate or de-activate immune cells, if external ligands are presented above or below a certain threshold density.
Our results highlight that universal physical mechanisms combining macromolecular assembly and statistical mechanics of multivalent binding can transform the non-specific (usually electrostatic) interactions into specific interactions that can efficiently control the processes in biomolecular systems.

Keywords: multivalent binding, receptor attraction, cell targeting immune system activation

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P.40

Biofunctionalized nanocomposite bioinks with anti-Nogo-A antibody for enhanced bone regeneration

Varvara Platania [1], Nikoleta Natalia Tavernaraki [1], Kalliopi Alpantaki [2], Nikoletta Triantopoulou[3], Marina Vidaki [3,4], Martin E Schwab [5], Thimios A Mitsiadis [6], Maria Chatzinikolaidou[1,7]

[1]Dept of Materials Science and Engineering, University of Crete, Heraklion, Greece
[2] Dept of Orthopedics and Trauma, Venizeleion General Hospital, Heraklion, Greece
[3] Dept of Basic Science, Faculty of Medicine, Univ. of Crete, Heraklion, Greece
[4] Institute of Molecular Biology and Biotechnology, FORTH, Heraklion, Greece
[5] Institute for Regenerative Medicine (IREM), Univ. of Zurich, Switzerland
[6] Orofacial Development and Regeneration, Institute of Oral Biology, Centre for Dental Medicine, Medical Faculty, University of Zurich, Switzerland
[7] Institute of Electronic Structure and Laser, FORTH, Heraklion, Greece

Presenting author's email: vplatania@materials.uoc.gr

Bone defect regeneration remains a clinical challenge, with conventional grafting methods often falling short. Injectable hydrogels offer a promising alternative, but their ability to mimic the extracellular matrix (ECM) and direct cell fate remains limited. This study explores the biofunctionalization of gellan gum (GG)/laponite nanocomposite hydrogels [1], with anti-Nogo-A antibodies to enhance osteogenic and angiogenic differentiation. Nogo-A, known for its role in neuronal inhibition [2], also influences stem cell differentiation and tissue regeneration [3]. By integrating anti-Nogo-A into a 3D-bioprinted construct alongside with Wharton's Jelly Mesenchymal Stem Cells (WJ-MSCs), we aim to promote bone and vascular tissue formation in critical-sized defects.

Cytocompatibility was assessed using PrestoBlue®, Live/Dead assays, and scanning electron microscopy. ECM deposition was quantified via collagen and glycosaminoglycan secretion. Osteogenic differentiation was evaluated through qPCR, alkaline phosphatase (ALP) activity, and calcium mineralization, while angiogenesis was assessed via qPCR and protein expression of VEGF, vWF, and PECAM. In vivo studies included subcutaneous implantation and a mouse femoral defect model analyzed via μCT imaging.

The antiNogoMatrix group showed higher metabolic activity and significantly enhanced osteogenesis, evidenced by increased ALP activity and upregulation of SPARK, OPG, BGLAP, and collagen, compared to the control. Angiogenic markers (VEGF, vWF, Ang1) were also elevated. In vivo, antiNogoMatrix implants demonstrated superior bone repair, increased cortical and trabecular density, and no adverse immune reactions.

Biofunctionalizing GG-laponite hydrogels with anti-Nogo-A antibodies enhanced osteogenic and angiogenic differentiation, supporting a novel approach for bone tissue engineering. This strategy offers a promising pathway for next-generation bioinks that control cell fate and improve bone regeneration.

Keywords: 3D bioprinting, vascularized bone regeneration, bioconjugated bioink

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P.41

Preliminary Comparative Analysis of Glioma Cell Survival Following FLASH Irradiation

P. Chuchała[1,2], A. Lenartowicz-Gasik[3], M. Araszkiewicz[1,3], R.Grzela[1], M. Jakielaszek[1] , P. Kamińska[1,2],U. Kaźmierczak[2], A. Korgul[1], J. Rzadkiewicz [3], W. Soroka[3], A. Stankiewicz-Drogoń[1], B. Wielgus-Kutrowska[1]

[1]Faculty of Physics, University of Warsaw [2]Heavy Ion Laboratory, University of Warsaw [3]National Centre for Nuclear Research

Presenting author's e-mail: p.chuchala@student.uw.edu.pl

FLASH is a relatively new and innovative radiotherapy technique, characterized by ultra-short exposure times and extremely high dose rates, offering promising prospects for cancer treatment. Due to its unique characteristics, FLASH has the potential to enhance the efficacy of cancer therapies while simultaneously reducing damage to healthy tissues [1]. This technique is gaining growing interest in radiotherapy research and represents a significant breakthrough compared to conventional fractionated methods.

The aim of this study was to evaluate the biological response of glioma cells to FLASH irradiation, laying the groundwork for future comparisons with conventional fractionated radiotherapy.

The M059K glioma cell line, derived from a human glioblastoma multiforme tumor, was used in the experiments. This cell line is highly sensitive to DNA-damaging agents, which makes it an excellent model for studying cellular responses to various stressors, including ionizing radiation. M059K cells are widely used in research focused on DNA repair mechanisms and cellular radiation responses [2].

Irradiation was conducted using a medical electron accelerator at the National Centre for Nuclear Research in Świerk, with doses ranging from 1 to 11 Gy, administered in three independent biological replicates. A control group (0 Gy) was included for comparison.

Cell survival was assessed using the MTT assay, in collaboration with the Department of Biophysics at the University of Warsaw, as well as the clonogenic assay. The MTT assay evaluates cellular metabolic activity, while the clonogenic assay determines the ability of cells to survive and proliferate following irradiation. The data collected provide a reference point for upcoming studies comparing the biological effects of conventional fractionated radiotherapy and the innovative FLASH technique. Preliminary results will be presented.

Keywords: FLASH therapy, MTT assay, glioma cell, ionizing radiation effects

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P.42

Photophysical activity of curcumin-based gold Nanoparticles: green synthesis and impact on toxicity on planktonic bacteria

Surita Basu[1], Pooja [2], Rakesh Kumar Sharma[2] and Rachel Meallet [1]

[1] Institut des Sciences Moléculaires d Orsay, CNRS, Universite Paris Saclay
[2] Department of Chemistry, University of Delhi, Delhi, India

Presenting author's e-mail: surita.basu@universite-paris-saclay.fr

Curcumin, a naturally occurring bioactive compound derived from turmeric, has garnered significant attention for its diverse biological and pharmacological activities, making it a versatile candidate for various biomedical applications [1, 2]. However, the clinical application of curcumin is low because of its poor aqueous solubility, rapid metabolism, and low bioavailability, which significantly hinders its efficacy in vivo. Gold nanoparticles have emerged as promising drug delivery vehicles due to their unique physicochemical properties, including tunable size, high surface area-to-volume ratio, biocompatibility, and ease of surface modification, offering a versatile platform for conjugating and delivering therapeutic agents like curcumin.
Green synthesis methods for gold nanoparticles, employing plant extracts as reducing and stabilizing agents, have gained prominence as eco-friendly and cost-effective alternatives to conventional chemical synthesis routes [3].
In this study, we have explored a new facile and green method to synthesize the bioactive reagents curcumin and gold nanoparticles together. Curcumin coated gold nanoparticles (CGNP) were synthesized using curcumin as both reducing and capping agent. CGNP were characterized by various techniques, including UV-Vis spectroscopy, Fluorescence Spectroscopy, dynamic light scattering (DLS), scanning electron microscope and transmission electron microscopy (TEM). Curcumin is insoluble in water in pH 7 but is soluble in basic pH so the synthesis were carried out in basic pH. The strong absorption band of the nanoparticle at 520 nm confirms the formation of spherical gold nanoparticles as shown in Fig. 1. The further study of characterization are related to Emission spectroscopy, SEM and TEM imaging. The effect of these nanoparticles on the toxicity on planktonic bacteria, in dark, with UV light and with white light is to be evaluated along with ability of macrophages to eliminate bacteria, by measuring internalization and killing of bacteria by macrophages. The formation of different self-assembled structure on the surface of polymeric thin film.

Keywords: Green synthesis, biology, curcumin, gold nanoparticles, toxicity

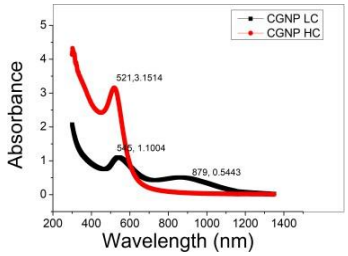

Figure 1. *UV Spectroscopy of curcumin coated gold nanoparticles.*

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P.43

In silico evolving monomer structures for directional self-assembly

Marija Krstić [1], *Anđela Šarić* [1]

[1]*Institute of Science and Technology Austria*
marija.krstic@ist.ac.at

Filamentous proteins inside cells assemble, disassemble, and reorganize to power cell division. These filaments undergo different types of turnover, one of them being treadmilling. Treadmilling is a form of polymer dynamics, where monomers keep preferentially attaching to one end of the polymer and detaching from another, making the polymer move directionally without directional movement of monomers. Even though experimental studies have shown treadmilling is key to sustaining cell division, the exact mechanism underlying it is unknown.

In an experimental study [1], many treadmilling actins and tubulins were found to exhibit a conformational switch, whose two states correlate to the monomer being either free in solution or polymerized. This motivated computational work [2], showing that robust treadmilling is achievable with different kinetics on different sides of the polymer. While different kinetics may arise from multi-strandedness of filaments, some of them still treadmill while forming single stranded filaments, such as FtsZ. The research gap that remains here is **how do filaments composed of identical monomers spontaneously develop such kinetic asymmetry in a single-stranded filament?**

In our work, we try to understand how different coarse-grained colloidal designs of a monomer influence self-assembly, with the goal of achieving polar growth. To navigate through the complex design space we use a genetic algorithm, which will help us gain insight into important design features. We combine a genetic algorithm with molecular dynamics to evaluate the self-assembly process and guide the algorithm towards building designs exhibiting polar growth.

Keywords: polar growth, genetic algorithm, monomer design, self-assembly

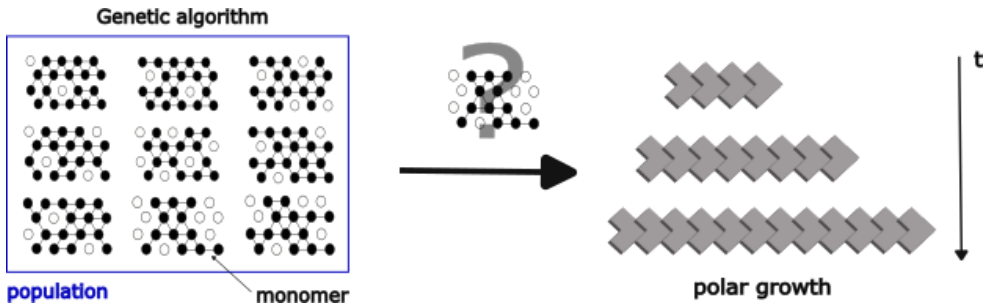

Figure 1. *Evolving different monomer designs using a genetic algorithm with the goal of achieving polar growth*

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P.44

Spatiotemporal patterns of membranes induced by surface molecular binding/unbinding

Hiroshi Noguchi

Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581, Japan
Presenting author's e-mail: noguchi@issp.u-tokyo.ac.jp

We studied the nonequilibrium dynamics of molecules binding and unbinding to a membrane [1-4]. We consider two types of bound states. It is a model system for chemical reactions on a membrane or molecular transport through a membrane. For the reaction case, the two states are reactant and product, and the membrane is a catalyst. For the transport case, the molecule can bind to both surfaces and flip between these two states. One cycle consumes chemical energy (reaction in buffer or transport between upper and lower solutions). We simulated cyclic dynamics using a square-lattice model and an off-lattice meshless membrane model.

In a cyclically symmetric condition, the homogeneous dominant states cyclically change (unbound to reactant, product, and unbound) via nucleation and growth at low cycling energy. In contrast, spiral waves are formed at high energy. The waves are generated from the contacts of three states. These two modes can temporally coexist in medium cycling energy. These transitions can be understood from the competition between nucleation and growth of different states [1].

When binding changes the membrane spontaneous curvature, these spatiotemporal dynamics are coupled with membrane deformation [4]. Moving biphasic domains and time-irreversible fluctuating patterns emerge. The domains move ballistically or diffusively depending on the conditions, as shown in Fig. 1.

Keywords: Curvature-inducing proteins, Spiral wave, Active Potts model

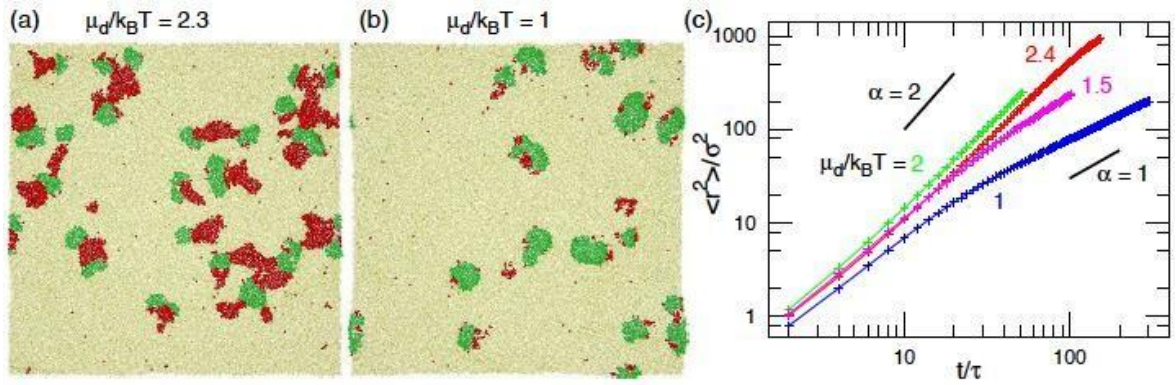

Figure 1. *Motion of biphasic domains [4]. (a, b) Snapshots of membranes. Green and red spheres represent upper and lower bound states with positive and negative spontaneous curvatures, respectively. (c) Mean squared distance $\langle r^2\rangle$ of the domain with different chemical binding potential μ_d for the binding to the lower surface.*

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P.45

Tracking Microorganisms in Complex Environments

Thierry Darnige[1], Daniel Midtvedt[2], Renaud Baillou[1], Benjamin Perez Estay[1], Changsong Wu[1], Alex Le Guen[1], Giovanni Volpe[2], and Eric Clément[1]

[1]Laboratoire PMMH-ESPCI Paris, PSL Research University, Sorbonne Université and Denis Diderot, 7, quai Saint-Bernard, Paris, France.
[2]Physics Department, University of Gothenburg, Sweden.

Presenting author's email: rbaillou@ub.edu

How microorganisms respond to and interact with their environment can vary significantly from individual to individual, which can have important microbiological and ecological implications. However, most microscopy techniques can only observe motile microorganisms for short times because of their limited fields of view.

Using Lagrangian tracking, a single microorganism can be followed in 3D potentially indefinitely, allowing to decipher individual phenotypical traits. Current Lagrangian tracking methods [1] use the fluorescence emitted by a microorganism as feedback to keep it in focus (see figure 1). However, over long times, epifluorescent imaging can induce photobleaching and photodamage, and importantly, not all microorganisms can be easily made fluorescent. Additionally, traditional algorithms used in feedback loops to determine microorganism position are prone to errors, especially in optically complex media.

Here, we present a faster, more reliable, and versatile Lagrangian tracking method that uses deep learning to determine the 3D position of the microorganism. This new method demonstrates enhanced accuracy and speed in tracking fluorescent bacteria with fluorescence microscopy also in optically complex media. Furthermore, we track bacteria with other microscopy modalities, such as brightfield microscopy---for example, this enables us to track magnetotactic bacteria, which cannot be made fluorescent without degrading their magnetotactic properties. These novel capabilities allow us to extract previously inaccessible quantitative information, significantly advancing the study of microorganism behavior---and thus opening new avenues for research in complex biological and ecological systems.

Keywords: Tracking - Living Matter - AI

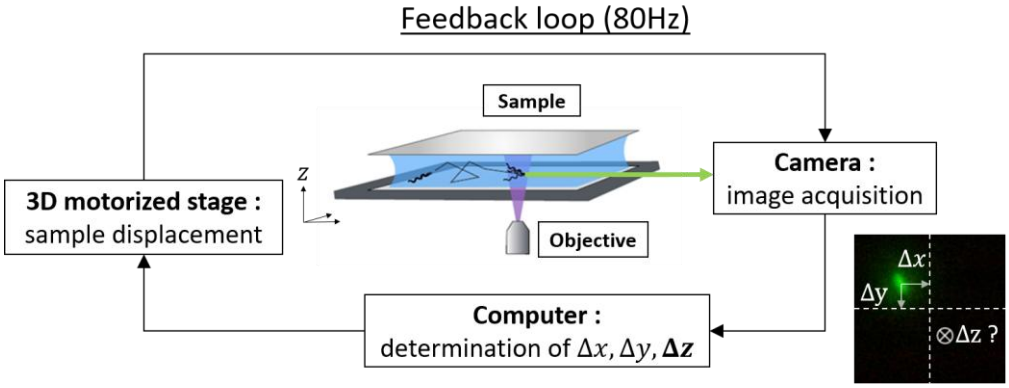

Figure 1. *Illustration of the 3D Lagrangian tracking system with the feedback loop between the camera image of a fluorescent bacteria body (in green) and the displacement of the 3D stage. AI is used to determine the live position of the motile object.*

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P.46

Where are the Bulk Lipids? A Combined Multiscale Small Angle Scattering and Computational Study

Enrico F. Semeraro [1,2], *Paulina Piller* [1,2], *Ladislav Bartoš* [3,4], *Rahul Deb* [3,4], *Sandro Keller* [1,2], *Robert Vácha* [3,4] *and Georg Pabst* [1,2]

[1] *Department of Molecular Biosciences, NAWI Graz, University of Graz, Graz, Austria*
[2] *Field of Excellence BioHealth, University of Graz, Graz, Austria*
[3] *CEITEC – Central European Institute of Technology, Masaryk University, Brno, Czech Republic*
[4] *National Centre for Biomolecular Research, Masaryk University, Brno, Czech Republic*

Presenting author's e-mail: enrico.semeraro@uni-graz.at

The dynamic interplay between lipid bilayers and integral membrane proteins (IMPs) is fundamental for understanding the physicochemical properties of cell membranes. Unlike classic model membranes, which reflect the so-called *bulk* properties of bilayers, the structural stress present in more complex membrane systems can impact the arrangement and function of IMPs [1,2]. In turn, when the hydrophobic portion of an IMP differs from the thickness of the acyl-chain region of surrounding lipids—a phenomenon known as hydrophobic mismatching—the insertion of such IMPs leads to a free energy penalty that is alleviated by membrane deformations. Currently, experimental measurements of lipid thickness near membrane proteins are limited and have only recently been explored through NMR [3,4], to the best of our knowledge.

In this study, we propose a multiscale model for small-angle X-ray scattering (SAXS) that simultaneously probes the average trans-bilayer structure and the number and arrangement of the outer membrane protein phospholipase A (OmpLA) within the spherical frame of the hosting large unilamellar vesicle (LUV). OmpLA, an integral enzyme that hydrolyses phospholipids upon dimerization, is reconstituted in LUVs, now referred to as proteoliposomes. LUVs composed of 1-palmitoyl-2-oleoyl-glycero-3-phosphocholine (POPC) or 1,2-dilauroyl-sn-glycero-3-phosphocholine (DLPC) are selected for their differing hydrophobic thicknesses, respectively exceeding or falling short of the OmpLA hydrophobic patch. We combined SAXS modeling with the results from all-atom molecular dynamics (MD) simulations focusing on a single IMP in membrane patches of different sizes.

The combination of MD results and SAXS data modeling allowed us to characterize the extension and profiles of membrane deformations near OmpLA as well as the presence or absence of bulk lipids, i.e., portions of stress-free bilayer (respectively for DLPC and POPC). Additionally, the results highlight the presence of effective repulsive interaction between OmpLA, which maintains its monomeric state.

Keywords: proteoliposomes; bilayer-structure; hydrophobic-matching; multiscale-model; small-angle-scattering; molecular-dynamics.

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P.47

Self-assembly of Pluronic L121 copolymers in aqueous solutions and their role as encapsu-lating agents

Isabella Munafò [1], Dino Costa [1], Giuseppe Milano[2], Gianmaco Munaò[1]

[1]Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra,
Università degli Studi di Messina, Viale F. Stagno d'Alcontres 31, 98166 Messina, Italy.
[2]Department of Chemical, Materials and Production Engineering, University of Naples Federico II, 80125 Napoli, Italy.
Presenting author's e-mail: isabella.munafo@studenti.unime.it

The implementation of polymeric materials in modern scientific research is practically ubiquitous [1]. A field of application that is attracting considerable interest is the use of polymeric materials for the creation of biocompatible structures [2]. This process is favored by the use of block copolymers, in which each polymer chain is typically made up of two (or more) polymers of different chemical nature. Here we present a Molecular Dy- namics simulation study focused on self-assembly of Pluronic L121 copolymers in aqueous solutions and their role as encapsulating agents. Pluronics at issue are nonionic triblock copolymers composed of a central hydrophobic chain of polyoxypropylene flanked by two hydrophilic chains of polyoxyethylene. By analyzing the dependence of self-assembled structures by Pluronic concentration ϕ, we observe that for 5% ≤ ϕ ≤ 10% a number of aggregates appears, finally coalescing into a single large aggregate for higher concentra- tions. The shape of this aggregate is spherical for ϕ = 15%, becoming ellipsoidal upon increasing ϕ to 20%. If the concentration further increases, the onset of compenetrating cylindrical structures is found, anticipating the development of lamellar structures for 60% ≤ ϕ ≤ 90%. The suitability of Pluronic L121 copolymers as encapsulating agents is investigated by simulating their self-assembly behavior in the presence of gallic acid and ibuprofen, finding that the polymer is able to efficiently encapsulate the latter, while gallic acid remains dispersed in the surrounding water. These results may provide useful recipes to drive the appearance of targeted structures in biocompatible materials.

Keywords: encapsulating agents, drug-delivery, gallic acid, ibuprofen, Molecular Dynamics Simulation, coarse-grained

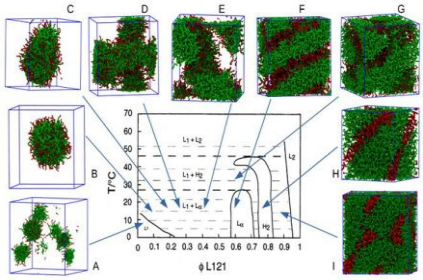

Figure 1. *Equilibrium microscopic configurations of L121 in water, upon different conditions of concentration nd temperature; EO in red, PO in green, water is omitted for clarity. In the central panel, the experimental phase for Pluronic L121 is reported[3]. Accordingly, L1 identifies a phase composed by unimers and large aggregates; La, lamellar phase; H2 reverse hexagonal phase; L2, concentrated polymer solution. Dashed areas* indicate two-phase coexistence regions, delimited by three-phase bold-dashed lines.

Acknowledgements: In case necessary, must be located at the end of the abstract, just before the references.

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P.48

Durable, thermally stable, plant-based moisture-protective wax coatings

Santhra Krishnan P[1], Sriharitha Rowthu[2], Sreeram K. Kalpathy[1]

[1] *Indian Institute of Technology Madras, Chennai - 600036, India*
[2] *Indian Institute of Technology Gandhinagar, Gandhinagar - 382055, Gujarat, India*

Presenting author's e-mail: mm21d009@smail.iitm.ac.in

Natural waxes offer an eco-friendly alternative to synthetic hydrophobic coatings. Given that several superhydrophobic species occur in nature, waxes from these sustainable sources are potential materials for creating non-wetting surfaces. This study examines the wetting properties of recrystallized wax coatings extracted from three naturally occurring superhydrophobic species, viz., Lotus (Nelumbo Nucifera) leaves, Bauhinia leaves, and purple Periwinkle (Vinca) flower petals, considering wetting behaviour, recrystallization time and temperature, durability, and stability [1].

Lotus wax coatings formed nanorods resembling natural Lotus leaves, while Periwinkle and Bauhinia waxes failed to replicate their natural micro/nano structures. Lotus wax exhibited a static contact angle (SCA) of ~150°, roll-off angle of ~8°, and self-cleaning properties. In contrast, Periwinkle and Bauhinia waxes had lower SCAs (~110°). All three drop-cast coatings maintained hydrophobicity for 180 days, showed thermal stability up to 100°C, and resisted pH variations from 2.6 to 11.5. They also withstood 3000 water droplet impacts without degradation. Additionally, the coatings had low moisture absorption rates: Periwinkle (5.5×10^{-4} wt.%/day) < Bauhinia (6.75×10^{-4} wt.%/day) < Lotus (1.075×10^{-3} wt.%/day). These properties make them ideal for applications like food packaging and protective wood finishes. In food packaging, they can prevent moisture infiltration, preserving freshness and preventing spoilage. As for wood finishes, they can create a moisture-repellent barrier that protects against swelling, warping, and fungal growth, enhancing durability.

Keywords: Superhydrophobicity, Natural waxes, Recrystallization, Durability, Moisture Repellency

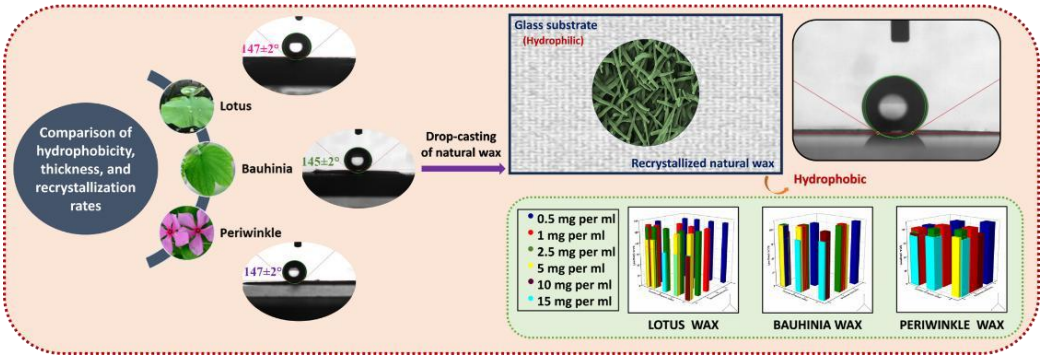

Figure 1. *Durable bio-based hydrophobic recrystallized wax coatings*

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BF. Biomedical & Food applications

P.49

Utilization of Insoluble Proteins from Wet Processing of Coconut for Stabilization of Pickering Emulsions

Selvakumar Murugesan[1], N Sai Prasanna[1], Trivikram Nallamilli[1], KSMS Raghavarao[1]

[1]Department of Chemical Engineering, Indian Institute of Technology Tirupati, Tirupati - 517619, Andhra Pradesh, India.

Presenting author's email: ch21d003@iittp.ac.in; princeselvam95@gmail.com

Edible particles, especially from plant sources, are of increasing interest for application in the development of food, and nutraceutical products. The present study deals with the utilization of insoluble protein particles (CIPP) from the wet processing of coconut for the stabilization of Pickering emulsions (PEs). Pepper Oleoresin (PO) and Pepper Essential Oil (PEO) are used as "oil phases". Dispersion studies were carried out using freeze-dried CIPP at different values of pH (3-10), temperature (30-60° C), and salt concentration (0.1-1M NaCl). The physicochemical properties of CIPP, such as wettability, particle size, surface potential, and thermal stability, were examined. The ultrasonication method is used to stabilize the O/W PEs. The optimal conditions for the ultrasonication method are identified as ultrasonication time-5 min, amplitude-40 %, and pulse mode 5s-ON /5s-OFF. The result indicated that the stability of PO and PEO emulsions increased with an increase in the concentration of CIPP. At low concentrations of CIPP (≤1% w/w), the coalescence of emulsion droplets resulting in phase separation is observed. At 2% CIPP, good stability is shown by both PO and PEO emulsions, with mean droplet sizes measured around 1 micron. The corresponding zeta potential are -25±1.3 mV and -29.4±1.6 mV, respectively. Other physical characteristics such as pH, viscosity, stability, and creaming index are examined for both PEs. The fluorescence microscopy studies revealed the adsorption of CIPP on the O/W interface. Overall, the CIPP have the potential to serve as a "Functional Ingredient" for producing "Surfactant- Free" Pickering emulsions.

Keywords: Pepper oleoresin; Essential oil; Pickering emulsions; Coconut byproducts; Protein particles

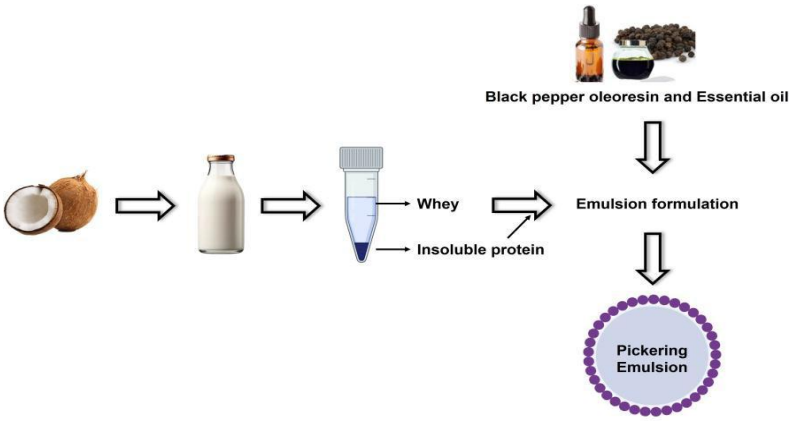

Figure 1. *Flow diagram for the development of Black pepper oleoresin emulsion using coconut insoluble proteins particles*

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P.50

Modern polysaccharide-based carriers for biomedical applications

Jagoda Chudzińska-Skorupinska [1], Agata Wawrzyńczak [1], Julia Kwiatkowska [1], and Agnieszka Feliczak-Guzik[1]

[1]Adam Mickiewicz University, Faculty of Chemistry, Uniwersytetu Poznańskiego 8, 61-614 Poznań, Poland

Presenting author's e-mail: agaguzik@amu.edu.pl

Standard methods of delivery of active substances (e.g. drugs) do not fully ensure that adequate efficacy is achieved. The reason for this is that these substances do not reach only the areas affected by lesions, but are spread throughout the body, also migrating to healthy tissues. For this reason, carriers of active substances targeting selective therapies are being increasingly used. The effectiveness of the active ingredient depends largely on the carrier of these substances used, as it plays a key role in the effectiveness of pharmaceutical products [1-2]. The role of the carrier is to deliver the active ingredient to the target site to ensure an appropriate cosmetic or pharmacological effect. During the development of an appropriate composition and form of the carrier, it is particularly important to determine the release rate of the incorporated active substances.

The aim of the ongoing research was to synthesize and characterize modern polysaccharide-based carriers, such as microneedles, and test their applicability as carriers of selected plant extracts with biomedical potential (e.g., red beet or parsley leaves extracts, that are rich in active substances with antioxidant and anti-inflammatory properties, specifically betanin and apigenin).

The study optimized the synthesis of microneedles by selecting (i) the concentration of the polysaccharide used (e.g. hyaluronic acid sodium salt); (ii) the method of sample preparation; (iii) the concentration of plant extracts incorporated into the resulting carriers. In addition, the antioxidant potential of the plant extracts used and the active substances present in them was evaluated. Based on the results, the optimal concentration of hyaluronic acid sodium salt was found to be 10 wt. %; and the aqueous solutions of hyaluronic acid sodium salt should be prepared using ultrasounds. Incorporation of the obtained carriers with 1 wt. % of red beet extract resulted in microneedles with an average diameter of 280 μm ± 32 μm per patch.

Keywords: microneedles, biomedical applications, plant extracts, betanin, apigenin, antioxidation potential.

Acknowledgements: The research was supported by the IDUB project S@R 177/04/UAM.

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P.51

Ordered mesoporous silica synthesized by the template- assisted approach as a platform for food additives delivery

Agata Wawrzyńczak [1], Agnieszka Kłosowska [1,2], Veronica Latini [1], Izabela Nowak [1], and Agnieszka Feliczak-Guzik [1]

[1]Adam Mickiewicz University in Poznań, Faculty of Chemistry, Uniwersytetu Poznańskiego 8, 61-614 Poznań, Poland
[2]Allsenses Poland, Święty Marcin 29/8, 61-806 Poznań, Poland

Presenting author's e-mail: agata.wawrzynczak@amu.edu.pl

Food additives such as flavors or aromas are usually composed of volatile substances that are susceptible to chemical reactions when exposed to air or light. To reduce this instability, the encapsulation process in more stable carriers is frequently used [1]. Ordered mesoporous silica (OMS) is often considered a platform that can adsorb or encapsulate a large number of compounds with potential applications, for example, in catalysis, sensors, separation, or delivery of drug and food ingredients [2].

OMS-based supports can be obtained by the organic-inorganic self-assembly process in the presence of soft matter, namely amphiphilic surfactants or biomacromolecules, as templates. This type of synthesis is driven mostly by weak noncovalent or electrovalent bonds between surfactant molecules and inorganic species. It is performed under basic or acidic conditions, where the polymerization and cross-linking rates of silica precursors can be easily controlled by the surfactant- templating assembly [3].

In the course of our study, OMS-based materials with different mesoporous structures, i.e. MCM-41 and MCM-48 with 2D hexagonal p6mm and 3D cubic Ia$\bar{3}$d mesostructures, respectively, were obtained. A two-step synthesis was used, which involved the formation of a liquid crystal phase coated with silicon dioxide through the interface reaction between a template agent (cetyltetramethylammonium bromide) and a silicon source (tetraethoxysilane), followed by removal of the template agent through calcination. The synthesis protocols used allowed silica matrices with mesoporous channels to be obtained with the appropriate structure and desired degree of ordering, as demonstrated, for example, by low-angle XRD measurements and TEM images. The OMS obtained served as carriers for citrus aroma (CA), in order to ensure its stability and controlled release in selected food products, such as flavored teas. The CA adsorption process was carried out with different concentrations of starting solutions (5 wt.%, 10 wt.%, 15 wt.%). The degree of loading of the silica carrier with CA was checked by FT-IR and TG measurements. The CA release profiles were controlled by GC measurements, taking into account the three main components of the aroma, namely limonene, linalool, and citral. The results obtained indicate a significant potential for OMS- based materials to be used in the food industry as platforms for the delivery of food additives.

Keywords: ordered mesoporous silica, surfactant-templating assembly, controlled release, citrus aroma, food additives.

Acknowledgements: The financial support of the IDUB project 177/04/UAM is highly acknowledged.

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P.52

Biobased viscoelastic materials for lung tissue engineering

Louise Overzet [1], Alexander Morozov[1], Andreia F Silva[1]

[1]School of Physics & Astronomy, The University of Edinburgh, Peter Guthrie Tait Road, Edinburgh EH9 3FD, UK

Presenting author's e-mail: loverzet@ed.ac.uk

Chronic obstructive pulmonary disease (COPD) is a severe, end-stage lung disease and the fourth leading cause of death worldwide[1]. Extracorporeal membrane oxygenation (ECMO) has been used as a life-support tool for critically ill patients who can no longer survive with optimal medical therapy. However, there is ongoing controversy over whether patients on ECMO should receive lung transplantation[2].

To date, lung transplantation remains the only definitive curative treatment for end-stage lung disease. Efforts have been made to use decellularized lungs scaffolds postmortem, and transplant in vitro. However, this method has been limited due to lack of donor and the suitability of the scaffold[3,4].

In the present study, we investigate how biobased materials can effectively contribute to regenerate pulmonary tissues. The native lung extracellular matrix (ECM) is a macromolecular structure that provides mechanical support, stability and elastic recoil for different pulmonary cells. The ECM plays an important role in lung development, remodelling, repair, and the maintenance of tissue homeostasis[5]. Investigating viscoelastic biomaterials to replicate the lung ECM could lead to the development of models and, ultimately, real-life solutions for pulmonary diseases.

In this work, we study the mechanical, flow and morphological properties of biopolymers, as cellulose based ones, with potential to be used for lung regeneration. Rheological measurements, microscopy techniques, and spectroscopy methods have been used to characterise the biomaterials under study. Results show that the mechanical properties of the polymers under study can be adapted by changing concentration, molecular weight and adding physical crosslinkers. Nevertheless, we find that due to lungs complex structure, finding polymers blends for lung regeneration is challenging and needs to be further explored.

Keywords: Biobased materials, Rheology, Lung Tissue Engineering.

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P.53

A double-layered skin analogue with antimicrobial activity

Aikaterini Gialouri[1], Maria Chatzinikolaidou [1,2]

[1] Department of Materials Science and Engineering, University of Crete, University Campus Voutes, 70013 Heraklion, Greece

[2] Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Nikolaou Plastira 100, Heraklion, 70013 Crete, Greece

Presenting author's email: katerinagialoyri@gmail.com

The development of complex biomimetic skin analogues for biomedical applications has attracted increasing attention recently. Bioengineered skin constructs address key challenges in wound healing, regenerative medicine, and drug testing, offering an alternative to animal testing. Such models aim to mimic the architecture and functionality of native skin. This study focuses on the development of a novel 3D skin model integrating electrospinning and bioprinting technologies to construct a physiologically relevant substitute. An electrospun poly(ethylene) oxide (PEO)/guar gum nanofibrous membrane covered with human keratinocytes has been designed to mimic the epidermis layer, while a supportive hydrogel of PEO/guar gum with encapsulated fibroblasts aims to mimic the dermis. A novel complex system based biomimetic hydrogels attempts to ensure the efficiency of the model, in terms of biocompatibility, mechanical support, biodegradability and drug release. The electrospun layer was functionalized with thymol, an FDA approved, plant-derived antimicrobial and antioxidant component.

The morphology of fibers was investigated by means of scanning electron microscopy, following thymol incorporation within the PEO/guar gum blend. Water contact angle, FTIR, degradation rate study and thermogravimetric analysis characterized the raw and composite materials. The mechanical properties of the membranes and the hydrogel were evaluated. Cell viability, proliferation and morphology of fibroblasts and human keratinocytes were evaluated.

A PEO/guar gum skin analogue was successfully developed, consisting of nanofibrous membranes and a supportive hydrogel layer. The mechanical characteristics of the complex model were close to physiological values, with tensile strength values of 12±6 MPa. Additionally, the skin analogue exhibited cytocompatibility up to 150% of the tissue culture treated polystyrene control and validated the native biological functionality. Moreover, the evaluation of the antibacterial activity of thymol-functionalized membranes against Gram-positive and Gram-negative strains highlighted the antimicrobial potential of the epidermis-like layer.

This study reports on the fabrication of a low-cost skin analogue comprising PEO/guar gum. Taken together, it was evident that this skin mimicking model serves as an analogue for drug testing applications.

C. Colloidal matter

P.54

Hierarchical Colloidal Assemblies from Crossed Electric and Magnetic Fields

Indira Barros [1], Sayanth Ramachandran [1,2], and Indrani Chakraborty [1]

[1]Department of Physics, Birla Institute of Technology and Science, Pilani-K K Birla Goa Campus, Zuarinagar, Goa 403726, India
[2]Max-Planck Institute for Polymer Research Mainz, Ackermannweg 10, 55128 Mainz, Germany

Presenting author's e-mail: indirabarros98@gmail.com

Tunable external fields offer a powerful way to direct colloidal assembly, enabling the creation of dynamic and reconfigurable materials [1]. While magnetic field mediated assembly is fairly straight forward—primarily governed by dipolar interactions—electric field mediated assembly is more intricate, with field parameters determining diverse structural outcomes. By tuning factors such as frequency, voltage, zeta potential, and ion concentration, one can achieve a variety of structures ranging from linear chains, crystalline and glassy states to oligomers and networks [2].

In this work, we explore the hierarchical self-assembly of colloidal particles under a combination of sequentially applied electric and magnetic fields. When subjected to an out-of-plane AC electric field within a frequency range where electrohydrodynamic (EHD) flows dominate over dielectrophoresis, the particles form planar or glassy structures. In contrast, an in-plane magnetic field induces chain formation due to magnetic dipolar interactions. However, when both fields are applied in succession, the particles reorganize in response to the latter field (electric or magnetic) while still retaining the order induced by the former, resulting in hierarchical structures. Specifically, at larger length scales (~100 μm), we observe planar ordering dominated by the electric field, whereas at smaller scales (a few micrometers), chain-like structures are observed due to magnetic interactions. The final morphology of the structure can be tuned by adjusting the magnetic or electric field strength, the frequency of the applied electric field, the particle concentration and the sequence of the applied electric/magnetic fields.

These findings demonstrate how controlled field sequences can tune colloidal assemblies, with potential applications in advanced adaptive and functional materials.

Keywords: colloids, self-assembly, field induced assembly, hierarchical structures

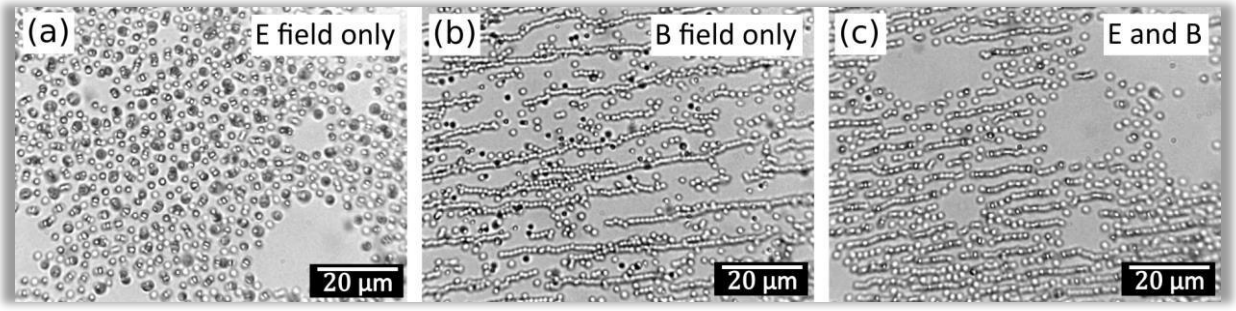

Figure 1. *1 μm particles showing (a) planar structure formation under an AC electric field, (b) chain-like structures under a magnetic field and (c) hierarchical structures composed of chain segments within planar electric field domains under combined electric and magnetic fields.*

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P.55

Training Depletion Colloidal Gels: Strengthening Through Oscillatory Shear

Vasiliki Chrysoulaki[1,2], *Manos Vereroudakis*[1], *Mohan Das*[3], *Esmaeel Moghimi*[4], *George Petekidis*[1,2]

[1]*IESL, FORTH, Heraklion, Crete, Heraklion 71110, Greece*
[2]*Department of Materials Science, Technology, University of Crete, 71003, Heraklion, Crete, Greece*
[3]*Universität Wien, Wien 3144A, Austria*
[4]*Georgetown University, Washington, WA*

Presenting author's email: chrysoulakiv@iesl.forth.gr

Depletion colloidal gels are versatile soft materials with mechanical properties that can be tuned through applied shear. The system under study is a depletion gel of (nearly) monodisperse Poly-methyl methacrylate (PMMA) particles at large volume fraction (44%). It is observed that oscillatory shear in the region of intermediate strain amplitudes weakens the gel network depending on duration of pre-shear. This drop of gel's moduli, according to confocal microscopy and molecular dynamics simulations is related to the crystallization of the gel structure and suggests that oscillatory shear "pushes" the system towards phase separation. However, this study focuses on a distinct regime where specific oscillatory shear conditions instead strengthen the gel, a phenomenon we term "training." Using rheology combined with confocal microscopy, we investigate how strain amplitude, frequency, and shear duration influence both the macroscopic mechanical properties and the microstructure of the gel. This study provides valuable insights into the mechanisms of gel strengthening and demonstrate how oscillatory shear can be used to enhance the mechanical properties of colloidal gels for a variety of applications.

Keywords: colloidal gels, rheology, oscillatory shear, depletion interactions, gel training

P.56

Ultrasound-induced softening in depletion colloidal gels

Vasiliki Chrysoulaki[1,2], Thomas Gibaud[3], George Petekidis[1,2]

[1]IESL, FORTH, Heraklion, Crete, Heraklion 71110, Greece
[2]Department of Materials Science, Technology, University of Crete, 71003, Heraklion, Crete, Greece
[3]Univ Lyon, Ens de Lyon, Univ Claude Bernard, CNRS, Laboratoire de Physique, 69342 Lyon, France

Previous studies have demonstrated that combining rheology with ultrasound provides valuable insights into the mechanical and structural dynamics of soft materials (T. Gibaud et al., Phys. Rev. X, 2014). Building on this, we investigate the effects of ultrasound on depletion colloidal gels, focusing on how ultrasound-induced vibrations influence their rheological properties. The system under study is a depletion gel of (nearly) monodisperse poly-methyl methacrylate (PMMA) particles at a large volume fraction (44%). A rheometer combined with an ultrasound transducer was used to apply controlled shear and ultrasound simultaneously, enabling precise tuning and monitoring of the system. Our findings reveal that the softening of the gel when exposed to ultrasound strongly depends on both the frequency of the ultrasound and the amplitude of the vibrations. By systematically varying these parameters, we observe distinct regimes of gel response, offering new insights into the interaction between acoustic energy and colloidal gel networks. This study highlights the tunability of mechanical properties of depletion colloidal gels through ultrasound and points to the need for further research whether ultrasound vibrations induce any microstructural changes within the gel network.

Keywords: colloidal gels, ultrasound, rheology, oscillatory shear, depletion interactions, gel tuning

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Effects of Dispersion and Preshear on Rheological Behavior of Needle shaped Clay Dispersions

Malavika Mekkat Narayanan [1,2], *Benoit Loppinet* [2], *Andrew Clarke* [3], *George Petekidis* [1,2]

[1] *Institute of Electronic Structure and Laser, Heraklion, Greece* [2]*Department of Material Science and Engineering, University of Crete GR 70013, Heraklion, Greece*
[3]*SLB, Schlumbergerger, Cambridge Research Ltd., High Cross, Madingley Road, Cambridge CB3 0EL, United Kingdom*

Presenting author's e-mail: mnmalavika@iesl.forth.gr

Recent studies have shown that importance of homogenisation and pre-shear in controlling the rheology of clay dispersions [1][2].This study explores the rheologicalproperties in aqueous dispersions, of needle-shaped sepiolite clay. By varying preparation protocols (homogenisation rate, time and temperature) for various particle concentration we establish the optimal protocol for individual needle dispersion by examining elastic modulus. In an attempt to tune the rheological response of dispersion we examine the effects of pre-shear on viscoelasticity, yield stress exploring different concentrations and temperatures [1] [3]. Rheological assessments, utilizing steady shear and dynamic oscillatory techniques, reveal significant changes in flow behavior influenced by these parameters.
We examine the gel network structure using combination of light scattering, small-angle X-ray scattering (SAXS)and SEM, to relate the gel network structure to the rheological variations [1]. Results demonstrate that controlled pre-shear effectively tailor the gel's yield stress and thixotropic behavior, critical for precise flow applications.

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P.58

Induced self-assembly of gold nanoparticles by depletion interactions

Tal Zeharia[1], Yaelle Schilt[2], Uri Raviv[2,3], Yael Levi-Kalisman[3], Rachel Yerushalmi-Rozen[1,4]

[1] Department of Chemical Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel
[2] Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
[3] The Center of Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
[4] The Isle Katz Institute for Nanoscience and Technology, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

Presenting author's e-mail: talze@post.bgu.ac.il

Depletion interactions, induced by non-adsorbing polymers, are well known to induce self-assembly (SA) of colloids and nanoparticles (NPs) (1). Monodisperse nanometric gold nanoparticles (AuNPs) that are stabilized by p-mercaptobenzoic acid (Au-pMBA NPs) (2) form stable dispersions of non-assembled NPs in aqueous dispersions, due to electrostatic repulsion between the (negatively) charged pMBA molecules. In the study presented here, we describe the effect of Gum Arabic (GA), a branched polysaccharide, that is negatively charged at pH> 2.4 (a weak polyelectrolyte) on SA of the Au-pMBA NPs. The polymer is observed to induce crowding of the NPs into hexagonal, open-branched meso-structures (Figure 1 a, b). Zeta potential measurements indicate that both Au-pMBA NPs and GA carry negative surface charge in these mixtures. The surprising observation of GA-induced SA indicates that depletion interactions are significant enough to overcome the native electrostatic repulsion among the NPs. The results of SAXS measurements (performed at the European Synchrotron Radiation Facility (ESRF)) reveal hexagonal packing of the NPs. The effect of different molar ratio between the Au-pMBA NPs and GA, added salt, and pH on the symmetry and meso-structure of the assemblies will be detailed. This observation indicates that GA can be used for engineering new meso-structures of nanometric NPs.

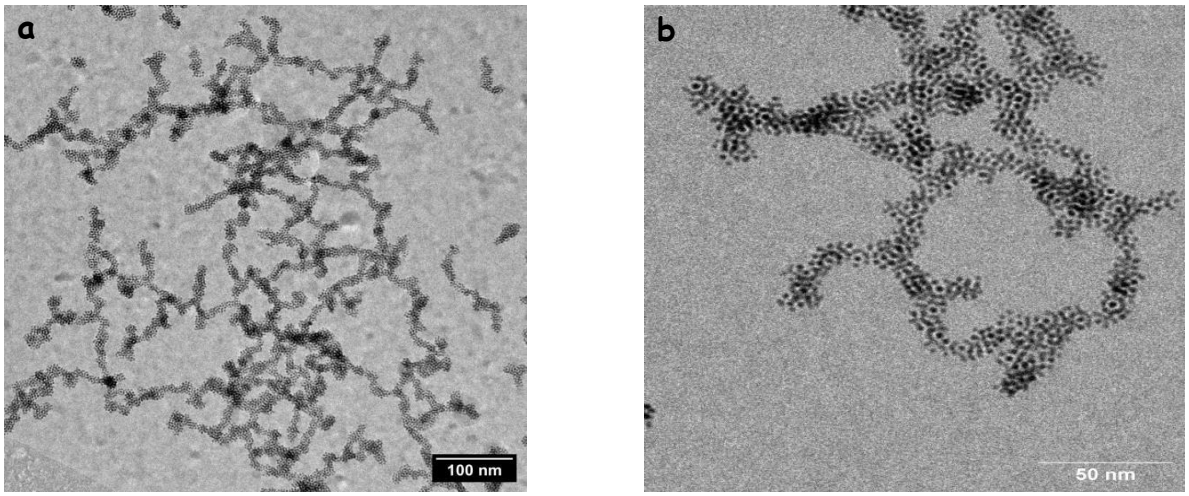

Figure 1. *Cryo-TEM image of a dispersion of 0.6mM AuNPs with 2wt% GA. (a) Lower magnification (b) Higher magnification showing the hexagonal meso-structures of the AuNPs.*

Keywords: Gold nanoparticles, self-assembly, depletion interactions, crowding, Gum Arabic.

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P.59

pH induced liquid-liquid phase separation of gliadin.

Roopesh P [1], Ethayaraja Mani[1], and Abhijit P Deshpande [1]

[1]Department of chemical engineering, Indian Institute of Technology ,Madras, India600036

Presenting author's e-mail: ch25d900@smail.iitm.ac.in

The liquid-liquid phase separation (LLPS) of proteins is a fundamental phenomenon underlying the formation of biomolecular condensates. Intrinsically disordered proteins(IDPs) have a higher affinity for LLPS. In this study, we investigated the behaviour of LLPS of gliadin, an IDP and a major wheat storage protein, under varying pH conditions. Gliadin of molecular weight around 37 kDa was solubilised at alkaline pH (~12) and then acidified to pH values between 4 and 6. A significant increase in turbidity was observed upon lowering the pH, indicating the onset of phase separation. To evaluate solvent effects, LLPS was performed in binary ethanol_water mixtures as well as in pure water, allowing a comparative analysis of the kinetics of phase separation. These findings highlight the potential of gliadin to undergo LLPS under tunable pH conditions and provide a foundation for further investigation into its phase behavior.

Keywords: Intrinsically disordered protein, Condensates, Phase separation, Gliadin.

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P.60

Electrostatic, depletion, and structural interactions of ions and nanoparticles across confined dispersions: Theory and comparison to AFM force-measurement

Gideon Onuh[1], Ofer Manor[1], Regine von Klitzing[2], Simone Riva[1]

[1]Chemical Engineering, Technion–Israel Institute of Technology, Haifa, Israel
[2]Physics, TU Darmstadt, Darmstadt, Germany

Presenting author's e-mail: gideon.onuh@campus.technion.ac.il

The collisions of micro-particles across a dispersion of nanoparticles confines the latter particles in layers, which yields oscillatory structural forces, a mixture of attractive depletion and repulsive steric effects between the micro-particles. The repulsive steric force supports energy barriers to micro-particle attachment. Moreover, the micro-particles and the nanoparticles may be charged, which leads to an array of many-body steric and electrostatic interactions at different length scales. All of which affect the interaction force between the micro-particles and hence their collision outcome.

We use theory devoid of fitting parameters to capture the interaction force measured previously [1] using atomic force microscopy (AFM) between a 2-micron silica particle and a flat silica substrate submerged in a dispersion of 15 nm silica particles in an aqueous electrolyte; see figure. A free energy description of the problem, using classical density functional theory, captures entropic and enthalpic contributions (from the nanoparticles of finite volume and from their electrostatic inter-nanoparticle interactions) to the force experienced by the micro-particle (attached to the AFM cantilever) as it collides with the flat solid. We capture the total ion population in the dispersion by accounting for both added salt and counter-ions released off the charged nanoparticle surface. We then capture the electrostatic interaction across the dispersion using the Jellium approximation and convert the nominal nano-particle diameter and their soft electrostatic interaction energy to an effective model of hard sphere interactions.

Quantitative agreement with experiment highlights the equilibrium packing structure of the confined nanoparticles and the specific contribution of each interaction mechanism to the measured force. We thus differentiate between the stabilizing and destabilizing contributions to charged micro-particles in a dispersion of charged nanoparticle.

Keywords: Colloids, Complex Fluid, Electrical Double Layer force, Structural force, AFM

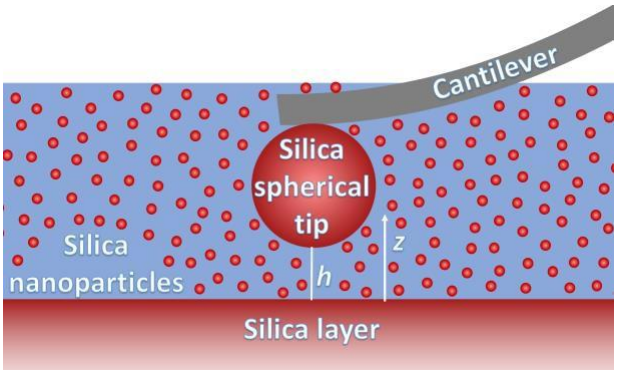

Figure 1. *Illustration of an AFM force measurement of the interaction between a colloidal probe–a silica microparticle attached to the AFM cantilever–colliding with a silica flat surface across a charged silica nano-particle suspension; the confined suspension introduces the measured short and long scale EDL and structural forces.*

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Tunable Colloidal Manipulation Using Critical Casimir Forces and Torques

Svyatoslav Kondrat [1,2,3,4], *Piotr Nowakowski* [3,4,5], *Gan Wang* [6], *Nima Farahmand Bafi* [1,3,4], *Mikael Käll* [7], *Giovanni Volpe* [6] *and S. Dietrich* [3,4]

[1]*Institute of Physical Chemistry, Polish Academy of Sciences, Poland*
[2]*Institute for Computational Physics, Stuttgart University, Germany*
[3]*Max-Planck Institute for Intelligent Systems, Stuttgart, Germany*
[4]*IV th Institute for Theoretical Physics, University of Stuttgart, Germany*
[5]*Ruđer Bošković Institute, Zagreb, Croatia*
[6]*University of Gothenburg, Gothenburg, Sweden*
[7]*Chalmers University of Technology, Gothenburg, Sweden*

Presenting author's e-mail: svyatoslav.kondrat@gmail.com; skondrat@ichf.edu.pl

Critical Casimir interactions emerge among objects immersed in near-critical fluids, offering a powerful and tunable mechanism for controlling the behavior of colloids [1]. These interactions can be finely tuned by minor temperature variations, while their sign and strength can be regulated by surface functionalization. In this talk, we will discuss how to utilize critical Casimir forces [2] and torques [3] to manipulate, align, levitate, and transport colloidal particles above chemically patterned surfaces. We find that circular patterns can stabilize the position and orientation of microdisks, while elliptical patterns induce a critical Casimir torque capable of reversibly flipping them [3]. More complex surface designs, such as bull's–eye and triangular patterns, enable the localized levitation of spherical colloids [2] and the controlled transport of microdisks [3], respectively. These findings open new opportunities for nanotechnological applications requiring precise positioning and orientation of microscopic objects.

Keywords: Critical Casimir forces; colloids; patterned surfaces; levitations; critical Casimir ratchets

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Line-tension dominated morphology of colloidal heterodimers

Koen Vermeulen[1], *Marlous Kamp* [1]

[1]*Van't Hoff Laboratory for Physical and Colloid Chemistry, Debye Institute for Nanomaterials Science, Utrecht University, Utrecht 3584 CH, The Netherlands*

Presenting author's e-mail: k.vermeulen1@uu.nl

Organoalkoxysilanes are a class of chemicals often used for modification of the surface chemistry of colloids. Additionally, 3-trimethoxysilylpropyl methacrylate (TPM) can nucleate and grow as an oil droplet onto pre-existing substrates, as first shown by Sacanna and coworkers [1]. Subsequent polymerization of the methacrylate groups results in solid particles, making TPM an ideal building block for the synthesis of complex colloids [2]. Such particles find applications in active matter research, for nanophotonic sensing, or as catalytic colloids [2].

To tailor complex colloids to specific applications, precise control over the morphology of the particles is required. Previous work has shown that the wetting behavior of hydrolyzed TPM on a substrate determines the morphology of the final particles [3]. Wetting is described by the Young's contact angle (θ_Y) between TPM, substrate, and medium. Additionally, a line-tension associated with the three-phase contact line must be considered for (sub-)micron sized droplets [4].

Here we show that the morphology of a TPM droplet nucleated onto a gold nanoparticle (AuNP) is determined not by θ_Y, but by the contribution of negative line-tension. Over a wide range of TPM sphere sizes (200-1000 nm) we consistently find the contact line to be positioned at the AuNP's equator, corresponding to equilibrium contact angles that differ from θ_Y. By varying the surface chemistry of the AuNP using different polymer ligands we find that this morphology persists even for varying θ_Y. Via contact angle measurements we determine the line-tensions to be on the order of $-10^{-7}N$. These negative line-tensions provide an energy gain upon maximizing the three- phase contact line, thus controlling the morphology by forcing the contact line to the AuNP's equator. Our findings provide crucial knowledge for the design and synthesis of functional complex colloids and contribute to the fundamental understanding of the wetting of spherical substrates by colloidal droplets.

Keywords: Line tension, gold nanoparticles, colloidal synthesis

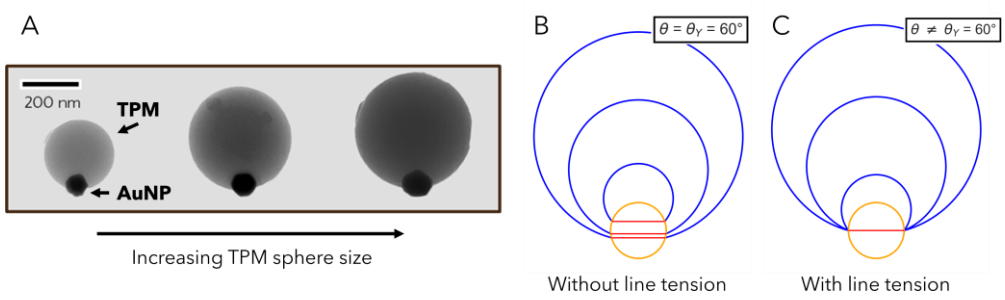

Figure 1. *(**A**) TEM micrographs showing AuNP-TPM heterodimers with increasing TPM sphere size. Scale bar denotes 200 nm. **(B, C)** Schematics showing the geometry of droplets of varying sizes wetting a spherical substrate. **(B)** In the absence of line-tension, the geometry is determined by* θ_Y *and the size of droplet. **(C)** For a negative line-tension the contact line of the droplet with the substrate is constant and the contact angle* θ *does not correspond to* θ_Y.

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Quantitative 3D Real-Space analysis of Photonic Supraparticles

J. I. Buckmann [1], L.D. Hoithink[1], R. Yang[1], A. Ulugöl[1], L. Filion[1], and A. van Blaaderen[1]

[1]Soft condensed Matter and Biophysics, Utrecht University, Princetonplein 1, Utrecht, The Netherlands. Colloid.nl

Presenting author's e-mail: j.i.buckmann@uu.nl

Colloidal self-assembly into ordered structures is being extensively investigated through both experiments and simulations [1]. These supraparticles exhibit a variety of unique properties, stemming from the collective structure of the individual colloidal particles. One such example is the angle-independent photonic properties of icosahedral supraparticles, arising from their highly symmetric structure [1]. In the literature, icosahedral supraparticles are often characterized using scanning electron microscopy (SEM) [2], but this method has limitations. SEM can only examine the outer structure, which is the last layer to crystallize, making it unsuitable for determining the number and nature of crystalline layers present. Instead, we analyze these supraparticles using 3D stimulated emission depletion (STED) and confocal laser scanning microscopy; techniques that are already widely used in the field of colloid science. These methods enable real-space analysis, allowing differentiation between icosahedral clusters and onion-shell structures, where the interior is crystalline while the exterior remains disordered. Such structures are often misidentified using conventional SEM analysis. Besides distinguishing between these structures. STED and confocal microscopy also reveal features like an off-center symmetry point or local defects, as shown in Figures 1C and 1D respectively. This opens up the possibility of comparing experimental and simulated photonic properties for structures with defects, disordered domains, and onion-shell configurations for statistically relevant numbers of supraparticles.

Keywords: Confocal Microscopy, Real-space Analysis, Icosahedral SPs.

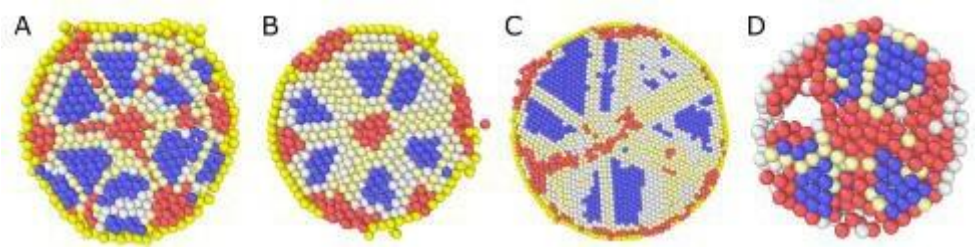

Figure 1. *Obtained particle coordinates, color coded by bond-order parameter machine learned clustering. A. Anti-Mackay icosahedral cluster. B. Onion shell icosahedral cluster. C. Off- center icosahedral cluster. D. Icosahedral cluster with a defect the size of several particles..*

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Unravelling and controlling crystallization pathways of colloidal cube superstructures

Dillip Kumar Mohapatra [1], *Teun W. J. Verouden* [1] *and Janne-Mieke Meijer* [1]

[1]*Soft Matter and Biological Physics, Department of Applied Physics and Science Education and Institute for Complex Molecular Systems, Eindhoven University of Technology, Eindhoven, The Netherlands*

Presenting author's e-mail: d.k.mohapatra@tue.nl

Recent advancements in anisotropic particle synthesis and self-assembly have enabled the formation of diverse superstructures and crystalline materials with novel mechanical, optical, and electronic properties. However, the precise mechanisms governing the self-assembly of anisotropic particles and their arrangement into final superstructures remain elusive at the single-particle level. Without a fundamental understanding of the self-assembly process, our ability to control and design these assemblies remains limited, constraining the full potential of emerging functional materials.

Here, we investigate the crystallization pathways leading to different final structures, namely square and Λ1, in anisotropic colloidal 'superballs', i.e. cubes with rounded corners[1] under the influence of critical Casimir forces[2,3]. The critical Casimir force provides precise tuning of the interparticle attraction via temperature allowing in- and out-of-equilibrium assembly. Using high-speed confocal microscopy and image analysis routines, we investigate different attraction strengths and cube concentrations and follow the particle dynamics, interactions, and superstructure formation in-situ on a single-particle level. We find that the final crystalline structures and cluster morphology are highly dependent on the pathway used to modulate the attraction strength. Additionally, we unravel the pathways for achieving dense, large clusters as well as thin and thick branched network structures with controlled cubic and Λ1 ordering. We finally demonstrate how by carefully tuning the attraction strength and assembly pathway, one can precisely control the formation of ordered crystals, defect-rich structures, or disordered network-like assemblies. Our findings provides fundamental insights into the forces and pathways governing the order and disorder formation during the self-assembly of anisotropic (nano)particle superstructures, contributing to the rational design of functional materials.

Keywords: Colloidal superballs, crystallization, critical Casimir force, self-assembly, anisotropy

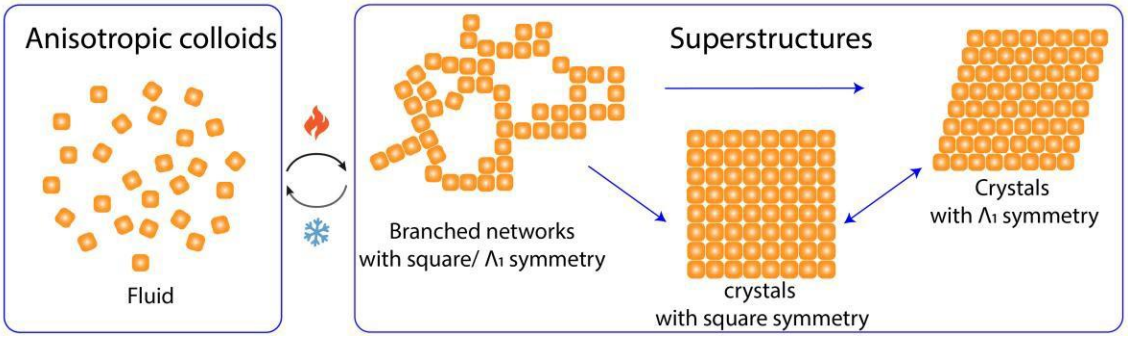

Figure 1. *Schematic representation of 2D crystallization of colloidal cubes in presence of critical Casimir forces.*

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Soft polydisperse particles expand after strong compression

Daisuke S. Shimamoto [1], *Miho Yanagisawa* [1,2]

[1] *Department of Basic Science, The University of Tokyo, Japan*
[2] *Komaba Institute for Science, The University of Tokyo, Japan*

Presenting author's e-mail: shimamoto-daisuke806@g.ecc.utokyo.ac.jp

Polydisperse particle mixtures, such as concrete, foams, intracellular molecules, exhibit complex packing behavior that differs significantly from monodisperse systems. In particular, systems with power-law size distributions, $N(r) \propto r^{-a}$, pose a fundamental challenge, as their mean and variance are ill-defined, preventing the emergence of a characteristic length scale [1]. Despite extensive studies on random packing in polydisperse systems, the structural and dynamical properties of power-law-distributed particles remain elusive.

Here, we investigate how the jamming transition in such systems depends on the packing protocol [2]. We find that after undergoing a cycle of compression and decompression, the system expands, resulting in a lower packing density than its initial state. This counterintuitive phenomenon, which we term "negative compaction," emerges uniquely in polydisperse systems following extensive mechanical annealing. While slight annealing promotes compaction, like monodisperse packings, strong annealing induces size segregation, leading to expansion (Fig. 1). Analysis of the pressure history and particle configurations reveals that particle-size-dependent effective attraction between particles drives this expansion.

Our findings underscore the pronounced history dependence of packing in polydisperse systems and uncover a novel energy-driven segregation mechanism. These results advance the understanding of granular materials and suggest broader implications for softly interacting systems, including charged colloids, polymers, and magnetic discs.

Keywords: Memory effect, ultrasoft potential, jamming

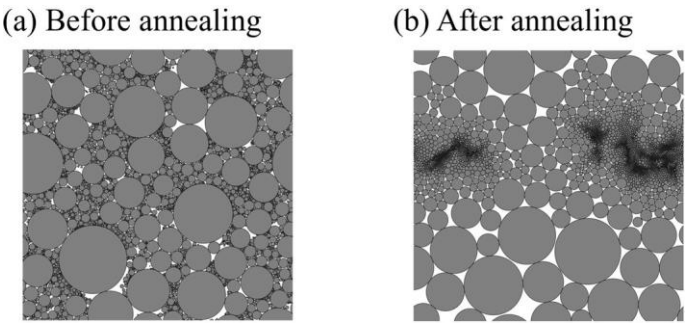

Figure 1. *The packing at jamming point (a) before and (b) after the mechanical annealing.*

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Self-assembly and thermal conductivity of nanofluids containing Janus particles

Takahiro Ikeda [1,2], *Yusei Kobayashi* [2], *and Masashi Yamakawa*[2]

[1]*Center for the Possible Futures, Kyoto Institute of Technology*
[2]*Faculty of Mechanical Engineering, Kyoto Institute of Technology*

Presenting author's e-mail: tikeda@kit.ac.jp

Nanofluids are a new class of fluids containing nanoparticles. They exhibit higher thermal conductivity than conventional fluids and higher dispersion stability than micrometer-sized particles. These properties make nanofluids suitable for applications in various industries, including electronics cooling and power generation [1].

The thermal conductivity of nanofluids relies on the surface properties and aggregation structure of nanoparticles. Thus, their conductive and convective properties can be adjusted by modifying the suspended nanoparticles. Janus particles exhibit surface anisotropy and a unique aggregation structure. Recent studies have shown that the surface anisotropy of Janus particles influences thermal conductivity enhancements, which correlate with the self-diffusivity of nanoparticles, [2] the interfacial interactions between nanoparticles and solvents, [3] and the aggregation structures of Janus nanoparticles. [4] However, the impact of the distinct self-assembly of Janus particles, such as micelles, on the thermal transport properties of nanofluids has not yet been explored. This study employs molecular dynamics to clarify the effects of the aggregation structure of Janus particles on thermal transport properties.

Figure 1 presents a representative snapshot of nanofluids containing Janus particles, along with their thermal conductivity at various temperatures. Janus particles transition from micellar to dispersed states as temperature increases. We analyze how these temperature-dependent structural changes affect the thermal conductivity of nanofluids.

Keywords: Nanofluids, Thermal conductivity, Janus particles, Self-assembly, Molecular dynamics

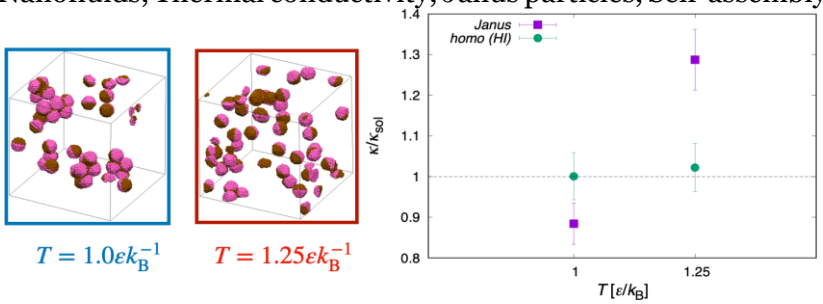

Figure 1. *Representative snapshots and the ratio of the thermal conductivity of nanofluids containing Janus particles to that of pure solvents at different temperatures T = 1.0 ε/k⁞ and 1.25 ε/k⁞. The notation "homo (HI)" indicates the thermal conductivity of homogeneously hydrophilic nanoparticles that are fully dispersed.*

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P.67

Effect of soft boundaries on Taylor dispersion

M. Gunny [1,2], A. Jha [3], A. Vilquin [1,2], Y. Amarouchene [4], J.D. McGraw [1,2]

[1] Gulliver, CNRS UMR 7083, ESPCI Paris, Université PSL, 75005 Paris, France.
[2] Institut Pierre Gilles de Gennes, ESPCI Paris, Université PSL, 75005 Paris, France.
[3] Cavendish Laboratory, University of Cambridge CB3 OHE, United Kingdom.
[4] LOMA, CNRS UMR 5798, Université de Bordeaux, 33405 Talence, France.

Presenting author's e-mail: joshua.mcgraw@espci.fr

Transport of colloidal particles in shear flow is influenced by both thermal fluctuations and advection along the flow. This coupling, termed Taylor dispersion, between advection and diffusion can significantly enhance particle spreading along the stream-wise direction [1], with a strong dependence on the characteristic shear rate of the flow field. Moreover, during the last few decades microfluidic systems have been greatly facilitated by the use of soft materials, typically silicone elastomers. In this context and under the imposed driving pressure, the soft walls bounding the flow may be deformed [2,3]. Indeed, such deformations can be seen in many biological systems, with the deformation of blood vessels upon pumping being one example. In this study, we examine how the elastohydrodynamic deformation of a soft microchannel leads to significant modifications of Taylor dispersion as compared to the case of rigid boundaries.

In particular, we use evanescent wave microscopy to study the coupling between (i) the softness of a microchannel and (ii) the dispersion of solute flowing through it. Owing to the softness of the microchannel and pressure gradients along the channel, the height profile under flow is non-constant along the axial direction. This change in channel height leads to variability of the near-wall shear rates for different positions along the microchannel, and altered pressure dependence for the shear rate, and thus dispersion. We make nanometrically resolved particle transport measurements [4] along the microchannel in order to elucidate the effect of channel softness on dispersion. Moreover, our experimental results are captured by a theoretical modelling of a simplified 2D microchannel with an elastic wall on one side. We use Winkler's elastic foundation, coupled to a lubrication model for the flow to describe our data quantitatively. Our results demonstrate the importance of considering softness in detailed analyses of solute dispersion at micro and nanoscales.

Keywords: Taylor dispersion, colloid transport, evanescent wave microscopy, microfluidics

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P.68

A colloidal viewpoint on the sausage catastrophe and the finite sphere packing problem

S. Marín-Aguilar[1], F. Camerin[1], S. van der Ham[2], A. Feasson[2], H.R. Vutukuri[2] and M. Dijkstra[1]

[1]Soft Condensed Matter & Biophysics, Debye Institute for Nanomaterials Science, Utrecht University, Princetonplein 1, Utrecht 3584 CC Utrecht, The Netherlands
[2]Active Soft Matter and Bio-inspired Materials Lab, Faculty of Science and Technology, MESA+ Institute, University of Twente, 7500 AE Enschede, The Netherlands

Presenting author's e-mail: m.dijkstra@uu.nl

The best way of packing spheres has a long history, dating back to the works of Kepler, Gauss, and Newton, while the British sailor Raleigh was also intrigued by this problem as he searched for an efficient way to stack cannonballs on his ship. Sphere packings also have applications in coding theory, crystallography, and in understanding mechanical and geometrical properties of materials. In 1611, Kepler conjectured that the densest packing of an infinite number of identical, non-overlapping spheres in three dimensions is the "cannonball" stacking or the face-centered cubic (FCC) crystal, which fills space with an efficiency of ~74%. This hypothesis was proven mathematically only very recently.

In reality, however, all packings are inherently finite. It is commonly believed that the most efficient way to pack a finite number of equal-sized spheres is by arranging them tightly in a cluster. However, mathematicians have conjectured that a linear arrangement may actually result in the densest packing. Here, our combined experimental and simulation study provides a physical realization of the finite sphere packing problem by studying non-close-packed arrangements of colloids in a flaccid lipid vesicle. We map out a state diagram displaying linear, planar, and cluster conformations of spheres, as well as bistable states which alternate between cluster-plate and plate-linear conformations due to membrane fluctuations. Finally, by systematically analyzing truncated polyhedral packings, we identify clusters of $56 < N < 70$ number of spheres, excluding N=57 and 63, that pack more efficiently than linear arrangements.

Keywords: colloids, self-assembly, packing

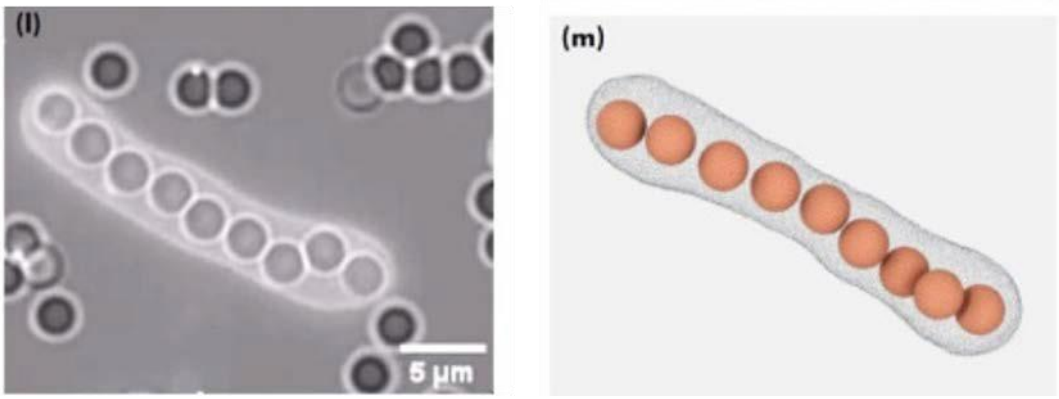

Figure 1. *Colloidal spheres in a vesicle in experiments (left) and simulations (right).*

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Controlling the microstructure of colloidal gels through ultrasound activated bubbles

Matthew Roniger [1], *George Petekidis* [2], *Valeria Garbin* [1]

[1]*Department of Chemical Engineering, Delft University of Technology, Delft 2629 HZ, the Netherlands*
[2]*IESL – FORTH and Department of Material Science and Technology, University of Crete, Heraklion, GR – 71110, Greece*

Presenting author's e-mail: m.j.r.roniger@tudelft.nl

Microstructural differences in colloidal gels determine their macroscopic properties, playing a critical role in their performance for applications in construction materials, personal care and food products. Recent work from our group [1] has demonstrated that ultrasound-driven microbubbles can locally rearrange the structure of depletion gels, with potential to tune their rheological properties. The underlying restructuring mechanisms are not fully understood due to the challenge of decoupling possible contributions from geometric frustration, bubble and particle microstreaming. In this work we attempt to decouple these potential restructuring pathways by flow visualization experiments and by examining the effect of the strength of the attractive interactions. The model colloidal gel used in the experiments consists of 541 nm PMMA particles in squalene with linear polybutadiene as polymer depletant. A single air bubble is injected in a geometry designed for transmitting ultrasound to the sample while allowing for confocal imaging of the microstructure. The bubble is driven into volumetric oscillations by ultrasound at 10-50 kHz for 10^3-10^4 cycles. The microstructure is quantified by order parameters that we previously introduced [1]. This work aims to develop an understanding of this phenomenon to close the gap between tuning and controlling the microstructure of colloidal gels. This research is conducted as a part of the CoCoGel Marie Skłodowska-Curie Industrial Doctoral Network.

Keywords: Colloidal Gels, Bubble dynamics

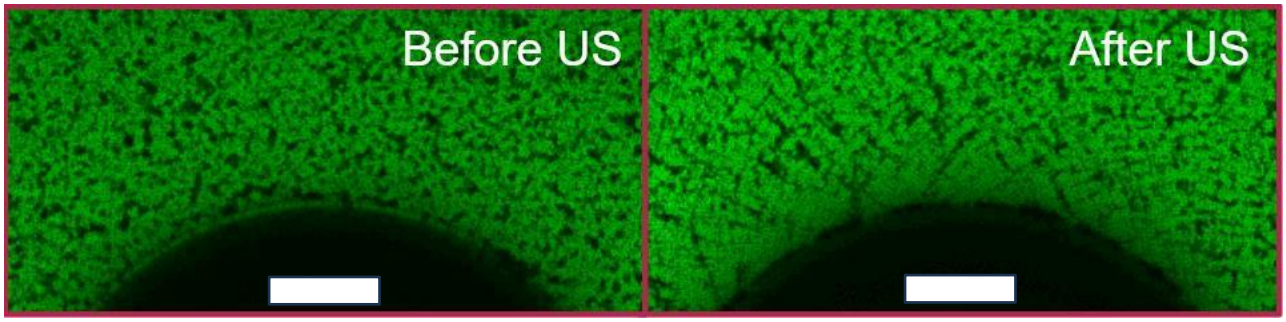

Figure 1. *Confocal microscopy images illustrating local microstructural rearrangements in a depletion gel due to ultrasound-induced microbubble oscillations. Scale bar is 20 μm.*

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P.70

Ordered Mesoporous Carbon/Graphene from Methane and Well-Ordered 3D-Structured Catalysts

Campanella Laura[1], Dr. Prof. Blaaderen (van) Alfons[1]

[1]*Soft Condensed Matter and Biophysics, Debye Institute for Nanomaterial Science, Utrecht University*

l.campanella@uu.nl, A.vanBlaaderen@uu.nl , www.colloid.nl, Ordered Mesoporous Carbon/Graphene from Methane and Well-Ordered 3D-Structured Catalysts - ARC CBBC

Well-ordered graphene materials are e.g. usable as catalyst support and many other applications (batteries, CO_2 capture etc) and thus of high value. Our aim is to use well-defined and 3D structured **supraparticles (SPs)** of catalytic **iron(cobalt) oxide nanoparticles (NPs)** to significantly increase the yield per gram of catalyst. With this porpuose, the mechanism of the well-ordered carbon formation is studied in detail. The catalyst supraparticles are also (strongly) magnetic and are therefore relatively easily recoverable at low cost after synthesis.

We are going to convert already existing methodologies to generate well-ordered mesoporous graphene using self-assembled NPs (SPs) as catalyst and methane as the carbon source (instead of the ligands). **Binary supraparticles**, having Au cores next to the ironoxide NPs, are used for surface enhanced Raman Spectroscopy (SERS) studies, next to high-resolution gas-cell TEM studies of the chemical conversions towards graphene. We also investigate the modification of part of the SP surface in order to prevent deactivation and direct the conversion into graphene.

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Rheological bi-stability in colloidal depletion gels with granular inclusions

Authors: Huadan Xu, Wilson C.K. Poon, John R. Royer

Colloidal gels are ubiquitous in industrial applications and products, frequently with the colloidal gel serving as a carrier to hold up larger 'granular' particles. However, the physics of these binary granular/gel composites remains poorly understood. Larger inclusions can in some conditions, strengthen the colloidal gel but can also potentially cause the gel to collapse under flow, resulting in a loss of the composite yield stress. This mechanical bistability has typically been observed using colloidal gels with poorly characterised particle interactions. Here, we investigate how the inclusion of larger particles alters the rheology and microstructure of a colloidal depletion gel, a canonical model system to understand colloidal phase behaviour. Using combined rheo-confocal imaging, we show similar mechanical bistability in this depletion system, with the composite collapsing into irregular chunks at low shear rates. Altering both the size and concentration of the polymer depletant, this model binary system allows us to explore how the details of the particle-particle attraction influence the composite bistability.

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Colloidal Gels tuned with magnetic field

Emmanouil Mathioudakis [1,2], George Petekidis [1,2]

[1]FORTH/IESL, 70013, Heraklion, Crete, Greece
[2]Department of Materials Science and Engineering, University of Crete, 71110, Heraklion Crete
Email: m.mathiou@iesl.forth.gr

Colloidal gels are characterized as functional materials that exhibit solid-like properties through the formation of a network by interconnected colloidal particles dispersed within a medium. Due to their distinctive structural and mechanical properties, they have become increasingly relevant for applications in food science, pharmaceuticals and materials engineering. Magnetorheological Fluids (MRFs) are a class of smart colloidal materials, with a variety of applications[1], such as shock absorbers[2], that upon the application of an external magnetic field, exhibit a rapid and reversible transition from liquids to soft yield stress solids with columnar and ring structures being formed[3– 5]. Fumed silica particles have uses in many industry and everyday applications such as raw materials for the effects of purity composition in optical fibers, as rheological additives for anti-sedimentation, for personal care products, adhesives sealants and many more[6]. They also function as effective thickening and thixotropic agents that can stabilize and modify the rheological response of a variety of systems, while based on the grade of fumed silica, hydrophobic or hydrophilic, and the chemical nature of the solvent, polar or non-polar, can form stable sols or gels with space-filling network and varying mechanical properties[7]. In almost every study conducted on these two materials, the main focus is investigating the effect of fumed silica on magnetorheological fluids to create the so called bi-disperse MRF's which present enhanced properties such as greater stability, a key disadvantage of magnetorheological fluids. We focus on the completely opposite, which the effect of magnetic particles on the properties of fumed silica gels to investigate whether a gel may be created with enhanced mechanical properties and by tuning its mechanical response[8,9] through the use of steady or oscillatory shear, whether we can create on demand different iterations of the same gel or possibly an even stronger gel with better stability.

Keywords: Colloidal Gels, Rheological Tuning, Magnetorheological fluids, Fumed Silica

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P.73

Linear and nonlinear rheology of colloidal suspensions via Brownian Dynamics simulations

Dimos Aslanis [1], *Joost de Graaf* [1]

[1] *Institute for Theoretical Physics, Center for Extreme Matter and Emergent Phenomena, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands.*

Presenting author's e-mail: d.aslanis@uu.nl

Understanding the dynamics and rheology of colloidal particle suspensions is crucial for many technological applications, including paints, batteries, and concrete [1]. While Brownian Dynamics (BD) has been used for decades [2], a clear picture of how shear protocols couple with polydispersity, interparticle forces, volume fraction, and hydrodynamic interactions (HIs) to set the stress response is still incomplete.

Hard-sphere suspensions have long served as model systems in rheology, and their linear and nonlinear responses have been extensively studied [3]. However, rigorous simulations of dense samples that incorporate different shear protocols and size distributions are still lacking. A central difficulty is that including detailed HIs at high volume fractions often leads to numerical instabilities. Repulsive effective potentials are commonly introduced to stabilize the simulations, but their influence on rheology has not been systematically evaluated. Clarifying these simplified systems is also important for guiding simulations of more complex structures such as colloidal gels [4].

To address these challenges, efficient simulations of polydisperse Brownian suspensions are developed on the Google JAX platform, which has proven effective in this context [5]. Benchmarks and initial results are presented for the open issues outlined above.

Keywords: colloids, rheology, Brownian dynamics, suspensions, polydispersity

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P.74

High pressure effects on the kinetics and gel properties of Laponite suspensions

Nikolaos A. Burger[1,2], Benoit Loppinet[1], Andrew Clarke[3], Yogesh Joshi[4], George Petekidis[1,2]

[1]IESL-FORTH, P.O. Box 1527, GR-711 10 Heraklion, Greece

[2]Department of Materials Science & Engineering, University of Crete, Heraklion 70013, Greece

[3]Schlumberger Cambridge Research, High Cross, Madingley Road, Cambridge CB3 0EL, UK

[4]Department of Chemical Engineering, Indian Institute of Technology Kanpur, Kanpur 208016, India

Presenting author's e-mail: burger_nikos@hotmail.gr

We study the gelation kinetics and the yield stress evolution of an attractive clay gel (Laponite) at high pressures. We combine state-of-the-art pressure dynamic light scattering (H-P DLS) and high- pressure steady shear rheology to probe the pressure dependence. Sol-gel kinetics and yield stress evolution with waiting time, t_w are probed experimentally by H-P DLS and non-linear shear rheology, respectively. We performed compressibility measurements to exclude the possibility of pressure-induced compression–shrinking of clay particles. H-P DLS predicts that application of pressure accelerates the liquid–gel transition of freshly prepared laponite dispersions. The latter were observed for different salt contents. Pressure has a big impact on the rheology (yield stress, σ_y) of laponite dispersions; the time dependence is much stronger under pressure. σ_y of laponite increases with t_w and most importantly, with pressure. Last, pressure cycle induces irreversible effects in laponite dispersions; pressure-treated gels are more matured; in other words, pressure affects the idle time (time after sample preparation) at will. Compressibility measurements predict that the suspensions have limited compressibility values, similar to those of water. Last, a fluidity model to capture the yield stress evolution with waiting time, t_w is developed.

Keywords: High-pressure dynamics/rheology, Clay Suspensions

P.75

Reversible electric-field-induced collapse of viscoelastic properties in colloidal gels

Jose López Luque[1] *and Thibaut Divoux*[1]

[1]*ENSL, CNRS, Laboratoire de Physique, F69342 Lyon, France*

Presenting author's e-mail: jose.lopez@ens-lyon.fr

Colloidal gels are viscoelastic materials that exhibit solid-like properties at rest and flow like liquids when subjected to sufficient strain or stress. At rest, their microstructure consists of a percolated network highly sensitive to external stimuli such as shear history, electric and magnetic fields, light, or power ultrasound. These external fields serve as control parameters to tune the gel's rheological response. Here, we focus on the impact of an electric field on colloidal gels obtained by dispersing hydrophobic fumed silica colloids with fractal-like shapes in light mineral oil. The silica particles, governed by attractive van der Waals interactions, form a physical gel that exhibits a stress threshold separating a solid-like regime at low stresses from a viscous regime at larger stresses. Additionally, these gels display a remarkable power-law linear viscoelastic response as well as pronounced aging. Our findings reveal the existence of a critical electric field E_c ~ 0.7 kV/mm below which the rheological properties of the gel remain unaffected. For $E > E_c$, both the elastic and viscous moduli exhibit a sharp decrease toward weak values, reflecting a collapse of the gel's viscoelastic properties. This collapse occurs over a timescale that decreases as a power-law of $E - E_c$. Remarkably, this electric-field-induced collapse is fully reversible: the gel recovers its original viscoelastic properties when the electric field is turned off. This phenomenology contrasts sharply with typical reports in the literature, where electric fields are shown to strengthen gel properties by forming chain-like structures. Here, we hypothesize an alternative microscopic mechanism involving the formation of large, compact colloidal clusters under the electric field leading to the observed collapse. Our results illustrate yet another strategy for tuning the rheological properties of colloidal gels reversibly, opening new avenues for the design of smart soft materials with tailored mechanical responses.

Keywords: Electro-rheology, colloidal gels, elecctric fields, fumed silica, viscoelastic collapse

P.76

Simulations of sheared stiff core models

John Melrose

Banbury, UK

Presenting author's e-mail: jrmelrose@gmail.com

Monolayers of polydisperse spheres with linear spring contact forces, lubrication forces and both frictionless (FL) and frictional contacts (F) were simulated under shear using quasi static equations of motion. A map will be shown of the rheological and contact networks (CN) states in both the linear and non-linear regimes above and below critical packing densities $\Phi_c(FL)$, $\Phi_c(F)$.
Results for power law divergences of shear, $\tau/\dot{\gamma}$, and normal viscosities $P/\dot{\gamma}$ include a variation of the exponents for $P/\dot{\gamma}$, resolving issues in literature. The rheology has been supposed due to scaling properties of a jamming point of isostatic contact coordination Z_I on the static axis – this emphasizes floppy models relevant to revolute joints. It does not address modes of contact dilation.
Collapsing results on $\mu = \tau/P$ and $J = \dot{\gamma}/P$ shows distinct regimes – changes between these occurs with percolation of sub-graphs of the CN $G(Z_I)$ defined on Z_I. This lies below Φ_c and likely extends towards the static axis as $\dot{\gamma} \to 0$. The system has spatial temporal fluctuations with the formation and relaxation of clusters of $G(Z_I)$. Both contact dilation and more localized, high dissipation zones are involved in the relaxation. Fluctuations in stress and coordination are stronger the smaller the system. The flowing states can be quenched $\dot{\gamma} \to 0$ to static states with a CN and non-zero stress or collapsed states depending on the starting coordination. The former even below $\Phi_c(F)$. The force distribution in the flowing states is fit by a generalized gamma distribution with a power law region and a stretched exponential tail. The tail makes a large contribution to stress tensors. It defines a set of low coordination (ca. 2) sub-graphs, $G(mx)$. Results for these will also be reported.

The results give a unification of different approaches to understanding the non-equilibrium physics of dense particulate systems.

Keywords: jamming, suspension rheology, dense particulate simulations

P.77

Many-Body Contact Forces in Microgel Suspensions

Fran Ivan Vrban [1], Antonio Šiber [2], and Primož Ziherl [1,3]

[1]Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[2]Institute of Physics, Bijenička 46, Zagreb, Croatia
[3]Jožef Stefan Institute, Jamova 39, Slovenia

Presenting author's e-mail: fran-ivan.vrban@fmf.uni-lj.si

Several classes of colloidal materials are based on deformable particles, a notable example being microgel sols. The interactions among such particles upon contact are rather complex, and they include both elastic and dissipative contributions. Despite many advances in understanding elastic interactions, the many-body nature of these forces is rarely considered, and the best-known model remains the Hertzian interaction [1].

Here, we theoretically explore the so-called liquid-drop model of deformable particles [2, 3]. To provide a coarse-grained description of the contact interaction for distinct faceting regimes, we employ two distinct geometrical approximations involving truncated superballs and spheropolyhedral shapes, respectively. We compare the deformation energy obtained from these two approximations with exact numerical results for selected local configurations, and we determine the range of indentations over which the drop–drop interaction is pairwise additive—a range that is generally quite limited. Our work provides insight and a basis for a consistent description of the mechanics, elasticity, and phase behavior of suspensions of microgels and nanocolloidal particles.

Keywords: Colloids, microgels, suspensions, many-body , superball

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Nematic Ordering of Colloidal Rods within Flexible Vesicles

André F. V. Matias[1], Stijn van der Ham[2], Susana Marín-Aguilar[3], Fabrizio Camerin[4], Hanumantha Rao Vutukuri[2] and Marjolein Dijkstra[1]

[1]Soft Condensed Matter & Biophysics, Debye Institute for Nanomaterials Science, Utrecht University, Princetonplein 1, Utrecht 3584 CC Utrecht, The Netherlands
[2]Active Soft Matter and Bio-inspired Materials Lab, Faculty of Science and Technology, MESA+ Institute, University of Twente, 7500 AE Enschede, The Netherlands
[3]Department of Physics, Sapienza University of Rome, Rome, Italy
[4]Physical Chemistry, Department of Chemistry, Lund University, SE-22100 Lund, Sweden

Presenting author's e-mail: a.f.valentematias@uu.nl

Colloidal rods exhibit liquid crystalline behavior, with their orientational and positional order varying with packing fraction. At low packing fractions, the rods remain disordered, while intermediate densities lead to nematic order. At even higher packing fractions, smectic order or crystallization can emerge. While these phases are typically studied in bulk, recent research has shown that a two-dimensional smectic phase of rods in elliptical confinement exhibit anchoring that depends on the local curvature of the confinement [1]. Here, we extend this investigation to rods confined within a three-dimensional flexible vesicle and reveal a more dynamic interplay between curvature and ordering. Similar to the quasi-2D case, we find that local curvature influences the anchoring of the rods. However, in a flexible vesicle, confinement enhances the rod ordering. At a fixed packing fraction, elongated vesicles, characterized by low reduced volume, promote nematic ordering of rods even at densities where bulk systems remain disordered, as illustrated by the state diagram and snapshots of Fig. 1. Furthermore, we show that the anisotropy of the rods allows the vesicle to deform into a range of shapes inaccessible when confining spheres, consistent with a previous study [2]. This leads to an interesting feedback mechanism, where the vesicle shape influences the rod alignment, while the ordered rods, in turn, constrains the vesicle shape. This geometry-order interplay provides new insights into the coupling between liquid crystalline phases and soft, deformable boundaries.

Keywords: Colloidal matter, Liquid crystals, Lipid membrane, Anisotropic matter

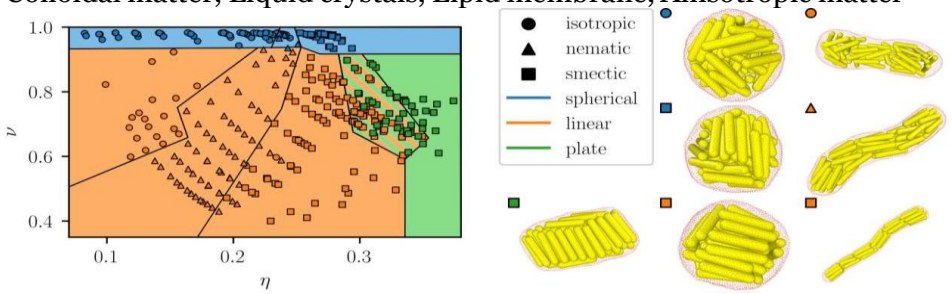

Figure 1. *State diagram of the rod ordering and vesicle shape as a function of packing fraction η and reduced volume ν. Different markers denote distinct vesicle shapes, while color indicate the degree of rod ordering.*

Acknowledgements: We acknowledge funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant agreement No. ERC-2019-ADG 884902, SoftML).

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Depletion Interactions in metastable colloidal systems

Néstor M. De Los Santos-López and Ramón Castañeda-Priego

(nestor92sl@gmail.com, University of Guanajuato)

The understanding of the effective interactions between the observable constituents of a complex material, for example, a colloidal dispersion, has been fundamental in Condensed Matter Physics to deal explicitly with the many-body problem, which becomes technically intractable due to the large number of degrees of freedom needed to describe the molecular nature of any material. Basically, effective interactions allow us to treat in a simplified way the description of systems that share multiple time and length scales. Since there is not a unique route to determine the effective interactions between atomsor molecules, several approaches based on highly demanding computer simulations and sophisticated theoretical frameworks have been proposed. In this contribution, we focus on the integral equations theory of liquids to account for the effective interactions in complex fluids. This formalism takes advantage of the covariant property of the Ornstein-Zernike equation when the degrees of freedom of the unobservable components of the fluid are integrated out from the description and are fully taken into account within the effective potential between the observable molecules. We particularly revisit in detail the key elements of this theoretical approach, which was originally developed to obtain the effective potential between colloidal particles immersed in an aqueous solution and under equilibrium conditions. We demonstrate that such a formalism quantitatively describes the effective potential among macromolecules when compared with either molecular simulations or experiments. Furthermore, we also show that this approximation can be accurately applied near to non-equilibrium conditions and to study effective interactions in highly dissipative granular systems.

P.80

RheoOCT-imaging and depth-resolved scattering: novel in-process characterization to resolve gel formation

Stefan Schmid [1,2], *Ivo Buttinoni* [2] , *Rut Besseling*[1] *and Michiel Hermes* [1,3]

[1]*InProcess-LSP, Oss, Netherlands*
[2]*Heinrich Heine University, Düsseldorf, Germany*
[3]*Utrecht University, Netherlands*

Presenting author's e-mail: s.schmid@inprocess-lsp.com

Colloidal gels are out of equilibrium structures formed due to attractive interparticle interactions between micro- or nanoparticles. They exhibit strong non-Newtonian behavior due to their out of equilibrium structure and arrested dynamics, and are sensitive to non-trivial shear effects including ageing, wall slip, banding and multistep yielding. This renders conventional rheological measurements difficult.

In this project, Optical Coherence Tomography (OCT) is investigated as a novel non-invasive approach to measure the structure and rheology of colloidal gels on previously inaccessible length and timescales. OCT extends the capabilities of classical Dynamic Light Scattering (DLS) by using coherence gating to acquire spatiotemporal scattering data. The OCT tool is coupled with a desktop rheometer for real-time, non-invasive measurements under controlled gel deformation as well as comparisons to macroscopic rheometry.

This project is one of 15 within the Industrial Marie-Curie Doctoral Network CoCoGel, that aim to investigate the tuning of colloidal gels.

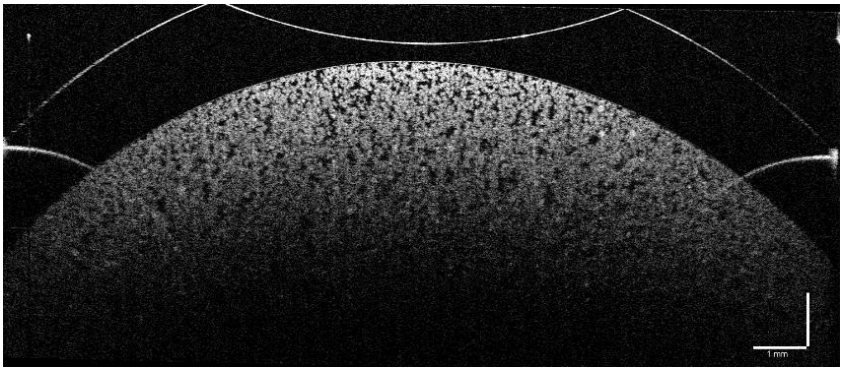

Figure 1. *OCT scan of a colloidal gel of 800nm particles in a sample vial. The scalebar is equal to 1mm*

Keywords: Optical Coherence Tomography, colloidal gels, rheology, microrheology

P.81

Ionic Strength and Crosslinking Density: Tuning pNIPAM Microgel Properties and Transition Temperatures

Syamjith K S and Alan R Jacob

Soft Matter Group, Department of Chemical Engineering, Indian Institute of Technology, Hyderabad, Sangareddy, 502284, Telangana, India

Presenting author's email: ch21resch01001@iith.ac.in

Poly(N-isopropylacrylamide) (pNIPAM) microgels exhibit a reversible thermoresponsive behavior, undergoing a volume phase transition. A plethora of data available in the literature regarding the relationship between crosslinking density [1-6] and the properties of pNIPAM microgels necessitates a consolidation and reexamination. This study aims to address three key objectives: (1) elucidate the relationship between crosslinking density and size/electrophoretic mobility of pNIPAM microgels, building upon existing knowledge, (2) examine the influence of crosslinking density on transition temperatures, particularly the electrokinetic transition temperature (ETT), which is not well explored and understood and (3) investigate the combined effects of ionic strength (concentration and valency) on the volume phase transition temperature (VPTT) and ETT of pNIPAM microgels with diverse crosslinking densities. To achieve these objectives, we synthesized 20 batches of pNIPAM microgels using two distinct synthesis routes 18 batches via conventional one-pot synthesis, with triplicate replicates for 6 crosslinking densities, and 2 batches of pNIPAM microgels via semi batch synthesis, a duplicate replicate for one crosslinking density. These microgels were characterized using a combination of dynamic light scattering (DLS) to determine size and thermoresponsive behavior, electrophoretic light scattering (ELS) to analyze electrophoretic mobility, and atomic force microscopy (AFM) to evaluate structural morphology and assess stiffness. The insights from the above characterization techniques enhance our understanding of how crosslinking density influences the size, electrophoretic mobility and electrokinetic properties of pNIPAM microgels, potentially creating a pathway for rational design of microgels tailored for specific applications.

Keywords: pNIPAM, microgel, transition temperatures, crosslinking density

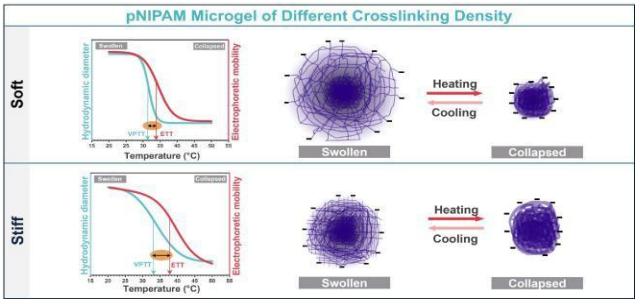

Figure 1. *Graphical Abstract: Schematic representation of pNIPAM microgels with varying crosslinking density (soft to stiff), illustrating their surface charge, size properties, and temperature-dependent transitions.*

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P.82

Novel synthesis route and characterization of low polydispersity hydroxypropyl cellulose nanogels

Mónica Ledesma-Motolinía[1], Fernando Soto-Bustamante[1], Gavino Bassu[1], Jacopo Vialetto[1] and Marco Laurati[1]

[1]*Dipartimento di Chimica 'Ugo Schiff' (DICUS), Università degli Studi di Firenze UNIFI, Via della Lastruccia, 3-13 - 50019 Sesto Fiorentino (FI)*

Presenting author's email: monica.ledesmamotolinia@unifi.it

Thermoresponsive hydroxypropyl cellulose (HPC) nanogels were synthesized via a novel route of polymerization. In this study, the optimal surfactant concentrations and reaction temperature were identified by analyzing the solution dispersity of different HPC molecular weights. The required surfactant concentration of dodecyltrimethylammonium bromide (DTAB) is inversely related to the polymer's molecular weight, with higher molecular weights requiring lower surfactant concentrations. Nanogels were synthesized at twice the polymer critical solution temperature (LCST). Divinyl sulfone (DVS) was used to crosslink the polymer network structure. Under this novel route, HPC nanogels exhibited a low polydispersity index. The thermoresponsive behavior of HPC nanogels as a function of the crosslinker concentration was characterized by dynamic light scattering (DLS). The results indicated that as expected the average size decreased with increasing crosslinker molarity. Small-angle neutron scattering (SANS) was used to provide information about the internal structure as a function of the temperature, indicating significant deviation from the fuzzy sphere structure characteristic of PNIPAM microgels.

Keywords: hydroxypropyl cellulose nanogel, polymerization, dynamic light scattering, small-angle neutron scattering.

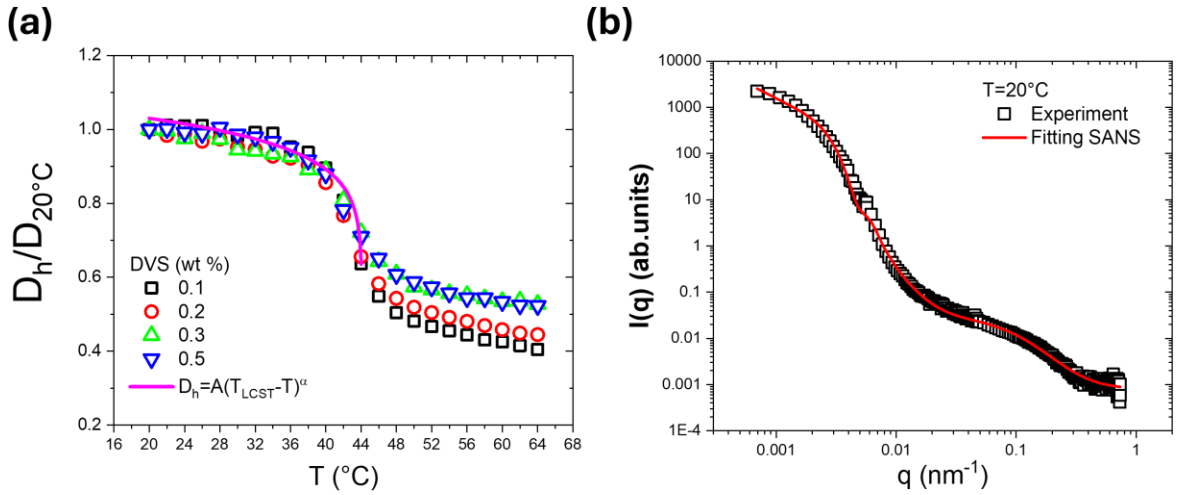

Figure 1. *(a) Temperature dependence of the hydrodynamic diameter (Dh) normalized by Dh=20°C at various crosslink concentrations. (b) SANS intensity profiles of HPC nanogel (0.1 wt% DVS) at 20°C.*

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P.83

Molecular dynamics simulation of Magneto-active elastomers

Júlio Santos, and Sofia Kantorovich

University of Vienna, Faculty of Physics, Kollingasse 14-16, 1090 Vienna, Austria

Presenting author's e-mail: julio.palma.de.assuncao.santos@univie.ac.at

Magneto-active elastomers (MAEs)[1-2], also known as magnetorheological elastomers (MREs), have seen growth in interest due to the programmability their mechanical properties using (relatively) low energy magnetic fields - one can change the material stiffness, surface roughness and shape. This coupled with clever engineering can lead to innovative designs and technology, especially in the field of soft robotics.

MAEs consist of an elastic matrix with embedded magnetic micro- or nano-particles, magnetically either hard (HM) or soft (SM). For very low concentrations of HM, we can simplify these systems to a distribution of HM connected to a random lattice of fixed points through springs [3-4]; for very high concentrations of HM, we can use a complex arrangement of springs that randomly bond nearby HM [5]. The biggest shortcoming of these models comes from the lack on incompressibility of the simulated materials, which is key to model physically relevant MAEs.

We aim to solve this problem and implement in ESPResSo[6] the necessary features for having access to a physically accurate MD simulation of MAEs. This will enable us to study the magneto-mechanical response of bulk and free surface MAE. We focus on the impact of SM particles on the surface relief of a MAE layer. We provide a critical comparison between HM and SM based MAE for optimizing controllable wetting properties of functionalism surfaces.

Keywords: magneto-active elastomers, magnetic soft matter, soft robotics

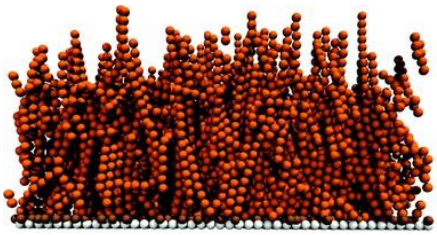

Figure 1. *Simulation snapshot of MAE taken from [5]. The surface roughness is magnetic field controlled.*

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Structure and rheology of cellulose nanocrystals from deep eutectic solvents

A. Tzeiranidi[1,2], E. Vasilaki[1,2], T. Athanasiou[1,2], S. Filonenko[3], M. Antonietti[3], M. Vamvakaki[1,2] and G. Petekidis[1,2]

[1] *Institute of Electronic Structure & Laser, FORTH, Heraklion, 70013 Greece*
[2] *Department of Materials Science and Technology, University of Crete, Heraklion, 70013 Greece*

[3] *Max-Planck Institute of Colloids and Interfaces, Department of Colloid Chemistry, Am Mühlenberg 1, 14476 Potsdam, Germany*

Corresponding author: tzeiranidi@iesl.forth.gr

Cellulose nanocrystals (CNCs) have attracted significant scientific attention lately due to their unique properties, such as high mechanical strength, biodegradability, non-toxicity and, most importantly, sustainability [1]. The conventional method for extracting CNCs employed both in laboratory and commercial scales, is acidic hydrolysis which utilizes strong acids, such as sulfuric acid. To this end acid hydrolysis with sulfuric acid is often deemed unsustainable and hazardous to the environment. Deep eutectic solvents (DESs) have emerged as an alternative that offers an environmentally friendly approach for the production of CNCs, aligning with the growing demand for sustainable technologies [2]. At high enough concentrations the CNC solutions in water form colloidal gels. Here we first characterize the structure and the rheological response of these "green" CNCs (produced via the use of eutectic solvents) near and above the gelation concentration. The effects of ultrasound application and ionic strength on the gel properties are also investigated. In comparison with commercial acid derived CNCs we find that Eutectic CNCs form gels at lower concentration. Secondly, we explore the changes induced by functionalization of CNCs with tyrosol, aiming to use them in antibacterial coatings application. We also explore how external shear can tune the microstructure and the mechanical properties of these different CNCs that due to their distinct interactions and functionalization can be used in several commercially applications.

Keywords: cellulose nanocrystals, rheology, deep eutectic solvents.

Acknowledgements: In case necessary, must be located at the end of the abstract, just before the references.

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On the optimality of osmotic and phoretic transport in porous media

*Jitendra Dhakar**, Kushagra Tiwari and Akash Choudhary#*

Department of Chemical Engineering, IIT Kanpur, Uttar Pradesh, India 208016

E-mail: jitendrad@iitk.ac.in (*lead presenter), achoudhary@iitk.ac.in (#correspondence)

Chemically induced gradients are widely employed to enhance particle transport in porous media. Diffusiophoresis (DP) and diffusioosmosis (DO) govern the movement of particles and near-surface fluid in response to electrolyte gradients. These transport mechanisms play a vital role in particle and drug transport in porous biofilms. Porous media contains both dead-end pores (DEP) and transmitting pores (TP) (Ref Fig. 1), making it essential to understand particle withdrawal and injection dynamics under different solute gradient modes: solute-out (solute emptying pore) and solute-in (solute saturating pore), which remain largely unexplored. This study shows the influence of solute gradient orientation on the osmotic and phoretic transport of colloids in porous media. We have found that these two modes (solute-out and solute-in) depict different qualitative performances for colloidal transport (Ref Fig. 2). Further, we have analyzed the effects of variable mobility and diffusioosmotic wall slip on colloidal transport in different pores (DEP and TP). The two kinds of pores (DEP and TP) are also shown to be significantly different qualitative insights for colloidal injection and withdrawal induced by both solute gradient modes. The analytical and numerical models highlight fundamental differences between solute-out and solute-in gradient generation in porous media. Beyond revealing the sensitivity of osmotic transport in porous media, insights from this study can inform alternative approaches for membrane filtration and enhanced oil recovery.

Keywords: Diffusioosmosis, Diffusiophoresis, Electrolytes, Porous media.

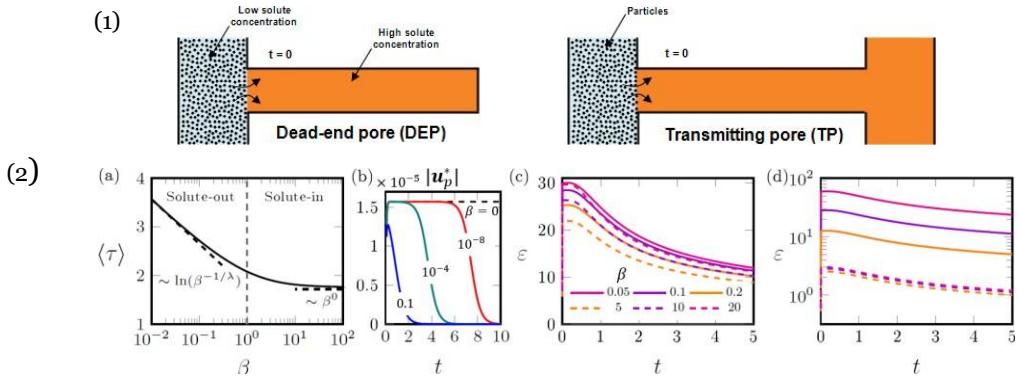

Figure. (1) Schematic representation of colloidal injection through DEP and TP pores. (2) Performance measures (persistence time, τ and effectiveness, ε) of colloidal withdrawal and injection in a dead-end pore.