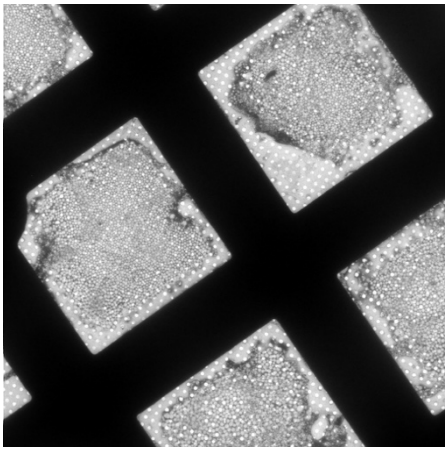
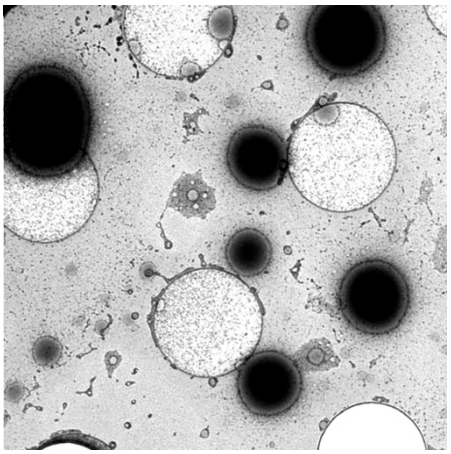
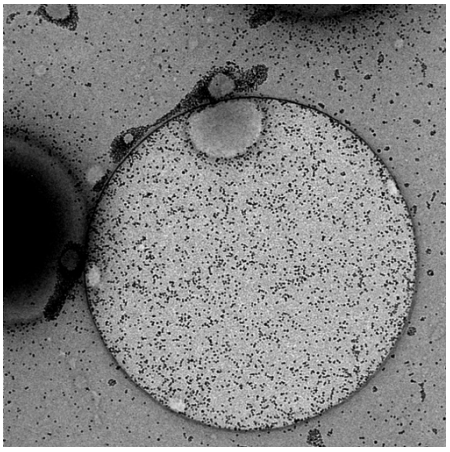
Supplementary figures

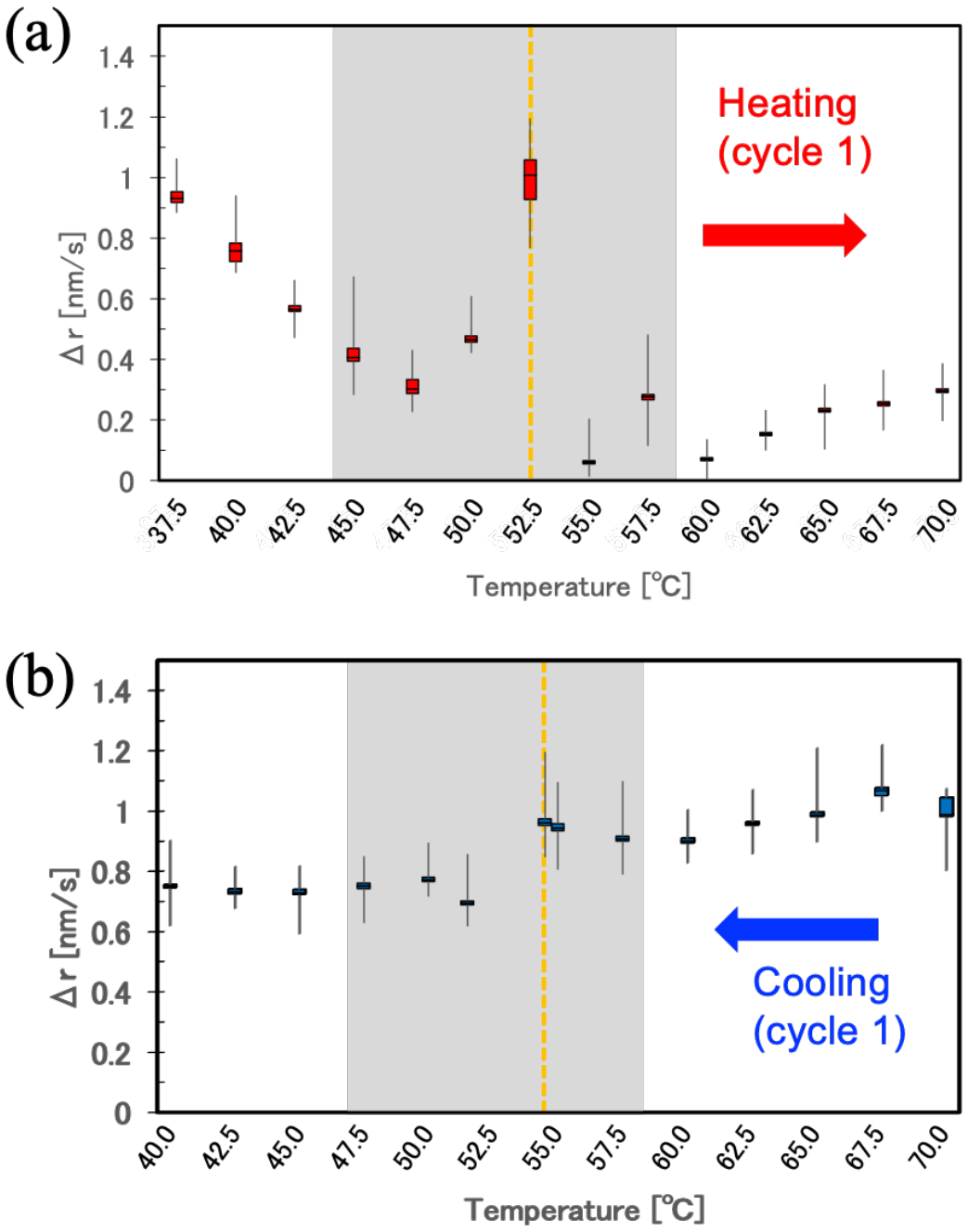






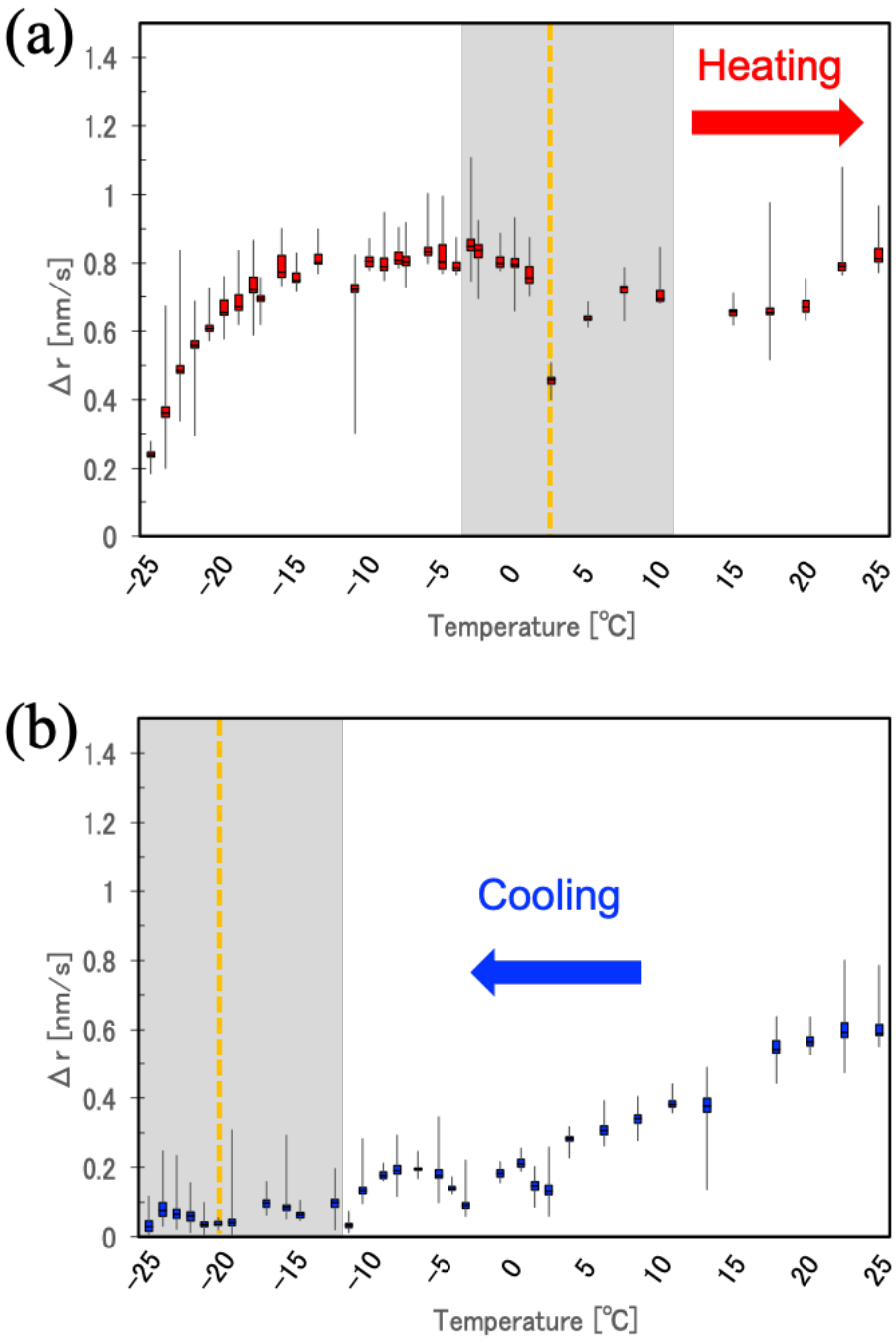
Supplementary figure 1 | Wide-area electron microscopy images of DPPC membranes on a Quantifoil grid.

A lipid solution dissolved in chloroform was applied to a Quantifoil Cu #200 R2/2 grid and air-dried. A 5 nm gold nanocolloid solution was then applied, blotted with filter paper, and air-dried at room temperature. Gold nanoparticles (5 nm diameter) are dispersed over both the 2 μm holes and the supporting carbon film. Enlarged views are shown in Fig. 1c.



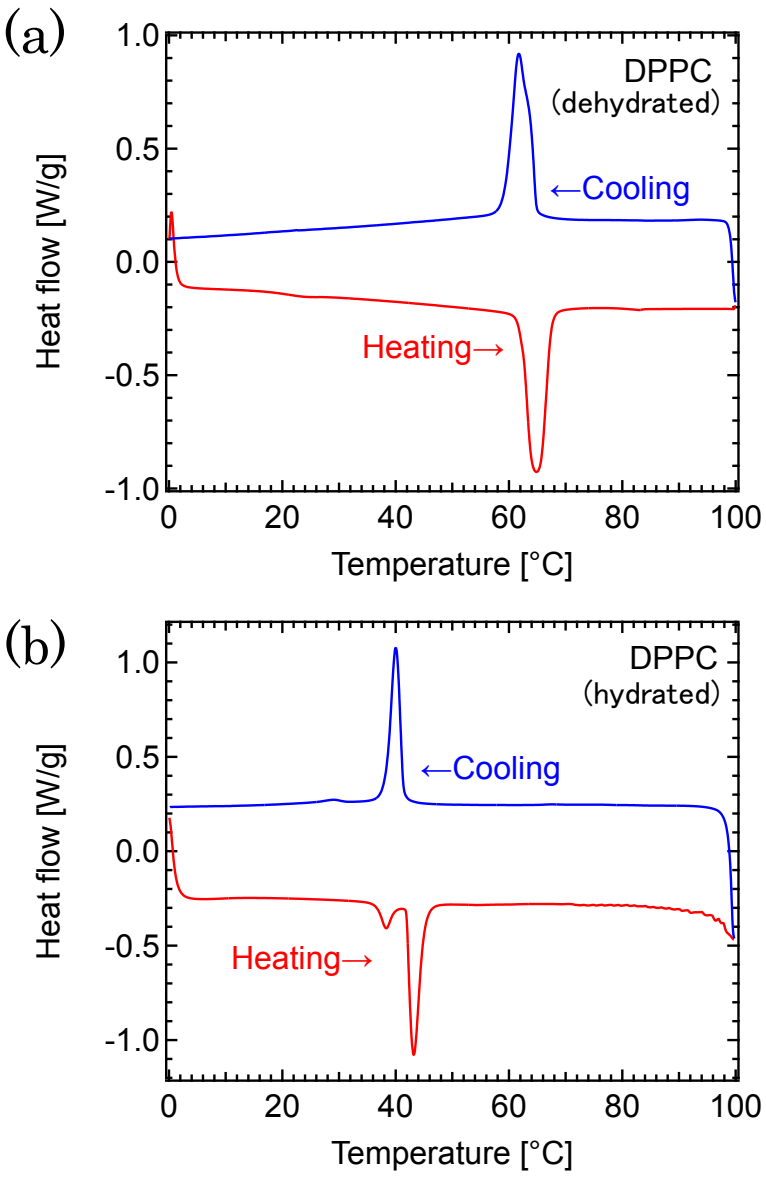
Supplementary figure 2 | Molecular dynamics of DPPC membranes during the first heating-cooling cycle.

Box plot representation of nanoparticle motion during (a) the first heating cycle and (b) the cooling cycle. Box plots indicate the minimum, 25th percentile, median, 75th percentile, and maximum values. Yellow dashed lines mark the approximate positions of MSD peaks manually identified. Zoomed-in histograms corresponding to the gray shaded regions are shown in the main figures (Figs. 3a and 4a, respectively).



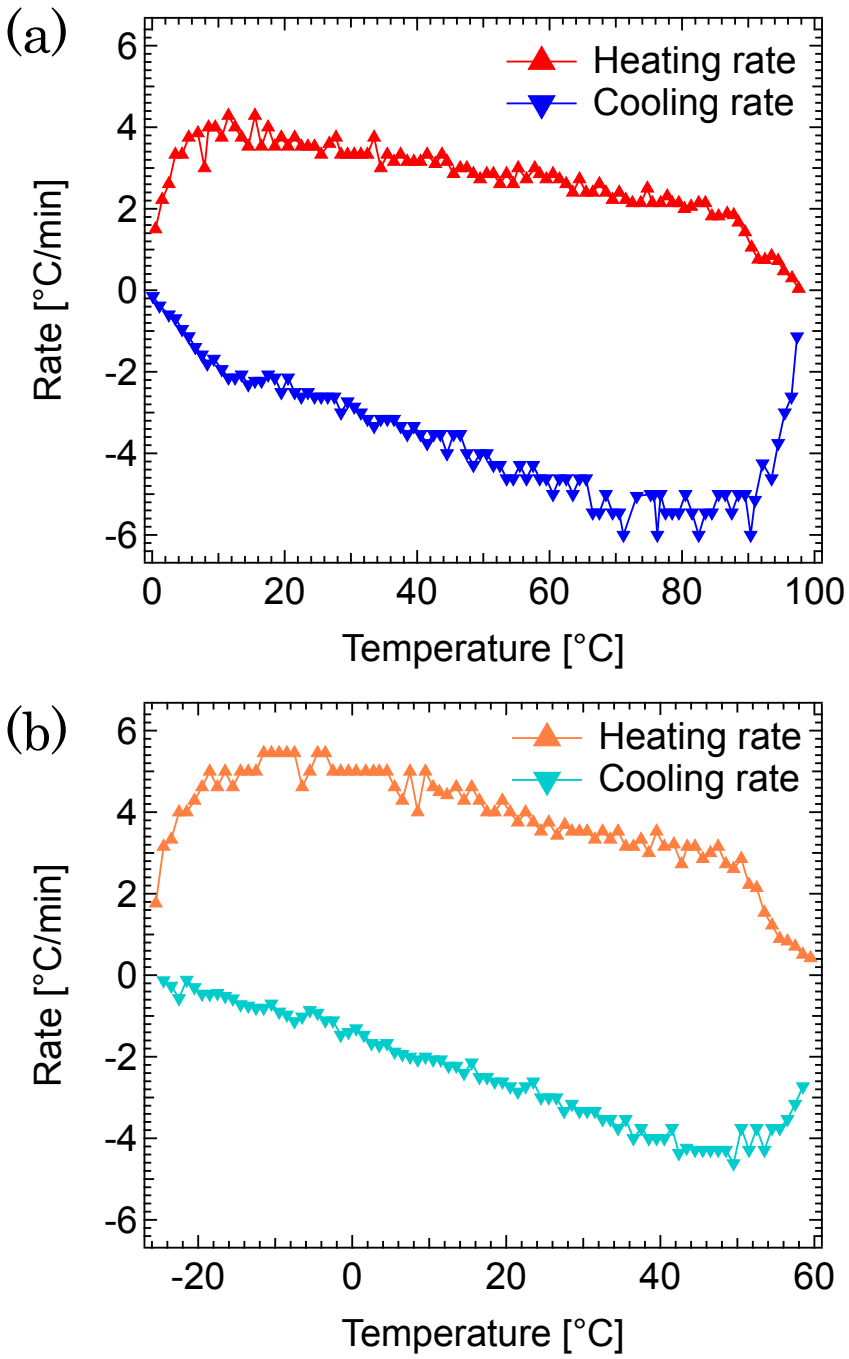
Supplementary figure 3 | Molecular dynamics of DOPC membranes during the first heating-cooling cycle.

Box plot representation of nanoparticle motion during (a) the first heating cycle and (b) the cooling cycle. Box plots indicate the minimum, 25th percentile, median, 75th percentile, and maximum values. Yellow dashed lines mark the approximate positions of MSD peaks manually identified. Zoomed-in histograms corresponding to the gray shaded regions are shown in the main figures (Figs. 5a and 5b, respectively).



Supplementary figure 4 | Differential scanning calorimetry (DSC) thermograms of DPPC.

(a) DSC trace of dehydrated DPPC, reproduced from Fig. 1 in the main text for comparison of dehydration effects on thermal transitions. (b) DSC trace of fully hydrated DPPC. The dehydrated DPPC was mixed with an equal weight of water, incubated for 30 min at room temperature to allow rehydration, and subsequently subjected to DSC measurement.



Supplementary figure 5 | Heating and cooling rate of EBMD.

(a) For DPPC, the heating rate of the instrument was 3–4 °C/min, while the cooling rate ranged from −2 to −6 °C/min. (b) For DOPC, the heating rate was 3.5–5.5 °C/min, and the cooling rate ranged from −2 to −4 °C/min.