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Dynamical Structure of Nano-Meter-Sized Domains on a Vesicle

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飽和リン脂質、不飽和リン脂質、コレステロールの３成分からなるモデル生体膜は、脂質アシル基の無秩序-秩序転移温度以下で相分離し、膜面上にドメイン構造を形成する。ナノメートルサイズのベシクルを用いることにより膜面上でのナノメートルスケールのドメインのダイナミクスを中性子スピンエコー法により調べた。臨界サイズに近い大きさを持つナノドメインはベシクル上で熱揺らぎにより融合・分裂を繰り返し、安定なモノドメイン構造にまで成長できない状態であると考えられる。

In recent years, lateral phase separation in cell membranes so-called lipid raft has gathered much attention. The lipid rafts are liquid domains rich in cholesterol, sphingolipid and specific proteins and responsible for the important biochemical reactions. In order to understand the roles of phospholipids and cholesterol in the lipid raft formation, the model biomembrane vesicles composed of saturated phospholipid, unsaturated phospholipid and cholesterol have been investigated extensively. The giant vesicles with micro-meter length scale show the phase separation and form micro-meter-sized liquid domains below a miscibility temperature. The behavior of the micro-meter-sized liquid domains on the model biomembranes is well understood by fluorescence microscope investigations, while that of the nano-meter-length scale domains is poorly understood due to the optical resolution limit of the microscopy. In this study we have investigated the dynamical nature of the nano-meter-sized domains on the model vesicles using a small unilamellar vesicles having nano-meter length scale and a contrast matching technique of a neutron scattering.

The small angle neutron scattering at the contrast matching composition where we can extract the concentration fluctuations on the ternary vesicles show a characteristic scattering maximum below the miscibility temperature. The scattering profiles is not described by a scattering function for a simple mono-domain model but fitted very well using a multi-domain model. Thus the growth of nano-domains is kinetically trapped on the small unilamellar vesicles. Then we measured the intermediate scattering function of the nano-meter-sized domains on the small unilamellar vesicles by means of the neutron spin echo technique at the contrast matching point. The intermediate scattering function can be described by the sum of two modes, a slow mode and a fast mode. The former and the latter modes correspond to the diffusion of the vesicles and the dynamics of the domains on the vesicle, respectively. In order to interpret the physical meaning of the domain dynamics mode, we performed a molecular dynamics simulation with a coarse grained model. The simulation shows that the dynamics of domains on a vesicle is classified into two modes. One is the mono-domain diffusion on a vesicle observed in the deep quench region and the other is the fission and fusion mode of the domains due to the thermal agitation in the shallow quench region. By comparing the experimental and simulation data, the fission and fusion mode is plausible to explain the observed relaxation profiles and consistent with the small angle neutron scattering profiles. Thus nano-meter sized domains do not have enough stability against thermal energy and show the life time of several ns. This dynamical behavior may be related to the stability of the lipid rafts in the living cell membranes.

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