Replica symmetry breaking in trajectory space for diffusion in logarithmically correlated random potentials

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A particle in a Gaussian random potential with logarithmic correlations appears in the contexts of a single vortex in a XY spin model with random gauge disorder in spatial dimension d = 2and two-dimensional Dirac fermions in a random magnetic field. In statics, the most intriguing result is that the model exhibits a localization phase transition. In particular, the equilibrium (Boltzmann-Gibbs) distribution in the low-temperature phase is dominated by a few distant states and described by replica symmetry breaking (RSB) [1], similarly to mean-field spin glass models. Furthermore, properties of the localized state is similar to those of directed polymers on the Cayley tree, rather than the random energy model (REM). The extreme-value statistics is described by a non-Gumbel distribution, differently from the Gumbel distribution for REM. In dynamics, according to a renormalization group analysis, subdiffusion occurs in all finite temperature. Furthermore, the existence of a dynamical transition between two subdiffusive phases was proved in d = 1, 2 [2]. Particularly, the dynamical transition temperature coincides with the static transition temperature in d = 1.

In this presentation, we study the dynamics of independent particles in a common random potential in d = 1. Such situation has been investigated in the context of relative diffusion. In many cases, relative diffusion is qualitatively different from single-particle diffusion. In our previous papers, we have developed the method to detect localization in trajectory space by using overlap between trajectories [3, 4]. When relative diffusion is strongly suppressed, the overlap takes a nontrivial value. Here, we apply this method to diffusion in logarithmically correlated random potentials, and numerically show that replica symmetry breaking in trajectory space occurs in the relaxation process in the low-temperature phase, which implies that a diffusion trajectory is localized into a few specific trajectories [5].

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^[1] D. Carpentier and P. Le Doussal, Phys. Rev. E 63, 026110 (2001).

^[2] H. E. Castillo and P. Le Doussal, Phys. Rev. Lett. 86, 4859 (2001).

^[3] M. Ueda and S. -i. Sasa, Phys. Rev. Lett. **115**, 080605 (2015).

^[4] M. Ueda and S. -i. Sasa, J. Phys. A: Math. Theor. 50, 125001 (2017).

^[5] M. Ueda, J. Stat. Mech. 053304 (2018).

Electrically-Controlled Kinetics of Topological Solitons in Nematics

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Topological solitary waves, dubbed "topological solitons", represent nontrivial and distorted vector fields, which are distinct to the far-field background, exhibiting particle-like nature. Generating and switching solitons¹⁻⁴, resembling topologically-protected states such as magnetic skyirmions, have risen up tremendous interests in understanding solitonic behaviors at microscopic scale. Recently, Li et al showed an electrically-driven solitonic movement⁵. The utmost challenge is to control the motions of the solitary waves.

Here, we present a novel example of generating a swarm of motile solitonic quasi-particles in nematic liquid crystals mediated by topological networks by using an electric field. We show that reversible generation-extinction processes of the solitons and the subsequent motion control with variable angles can be achieved by simply tuning frequency and amplitude of the electric field.



Figure 1 (Left) Electrically-pumped topological solitons, floating in planarly-aligned nematic background. Diameter of solitons is about $10\mu m$; (Right) Snapshots of solitons upon movement under an electric field of $5V_p$ at 20Hz.

References

[1] P. J. Ackerman, R. P. Trivedi, B. Senyuk, J. van de Lagemaat, Ivan I. Smalyukh, *Phys. Rev. E* **90**, 012505 (2014).

[2] P. J. Ackerman, Ivan I. Smalyukh, Phys. Rev. Lett., 7, 011006 (2017).

[3] P. J. Ackerman, Ivan I. Smalyukh, Nature Mater., 16, 426 (2017).

[4] A. Nych, J.-ichi Fukuda, U. Ognysta, S. Žumer, I. Muševic, *Nat. Phys.*, **13**, 1215 (2017).

[5]B.-X. Li, V. Borshch, R.-L. Xiao, S. Paladugu, T. Turiv, S. V. Shiyanovskii, O. D. Lavrentovich, *Nat. Commun.* **9**: 2912. doi: 10.1038/s41467-018-05101-y (2018).

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Separating long-wavelength fluctuation from structural relaxation in 2D glassy dynamics

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In a two-dimensional (2D) crystalline solid, a special type of melting transition takes place owing to Mermin-Wagner theorem, which means that thermal strain adds up logarithmically as a function of interatomic distance at finite temperatures. This is a direct consequence of its softening behavior caused by the superposition of long-wavelength phonons, which would also arise in a 2D amorphous solid on the continuum scale to which the linear elasticity applies. Recently, large-scale simulations [1] and colloidal experiments [2] have been conducted to show that the 2D glassy fluctuation is profoundly different from that in 3D systems owing to the Mermin-Wagner theorem, but nonetheless 2D glassy structural relaxation represented by neighbor switching events seems similar to the 3D counterpart.

In this presentation, we address cage-relative (CR) displacement, which is key to separate the structural relaxation from the long-wavelength fluctuation [3]. CR displacement well captures structural relaxation after removing the effect of long-wavelength fluctuation, capturing the neighbor switching events [1]. We further evaluate the amplitude of long-wavelength fluctuation by combining the normal and the CR displacements. As a consequence, we find its quantitative agreement with the Debye approximation results. This evaluation is valid up to a certain system size, before the time-scale of the long-wavelength phonons becomes too long to overlap with the structural relaxation time.

^[1] H. Shiba, Y. Yamada, T. Kawasaki, and K. Kim, Phys. Rev. Lett. 117, 245701 (2016).

^[2] B. Illing, S. Fristschi, H. Kaiser, C.L. Klix, G. Maret, and P. Keim, Proc. Natl. Acad. Sci. USA 114, 1856-1861 (2017); S. Vivek, C. P. Kelleher, P. M. Chaikin, and E. R. Weeks, Proc. Natl. Acad. Sci. USA 114, 1850-1855 (2017).

^[3] H. Shiba, P. Keim, and T. Kawasaki, J. Phys.: Cond. Matt. 30, 094004 (2018).

Propelled motion of a Janus particle in binary mixtures

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Janus particles, which have heterogeneous surface properties, are often employed as artificial self-propelled systems. For example, Bechinger and his coworkers studied Janus particles immersed in binary mixture of lower critical solution temperature [1]. The half hemisphere of the particle is covered by a metal. Under a light illumination, the temperature is increased locally around the capped surface, and then, the concentration field of the binary mixture becomes heterogeneous around the particle. They observed the particle move spontaneously along the orientation of the Janus particle.

In this study, we consider such propelled motions of the Janus particle in binary mixtures. We numerically solve the dynamics of the particle, the concentration field, the temperature field and the hydrodynamic flow by means of fluid particle dynamics method. The binary mixtures under an inhomogeneous temperature field are modelled by dynamic van der Waals theory [2]. We assume that the head side of the particle is selectively heated by an external source.

We found that the concentration field around the head becomes remarkably heterogeneous under the illumination. This concentration variation causes asymmetric hydrodynamic flow and this flow tends to push the particle toward its head. Our simulations indicate the particle motion is due to the Marangoni effect of the interface tension under the temperature gradient, not due to the thermos- or diffusio-phoretic effects. The speed and the direction of the particle motion depends not only on the heating rate, but also the wettability. When the particle surface is homogeneously neutral in the wettability, the particle does not move under a weaker illumination than a threshold. Above the threshold, the particle speed is increased with the heating rate. Interestingly, we found the particle changes its motion direction with the heating power when the particle wettability is asymmetric and the tail side prefers one of the solvent components more than the head side. When the heating power is weak, the particle moves toward its tail, while it moves forward when the heating power is strong. This motion inversion can be explained by the crossover of the concentration variation between near the head and near the tail.

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[1] I. Buttinoni et al., J. Phys.: Condensed. Matter 24, 284129 (2012).

[2] A. Onuki, Phys. Rev. Lett. 94, 054501 (2005), Phys. Rev. E 75, 036304 (2007).

viscosity-reduced substrates for the high performance liquid crystal display

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Dynamics of nematic LC under in-plane rotational fields, in a partially slippery LCD cell. Flows are induced because of the polarized charges.

Abstract: The conventional liquid crystal technology (LCD) has been dominating the display market for decades, until recent years. New types of optical device, such as solid-state organic light-emitting diode (OLED), have been challenging the long-established with a desired faster material response (LCD: 5ms vs OLED: 0.1ms). Facing the life-and-death situation, high performance LCD is expected to achieve fast response by reduced LC rotational viscosity on the substrates, hence it would also need smaller driving voltage for this new device. The new types of substrates are being prepared for the use in next generation LCD technology. The proposed concept has been proved for its practicability, first by polymer-coating on glass substrates, for which it leads to a slippery surface with reduced rotational viscosity. In addition, a second type of slippery substrates is also achieved by adding impurity dves in LC samples. The accumulation of dye molecules on substrates, for which it is a wetting process, isolates the original anchoring effect from substrates hence creates free rotational environment for LC molecules. As a counterpart study to the experiments, we also use a modified mesoscopic liquid crystal Q-tensor model to simulate the LC dynamics under external rotational fields. In our simulation the polymercoated/impurity-induced slippery surfaces are modeled by a numerical polymer layer, and this approach gives us informations of the substrate conditions when compare with experimental data. The extended applications of this technology will also be discussed in the talk.

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Relationship between an internal structure of granular material and a force chain

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Granular materials are composed of grains in contact, which exhibit solid-like frictional properties. Therefore, these materials have highly heterogeneous structure. Due to such nonequilibrium system, the mechanical behavior of granular materials is quite complex. In general, a force network is formed in the granular systems, which is known as 'force chain'. It has a key role in physical properties of granular materials.

We conducted experiments using 2D granular system consisting of photoelastic polymer particles, which make the force chain to be observed. By controlling the dispersion of a particle size composing of the system, we investigated the force chains in two structures; 'order' and 'disorder' structures. Then we conducted quantitative analysis of the force chain with changing the structure. We measured not only the force chain but also a bond order parameter such as

$$\psi_{\ell}^{j} = \frac{1}{n_{j}} \sum_{k} exp\left(i \,\ell \,\theta_{jk}\right)$$

which correspond to the degree of crystal of the system (where n_j is the number of neighbours of particle j and θ_j k is the angle between the vector connecting particles j and k and the horizontal axis. The parameter ℓ specifies the type of symmetry in which we are interested). We focused on the magnitude of the force and the bond order parameter between the two particles. In the ordered structure, we observed that the force is strongly applied to the crystal-like substructure. On the other hand, in the disordered structure, the force is strongly applied to a grain boundary between the crystal structure and a defect. That is, as the dispersion of the particle size increases, a transition of the force chain is observed from the ordered structure to the disordered structure.

- (1) K E Daniels, J E Kollmer, and J G Puckett. Rev Sci Instrum, 88(5):051808, 2017.
- (2) N. Iikawa, M. M. Bandi, H. Katsuragi, Phys. Rev. Lett. 116, (2016)
- (3) S. Luding, Adv. Compl. Syst. 04, 379 (2001)

Dynamics of recrystallization of droplet with pinning the edge

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Different macroscopic crystal patterns are observed even though microstructures are same such as snow crystals. The crystal pattern has influence on many material properties, such as macroscopic heat conduction, electrical conduction, and so on. Therefore the patterns are the focus of significant scientific and industrial interest. The crystal patterns formation has been investigated in bulk, while there are a few study for the pattern formation of recrystallization via evaporation of droplets on a substrate. Since recrystallization via evaporation is a complex process, the pattern formation is unclear yet. A droplet on a substrate shrinks during evaporation. Since an evaporation rate of the droplet is proportional to the perimeter of droplet [1], the evaporation rate changes with changing the perimeter of droplet during evaporation.

When a droplet including colloidal particles evaporates, the colloidal particles flow to the edge of droplets, and pin a edge of the droplet. It is called a coffee-ring effect. Benefit of using coffee-ring effect is that it is possible to keep the evaporation rate constant. Here, our purpose is revealing the recrystallization of droplet in a droplet with pinned the edge.

Here, we study the morphology of the crystal formed by the evaporation of a droplet of sodium bicarbonate (NaHCO3) solution. We mix the solution with latex particles (a diameter is $0.052 \ \mu m$) in order to pin the edge and to prevent the droplet shrinking.

As the result, a droplet of sodium bicarbonate solution without pinning the edge provided cluster pattern (Fig. 1a), in contrast the droplet with pinning the edge provided a concentric pattern and a dendritic pattern (Fig. 1b, c). The formations of two patterns depend on the evaporation rate and an initial concentration of the solution. When the evaporation rate is large and the initial concentration is small, the concentric pattern forms. In contrast, when the rate is small and the initial concentration is large, the dendritic pattern forms. In addition, we suggest that the pattern formation depend on local supersaturation in the droplet [2].



Figure 1 (a) the crystal pattern from droplet of sodium bicarbonate solution without latex particles and (b) (c) that with latex particles. We obtain crystal only at the edge of the droplet without latex, while the crystal forms in the whole of the droplet with latex

[1] R. D. Deegan, O. Bakajin, T. F. Dupont, G. Huber, S. R. Nagel, and T. A. Witten, Phys. Rev. E 62, 756(2000)

[2] K. Morinaga, N. Oikawa & R. Kurita, Sci. Rep. 8, 12503 (2018)

Relaxation dynamics in a quasi-two-dimensional foam.

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A liquid-gas foam is a non-equilibrium jammed state system composed of gas bubbles and liquid films. The foam, which has a cell structure of gas bubbles, is widely used in daily life. For foams, the liquid fraction φ is one of the most important parameters. The foam is empirically classified into dry state when φ is lower and the shape of the bubbles is polygonal, while it is empirically classified into wet foam when φ is higher and the shape of the bubbles is circular. By the recent study, the dry-wet transition has been found by characterizing the rearrangement of bubbles [1,2]. Also, in the very dry state when φ is below 1%, the collective bubble collapse phenomenon occurs during the collapse of foams and the mechanism behind this is clear [3]. Thus, the foam indicates a variety of the property for different liquid fraction.

When the liquid fraction increases, the bubbles in the foam move to equilibrium state In our study, we investigate the relaxation of the foam under small perturbation by changing the liquid fraction.

We used a household detergent solution in deionized water. We put the foam at a center of a glass plate and cover it with the other glass plate. The foam is regarded as quasi two dimensional. When the small amount of solution is injected in a foam, the liquid fraction increases. Then, the bubbles in the foam can rearrange their position and move to the equilibrium state. We took this relaxation process by using a high speed camera. As a result, we find that the number of rearranged bubbles increases as increasing the liquid fraction. Moreover, as the state becomes close to bubbly, the bubbles move cooperatively.



FIG. 1: The images of foam state for different φ . (φ is lower for left, and higher for right)

[3] N. Yanagisawa and R. Kurita, Submitted

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^[1] Y. Furuta, N. Oikawa and R. Kurita, Scientific Reports 6, 37506 (2016)

^[2] R. Kurita, Y. Furuta, N. Yanagisawa and N. Oikawa, Phys. Rev. E. 95, 062613 (2017)

Phase separation in charged lipid membranes under isothermal conditions: multivalent cation and membrane tension

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Phase separation in multicomponent lipid membranes has attracted great attention in association with raft model. Most of the studies about phase separation used only electrically neutral lipids, although several kinds of negatively charged lipids, such as phosphatidylserine and phosphatidylglycerol, are present in plasma membranes and biomembranes. In addition, phase separation is induced by changing the temperature despite our body temperature being kept almost constant. We have investigated the phase separation in charged lipid membranes induced by the addition of salt under isothermal conditions [1, 2].

In this presentation, we discuss the phase separation in negatively charged lipids-containing membranes induced by multivalent salts or membrane tension. We reveal cation valence, size, and structure dependencies in salt-induced phase separation. Depending on the kind of salt, the salt concentration where phase separation occurs is greatly different (Fig.1(a,b,c)). Moreover, it was reported that phase separation is also induced by applying membrane tension under isothermal conditions. We observed osmotic pressure-induced phase separation in charged lipid membranes. Interestingly, we found three-phase coexistence even in binary charged lipid membranes (Fig.1(d)). We consider that the phase separation depends on ionization state of charged lipid.



FIG. 1: (a,b,c) Phase separation in $DOPS^{(-)}/DPPC/Chol=40:40:20$ at 1 mM putrescine (+2) solution in (a), 50 μ M spermidine (+3) solution in (b), and 10 μ M spermine (+4) solution in (c). (d) Osmotic pressure-induced phase separation in $DOPS^{(-)}/DPPC=30:70$. Scale bar: 10 μ m.

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^[1] N. Shimokawa, M. Hishida, H. Seto, and K. Yoshikawa, Chem. Phys. Lett. 496, 59 (2010).

^[2] H. Himeno, N. Shimokawa, S. Komura, D. Andelman, T. Hamada, and M. Takagi, Soft Matter 10, 7959 (2014).

AC electrophoretic mobility of a single colloidal particle studied by holographic video microscopy

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In order to obtain information on the dynamics of colloidal particles, it is useful to track them in three-dimensions. In this study, the three-dimensional motion of colloidal particles under alternating electric field was tracked using a holographic video microscope [1]. In this method, interference image (hologram) of scattered and direct light from the particle by irradiation of collimated laser light is measured by video microscopy. The three-dimensional position of the particle is estimated using optical diffraction theory. For the simplicity of experimental realization, we used a collimated LED light instead of a laser beam and reconstructed a three-dimensional optical field from the hologram by Rayleigh-Sommerfeld back-propagation (RS) method [2].

Fig.1(a) shows the setup of our measurement system. Polystyrene spherical particles of 1.9μ m diameter were dispersed in water and the alternating electric field was applied in the vertical direction. Then the hologram was captured by a high speed camera. Fig.1(b) shows an example of volumetric reconstruction of the optical field from the hologram using the RS method. The center of the reconstructed optical field is regarded as that of the particle. The three-dimensional trajectory of a particle is shown in Fig.1(c). In this way, we measured the distribution of the mobility of a single particle and observed the frequency change of the mobility from 0.5 to 500Hz.



FIG.1 (a) Schematic of measurement system. (b)Volumetric reconstruction of the scattered optical field by a spherical polystyrene particle using RS method. (c) Three-dimensional trajectory of the polystyrene particle under a sinusoidal electric field.

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[1] F. C. Cheong, B. J. Krishnatreya, and D. G. Grier, Opt. Express 18, 13563 (2010).

[2] J. Goodman, Introduction to Fourier Optics (McGraw-Hill, New York, 2005).

AC electrophoretic mobility of an optically trapped colloidal particle

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Colloidal particles in aqueous solution are usually charged, and their surface charge (zeta potential) is important parameter for the stability of colloidal dispersion [1]. Conventionally, surface charge has been evaluated by the measurement of electrophoretic mobility under DC electric field. Although the frequency dependence of the mobility is expected to reflect the charge dynamics at the surface of the particles [2], it has not experimentally been studied much. In this study, we measure the complex electrophoretic mobility from 10 Hz–10 kHz by detecting the displacement of an optically trapped single colloidal particle driven by an AC electric field (FIG. 1).

The apparent spectrum of complex electrophoretic mobility at low frequencies becomes zero due to trapping of the particle by optical tweezers. We remove effect of binding force from the apparent spectrum using thermal fluctuation without electric field.

FIG. 2 shows the amplitude and the phase of AC electrophoretic mobility spectrum of a 1 μ m-silica particle in water. The mobility is found to be independent of frequency at lower frequency than 1 kHz and shows relaxation behavior at high frequencies. Detail on the measurement result will be discussed by taking into account the electro-osmotic flow induced in the experimental cell [2].







FIG. 2: Frequency dependence of complex electrophoretic mobility of a 1 μ m-silica particle in water.

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[1] W.B. Russel, D.A. Saville and W.R. Schowalter, *Colloidal Dispersions* (Cambridge University Press, Cambridge, 1989). [2] H. Morgan and N.G. Green, *AC Electrokinetics: colloids and nanoparticles* (Research Studies Press Ltd., Baldock, 2003).

Anomalous diffusion and fluctuation of a cell-sized actomyosin droplet

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Living cells actively regulate the generation of force during various biological processes. Actin filament, which is one of the cytoskeletons plays a major role in force generation of living cells. For example, muscle actin generates contraction force in cooperation with the motor protein myosin. Actomyosin, which is a composite material of actin and myosin also works in deformation and maintenance of the cell shapes. We have performed *in vitro* experiments by using artificial cells to clarify the primitive mechanism of the deformation induced by actomyosin [1,2]. These works figured out the dynamic interface deformation and analyzed their statistical features, however, it has not yet examined internal dynamics inside the artificial cells correlated with the interfacial deformations.

We here studied active fluctuation induced by actomyosin through the motion of probe beads encapsulated in the actomyosin droplet [3]. The basic behaviors of the interface were consistent with the results of previous studies, i.e., induction, nonperiodic oscillation, and winkling phases were emerged in order. Through the experiments, fluctuation of microbeads accompanied with motion transition of the interface exhibited correlations as shown in Figs. 1. (a) and (b). In induction phase (0 - 300 s), microbeads fluctuated around the initial position, and then the motion became larger in the nonperiodic oscillation phase (400 - 500 s). In the early winkling phase (600 - 700 s), the microbead was fallen into the interface where the actomyosin cortex formed. In the former phases, anisotropic fluctuation was observed, e.g., diffusion coefficient in the tangential direction was different from that of radial direction. The result suggests anisotropic formation of actomyosin bundles and their force network due to the small spherical boundary condition.



Fig. 1. (a)Trajectory of microsphere in actomyosin droplet. (b)Displacement of microsphere from initial position.

- [2] Y. Nishigami, H. Ito, S. Sonobe, M. Ichikawa, Sci. Rep. 6, 18964 (2016).
- [3] H. Ito, M. Makuta, Y. Nishigami, M. Ichikawa, J. Phys. Soc. Jpn 86 (2017)

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^[1] H. Ito, Y. Nishigami, S. Sonobe, M. Ichikawa, Phys. Rev. E 92, 062711 (2015).

Close relation for the gravitational instability between a physical gel and granular material

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Rayleigh-Taylor instability, which is a typical example of hydrodynamic instabilities, occurs due to density difference. When a heavy fluid lies over a light fluid in a constant gravitational field, fluctuations at the interface gradually increase and then macroscopic flows occur. Especially, the non-equilibrium phenomenon accompanied by hydrodynamic instability are related not only to fluid mechanics but also to various scientific fields. Thus, the hydrodynamic instabilities have been extensively investigated by many theoretical and experimental researches [1-2].

The Rayleigh-Taylor instability can be found not only in liquid-liquid interface but also in the gravitational settling of granular materials (granular-gas interface) [3-4]. However, the Rayleigh-Taylor instability of liquid systems and granular systems have been discussed individually in most cases.

In granular materials, the patterns of the interconnected force chains are known as a force network and these network cover the entire system (percolation). Another percolating system is a physical gel. By heating the physical gel from below, the percolation (polymer networks) gradually disappears. We thought this system was similar to the gravitational settling behavior of the granular. Therefore, we performed an experimental study of Rayleigh-Taylor instability (gravitational instability) in physical gel and granular [5].

We find a close relationship between the granular system and the physical gel. We also find that those behaviors are determined by the depth of the fluidization. In this presentation, detailed investigation on gravitational instability in a physical gel and granular material will be discussed.

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^[1] D. H. Sharp, Physica D 12, 3 (1984); Y. Zhou, Phys. Rep. 720-722 (2017).

^[2] K. U. Kobayashi and R. Kurita, submitted.

^[3] C. Voltz, W. Pesch, and I. Rehberg, Phys. Rev., E 65, 011404 (2001).

^[4] J. L. Vinningland, O. Johnsen, E. G. Flekkoy, R Toussaint, and K. J. Maloy, Phys. Rev., Lett. 99, 048001 (2007).

^[5] K. U. Kobayashi and R. Kurita, in preparation.

Electric double layer composed of an antagonistic salt in an aqueous mixture: Local charge separation and surface phase transition

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We examine an electric double layer containing an antagonistic salt in an aqueous mixture, where the cations are small and hydrophilic but the anions are large and hydrophobic. In this situation, a strong coupling arises between the charge density and the solvent composition. As a result, the anions are trapped in an oil-rich adsorption layer on a hydrophobic wall. We then vary the surface charge density σ on the wall. For $\sigma > 0$ the anions remain accumulated, but for $\sigma < 0$ the cations are attracted to the wall with increasing $|\sigma|$. Furthermore, the electric potential drop $\Psi(\sigma)$ is nonmonotonic when the solvent interaction parameter $\chi(T)$ exceeds a critical value χ_c determined by the composition and the ion density in the bulk. This leads to a first order phase transition between two kinds of electric double layers with different σ and common Ψ . In equilibrium such two layer regions can coexist. The steric effect due to finite ion sizes is crucial in these phenomena.



FIG. 1: Illustration of coexistence of two layer regions

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^[1] S. Yabunaka and A. Onuki, Phys. Rev. Lett. 119, 118001 (2017).

Dependence of effective interaction between charged colloidal particles on co-ion charge; An analysis using HNC-OZ theory

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Charged colloidal particles interact in an electrolyte solution through electric double layers. The effective interaction has been discussed on the bases of the Debye-Hückel (DH) theory. The DH theory shows the ion charge independent behavior when the ionic strength is constant. In contrast, some studies have shown that it depends on the charge under condition in which the DH theory is not adequate [1, 2]. In this study, the effective potential is calculated by the integral equation (HNC-OZ) theory for some anion valence.

In our results, the dependence of effective potentials on anion valence is quite small when the valence is changed at constant cation density (Fig. 1 (a)). On the other hand, the dependence appeared at constant ionic strength (Fig. 1 (b)). This independence is obtained in most of the region at $l_{GC}/\lambda < 1$ (l_{GC} : Gouy-Chapman length and λ : Debye length) except at $l_{GC}/\lambda << 1$. We will show the calculated effective interactions and the new picture of the electric double layer.



FIG. 1: The effective potentials calculated by HNC-OZ theory. The cation density is 10^{-2} M, and the ionic strength is 10^{-2} M. The charge of macroanions is -6e, and the diameter is 16.8 Å. The diameter of anions and cations is 16.8 Å.

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- [1] M. Hishida et al., Phys. Rev. E 96, 040601 (2017).
- [2] G. Trefalt, I. Szilagyi, and M. Borkovec, J. Colloid Interface Sci. 406, 111 (2013)

Multi-Particle Tracking Analysis of Gelatin/Water during Gelation Process

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Gels are dynamically arrested systems and typically exhibit frozen structural inhomogeneity at the scale of microns, which has been revealed by light scattering studies [1,2]. Multi-particle tracking analysis, an analysis of Brownian motion of a large ensemble of tracer particles embedded in soft materials, is an effective method for investigating spatial inhomogeneity of the mechanical properties of the materials [3] and therefore could be used for quantifying inhomogeneous mechanical properties corresponding to the inhomogeneous structure as detected by light scattering, which emerges at the sol-gel transition point.

In this study, the gelation process of aqueous gelatin solutions was studied by the timeresolved multi-particle tracking analysis. Figure 1 shows the probability density function (PDF) of the particle displacement Δx within time τ (van Hove correlation function) counting all observed tracer particles. The PDF for the sol state (before the gelation time) was Gaussian (Fig. 1(a)), as expected for the diffusion of particles in the Newtonian liquid, but the PDF for the gel state (after the gelation time) was non-Gaussian (Fig. 1(b)). The non-Gaussian PDF of the gel state was attributed to the spatial heterogeneity of the gel stiffness because PDFs of each tracer particle for the gel state were represented by Gaussian functions with different widths.



FIG. 1: Probability density function of polystyrene beads (d = 600 nm) in 10 wt% gelatin solution for several lag times τ measured at 20 min (a) and 360 min (b) after the quench.

- [2] M. Okamoto, T. Norisuye and M. Shibayama, Macromolecules 34, 849 (2001).
- [3] E. M. Furst, and T. S. Squires, *Microrheology* (Oxford University Press, 2017).

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^[1] M. Shibayama, Macromol. Chem. Phys. 199, 1 (1998).

Pattern formation during phase separation by radial quenching

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Understanding pattern formation during phase separation is a key subject since the pattern greatly affects macroscopic physical properties. As a way of the pattern control, a directional quenching, where the quench region propagates, is suitable. Recently, Kurita reported a two-dimensional pattern formation during phase separation using a directional quenching spreading from a center (radial quenching) [1]. Several patterns were observed depending on the constant velocity v at which the quenching region spreads. They observed a random droplet pattern when v is fast, a concentric circles pattern when v is comparable to the phase separation speed, a dendritic pattern when v is slow. In case of an actual experiment, temperature control on a bottom surface is usual, while it is difficult to control the temperature three-dimensional pattern formation during phase separation when the temperature was controlled only on the bottom surface and the temperature was propagated to the internal region by the thermal diffusion equation.

The quenching region was expanded radially from the center of the bottom surface. The temperature propagates by the thermal diffusion equation except for the bottom surface. Periodic boundary condition was applied only on the side. We used a modified Cahn-Hilliard equation proposed by Jaiswal [2], well-known as an equation describing the kinetics of phase separation in inhomogeneous temperature system. For simplicity, hydrodynamic interactions and effects due to temperature gradients are not considered.

Figure 1 is the concentration in the xz plane. We find a layered structure formed when v is so slow. we also find that the thickness of the layers ξ depends on the v, and we obtain from a power law fit, $\xi \propto v^{-0.45}$. In addition, we showed that this proportional relationship can be simply explained by considering the flux *j* from the *z* direction. [3]



Figure1 : The concentration in the xz plane. Left panel:v=0.1, Right panel:v=0.01

[3] T. Tsukada, and R. Kurita, submitted

^[1] R. Kurita, Sci. Rep. 7, 6912 (2017)

^[2] P.K. Jaiswal, S. Puri, K. Binder. Eur. Phys. Lett. 103, 66003 (2013)

Motion transition of a self-propelled water-in-oil droplet studied with measurements of the internal convection

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Active matter is composed of self-moving objects which convert chemical energy into kinetic energy. It has become one of popular subjects in non-equilibrium science. We here focus on single droplet motions of a water-in-oil droplet system. When a micrometer-sized water droplet is introduced into an oil medium accompanied with surfactants, the droplet starts to move spontaneously due to Marangoni effect [1].

We found that a small droplet swims linearly, whereas a large droplet swims curvedly [Fig. 1]. Internal convections of the droplets beside the motion transition were yielded through Particle Image Velocimetry (PIV). The flow fields yielded in the experiments were decomposed into spherical harmonic modes to compare with those discussed by the previous theory on a swimming droplet [2].



scale bar:200 µm

FIG. 1: Characteristic motions of water-in-oil droplet as a function of droplet size. The lines are the trails of the center-of-mass of the droplets.

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^[1] Z. Izri, M. N. van der Linden, S. Michelin, and O. Dauchot, *Phys. Rev. Lett.* **113**, 248302 (2014).

^[2] M. Schmitt and H. Stark, Phys. of Fluids 28, 012106 (2016).

Size and density dependency on radial segregation in a rotating cylinder

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Granular materials tend to segregate under mechanical agitation e.g. vibration. When a cylinder is partially filled with a mixture of two kinds of grains and rotated horizontally, three possible final states can be observed. The first state is mixed state. After several rotations, large particles cover the outer region of the granular media along the side wall of the cylinder and small particles form a core along the axis. This state is called radial segregation. Then axial segregation appears demonstrating stripe pattern perpendicular to the axis [1]. The final state is chosen depending on the combination of two particles. Based on the past experimental studies, radial segregation is considered to be precursor to the axial segregation. Heuristically, it is widely believed that axial segregation occurs when the dynamics angle of repose of large species is smaller than that of small species, although there was not enough systematic and quantitative evidence [2]. Our recent research found that axial segregation occurs even when there is no significant difference in the dynamic angle of repose. The dynamic angle of repose depends on various parameters such as particle size, shape and rotation speed, but it is unknown that how it was determined explicitly. In order to understand segregation mechanism of granular media, it is essential to reveal which parameter plays a significant role quantitatively.

In this study, we investigate the effect of size and density (specific gravity) of the particles. Spherical particles, such as glass, alumina, and zirconia beads, are used with different sizes and densities. The difference of the dynamic angles of repose are found to be insignificant. In our experiments, the three final states are realized by changing size and density systematically. The detail will be reported at the poster presentation.



Figure 1: View from the top and the side after 10 minutes from the start of rotation. Alumina size fixed at 2mm. Densities (specific gravity) of glass and alumina are 2.5 and 3.6 g/cm^{-3} , respectively.

References

- [1] J. M. Ottino and D. V. Khakhar, Annu. Rev. Fluid Mech. 32, 55 (2000)
- [2] K. M. Hill and J. Kakalions, *Phys. Rev. E* **49**, R3610 (1994); **52**, 4393 (1995)

Unique motion of a highly asymmetrically-shaped self-propelled particle

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Directed motion of an active agent requires asymmetry such as the Janus structure in physical/chemical properties of a particle, biological structures in a microorganism, or physical structures of an animal. Here we experimentally study the role of shape anisotropy of a selfpropelled particle by the induced charge electrophoresis (ICEP), where the anisotropy is coupled with the propulsion mechanism itself, gravitational potential energy, etc. We photolithographically produced rectangular solid particles whose thickness $h \approx 1.4 \,\mu\text{m}$, width w = 1 to 4 µm, length l = 5 to 40 µm, and deposited a 25 nm-thick chromium layer on an $l \times w$ face (see Fig. 1). The particles were dispersed in 0.1 mM aqueous solution of NaCl together with a surfactant (Pluronic F-127) as a dispersion stabilizer. The dispersion was sandwiched between ITO electrode-coated glass slides with a 100 µm gap, and then AC rectangular wave voltage was applied to the vertical direction to induce the ICEP motion (Fig. 1).[1] When the voltage was gradually increased from Vpp = 0 V, where Vpp is the peakto-peak value, the velocity of a particle lying on the substrate increased in proportional to Vpp^2 . At $V_{pp}^{h \rightarrow v}$ (horizontal mode), a particle suddenly stood up and the velocity jumped down, still exhibiting the proportionality to Vpp^2 (vertical mode). The particle lay down at $V_{pp}^{\nu \to h}$, which was smaller than $V_{pp}^{h \rightarrow v}$, indicating the bistability between the two kinetic modes. In addition to the bistability, the dependence of the velocity on w and l was measured and characteristic interaction between the particle and an obstacle was also found.



FIG. 1: Schematic drawings of the particles and its velocity against Vpp^2 .

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[1] S. Gangwal *et al.*, *Phys. Rev. Lett.* **100**, 058302 (2008); D. Nishiguchi & M. Sano, *Phys. Rev. E* **92**, 052309 (2015); J. Yan *et al.*, *Nat. Mater.* **15**, 1095 (2016).

Microrheology of dense colloidal suspension under localized force

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Concentrated suspensions of colloidal hard spheres are good model systems of soft matters used in our everyday life. They show variety of non-Newtonian behaviors typically represented by shear thickening after thinning while increasing the shear rate. Although such nonlinear flow responses have been extensively investigated under homogeneous flow applications using macrorheometers, fundamental understanding of the phenomena requires investigations at a microscopic level. In this study, we carried out nonlinear microrheology in dense suspensions of colloidal hard spheres (PMMA: $2a = 0.38 \mu m$ on average, polydisperse size distribution) at the volume fraction of 57%, very close to glass transition. Feedback-controlled optical-trapping forces were applied to a probe particle (melamin: $2a = 1\mu m$) dispersed in the suspension and its nonlinear response was observed.

The probe particle (diameter of 1 μ m melamine) hardly moved (Fig. 1 left insert) during the observation time period (40 s) when applied forces were smaller than ~10 pN. In this range, the fluctuation of probes decreased by increasing the applied force (Fig. 2), which indicates sample thickening. By further increasing the force, the particles began to move intermittently (Fig.1 right insert) and their fluctuation at low frequencies increased.

This result suggests that the externally applied force induced jamming of colloids surrounding the probe, and this force-induced jammed region was yielded at the threshold of $\sim 10 \text{ pN}$ fore.



FIG.1: Velocity dependence of effective friction of probe particle.



FIG.2: Applied force dependence of probe fluctuations (power spectral density: PSD).

Metabolic Activity and Rheology of in vitro Cytoplasm

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It was found that cell cytoplasm becomes glassy when metabolic activities are removed [1]. However, dynamics in living cells are not frozen. This suggests that rheological properties of living cells are profoundly affected by their metabolism that is essential for any physiological processes. In order to investigate the physical mechanism, we perform microrheology experiments on cell extracts [2]. Fluctuations and mechanical responses of probe particles are measured while controlling their metabolic activities. For instance, *E. Coli* extracts that maintained metabolism showed viscosity aging whereas extracts lacking metabolism were stable (FIG. 1). For further investigation of this phenomenon, we measured the amount of ATP consumed during the aging process. We discuss out-of-equilibrium machinery how intracellular fluidization occurs under metabolic activity.



FIG. 1: Viscosity of intact cell extract (circles) and cell extract that lack metabolism (triangles). Intact cell extract shows aging behavior. Figure is form supplementary information of Ref. [1].

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^[1] K. Nishizawa, et al. Sci. Rep. 7, 15143 (2017).

^[2] K. Nishizawa, et al. Sci. Adv. 3(9), e1700318 (2017).

Shear-thickening in a dilute suspension of spheres in a weakly viscoelastic fluid: an approach with a direct numerical simulation

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Most recently, the shear thickening of the viscosity in dilute suspensions of spheres in weakly viscoelastic fluids has been investigated theoretically (Koch et al. 2016, Einarsson et al. 2018) and numerically (Yang et al. 2016). These studies suggested that an increase in the particle-induced fluid stress is the main cause of the shear thickening. However, the physical interpretation of the changes in the stress contributions is still unclear. In this work, we study the underlying physics of the shear-thickening in dilute suspensions in viscoelastic fluids. For this purpose, we developed a three dimensional direct numerical simulation (DNS) for suspensions in viscoelastic fluids based on the Smoothed-Profile method for solid-fluid coupling which allow us to use fixed regular grids for suspensions rather than surface-conforming grids (Nakayama et al. 2005,2008). Our numerical resuts with the Oldroyd-B fluid for the suspending medium show the shear viscosity thickens with the Weissenberg number (Wi) consistent with the prior works. Analysis of the changes in the flow pattern and the distribution of the viscoelastic stress with Wi reveals that a fraction of shear-flow-driving energy stored in the conformation stretch increases with Wi inducing two effects; (i) a decrease in the stresslet contribution, which is consistent with the reduction of the rotation speed of the particle (ii) an increase in the region and the magnitude of the elastic stress around the particle. The latter effect overwhelms the former one, resulting in the shear thickening. The increase in the fluid stress contribution turns out to be attributed to the spatial expansion of unrelaxed polymer stress caused by the advection and the stretching around the sphere. The DNS based on the Smoothed-profile method for viscoelastic suspensions is found out to be accurate so that it can be applicable to more complex phenomena in dense particle suspensions which are important in many industrial products.

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Coarse-grained molecular dynamics simulation of phase separation and morphological dynamics of a charged lipid vesicle

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Lipid bilayer vesicles composed of multiple lipid species spontaneously form phase separated domains due to the interaction between lipid molecules. Such heterogeneous structure formation in two-dimensional fluid systems may exist in biological membranes. Recently, longrange electrostatic interaction in such membrane systems attracts increasing attention because plasma membranes and some organelles are enriched with electrically charged lipids. Here we performed coarse-grained molecular dynamics simulations of phase separation and accompanying morphological dynamics of a charged lipid vesicle [1].

Figure 1 shows the results of phase separation dynamics for electrically neutral vesicles (top, red/yellow corresponds to different neutral lipid molecules) and charged vesicles (middle and bottom, red/yellow corresponds to charged/neutral lipid molecules, respectively). n_0 is the concentration of monovalent salt in the surrounding aqueous phase. We can see the apparent delay of phase separation process in the case of charged lipid vesicles with low salt concent-

ration $n_0 = 100$ mM, because of electrostatic repulsion between charged lipids. Growth exponent of typical domain size indicates that the charged lipid vesicles undergo nucleation growth, rather than spinodal decompo sition in the case of neutral lipid vesicles. For longer-time calculation, only the charged vesicles undergo morphological changes into disk, bicelle string, and shapes triggered by the spontaneous pore formation at a charged lipid domain.



FIG. 1: Phase separation dynamics of a lipid bilayer vesicle composed of only electrically neutral lipids (top), and that composed of charged lipids and neutral lipids (middle and bottom). n_0 is concentration of monovalent salt.

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^[1] H. Ito, Y. Higuchi, and N. Shimokawa, Phys. Rev. E 94, 042611 (2016).

Shape controls polarization: Self-organization into ferroelectric and antiferroelectric crystals by shape-anisotropic particles

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Ferroelectricity and antiferroelectricity are widely seen in various types of condensed matter and are of technological significance not only due to their electrical switchability but also due to intriguing cross-coupling effects such as electro-mechanical effects. The control of the two types of polarization ordering has practically been made by changing the ionic radius of a constituent atom or externally applying strain for inorganic crystals and by changing the shape of a molecule for organic crystals. However, the basic physical principle behind such controllability involving structural organization is still unknown. By using a simple particle model with strong coupling between polarization ordering and structural ordering [1], here we show that energetic frustration between the two types of anisotropic interactions, dipolar and steric interactions, is a key to control not only the phase transition but also the coupling between polarization and strain [2]. By utilizing this coupling, we also realize electric/mechanical switching between ferroelectric and antiferroelectric states (see Fig.1).



FIG. 1: Mechanical switching from antiferroelectric to ferroelectric state under uniaxial stretching. Simultaneous transformation of crystalline structure and polarization ordering is observed.

[2] K. Takae and H. Tanaka, Proc. Natl. Acad. Sci. 115, 9917 (2018).

^{*} Corresponding author: takae@iis.u-tokyo.ac.jp

^[1] K. Takae and A. Onuki, J. Phys.: Condens. Matter 29, 165401 (2017).

Rheology of active gels with microbial migrations

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In living cells, molecular motors (e.g. myosin) interact with biopolymer networks (e.g. actin) and generate non-thermal forces by which rheology of cells are profoundly affected. Nonequilibrium statistical mechanics of such out-of-equilibrium situation have been studied intensively using reconstituted model systems called "active gels". For instance, when cross-linked actin gels were actuated by myosins, their viscoelasticities increased by orders of magnitude (active stiffening). On the other hand, if actin networks were not crosslinked, it has been suggested that the structural relaxation due to reptation could be enhanced.

In this study, we prepared a novel active model system composed of entangled network of polysaccharides polymers (xanthan gum) in which microorganism (spiroplasma) migrate. Probes dispersed in this active gel (video microrehology) showed remarkably enhanced fluctuation whose distribution was non-Gaussian (Fig. 1), that confirmed the presence of non-thermal activation. Mechanical properties of this active gel were measured by using a macro rheometer and compared with inactive gels where spiroplasma migrations were prohibited (Fig. 2). We indeed observed the shift of viscoelastic relaxation towards a higher frequency, that implies the enhancement of reptation.



Figure 1: Probability density distribution P(Δu) of probe displacements $\Delta u = u (t + \Delta t) - u (t)$ in a 5% xanthan gum. $P (\Delta u)$ of ATPdeleted sample was Gaussian because fluctuations are thermal. $P (\Delta u)$ was broadened and exhibited non-Gaussian tail in a sample with migrating microorganism (spiroplasm).



Figure 2: Viscoelastic modulus of xanthan gum 0.5% solution, measured using a macro rheometer. A gel with spiroplasma migration $(\bullet, \blacktriangle)$ and without migration (\odot, \bigtriangleup) are shown. Circles and triangles indicate storage (G') and loss modulus (G"), respectively. Structural relaxation was enhanced by the migration of spiroplasma.

Diffusiophoretic motion of a charged particle undergoing chemical reaction on its surface

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A new mechanism for diffusiophoresis of a charged colloidal particle undergoing surface chemical reaction is proposed. A theoretical model is constructed to describe dynamics of the particle and surrounding solution of weak electrolyte. Since in our model the solute is an undissociated electrolyte, its concentration gradient cannot generate electric field in the bulk far from the particle. However, the dissociation reaction with the solute yields anisotropic charge distribution, which gives rise to net force on the particle and leads to directional motion of the particle. Theoretical analysis and numerical simulations of the model reveal that phoretic motion of the particle emerges in response to a concentration gradient of electrolyte which breaks the spherical symmetry of surface charge distribution on the particle. The particle velocity is determined as a function of the electrolyte concentration, its gradient, and κa , where κ^{-1} is the Debye screening length and a is the particle radius. It is also shown that sign of the particle velocity changes depending on the ratio of dielectric constant of the solution to that of the particle.

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Non-monotonic segregation dynamics in a half-filled rotating cylinder

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Granular materials often segregate under mechanical agitation such as flowing, shaking, or rotating, in contrast to an expectation of mixing. One of the most fascinating examples of segregation is demonstrated by a cylinder that is partially filled with grains of different sizes [1, 2]. When mixtures of grains are steadily rotated in a horizontal cylinder around its axis, the binary mixture segregates into alternating bands of relatively pure single concentrations along the axis of rotation. In our past studies, we have investigated spatio-temporal dynamics especially at high fill level. By increasing the fill level, we intend to suppress the effect of avalanche. In a single cylinder, we found a steady annihilation and creation of bands which lasted more than a week [3]. In a double cylinder, oscillating band dynamics was also found at high fill level [4].

In this study, we carried out experiments with low fill level and low rotation rate. By decreasing fill level and rotation rate, we try to suppress the avalanche in a different way from high fill level cases and see how the spatio-temporal dynamics would vary. In half-filled cases, monotonic merging of bands has been recognized as the only spatio-temporal dynamics if the experiment was launched with a nearly homogeneous mixture. We will report the experimental result in this poster presentation.



FIG. 1: Spatio-temporal plot of segregation pattern in a cylinder (fill level is 24.6%, rotation rate is 5.4 rpm, diameter and length of cylinder are 8 cm and 30 cm, respectively).

* Corresponding author: inagaki@phys.kyushu-u.ac.jp

[1] V. Frette and J. Stavans, Phys. Rev. E 56, 6981 (1997).

[2] J. M. Ottino and D. V. Khakhar, Annu. Rev. Fluid Mech. 32, 55 (2000).

- [3] S. Inagaki and K. Yoshikawa, Phys. Rev. Lett. 105, 118001 (2010).
- [4] S. Inagaki, H. Ebata, and K. Yoshikawa, Phys. Rev. E 91, 010201(R) (2015).

Shear Thinning and Nonlinear Structural Distortion of Ionic Liquid with Long Alkyl Chain

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Room-temperature ionic liquid (RTIL) with a long alkyl chain is known to exhibit three characteristic peaks in its static structure factor. These peaks are currently assigned to, from low-*q* to high-*q*, the polar-nonpolar domain structure, the charge-alternation mode, and the number density mode, respectively. It is thus interesting how the multi-scale character of RTIL is related to its macroscopic viscoelastic properties. From the cross-correlation analysis between the two-body density and the shear stress, our equilibrium molecular dynamics (MD) simulation study suggested that the strongest viscoelastic relaxation is assigned to the dynamics of the charge-alternation mode [1]. In this work, we performed non-equilibrium MD simulation, and the shear rate dependence of the viscosity is compared with the nonlinear distortion of these characteristic structures.

The system we study is 1-methyl-3-octylimidazolium bis(trifluoromethanesulfonyl)amide,

which is the same as that used in [1]. Non-equilibrium MD simulation runs were performed under simple shear, where the flow in the *x*-direction possesses the gradient in the *y*-direction. The anisotropy of the structure factor was analyzed together with the shear-rate dependent viscosity.

Figure 1 shows the *xy*-component of the anion-anion part of the structure factor under three different values of the shear



FIG. 1: *xy*-component of the anion-anion part of the structure factor under shear.

rate. Strong responses are found at the wavenumbers of q = 3, 12 and 14 nm⁻¹. The first one is related to the polar-nonpolar domain structure, and the latter two are to the charge-alternation mode. The nonlinearity of the domain mode is stronger than that of the charge-alternation mode, reflecting the slower relaxation of the former. The nonlinearity of these modes will be compared with the shear viscosity to analyze the microscopic origin of the shear thinning in the presentation.

Shape deformation dynamics of lipid bilayer membrane induced by a chemical stimulus

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Recent advanced electron microscopes have revealed the internal structure of mitochondria, criste, is a dynamic tubular structure. However, the mechanism of the dynamic formation of the tubular structure in mitochondria has not been clarified yet. In the previous experiment mimicking the situation in a mitochondria by Fournier et al[1], they observed a deformation induced by a pH gradient. In this study, we constructed a model to explain the phenomenon observed in this experimental system and performed simulations of the system corresponding to their experiments by using the model. Fig.1-(a) shows the time evolution of shape deformation after injecting an alkalic solution. We can see the deformation obtained here grasps the experimentally observed ones[1][2], a formation of protrusion of the bilayer membrane. Fig.1-(b) shows the time evaluation of the scaled height, $H(\tilde{t}) = h(\tilde{t})/h_{\text{max}}$ where h(t) is the height of the induced protrusion and h_{max} the maxium of h(t). In Fig.1-(a) the left-end figure shows the initial state, and the circle spot drawn above the vesicle located at the center is the place where the NaOH aqueous solution is put. The protrusion structure obtained in our simulation is similar to those observed in the prior experiment. Furthermore, we investigated the effect of flow hydrodynamic flow on the dynamics of deformation to understand the mechanism of tube deformation in more detail. We found that the dynamics of the tubular structure is determined essentially by those of ion concentration distributions around the membrane and the hydrodynamic effect does not play signicant role in the dynamics. Finally, we investigated effects of dimensionality of the system by comparing the results obtained in two dimensional system and axi-symmetric three dimensional system, and found that there is no significant difference between them in the formation of a tubular structure.



FIG. 1: (a) Shape deformation dynamics of a vesicle after adding a NaOH aqueous solution at the white spot place (in the left-end figure) close to the membrane. From the left to right, the figures are correspond to those at the initial state, at a middle time, and at a finally relaxed state, respectively.

(b) Time evaluation of the height of the protrusion $H(\tilde{t})$. The dashed line is a fitting line in the decaying region. (Inset) A fitted result of $H(\tilde{t})$ with $\exp(-\tilde{t}/\tilde{\tau})$ in the decaying region $(1 < \tilde{t} < 500)$, and $\tilde{\tau}$ is found to be $\tilde{\tau} = 353$.

[2] A. -F. Bitool et al., J. Phys. : Condens. Matter 23, 284102 (2011).

Non-equilibrium fluctuation in microorganism suspension

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We investigate the hydrodynamic fluctuations in suspensions of swimming microorganisms (Chlamydomonas) by observing the probe particles dispersed in the media. Hydrodynamic fluctuations caused by force generators (swimming microorganisms) dispersed in 3D space exhibit heavily tailed distribution, which is not Gauss nor Levy, despite the classical and extended central limit theorems[1]. In this study, we therefore investigate the dimensionality dependence of the hydrodynamic fluctuations in active swimmer suspensions. By making use of the apparatus for the acoustic force spectroscopy , swimmers and probes were confined in a 2D layer at the center or the surface of the sample chamber.



FIG.1 Probability density distribution in 3D



FIG.2 Probability density distribution in 2D

FIG. 1 In the statistical distribution of the particle fluctuation in the system in which Chlamydomonas migrates in the three dimensions, it was shown that the observed distribution coincides with the obtained theoretical formula accurately [2].

FIG.2 As in the case of Chlamydomonas migrating in three-dimensional space, a non-Gaussian distribution with a wide heavy tail was observed even in a system confined in two dimensions.

However, in center part of distribution, the thermal fluctuation is dominant in the two-dimensional system as compared with the three-dimensional system.

^[1] D.Mizuno, C.Tardin, C.F.Schmidt, F.C.Mackintosh, Science 315 370,2007
[2] Takashi Kurihara, et al. Non-Gaussian limit fluctuations in active swimmer suspensi ons, PRE,2017

Direct Numerical Simulation of Induced-Charge Electrophoresis of Janus Colloidal Particles

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Understanding the dynamics of colloidal particles dispersed in aqueous media is important for industrial applications. In the classical theory of Electrophoresis, the surface charge of a colloidal particle is assumed to be fixed at an equilibrium state. Therefore, the zeta potential becomes constant and the mobility exhibits a linear response to the electric field E. However, in cases where the particles are polarizable, nonlinear electrokinetic phenomena can be observed. The ionic flow due to the induced charge on the polarizable surface is referred to as the induced-charge electro-osmotic (ICEO) flow. The ICEO flow velocity scales as

$$U_0 = \frac{\varepsilon a}{\eta} E^2 \tag{1}$$

where ε is permittivity, η viscosity of the surrounding fluid and a radius[1].

Induced-charge electrophoresis (ICEP) results from using anisotropic particles. This symmetry breaking yields a non-uniform ICEO flow that causes the uncharged particle to start swimming, even under a uniform electric field. Metallodielectric Janus particle attracts high attention to see the ICEP behavior. Several works have reported that a Janus particle is able to switch its moving direction as the frequency increases[2]. However, this phenomena is not yet fully understood, so we are tackling this problem with numerical simulations. We applied smoothed profile method to couple the particle dynamics and electrohydrodynamics[3]. Our model qualitatively aglees with the existing ICEP theory. In addition, our model is able to calculate the dynamics of many body systems. This will be helpful to understand the balance between electrostatic and hydrodynamic forces.

[3] K. Kim, Y. Nakayama and R. Yamamoto, Phys. Rev. Lett. 96, 208302 (2006).

^{*} Corresponding author: oguri_2016@cheme.kyoto-u.ac.jp

^[1] M. Z. Bazant and T. M. Squires, Phys. Rev. Lett. 92, 066101 (2004).

^[2] J. Yan *et al*, Nature Mater. **15**, 1095-1099 (2016).

Mechanosensitivity of fast-crawling cells

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The ability of cells to actively respond to signals received from their environment is crucial for all biological systems and holds great promise for future applications in medicine and tissue engineering. In this work, we focus on the mechanosensitive response of crawling cells. Experimentally, this can be studied by placing the cells on cyclically stretched substrates, whereby they are observed to reorient in a cell-specific manner. While much is known about slow-crawling cells, our understanding of how fast-crawling cells move is still limited. They are observed to reorient perpendicular to the direction of stretching[1, 2], but the precise mechanism responsible for this is not completely understood.

To address this issue, we have developed a computational model capable of relating the mechanosensitive response of fast-crawling cells on cyclically stretched substrates to their sub-cellular dynamics[3]. This includes the dynamics of the cell membrane, the actin-cytoskeleton, and the focal adhesion sites. Depending on which process is probed by the stretching, and the type of coupling to the substrate, we observe significantly different realignment dynamics. We show that an asymmetry in the stability of adhesions during extension/compression can be exploited to align the cells at specific orientations (Fig. 1), and can account for the realignment observed experimentally.



FIG. 1: Phase diagram showing the final orientation of the cells as a function of frequency ω and adhesion response function d. Red (blue) ellipses correspond to complete perpendicular (parallel) alignment.

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^[1] C. Okimura, K. Ueda, Y. Sakumura, Y. Iwadate, Cell Adhes. Migr. 10, 331 (2016).

^[2] C. Okimura and Y. Iwadate, Cell. Adhes. Migr. 10, 406 (2016).

^[3] J. J. Molina and R. Yamamoto, arXiv:1807.02295.

Crystallization of transmembrane protein and phase diagrams of binary hard disks

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Bacteriorhodopsin (bR) is a kind of transmembrane proteins. They make a two dimensional crystal on living membrane. In the case of native bR, they construct trimers and the trimer becomes a unit in the crystal. Here, we examined the binary hard disc model to discuss the packing effect on the critical concentration for the crystallization.

We assumed that the membrane was a flat two dimensional system. Small and large disks were adopted as lipid molecules and as the proteins, respectively. To obtain the pressures and chemical potentials of fluid phase and of solid phase were calculated by using free volume theory and scaled particle theory. Various size ratios and packing fractions of lipid in a reservoir were examined and the critical concentrations were obtained.

In our poster, two types of systems will be discussed because some mutants do not construct the trimer. One is a system consisting of lipids (diameter = 0.5 nm) and monomer bRs (diameter = 3.0 nm), and the other is a system consisting of lipids and trimer bRs (diameter = 6.2 nm). When the packing fraction of the reservoir was 0.40, critical concentration for the monomer crystallization was 17.04 times that for the trimer (Table.1). This result was consistent with experimental result qualitatively, because the critical concentration ratio (mutant, G113I / wild type) was 12.25 [1]. Here, the mutant G113I cannot form trimer [2].

Packing fraction of small	Critical concentration of monomer
disks in reservoir	/ critical concentration of trimer
0.50	454.4
0.45	71.00
0.40	17.04

Table.1: Dependence of critical concentration ratio on the packing fraction of small disks in reservoir.

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[1] T.A.Isenbarger and M.P.Krebs, Biochemistry. 38, 9023-9030 (1999)

[2] M.P.Krebs, W.L.Timothy and P.Halambeck, J. Mol. Biol. 267, 172-183 (1997)

Shear-thinning in glassy liquids

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We propose a simple mechanism for describing the onset of shear thinning in a high-density glassy liquid. In a shear flow, along the compression axis, the overlap between neighboring particles is more enhanced than that at equilibrium, meaning that the "effective" size is reduced along this axis. On the other hand, along the extension axis perpendicular to the compression axis, the average structural configurations are stretched, but it does not indicate the expansion of the "effective" size itself. This asymmetric shear flow effect for particles results in a small reduction of the "effective" density. Because, in glass-forming liquids, the structural relaxation time τ_{α} strongly depends on the density ρ , even a very small reduction of the effective density should lead to a significant decrease of the relaxation time under shear flow. We predict that the crossover shear rate from Newtonian to non-Newtonian flow behaviors is given by $\gamma_c = [\rho(\partial \tau_{\alpha}/\partial \rho)]^{-1}$, which can be much smaller than $1/\tau_{\alpha}$ near the glass transition point. It is shown that this prediction is consistent with the results of molecular dynamics simulations.