Mechanical property of a giant liposome studied by laser tweezers

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リポソームは脂質分子でできたベシクル (小胞) で、細胞のモデルシステムにもなる。リポソームをレーザーピンセットを用いて変形させることで、変形に必要な力とその形状から、リポソームの表面張力と剛性を定量的に求めた。また、脂質複合膜である細胞膜の基礎的知見を得るために、リポソームの構成成分の違いによる力学的物性の違いを調べた。

1 Introduction

Biological membrane is mainly composed of lipids and proteins. Since lipids tend to form bilayer in aqueous solution due to its amphiphilic nature, the lipid bilayer is one of ubiquitous structures in biological systems. Phospholipid is known to be a typical lipid in a biological cell. A vesicle made of phospholipids is called liposome and has been studied intensively as a model system of a biological cell. For example, when microtubules (one component of the cytoskeleton) are polymerized in a liposome, they deform the liposome and finally transform it to the combined structure of a spheroid and a tube [1]. In this paper, we study mechanical property of liposomes by deforming them with laser tweezers.

2 Experiment

Liposomes with encapsulated silica beads (1μm in diameter) were prepared by adding aqueous dispersion of beads (0.5%) to the lipid dry films. Two silica beads encapsulated in a liposome were manipulated separately by a dual-beam laser tweezers [2]. The position of one bead was fixed and the other one was moved by constant speed (0.2~0.3μm/s). A spherical liposome was pushed from its inside by the beads and transformed into two parts (Figure 1).

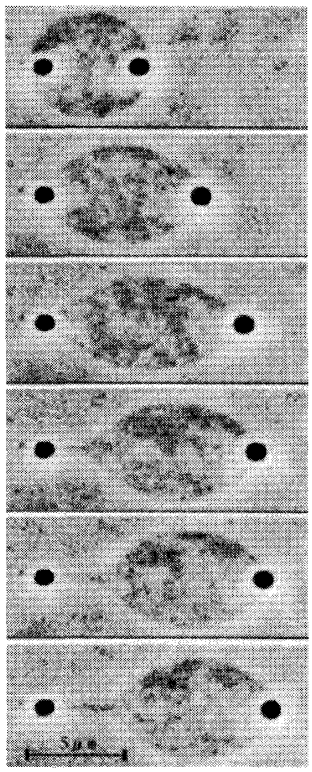

Figure 1: Deformation of a liposome.

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In this study, we made two liposomes to clarify the difference in their mechanical properties. One is made of a single lipid DOPC(dioleoyl phosphatidylcholine) and the other is made of mixture of DOPC:DOPG(dioleoyl phosphatidylglycerol)=4:1.

3 Results

The force required to deform the liposome was determined from the displacement of silica beads relative to the center of the laser beam and the profile of the optical trap potential. Figure 2 shows that the force increases with deformation but maintains a certain constant value after a maximal force. This peak apperars together with the tubular part.

For a tube of length L and radius R, the free energy of the tubular part can be written as $f_{tube} = [\kappa/2R^2 + \sigma]2\pi RL - fL$, where σ is the surface tension, κ is the bending rigidity, f is the external force. From the equilibrium conditions $\frac{\partial f_{tube}}{\partial R} = 0$ and $\frac{\partial f_{tube}}{\partial L} = 0$, the radius R_0 and the force f_0 can be written as [3],

$$R_0 = \sqrt{\frac{\kappa}{2\sigma}}, \quad f_0 = 2\pi\sqrt{2\sigma\kappa}.$$

From the deformation force f_0 and the tube radius R_0, we can inversely obtain two mechanical properties of a liposome, the surface tension σ and the bending energy κ. Comparing the results for two liposomes, the multi-component liposome is found to be more rigid.

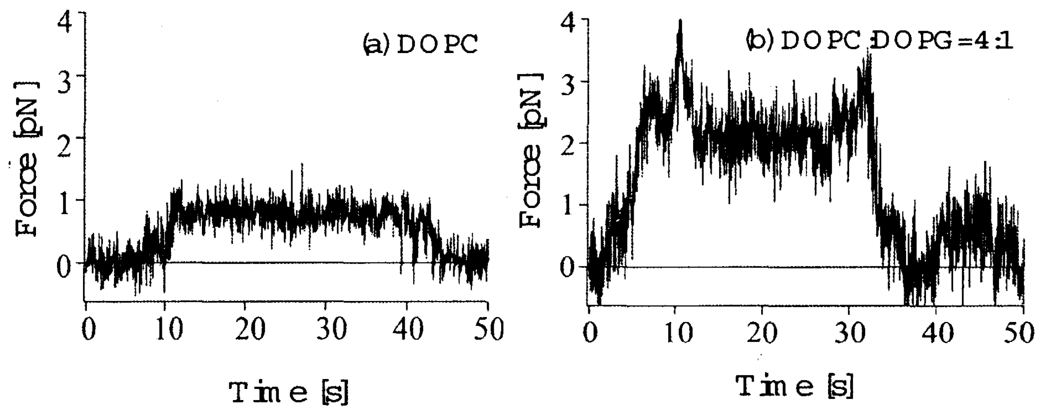

Figure 2: Temporal change of the pulling force required to deform liposomes.

References

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