Supporting Information for

Size-dependent partitioning of nano/micro-particles mediated by membrane lateral heterogeneity

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Contents:

1. Partitioning of nano/micro-particles within Lo/Ld phase-separated membranes

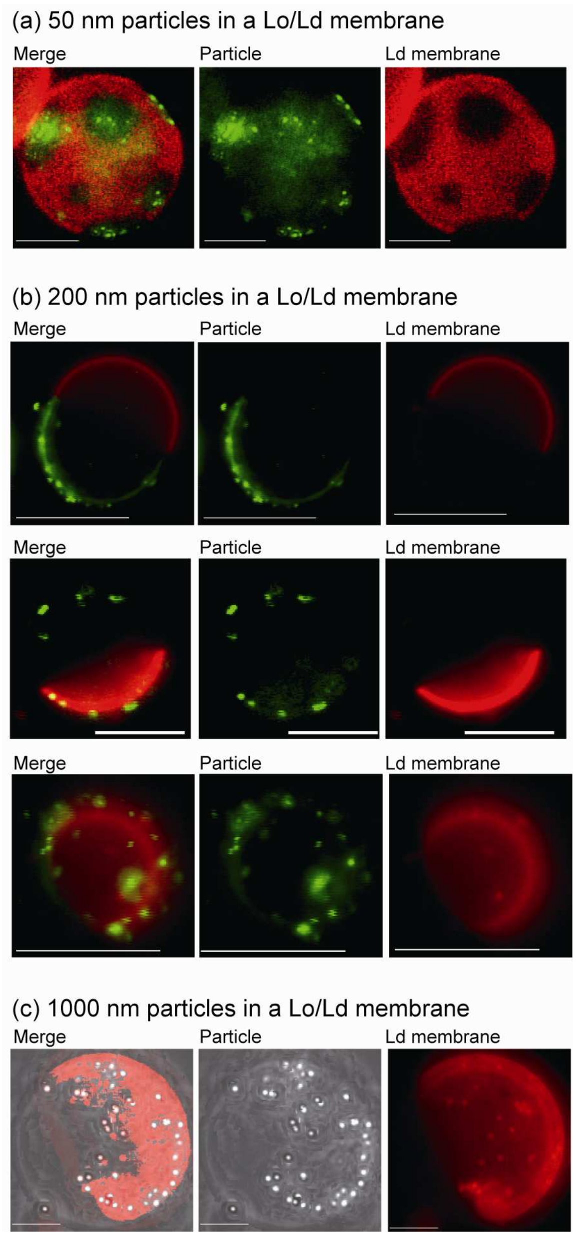

Figure S1. Selective partitioning of nano/micro-particles on Lo/Ld phase-separated membranes, where the membranes were stained by rho-PE (red), which partitions into the Ld phase. (a) 50 nm particles (green) distributed in the Lo phase. (b) 200 nm particles (green) localized in the Lo (upper), both Lo/Ld (middle) or Ld (lower) phase. (c) 1000 nm particles (without a fluorescent tag) partitioned into the Ld phase. Scale bars are 10 μm.

2. Partitioning of nano/micro-particles within So/Ld phase-separated membranes

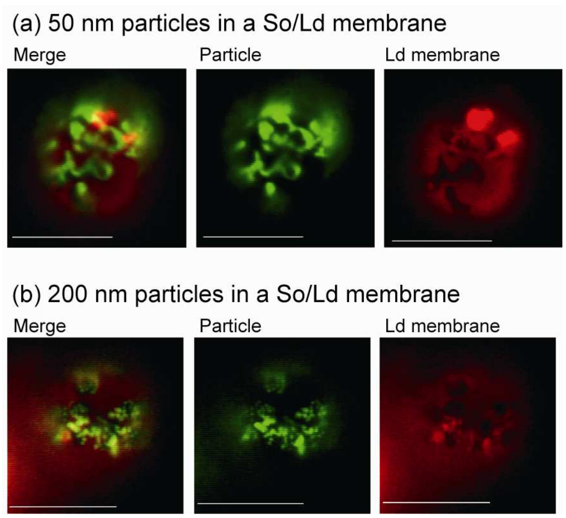

Figure S2. Selective partitioning of nano/micro-particles (green) on So/Ld phase-separated membranes, where the membranes were stained by rho-PE (red), which partitions into the Ld phase. 50 nm (a) and 200 nm (b) particles distributed in the So phase. Scale bars are 10 μm.

3. Adsorption of nano/micro-particles on homogeneous membranes

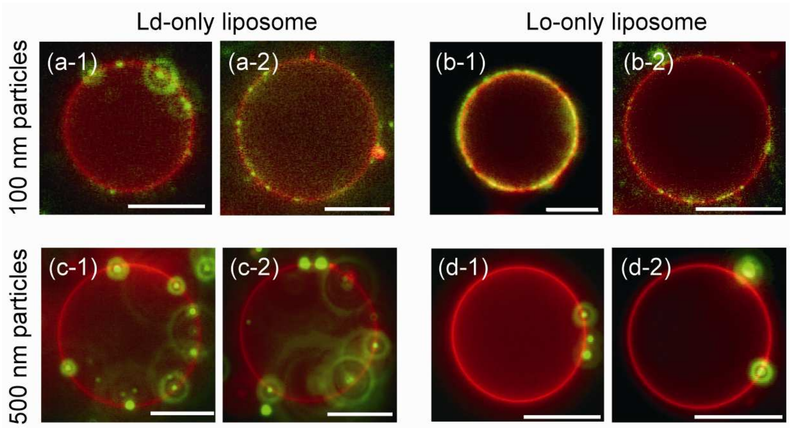

Figure S3. Adsorption of nano/micro-particles on Ld-only and Lo-only homogeneous membranes. (a) 100 nm particles on Ld-only DOPC liposomes. (b) 100 nm particles on Lo-only DPPC:Chol=50:50 liposomes. (c) 500 nm particles on Ld-only DOPC liposomes. (d) 500 nm particles on Lo-only DPPC:Chol=50:50 liposomes. Scale bars are 10 μm.

4. Comparison between bending and undulation energies

We estimate the energy contribution of thermal undulation and bending deformation for large particles of $r > r^*$. From equation (2), the partitioning energy per unit area due to undulation is given by

$$\frac{3(k_B T)^2}{2\pi^2}\left(\frac{1}{\kappa_{Ld}} - \frac{1}{\kappa_{Lo}}\right)\frac{1}{d^2}.$$

By substituting typical values of $k_B T = 4 \times 10^{-21}$ J, $\kappa_{Ld} = 10^{-19}$ J, $\kappa_{Lo} = 1.25 \times 10^{-19}$ J and d = 10 nm (we assumed that the length of the undulation space is 10 nm, which should be somewhat larger than the expected particle-membrane distance (~3 nm), because only a particle-adhered one surface restricts membrane undulation.),[1] we obtain $\frac{12}{\pi^2} \times 10^{-5} \times k_B T$ nm^{-2}. Assuming that one third of the surface area of a 500 nm particle is wrapped and this area contributes the restriction of membrane undulation, the total energy cost due to undulation is estimated to be 3.2 $k_B T$. In contrast, typical energy contribution due to bending for the wrapping of one third of the particle is $\frac{1}{3} \times 8\pi(\kappa_{Lo} - \kappa_{Ld}) \cong 52 k_B T$ (we assume that the spontaneous curvature of the membrane is zero), witch is one order larger than energy contribution of undulation.

5. Energy comparison of laser-transportation and phase-partitioning

The order of the transportation energy can be estimated by considering the domain that is deformed due to particle movement as shown in Fig. 3e; the energy cost of domain deformation can be described as $\sigma\Delta l \sim 10^{-18}$ J, where σ is the line tension ($\sim 10^{-12}$ N) [1] and Δl is a change in the boundary length of a domain (from the microscopic images, Δl is essentially on the order of 1 μm). On the other hand, based on our present model, the partitioning energy of a 1000 nm particle, which is larger than r^*, is shown as the bending deformation energy with eq. (1). Although a detailed calculation for particle-induced membrane deformation is beyond the scope of this paper, the bending energy may be attributed to the curved region needed to wrap the particle ($8\pi\kappa \sim 2\cdot10^{-18}$ J for complete wrapping) and to the region of the membrane-particle contact line [2]. Therefore, the expected total bending energy that governs particle-partitioning would be expected to be greater than the transportation energy ($\sim 10^{-18}$ J).

References:

(1) Baumgart, T.; Hess, S.T.; Webb, W.W. *Nature* **2003**, *425*, 821.

(2) Dietrich, C.; Angelova, M.; Pouligny, B. *J Phys II* **1997**, *7*, 1651.