FURUKAWA LAB.

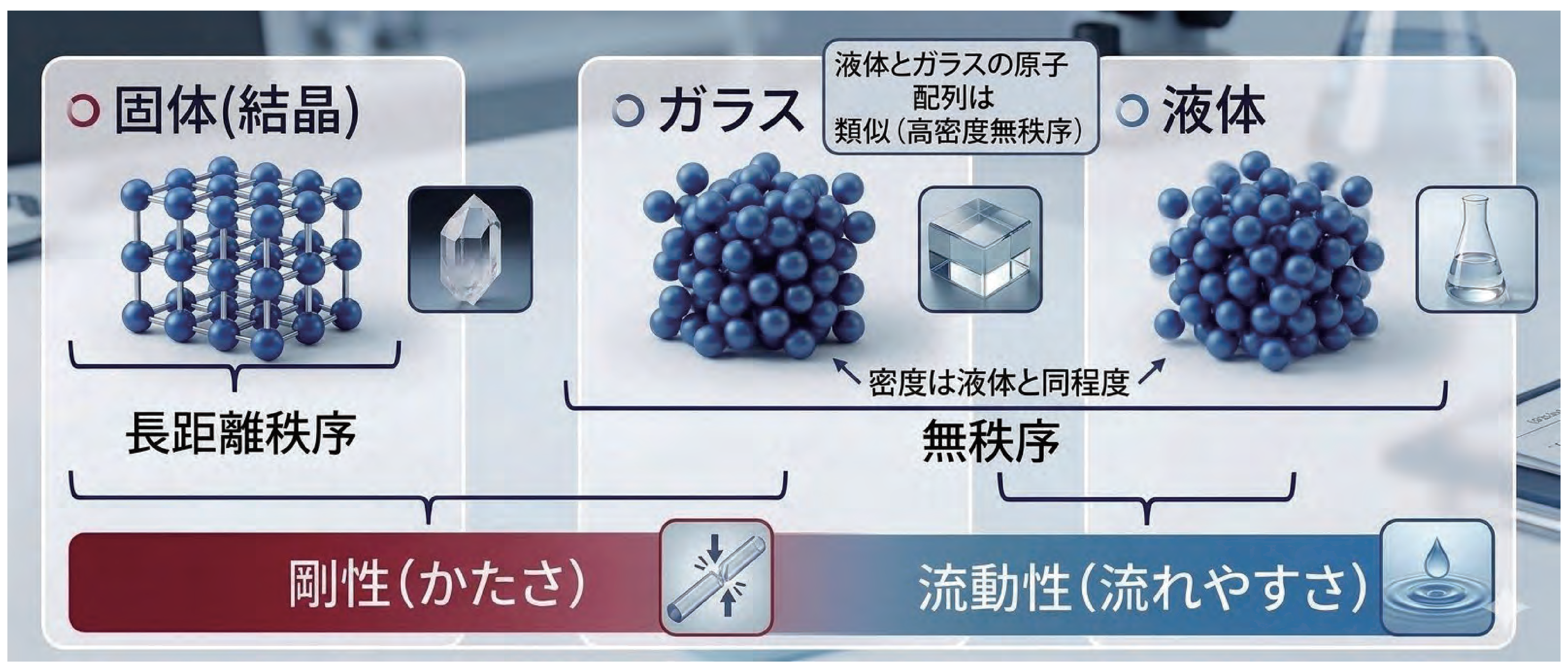
Exploring Nonlinear and Nonequilibrium Dynamics in Soft Matter

Department of Fundamental Engineering
Center for Research on Innovative Simulation Software

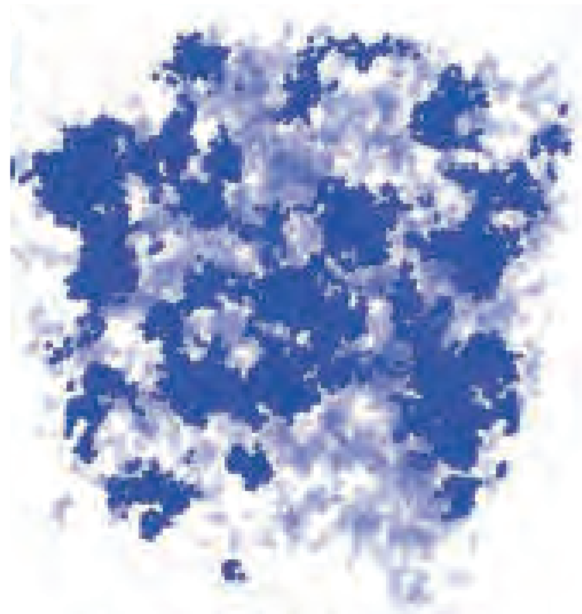
Soft Matter Physics
Department of Applied Physics, Graduate School of Engineering

We study nonlinear and nonequilibrium phenomena in soft matter systems, focusing on glasses, colloids, and active matter. Although these materials are familiar in everyday life, many of their properties remain poorly understood. Our goal is both to clarify their underlying physics and to apply that understanding to materials design.

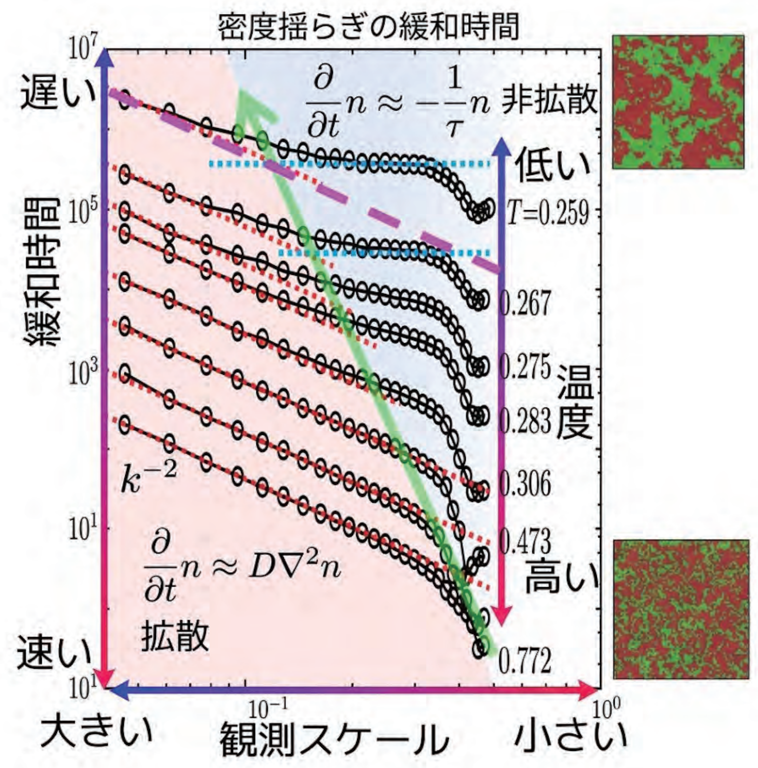
1.The mystery of the glass transition: Why does solidification occur while the material retains a liquid-like structure?



A glass preserves a disordered, liquid-like structure, yet it exhibits rigidity similar to that of a crystalline solid.

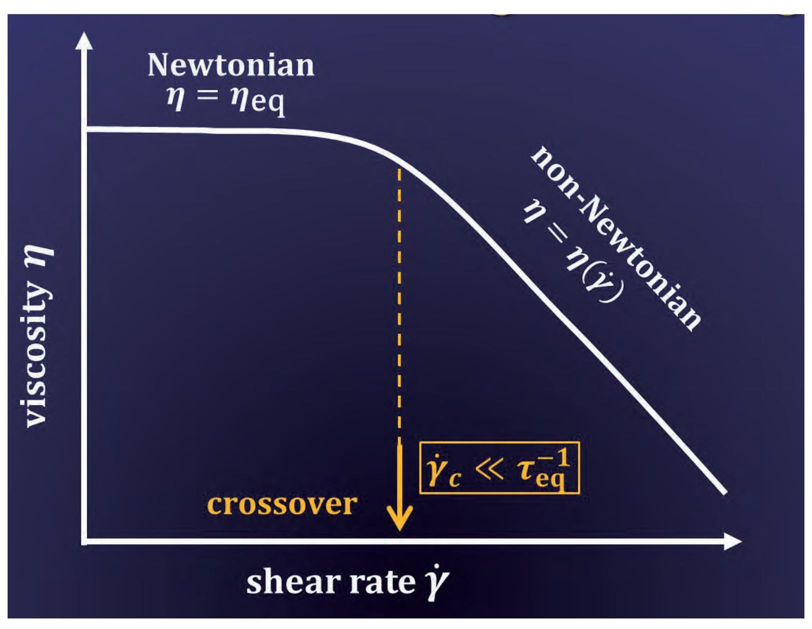


Dynamic heterogeneity: in deeply supercooled liquids approaching the glass transition point, mobile and immobile regions coexist heterogeneously.

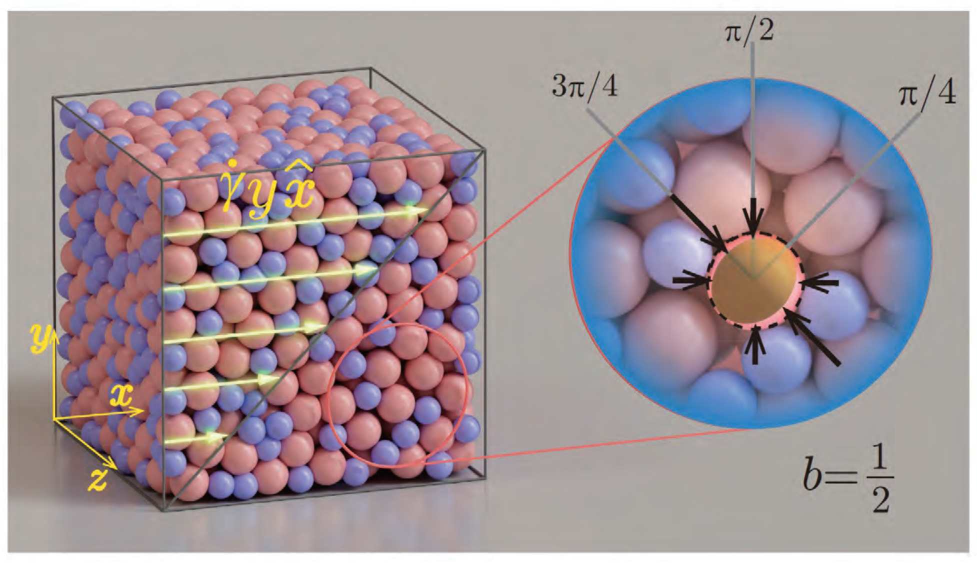


Length-scale dependence of density-fluctuation dynamics

2. Rheology of glassy materials: Why can the flow of a glassy liquid be accelerated so easily?



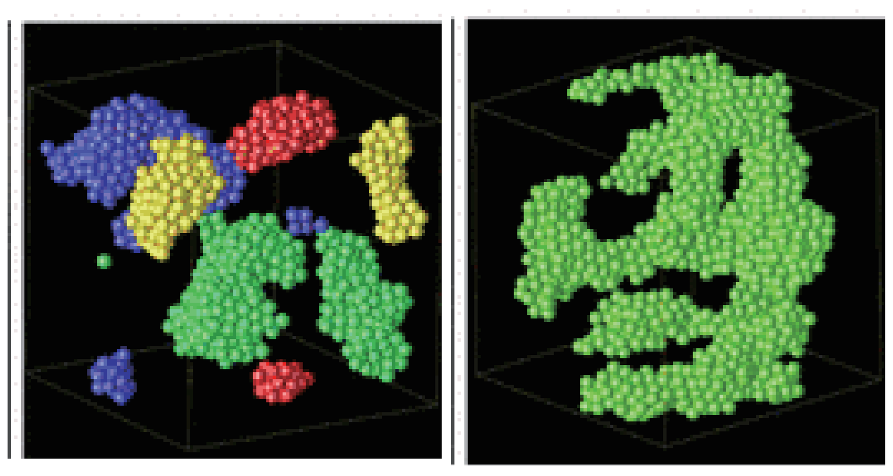
$$\hat{\tau}_\alpha(n, T, \dot{\gamma}) = \tau_\alpha^{(eq)}(n(1 - c_g \dot{\gamma} \hat{\tau}_\alpha), T)$$



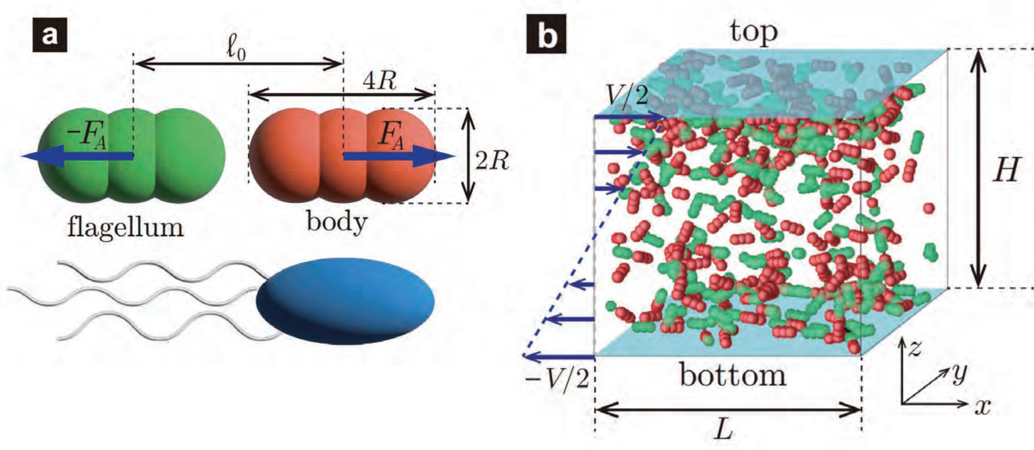
Schematic of the effective volume under shear flow (top) and the theoretical prediction of the rheological curve based on this concept (left)

Under deformation, glassy materials and glassy liquids exhibit complex flow behaviors such as shear thinning, shear thickening, and plastic deformation.
These flows are also often accompanied by structural heterogeneity, fatigue, and fracture. We aim to develop a comprehensive understanding of these phenomena.

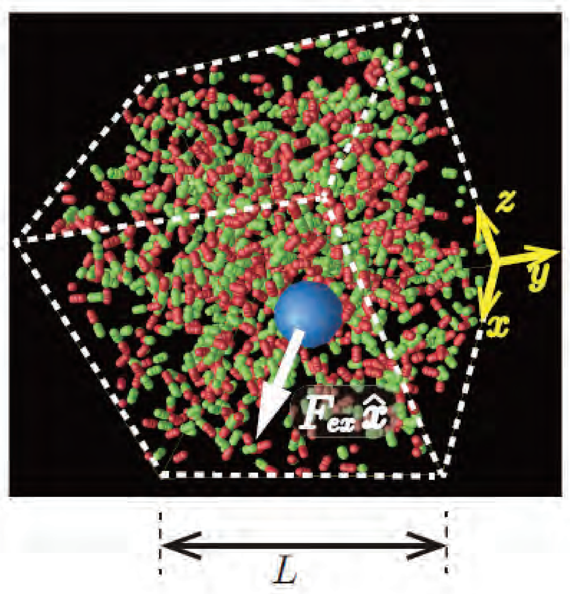
3. Hydrodynamic interactions governing suspension dynamics: Fluid is not a simple background



Gelation of a colloidal suspension: without hydrodynamic interactions (left) and with hydrodynamic interactions (right)



A minimal model of an E-coli like microswimmer (left) and a rheological simulation (right)



Microrheology of active suspensions

Hydrodynamic interactions are regarded as a key factor in understanding the properties of suspensions of microorganisms and colloidal particles.
This is particularly true for microorganisms, whose self-propelled motion continuously disturbs the surrounding fluid, making hydrodynamic effects impossible to ignore.