**[Supporting Information]**

# Scalable Fabrication of Nanopores in Silicon Nitride Membranes via Thermal Annealing of Au Nanoparticles

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KEYWORDS: scalable nanopore fabrication, nanopore membrane, Au nanoparticles, thermal annealing, conical nanopore

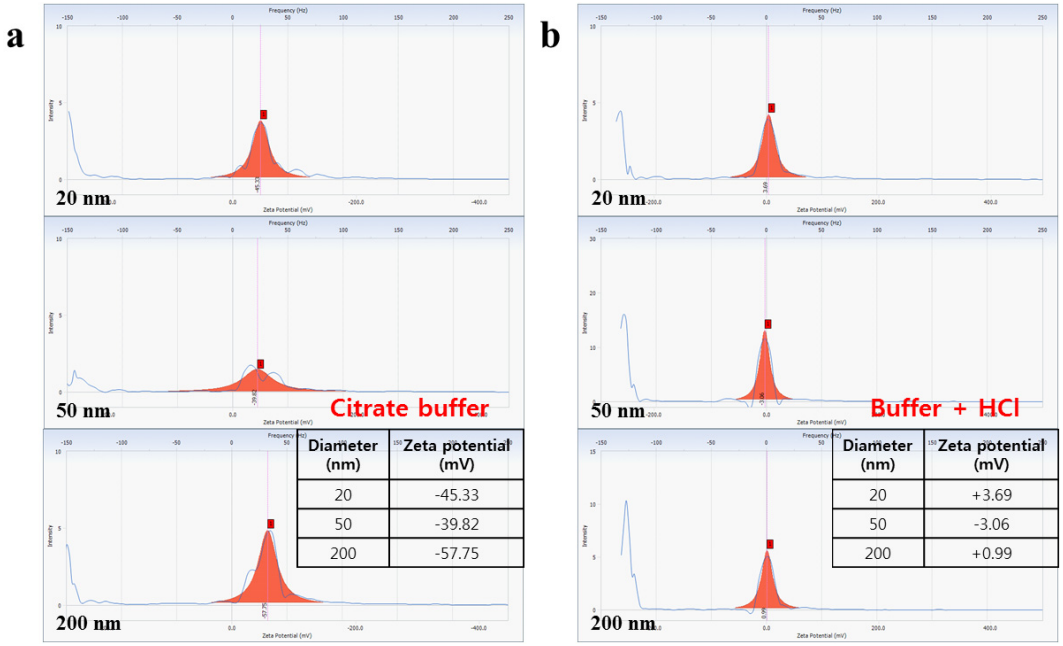


**Figure S1. Zeta potentials of AuNPs dispersed in citrate buffer and in mixing with 0.1 M HCl solution.** Zeta potentials of (a) 20, 50 and 200 nm AuNPs, dispersed in citrate buffer and (b) 20, 50 and 200 nm AuNPs in mixing solution of citrate buffer and 0.1 M HCl solution in the ratio of 2:1.

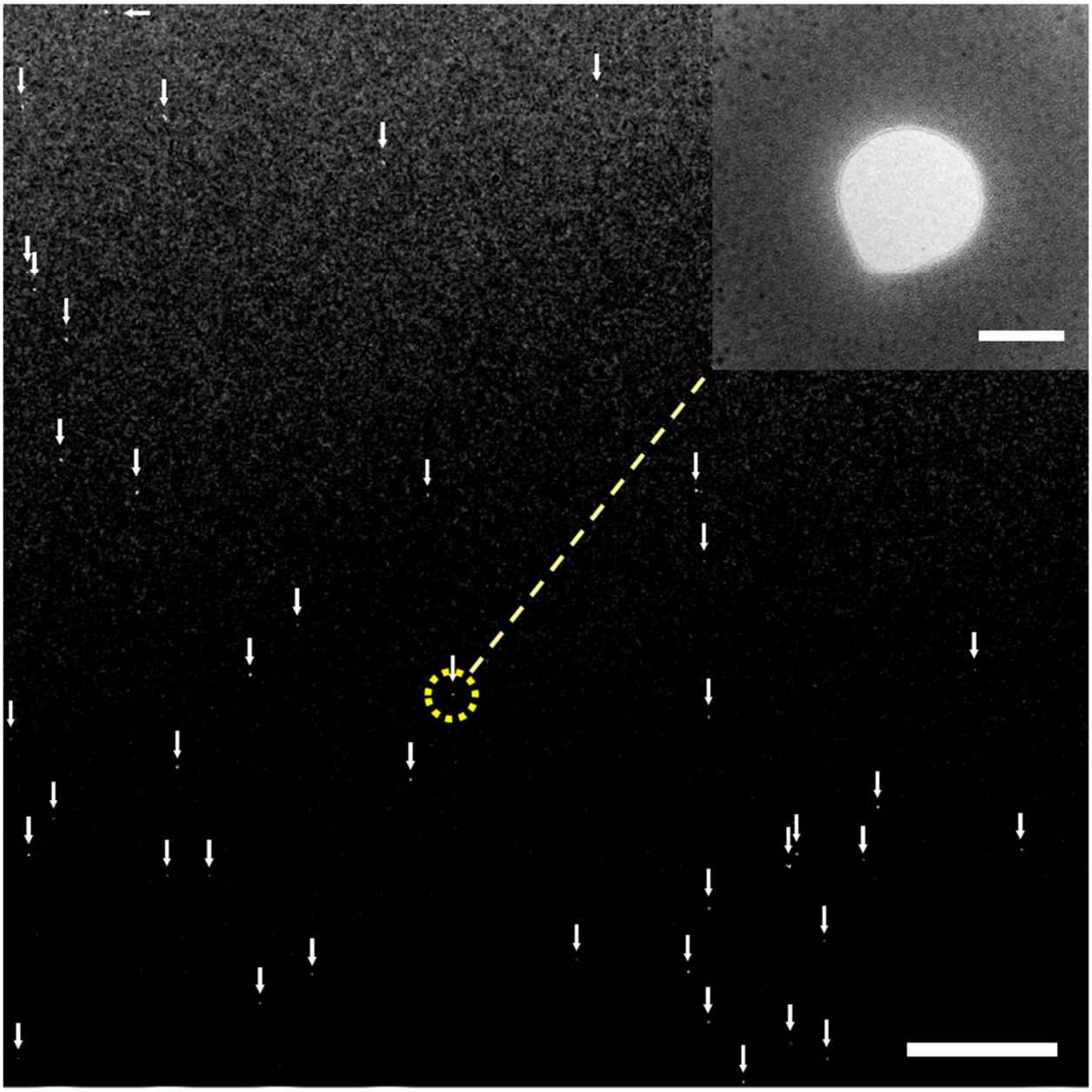

**Figure S2. Formation of nanopores on a 30-nm-thick $Si_3N_4$ membrane fabricated by successive changes in the thermal annealing conditions from 1060 °C for 2 h to 1000 °C for 1 h.** The AuNPs are 200 nm. Scale bar indicates 5 μm, while the scale bar in the inset represents 40 nm. Each arrow points to a single, isolated nanopore.

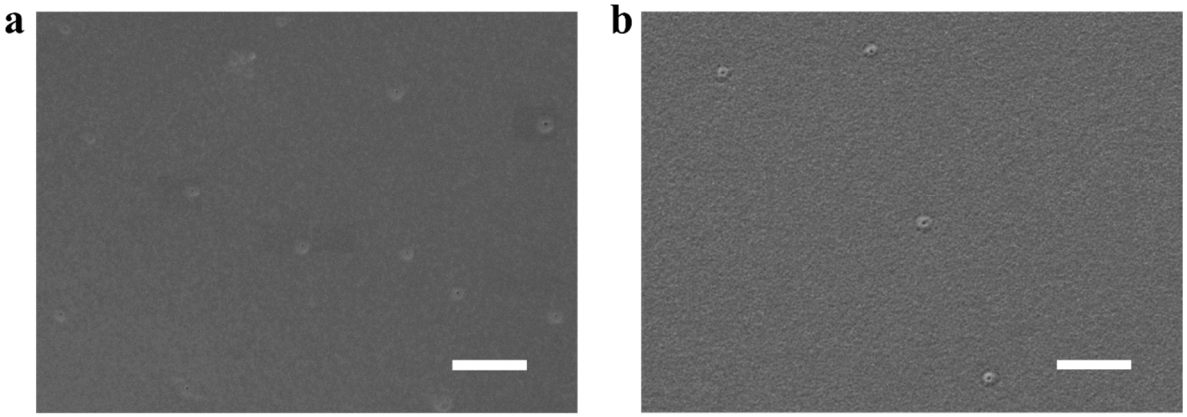


**Figure S3. Controllable distribution density of nanopores on a $Si_3N_4$ membrane via preliminary adjustment of the AuNPs distribution. (a)** High and **(b)** low distribution density of nanopores fabricated by 50-nm diameter AuNPs on 30-nm thick $Si_3N_4$ membranes. The density distribution was controlled by the preliminary manipulation of AuNP-dispersed solution. Scale bar indicates 500 nm.

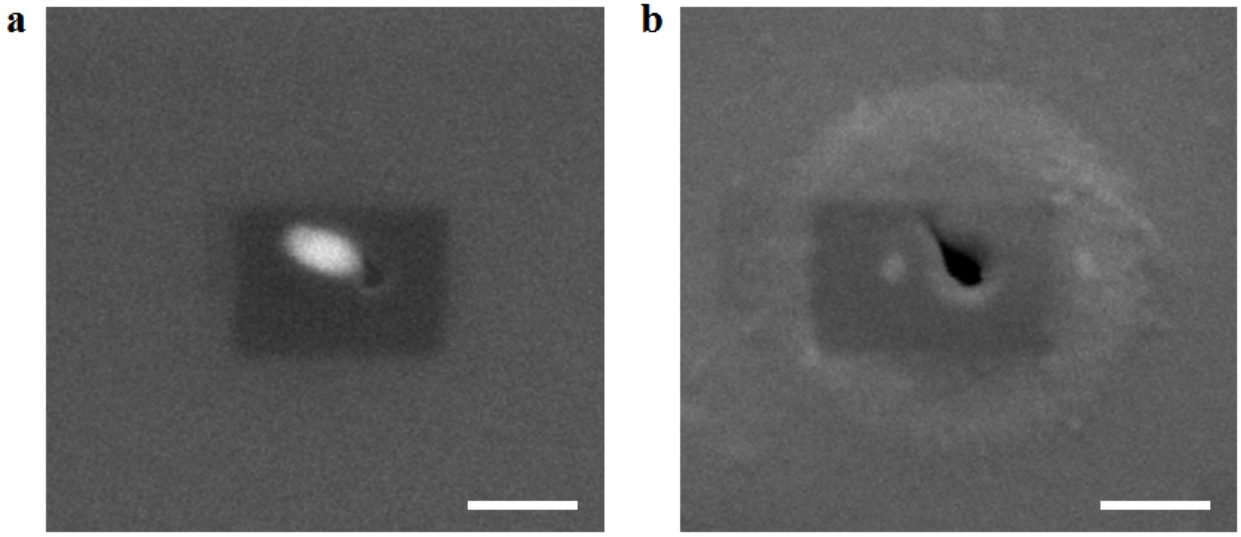


**Figure S4. SEM images of asymmetric penetration of AuNPs.** Two states of asymmetric nanopores with and without Au droplets were fabricated by thermal annealing at **(a)** 990 °C for 30 min and **(b)** 1000 °C for 3 h. The AuNPs are 200 nm. Scale bar indicates 200 nm. The rectangular traces are caused by focusing the SEM beam.

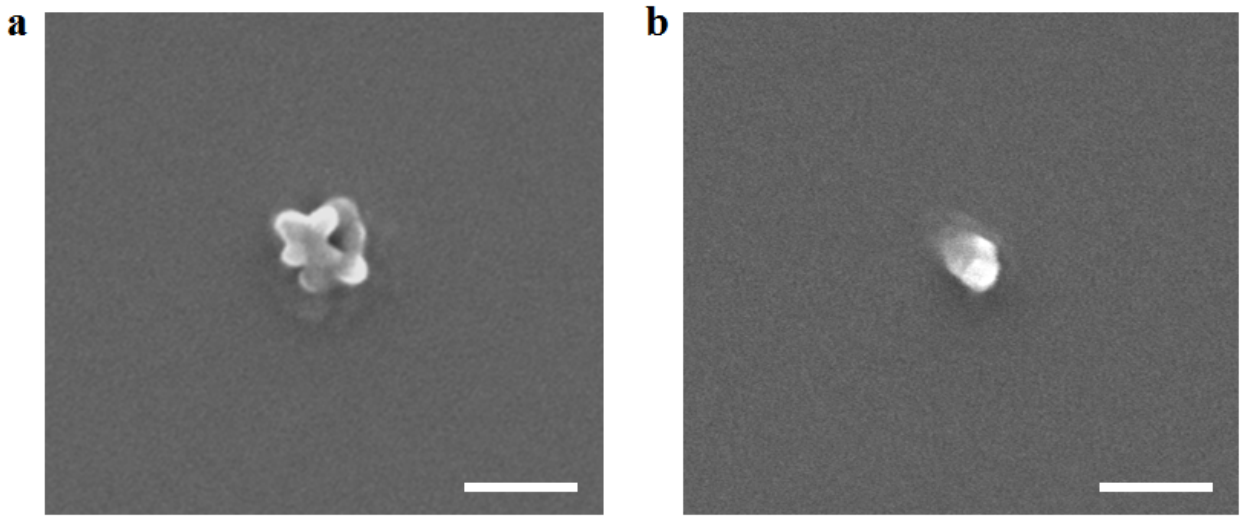


**Figure S5. SEM images of Au-embedded nanopores during thermal annealing.** Au inside nanopores fabricated by thermal annealing at **(a)** 1010 °C for 1 h and **(b)** 1020 °C for 1 h. The AuNPs are 200 nm. Scale bar indicates 200 nm.

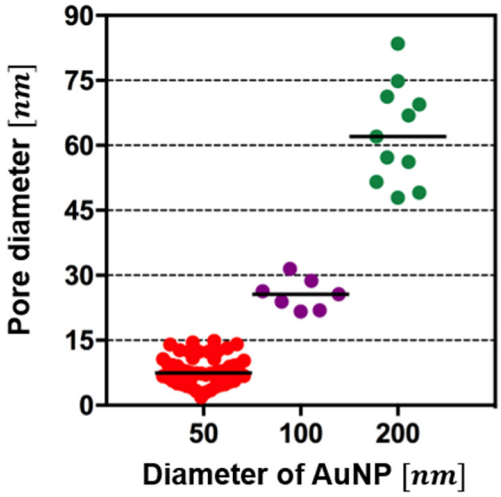


**Figure S6. Diameter distribution of nanopores fabricated by thermal annealing of 50-, 100-, and 200-nm-diameter AuNPs on the 30-nm thick $Si_3N4$ membrane.** Pore diameters indicate the measured diameters at the exit of conical nanopores, after thermal annealing of the AuNPs. The diamters of the AuNPs were constant as 50 nm, 100 nm and 200 nm, but the scattered distribution along x-axis was used to visualize the resulting distribution of the pore diameters at the exit.

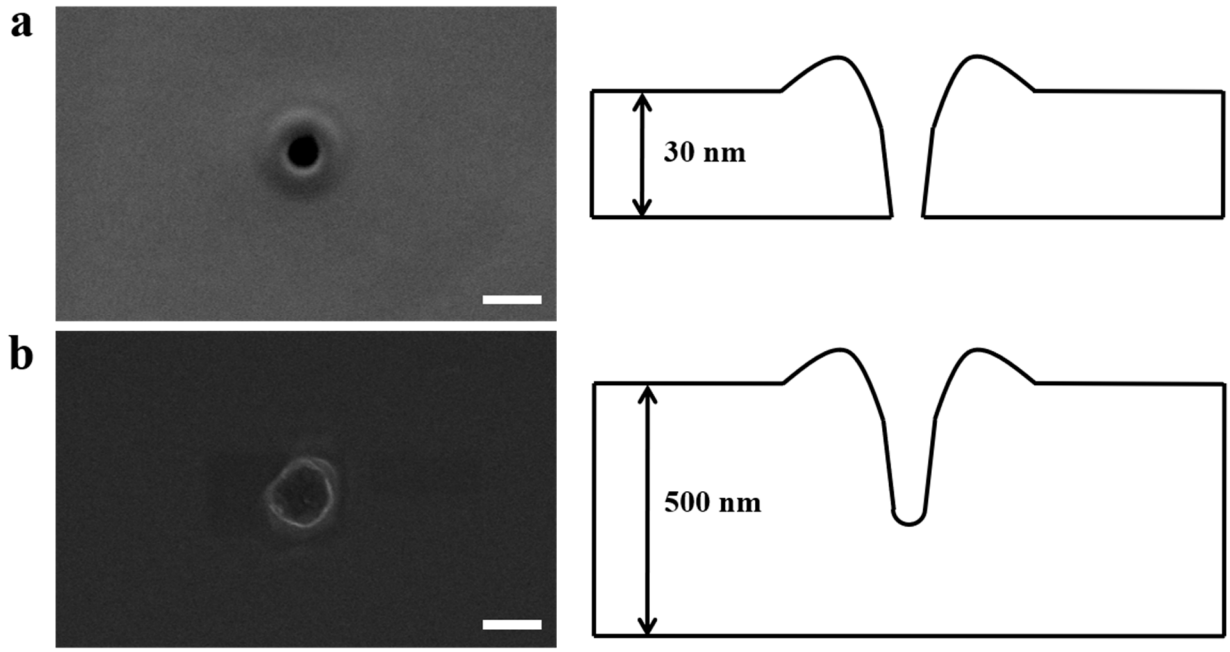


**Figure S7. Controlling the opened and closed pores using different membrane thicknesses.** SEM images and corresponding schematics of **(a)** an opened single nanopore in a 30-nm-thick $Si_3N_4$ membrane and **(b)** a closed single nanopore in a 500-nm-thick $SiO_2$ membrane. Scale bar indicates 200 nm.

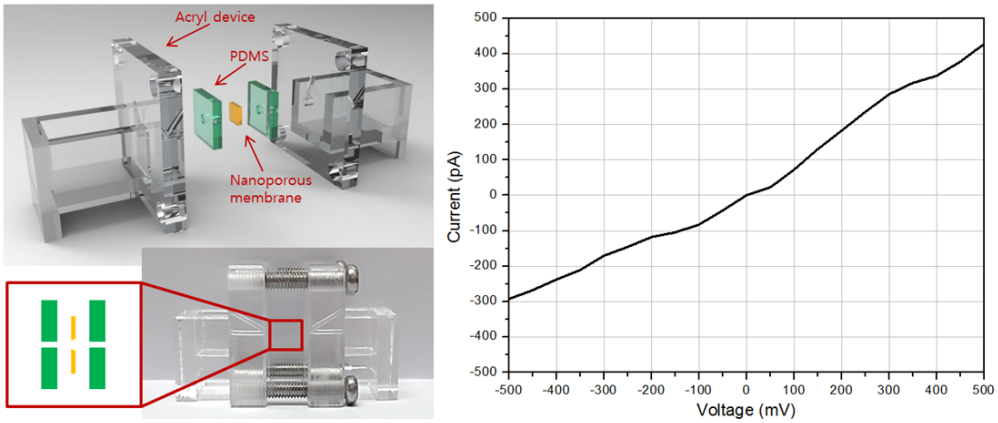


**Figure S8. I-V curve measurement of the 30-nm thick $Si_3N_4$ membrane having the nanopores, fabricated by thermal annealing of 50-nm diameter AuNPs.** Design of a nanofluidic platform and typical I-V trace in 0.1 M NaCl.