<table>
<thead>
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<th>Title</th>
<th>Domain induced budding in buckling membranes (Poster session 1, New Frontiers in Colloidal Physics: A Bridge between Micro- and Macroscopic Concepts in Soft Matter)</th>
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</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Minami, Akihiko; Yamada, Kohtaro</td>
</tr>
<tr>
<td>Citation</td>
<td>物性研究 (2007), 89(1): 93-94</td>
</tr>
<tr>
<td>Issue Date</td>
<td>2007-10-20</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2433/110928">http://hdl.handle.net/2433/110928</a></td>
</tr>
<tr>
<td>Type</td>
<td>Departmental Bulletin Paper</td>
</tr>
<tr>
<td>Textversion</td>
<td>publisher</td>
</tr>
</tbody>
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Domain induced budding in buckling membranes

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1 Introduction

In this study, we consider fluid-like membranes and focus on the phase separation on the buckling membranes to understand the budding and the coarsening on membranes.

2 Model equation

We assume that the membrane is initially not deformed, and set this as a reference state and set the z-axis of the Cartesian coordinate \((x, y, z)\) perpendicular to the membrane. A displacement vector \((u, h) = (u_x, u_y, h)\) is also introduced to describe elastic deformation of the membrane (see Fig. 1).

\[
\begin{align*}
\mathcal{F}_\text{el} &\approx \int dr \left[ \frac{\lambda}{2} \left( \bar{\varepsilon} + \frac{1}{2} \left( \nabla h \right)^2 \right)^2 + \frac{\kappa}{2} \left( \nabla^2 h \right)^2 \right], \\
\mathcal{F}_0 &\approx \int dr \left[ \frac{r}{2} \phi^2 + \frac{u}{4} \phi^4 + \frac{C}{2} \left( \nabla \phi \right)^2 \right].
\end{align*}
\]

(1) (2)

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where $\phi$ is the order parameter and $r$ and $u$ are constant parameters. $\lambda$ and $\kappa$ mean the surface tension and the bending coefficient. $\bar{e}$ is an applied extension or compression of the membrane. If $\bar{e} < 0$, the membrane is buckled. The third term of eq (2) is the gradient energy evaluated on the deformed surface.

The total free energy is written as

$$\mathcal{F} = \mathcal{F}_{el} + \mathcal{F}_0.$$  \hfill (3)

The dynamic equation of $h$ and $\phi$ are written by

$$\tau_h \frac{\partial h}{\partial t} = -\frac{\delta \mathcal{F}}{\delta h},$$  \hfill (4)

$$\tau_\phi \frac{\partial \phi}{\partial t} = \nabla^2 \frac{\delta \mathcal{F}}{\delta \phi}. \hfill (5)$$

3 Results

We show the results of numerical simulation for $\bar{e} = -0.001$ and $\langle \phi \rangle = -0.3$ in figure 2. In this case, the membrane is compressed because $\bar{e}$ is negative. Therefore, the domain budding can be observed at $t = 9400$. The membrane is deformed at the domain boundary. The minority domains form caps and the majority domains become flat (see figure 2 (C)).

References