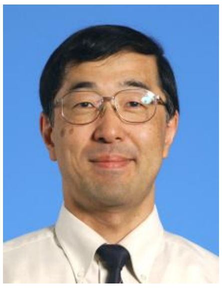
【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Mathematics/Physics)



Title of Project : Physics of structural and dynamical hierarchies: from simple liquids to soft matter

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Research Area : Chemical Physics/Biophysics

Keyword : Glass transition, liquid-liquid transition, water anomaly, crystallization, soft matter

【Purpose and Background of the Research】

The liquid state is one of the most important fundamental states of matter and its deeper understanding will have a strong impact on various fields of science, including physics, chemistry, materials science, and bioscience. Despite its significance, however, its physical understanding lags far behind the other fundamental states, gases and solids. In this project, we tackle the unsolved fundamental problems in liquid science and also elucidate the roles of a liquid component in the dynamic behavior of soft and biological matter, focusing on the structural and dynamical hierarchies of these systems (see Fig. 1). More specifically, we study (1) thermodynamic and kinetic anomaly of water and water-like liquids, (2) mechanism of liquid-liquid transitions (LLT), (3) mechanism of liquid-glass transition, (4) roles of a hidden structural order of liquids during crystallization, (5) nonlinear flow behavior of glassy liquids and granular matter and the mechanism of flow instability and fracture, and (6) roles of hydrodynamic interactions on the dynamics of soft and bio matter.

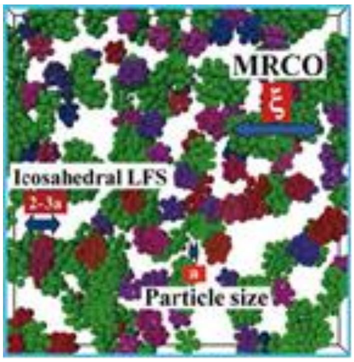

Fig. 1 Hierarchical structure of hard-sphere liquid

【Research Methods】

We are planning to study the above six topics (1)-(6) by combining experiment, theory, and simulation, to draw a novel physical picture of the liquid state itself, identify the principle of state selection under shear deformation, and reveal how the presence of the liquid component affects dynamic behavior and pattern evolution in soft and bio matter.

【Expected Research Achievements and Scientific Significance】

Liquids play crucial roles in bio- and chemical reactions and numerous industrial processes. For example, if we can control various physical (density, viscosity, …) and chemical (reactivity, miscibility, …) properties of a liquid by transforming a liquid to another liquid through external fields (temperature, pressure, flow, light, …) using LLT, the impact would be dramatic. Elucidation of instability mechanisms of liquid, amorphous, and granular matter under shear deformation will allow us to theoretically predict the onset of instability (or fracture) and slipping in a confined liquid. Furthermore, if the rule governing state selection under nonequilibrium situations is clarified, it should have a large impact on our understanding of nature. In the field of soft matter, we seek to reveal how the liquid component affects the dynamics of soft matter through dynamic couplings between different levels of the structural hierarchy. The basic understanding of features common to two spatio-temporal hierarchical systems, liquid and soft matter, will eventually contribute to the creation of highly functional materials, as seen in biological systems.

【Publications Relevant to the Project】

- A. Furukawa and H. Tanaka, Inhomogeneous flow and fracture of glassy materials, *Nature Mater.* **8**, 601-609 (2009).
- H. Tanaka et al., Critical-like behaviour of glass-forming liquids, *Nature Mater.* **9**, 324-331 (2010).
- K. Murata and H. Tanaka, Liquid–liquid transition without macroscopic phase separation in a water–glycerol mixture, *Nature Mater.* **11**, 436-443 (2012).

【Term of Project】 FY2013-2017

【Budget Allocation】 368,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://tanakalab.iis.u-tokyo.ac.jp/