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Supporting Information

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Differentiating Single Multiple Nanopore Through Conductance Distribution Analysis

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Supporting Information

Differentiating Single and Multiple Nanopore Through Conductance Distribution Analysis

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1. DNA testing experiment

We studied the λ-DNA translocation process using single and dual-nanopore chips, respectively. These two chips have similar conductance (352.91 nS for the single-pore chip and 318.55 nS for the chip with two pores). The current-voltage (IV) curves of these two chips are shown in Figure S1. Figure S2 shows the curve of the current over time for the testing experiments of λ-DNA using single and dual-nanopore chips with the operating voltage setting to be 120mV. It can be seen from the Figure S2 that both chips have obvious λ-DNA has a shorter time interval when passing through a dual-pore chip compared to a single-pore chip.

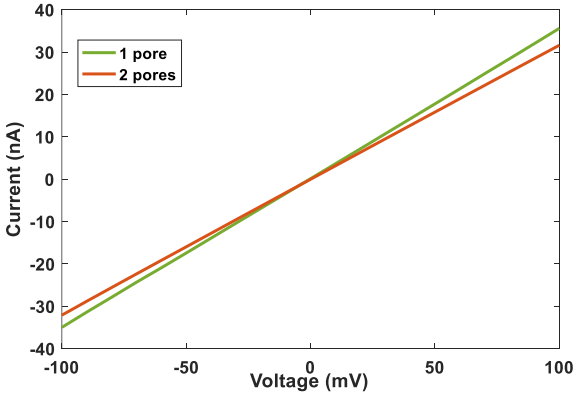


Figure S1. The IV curves of single and double nanopores.

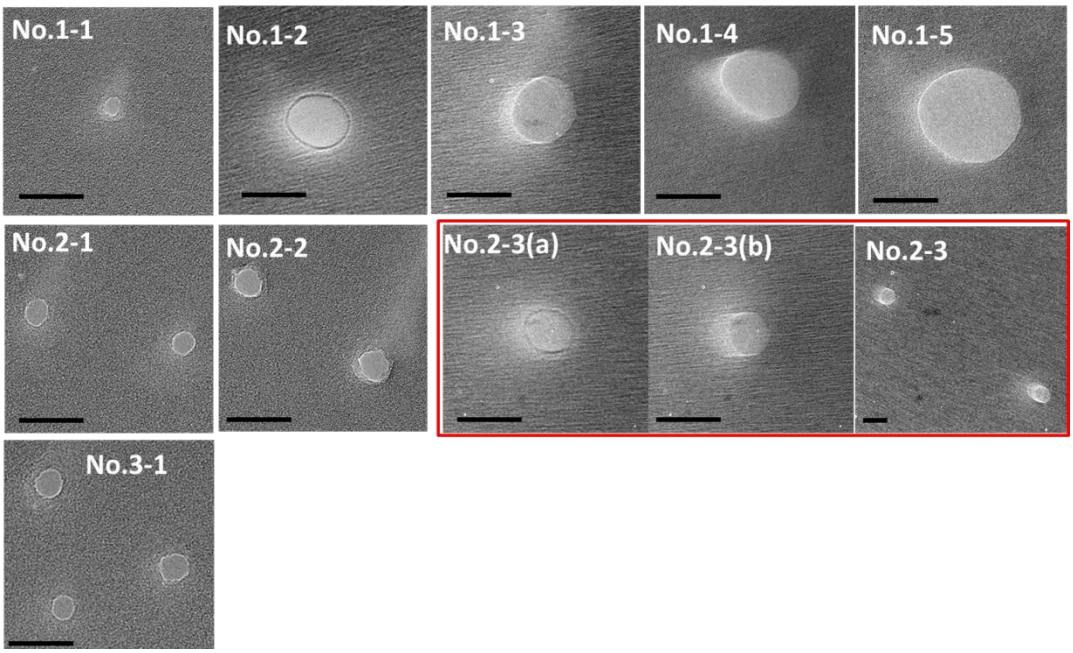


Figure S2. TEM images of all nanopores used in the experiment. Among them, No.1-2 represents the second chip with a single pore. No.2-3 (a) and (b) represent the first and second pores in the third device with dual pores. Due to the large spacing between the two pores in the device, each pore was taken separately by TEM. The subsequent No.2-3 represents the complete TEM image of this device. No.3-1 represents the first device with three pores (the scale bar is 20 nm).

2. Poisson-Nernst-Planck (PNP) model

The PNP model consists of two parts: the Poisson equation, and the Nernst-Planck equation. Their specific equations are described as follows.[1]

$$-\varepsilon_0\varepsilon_r\Delta\varphi = \sum_i F z_i c_i \quad \text{(S.1)}$$

$$\nabla\cdot\left(-D_i\nabla c_i - z_i\frac{D_i}{RT}Fc_i\nabla\varphi\right) = 0 \quad \text{(S.2)}$$

$$N_i = -D_i\nabla c_i - z_i\frac{D_i}{RT}Fc_i\nabla\varphi \quad \text{(S.3)}$$

Here, φ represents the electric potential, c_i is the concentration of the ith ion, i is the ionic type (K^+ or Cl^-), ε_0 represents the vacuum dielectric constant, ε_r is the relative dielectric constant, F represents the Faraday constant, z_i represents the amount of charge of the ith ion, D_i is the Diffusion coefficient of the ith ion, N_i is the ionic flux density of the ith ion, R represents the Gas constant, and T represents the temperature.

Table S1 Parameter value for the model

Parameter name	Parameter Value	Ref.
D_{K+}	1.957E-9 [m^2/s]	[1]
D_{Cl-}	2.032E-9 [m^2/s]	[1]
F	96485 [C/mol]	[2]
R	8.314 [J/K/mol]	[3]
T	298.15 [K]	

ε_0	8.854E-12 [F/m]	[1]
ε_r	80	[1]

3. Simulation detail

The simulation is completed based on the Freefem++ package (see http://www.freefem.org//ff++). The simulated structure of the nanopore channel is shown in Figure 2(a). Here, we choose a two-dimensional axisymmetric structure to analyze the transport characteristics of ions in nanopores. The length of the nanopore is set to 30 nm, and the radius is set to 10 nm. Boundary 8 represents the axis of symmetry. Boundaries 1 and 7 in the figure correspond to the entrance and exit of the channel. Boundaries 3, 4, and 5 represent the surface of the nanopore.

The specific boundary conditions are set as follows. The electric potential boundary is set as follows[4]

$$\varphi = 0 \text{ , on boundary 1} \quad \text{(S.4)}$$

$$\varphi = V \text{ , on boundary 7} \quad \text{(S.5)}$$

$$\boldsymbol{n} \cdot \nabla\varphi = -\frac{\sigma}{\varepsilon_0 \varepsilon_r} \text{ , on boundaries 3, 4, 5} \quad \text{(S.6)}$$

$$\boldsymbol{n} \cdot \nabla\varphi = 0 \text{ , on other boundaries} \quad \text{(S.7)}$$

Here, σ represents the surface charge density. $\sigma = -60\ mC/m^2$ for the situation with a charged surface, and $\sigma = 0\ mC/m^2$ for the situation with an uncharged surface. The applied voltage V is $0.1V$.

The concentration boundary is set as follows

$$c_i = c_0 \text{ , on boundaries 1 and 7} \quad \text{(S.8)}$$

$$\left(-D_i \nabla c_i - z_i \frac{D_i}{RT} F c_i \nabla\varphi\right) \cdot \boldsymbol{n} = 0 \text{ , on other boundaries} \quad \text{(S.9)}$$

PNP equation is solved in the weak form.[5] By solving the above PNP equation, we can obtain the ion flux density of K^+ ion and Cl^- ion in the presence of surface charge and without surface charge. Then the total ion flux density can be obtained in the presence and absence of surface charges.

3. Deviation statistics

The deviation of experimental data from different pores under model curves (Figure 5) with different numbers of pores was shown in Table S2.

Table S2 Deviation of experimental data from different pores under model curves (Figure 5) with different numbers of pores

	No.1-1	No.1-2	No.1-3	No.1-4	No.1-5	No.2-1	No.2-2	No.2-3	No.3-1
Model (1 pore)	0.0547	0.0202	0.0321	0.0043	0.0070	0.2335	0.3053	0.1224	0.2899
Model (2 pores)	0.2679	0.1732	0.1127	0.1255	0.1043	0.0289	0.0334	0.0377	0.0628
Model (3 pores)	0.3682	0.2661	0.2046	0.2104	0.1736	0.1627	0.1074	0.1385	0.0675

The ratio of the deviation of the conductivity distribution was obtained by $\left|\frac{G_{1,0.1M} - G_{2\text{dis},0.1M}}{G_{1,0.1M}}\right|_{G_{1,1M}=G_{\text{x},1M}} / \left|\frac{G_{1,0.1M} - G_{2,0.1M}}{G_{1,0.1M}}\right|_{G_{1,1M}=G_{2,1M}}$ and was shown in Figure S3..

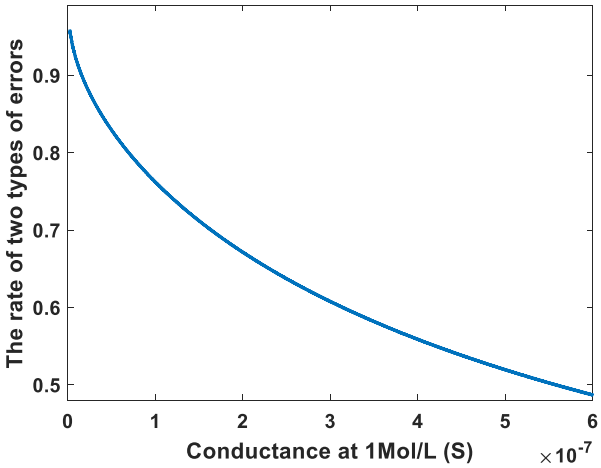


Figure S3. The ratio of the deviation of the conductivity distribution obtained when the distance between the two pores is 25nm from the ideal single pore and the deviation of the ideal double pore from the ideal single pore (if the ratio is less than 0.5, it is considered impossible to determine whether it is a single pore)

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