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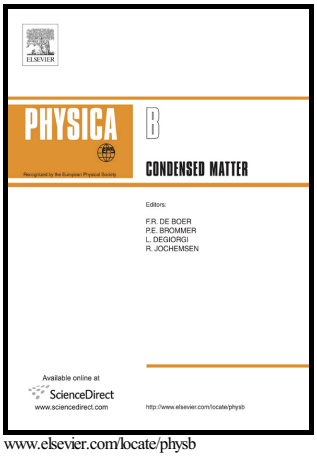

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Diffusion mediated coagulation and fragmentation based study of domain formation in lipid bilayer membrane

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Abstract

We estimate the equilibrium size distribution of cholesterol rich micro domains on a lipid bilayer by solving Smoluchowski equation for coagulation and fragmentation. Towards this aim, we first derive the coagulation kernels based on the diffusion behaviour of domains moving in a two dimensional membrane sheet, as this represents the reality better. We incorporate three different diffusion scenarios of domain diffusion into our coagulation kernel. Subsequently, we investigate the influence of the parameters in our model on the coagulation and fragmentation behaviour. The observed behaviours of the coagulation and fragmentation kernels are also manifested in the equilibrium domain size distribution and its first moment. Finally, considering the liquid domains diffusing in a supported lipid bilayer, we fit the equilibrium domain size distribution to a benchmark solution.

Keywords

Smoluchowki equation; Diffusion; Aggregation; Lipids

1 Introduction

The membranes of an animal cell are laterally inhomogeneous [1, 2, 3]. The inhomogeneities are in the form of lipid micro domains, sometimes called rafts, and have sizes in the range of 80−100 nm. They are formed by sphingolipids and cholesterol and exhibit detergent insolubility [4]. These microdomains carry different membrane proteins in them [2, 5, 6, 7, 8] and are thought to play a very important role in cell biological processes [1, 9, 10, 11, 12, 13]. These studies supported the belief, contrary to the fluid mosaic model of Singer-Nicolson [14], that the lateral membrane heterogeneities in bilayer membrane exist and motivated researchers to understand the basic principles governing the dynamics of the microdomains.

Because of the complexity of a cell membrane structure and very small sizes of the microdomains, a systematic study, exploring both experimental and theoretical understanding, for the microdomains in cell membrane is difficult. The model lipid bilayer membranes as developed artificially in laboratories, called giant unilamellar vesicles (GUVs), consists of phase separated liquid domains, and provide a simpler model system for the study of the microdomains [15]. Phase separated GUVs can be formed from a ternary lipid mixture of a saturated lipid (e.g., DPPC or Sphingomyelin), an unsaturated lipid (e.g., DOPC), and cholesterol and when the composition is chosen appropriately they form the liquid ordered L_o domains in a liquid disordered L_d phase below a certain miscibility transition temperature associated with the composition [16, 17, 18]. Such a lipid bilayer membrane are thought to be closest model system for the cell membrane, where the liquid ordered domains are similar to the cholesterol rich microdomains in cell membranes.