Electronic Supplementary Information

Nanoparticle mechanics: deformation detection via nanopore resistive pulse sensing
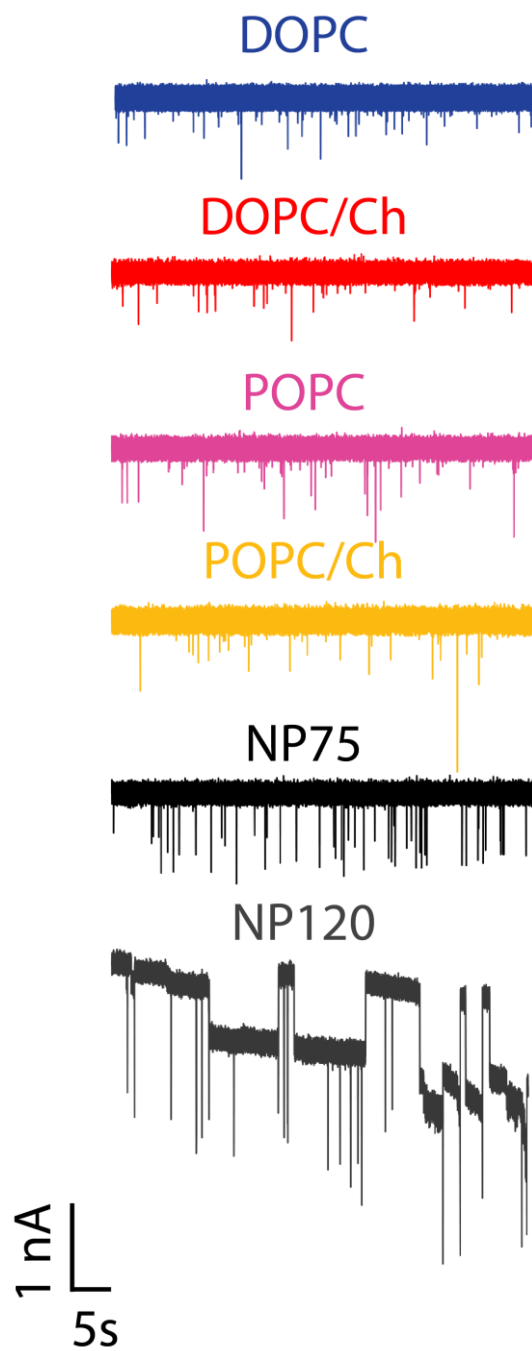
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The electronic supplementary information includes:

1- Supplementary Figures

2- Signal Processing and Event Detection

3- Multiphysics Simulation in COMSOL

1. **Supplementary Figures**

DOPC

DOPC/Ch

POPC

POPC/Ch
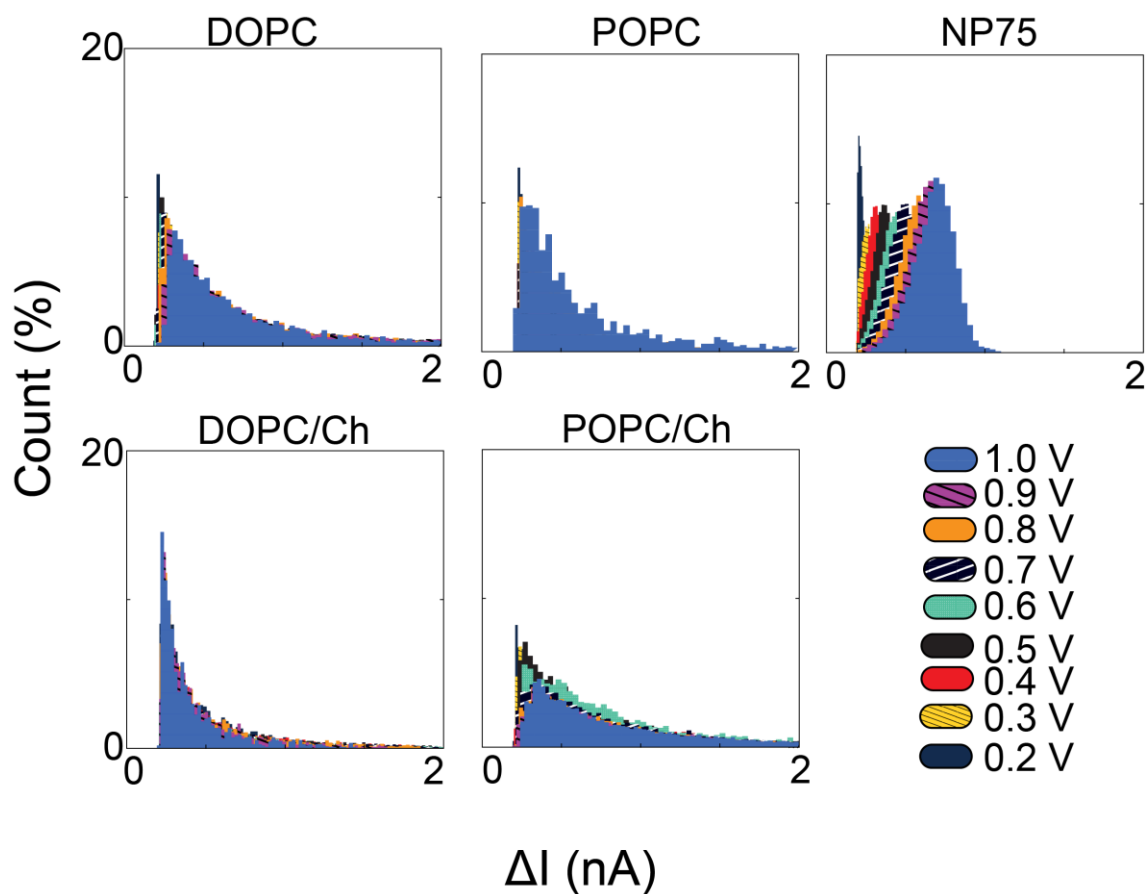
NP75

NP120

1 nA

5s

Figure S1. Representative ionic traces for liposomes and polystyrene nanoparticles measured at an applied voltage of 1V.
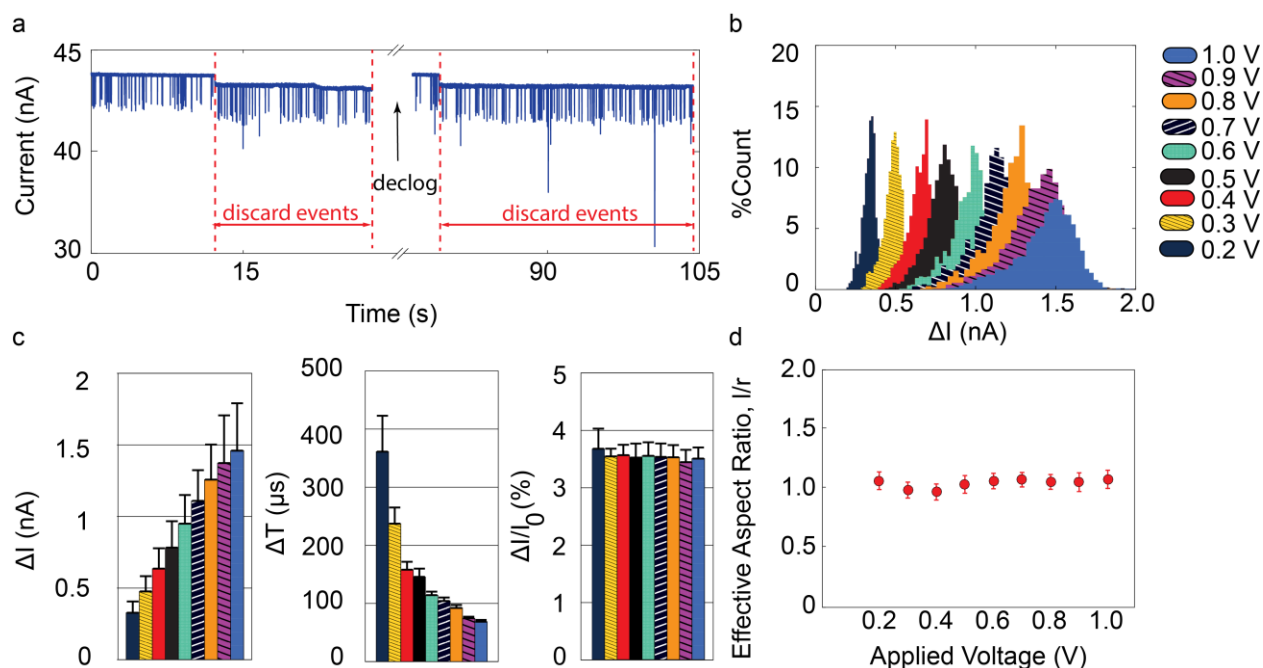
Figure S2. *Resistive pulse data of NP120; (a) the pore was frequently clogged. Even though it could be declogged by reversing voltage or applying cyclic voltages, it kept clogging shortly after again. Thus it was not possible to collect as many translocation events comparable to other samples. We collected data for lots of events (>6000 events for each applied voltage) and removed any translocation event that was accompanied by clogging (i.e. baseline was lower than open pore). (b) Distributions of resistive pulse heights (ΔI) for NP120 at different applied voltages. All distributions could be fit with a Gaussian distribution. (c) Histograms of different pulse characteristics for NP120. The bars show the mean calculated from Gaussian fits. Since we did not replicate the data for this sample, instead of standard error, the error bars show the standard deviation of measurements in one experiment. (d) Estimated aspect ratios for NP120 calculated from numerical simulation results.*
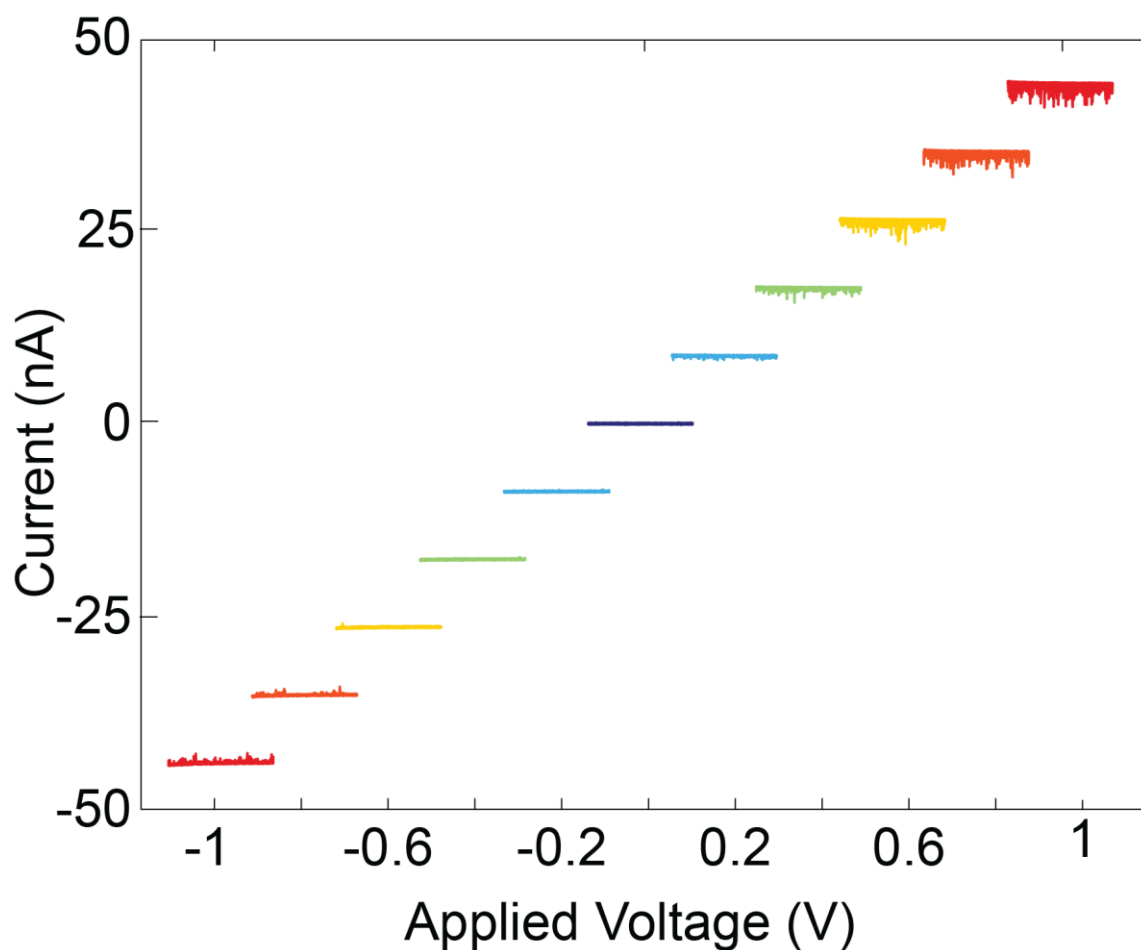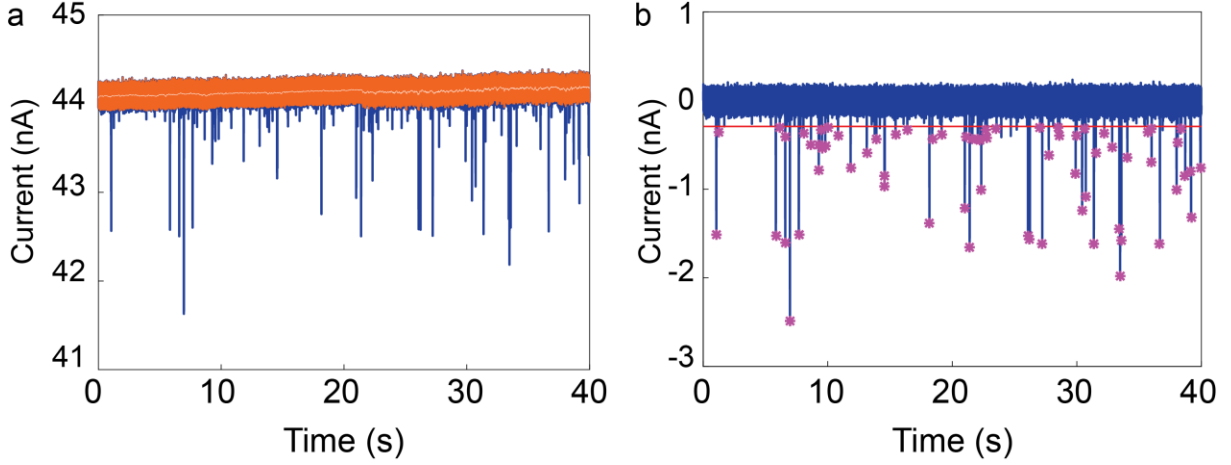
Figure S3. *Translocation events of sample liposomes (POPC) vs. applied voltage. Liposomes were placed in the trans chamber (+ polarity). As can be seen, translocation events are more frequent at positive applied voltages, when diffusion and electroosmotic flow cooperate in the same direction; hence, we collected all our data by placing liposomes in the trans chamber under a positive applied voltage.*

Figure S4. *Histograms of ΔI values. ΔI values of NP75 translocation have Gaussian distributions with the mean increasing with voltage. In contrast ΔI values of liposomes are all positively skewed and overlap at all applied voltages. DOPC-based liposomes show more skewness compared to POPC-based liposomes as well. Note that the numbers of bins were selected using Freedman-Diaconis method.*

2. Signal Processing and Event Detection

Various groups in the nanopore field have used different methods for event detection. Some use a user-defined threshold while others prefer using standard deviation of the current trace. For the latter, some groups pick the standard deviation of the entire recorded trace (including events) and others use some initial points to avoid the effect of translocation events on the standard deviation. Here we used an iterative algorithm similar to what was recently reported by Plesa and Dekker[1] to first separate the baseline noise from translocation events and then used the standard deviation of the baseline noise to define threshold for event detection. While this is costly in terms of computation time, it gives the most accurate results compared to other methods and can be reliably used to compare several samples because the event detection threshold is not affected by the translocation events at all. First, we used 5x standard deviation of the recorded signal as initial threshold to separate the baseline from translocation events (Figure S5a) and in an iterative process removed all the events from the signal until the standard deviation did not decrease by more than 1%. Then we used 6x the standard deviation of this separated baseline noise as the threshold to detect translocation events. The baseline current for each event was calculated by averaging the separated baseline signal over the length of each resistive pulse. The magnitude of each resistive pulse was determined by the difference between the lowest point in the pulse and the baseline. The translocation time was estimated by the full width at half maximum of the pulse. The most probable values were detected from histograms of current drop and translocation times. Gaussian or modified Gaussian distributions were used to fit the histograms.

Figure S5. *Signal processing of a sample current trace. (a) Using an iterative algorithm, the baseline noise (orange) is separated from translocation events (blue) and the average baseline (middle white line) is found by taking a moving average of the baseline noise. (b) 6x standard deviation of the baseline noise is used as threshold to detect translocation events from noise.*

3. Multiphysics Simulation in COMSOL

For numerical simulation we used a 2D axis-symmetric model in COMSOL to simultaneously solve Poisson, Nernst-Plank and Navier-Stokes equations with finite element simulation. The geometry used for the pore and the flow cells are shown in Figure S6. A fine mesh (maximum size of 1 nm) was used on the pore surface (Figure S6b). A surface charge of -0.2 mC/m^2 was applied on the Si_xN_y membrane surface (nanopore surface) and all other surfaces were set free of charge. For boundary conditions of Poisson equation, we used the applied voltage (V= 1V) on one boundary and ground potential on the other (V=0). For Nernst-Plank equation the concentration on both boundaries were set equal to bulk concentration of ions ($C_{k+}= C_{cl-}$ =C_{bulk}=140 mM). For Navier-Stokes equation, we used no-slip walls and the pressures on both boundaries were set equal to zero.
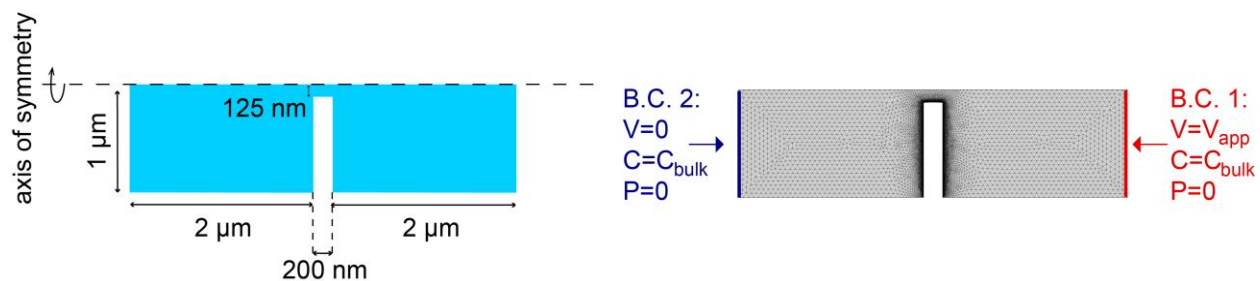
Figure S6. *Simulation Model. (a) Geometry of flow cells and nanopore in a 2D axis-symmetric model. (b) The mesh, as well as boundary conditions used in the simulation.*

REFERENCES FOR SUPPLEMENTARY INFORMATION

1.   Plesa, C.; Dekker, C. Data analysis methods for solid-state nanopores. *Nanotechnology* 2015, 26.