# Thermal fluctuation of a lipid bilayer in the anomalous swelling regime

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Biomembrane is mainly composed of a phospholipid bilayer, which is spontaneously formed by mixing of lipid and water. A various kinds of physical and chemical properties of phospholipid bilayers have been investigated, and a number of applications have been provided. Spontaneously formed structure of phospholipid by mixing with water is multi-lamellar vesicles, while living cell membranes are uni-lamellar vesicles. It is important to understand the formation of cell membrane self-organization of lipid bilayers in context with the interactions between bilayers such as van der Waals interaction, hydration repulsion and steric repulsion by thermal fluctuation of bilayer.

In order to understand interactions of lipid bilayers, we focused on a phenomenon called " anomalous swelling " [1]. In the anomalous swelling regime, i.e., temperature just above the main transition temperature from the liquid-crystalline phase to the gel phase, the repeat distance between stacked bilayers increase drastically. The driving force for the increase has been considered to be amplified steric repulsion due to the softening of lipid bilayer [2]. However, the softening is not confirmed enough especially by microscopic picture, and the mechanism of anomalous swelling is under dispute.

In the present experiment, we performed neutron spin echo spectroscopy (NSE) for the lipid bilayers in the anomalous swelling regime at iNSE, JRR-3, JAEA. Both multi-lamellar vesicles and uni-lamellar vesicles of DMPC were measured in the same condition. Figure 1 shows the typical intermediate correlation functions of DMPC small uni-lamellar vesicles. The bending modulus of lipid bilayer is calculated using the theory by Zilman and Granek, and the values exhibit that bilayers become harder in the anomalous swelling regime. The same tendency is observed in the case of multi-lamellar vesicles. This tendency is reasonable since the hydrocarbon chain of lipid molecules freeze in the gel phase. The value of the bending modulus estimated from the experiment is two orders of magnitude larger than kT. This result suggests that static disordering of stacking of bilayers such as metastable ripple phase is induced just above the main transition temperature, and the multi-lamellar structure is swollen.

[1]J. F. Nagle et al., Phys. Rev. E 58 7769 (1998)
[2]N. Chu et al., Phys. Rev. E 71 041904 (2005)

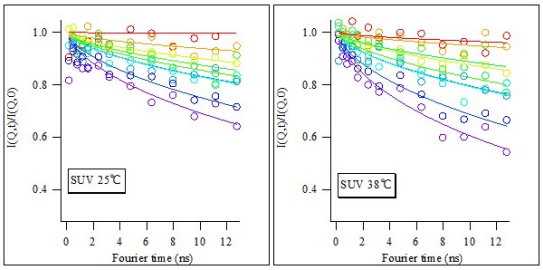


Fig. 1. Intermediate correlation functions of DMPC small uni-lamellar vesicles at 25 C and 38 C. Open circles are the data from NSE and solid lines are fitting results by Zilman and Granek theory.