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PROCEEDINGS

Theoretical Studies on Mechanical Behavior of Vesicles with Confined Filaments

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ABSTRACT

The intricate packing of elastic filaments, including cytoskeletal microtubules, actin filaments, and artificial nanotubes, is fundamental to understanding a plethora of cellular functions and their applications in cellular engineering. Through rigorous theoretical analysis, we investigate the packing dynamics of filaments within vesicles and explore the axial stretching of the vesicle–filament system. Our examination reveals how the interplay of stiffness and size ratios between filaments and vesicles drives transitions in vesicle configurations, prompting filament bending or coiling. We construct morphological phase diagrams to elucidate these transitional phenomena, highlighting the influence of pressurized vesicles in enhancing resistance to deformation by mitigating filament bending energy. Furthermore, it is observed that the filament–vesicle system can exhibit a spring-softening or -stiffening response during stretching, depending on the vesicle scenario, offering insights into the mechanical behavior of cellular structures. Additionally, effects of filament inhomogeneity on the stretching process are studied, providing further depth to our understanding. These findings not only contribute to elucidating cell morphology and cellular stability but also inform the development of artificial cells in both biomedical and engineering domains.

KEYWORDS

Filament–vesicle system; cellular packing; filament loops; membrane tubulation

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