Shape Deformation of Vesicle Coupled with Phase Separation

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1. INTRODUCTION

Homogeneous lipid bilayer vesicles show a variety of shapes in water such as sphere, prolate, oblate, starfish, stomatocyte, tube and so on. These shape deformations may play important roles in the biomembrane transport processes of the living cell membranes and well described by an area-difference free energy (ADE) model [1], which consists of two terms, the Helfrich bending energy and the elastic energy originating from area difference between inner and outer leaflets under constraints of fixed total volume and total surface area [2]. The important parameters to determine the shape of the vesicle are excess area defined by a ratio of the total area to total volume, and the area difference. If we add salts outside of the vesicle, the excess area increases with elapse of time due to the osmotic pressure difference and the vesicles show a parade of deformation with repeating bifurcations.

On the other hand, multi-component vesicles show a phase separation, which forms domain structure on the vesicle [3]. In this case the domain boundary energy governs the total free energy and leads the domain coarsening and the budding. Recently we found that the dynamical coupling between the shape deformation and the phase separation brings astonishing shape deformation pathways.

2. RESULTS AND DISCUSSION

In this study, we prepared the spherical ternary vesicles in homogeneous one phase region and then added salts outside of the vesicles. When the vesicles deformed to appropriate shapes, we decreased the temperature to the coexisting two phase region where the shape deformation induced by the osmotic pressure difference couples with the phase separation. In the domain coarsening stage, every polygonal (prolate, discocyte, and starfish) vesicle showed a shape convergence to discocytes with two large domains in both flat sides. This shape convergence indicates that in the presence of two stiff domains the morphology minimizing the ADE energy is a discocyte shape. Meanwhile, a tube vesicle deformed to a necklace structure composed of a chain of discocytes with two domains in both flat sides, like a pearling instability. For a short tube having a small excess area, the domains showed coarsening and the vesicle finally transformed into a discocyte, whereas for a long tube having a large excess area, the domain coarsening was kinetically trapped, which may be due to the bending penalty of the matrix. After the coarsening, domains started to bud toward inside or outside of the vesicle depending on the excess area. These unique shape-deformation branches can be explained by the free energy analyses based on the ADE model for a multi-domain vesicle under the geometrical constraints [4].

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