Supporting Information

Morphology Around Nanopore Fabricated By Laser-Assisted Dielectric Breakdown and Its Impact On Ion and DNA Transport and Sensing

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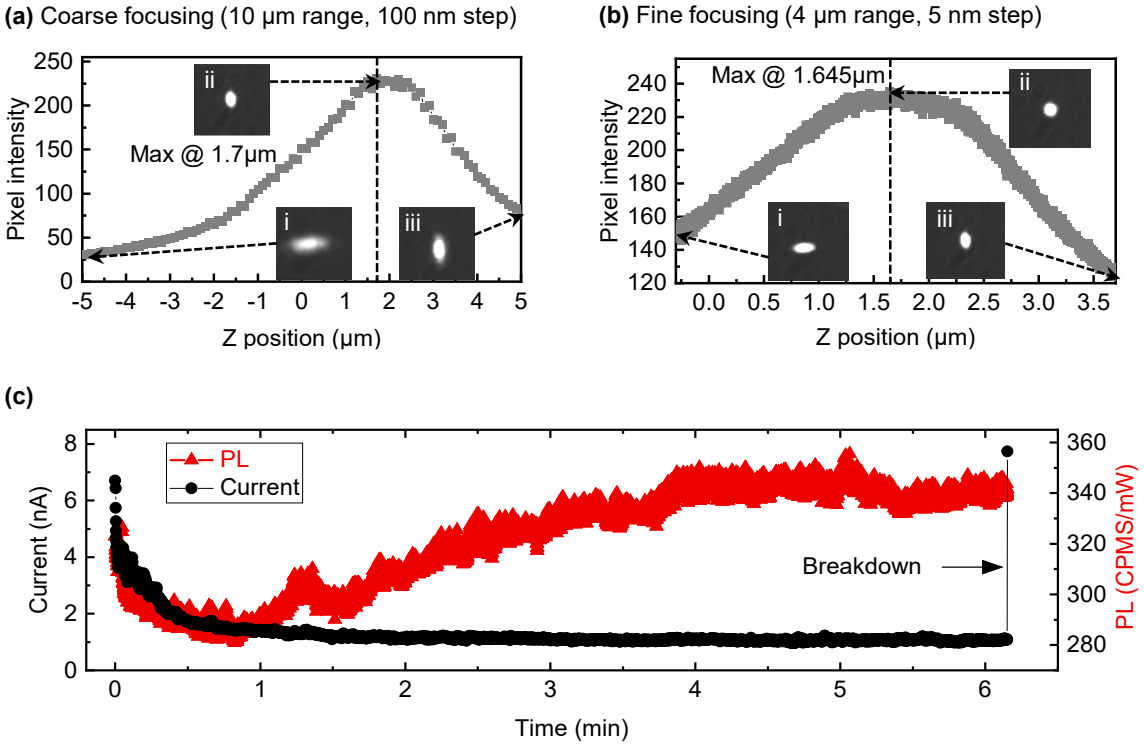


Figure S1. The auto-focusing of the laser via gray-scale pixel intensity. (a) The coarse focusing in the 10 μm ranges with a 100 nm step. (b) The fine focusing in the 4 μm ranges with a 5 nm step. The stage will automatically return to the position with the maximum pixel intensity. 1mW laser was used during the focusing. (c) An example of current and PL changes during the LaCBD nanopore fabrication (+3 V voltage and 40 mW laser applied).

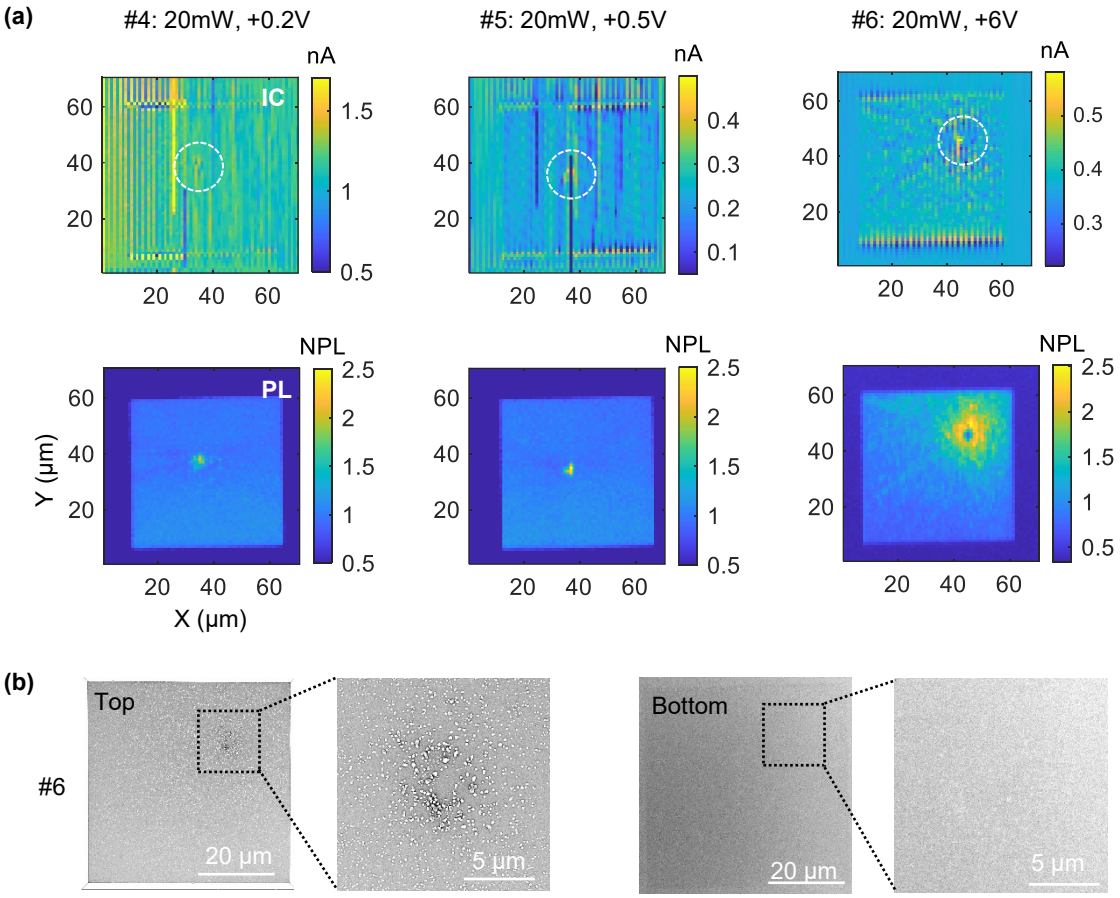


Figure S2. (a) Three different La-CBD nanopore sample shows PL increment around the pore. The top row is the ionic current map (White dashed circles indicate the fabricated nanopore location), and the bottom row is the corresponding PL map. NPL is the normalized PL intensity over an intact membrane region. (b) SEM images of sample #6. The image also shows top side has much more debris than the bottom side.

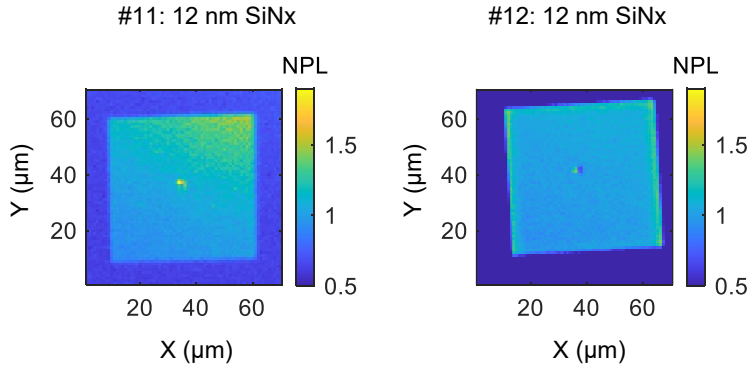


Figure S3. PL map of two LaCBD nanopore samples fabricated with 12 nm thick SiN_x membrane. The PL increment is also observed around the pore region. The nanopores were

fabricated via a 20 mW laser and +4.8 V voltage.

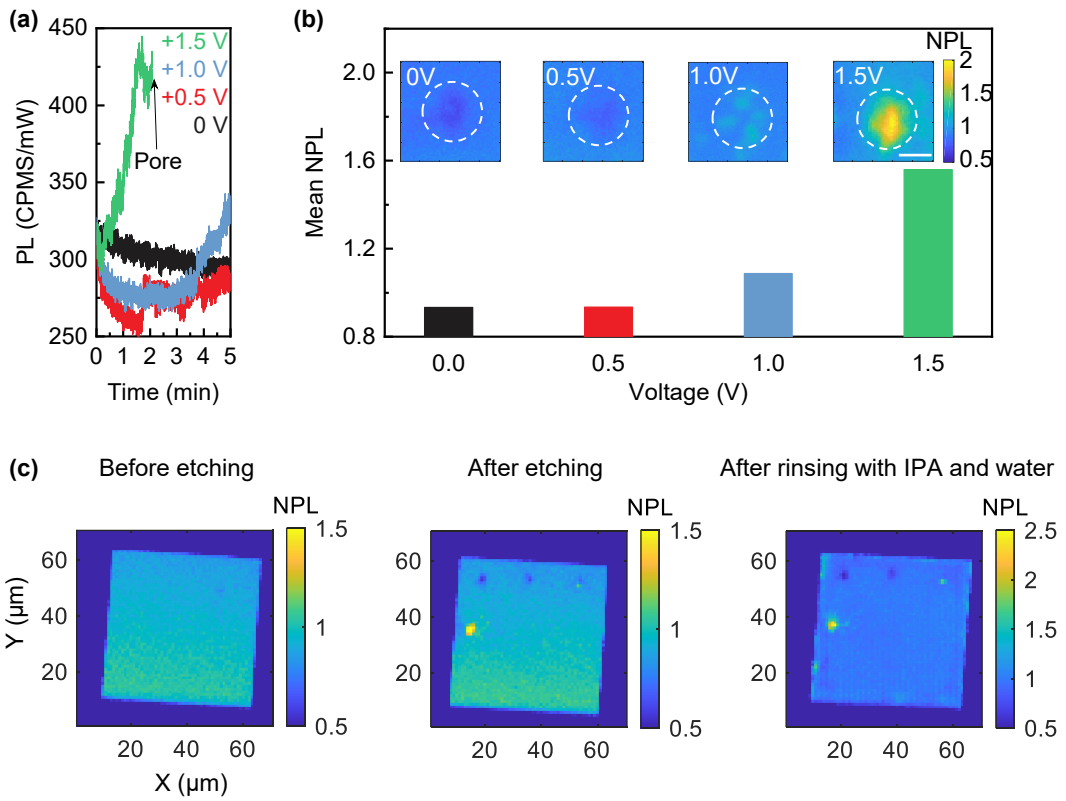
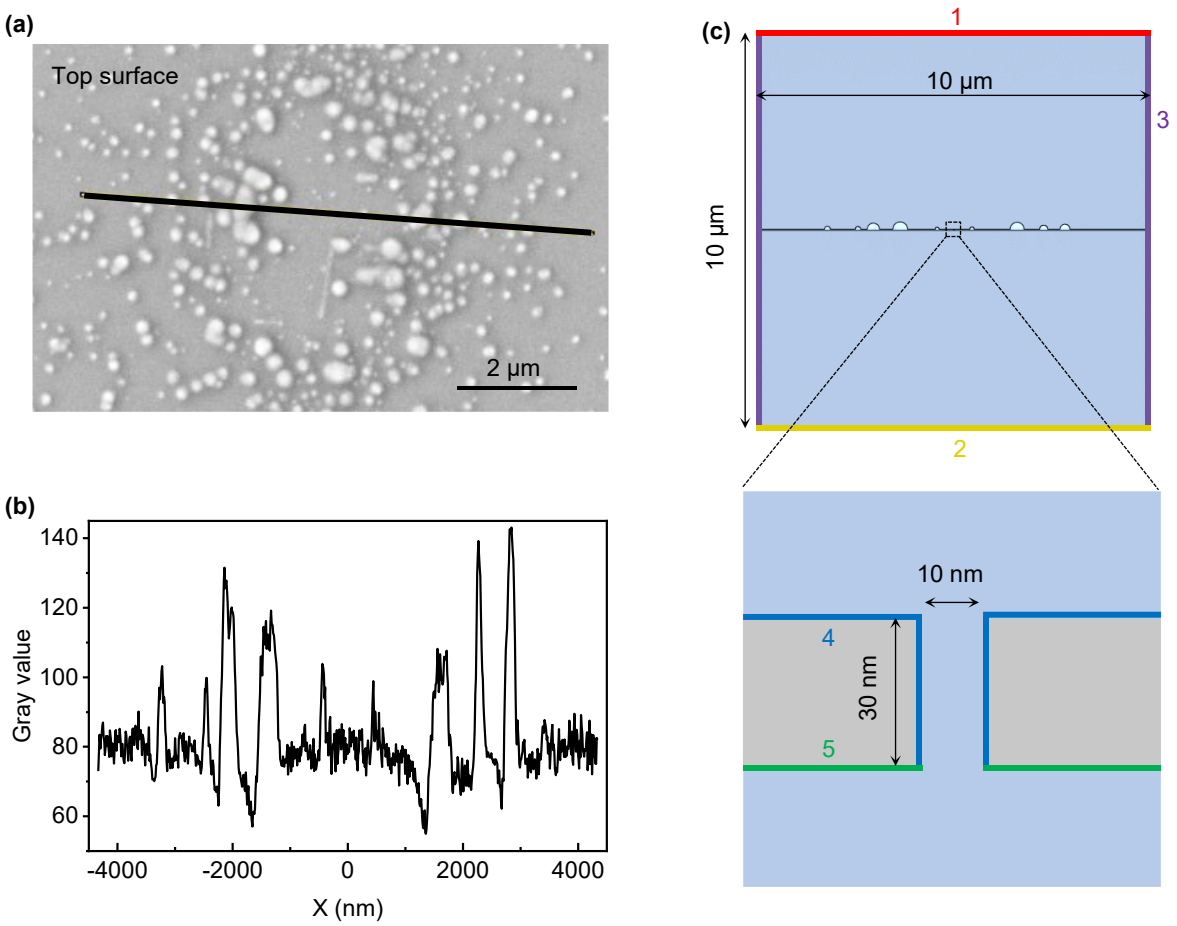


Figure S4. Another sample shows the correlation between voltage stress and PL increment. (a) Real-time PL intensity during laser etching. 0 V, +0.5 V, +1.0 V, and +1.5 V positive voltages were used, and a 20 mW laser was applied. (b) PL mapping of the etched region and the mean PL inside the white dash circle. The PL maps and mean NPL indicate that more debris accumulated around the pore when higher voltage was applied. The scale bar is 5 μm. (c) The PL map of SiN_x membrane before etching, after etching, and after rinse.



(d)

Boundary \ Equation	Poisson	Navier–Stokes	Nernst–Planck for ions	Nernst–Planck for molecules
1	Voltage = V_0	Pressure = 0	C_{ion}	0
2	Ground	No-slip	C_{ion}	$C_{molecule}$
3	Zero flux	No-slip	Zero flux	Zero flux
4	Surface charge density	No-slip	Zero flux	Zero flux
5	Surface charge density	No-slip	Zero flux	Zero flux

Figure S5. (a) The SEM image around the pore. The black line is used to acquire the line profile of morphology. (b) The morphology line profile around the pore. Data is processed by image J. The debris diameter is estimated using the width of the peaks. (c) The geometry parameters and boundaries used in the simulation. The reservoirs (10 um ×5 um) were assumed large enough for the ionic concentration far away from the pore to maintain its bulk value C_{ion}. (d) The table shows the boundary condition for each set of equations: Poisson, Navier–Stokes, and Nernst-Planck for ions and molecules (DNA).

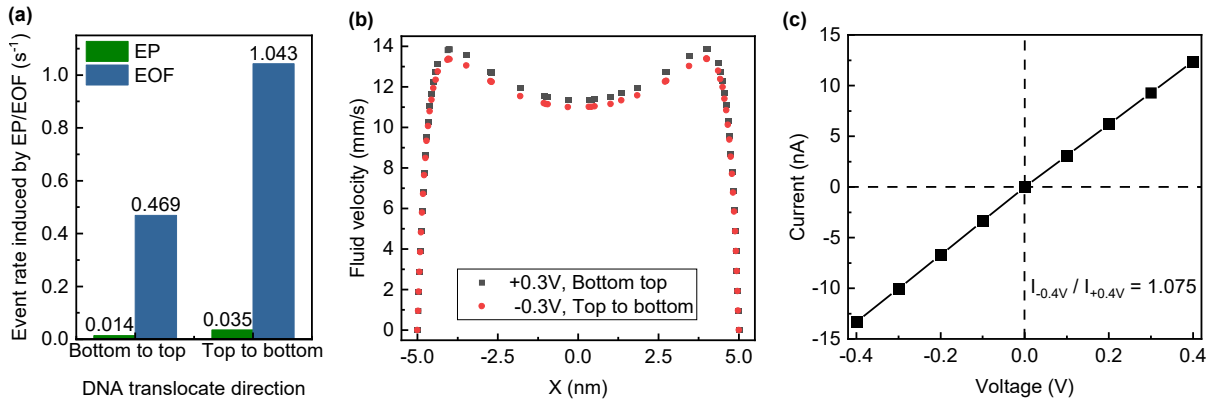


Figure S6. Simulation results of molecular and ionic transport. (a) The DNA translocates event rate induced by electrophoresis (EP) or electroosmotic flow (EOF). The result indicates that EOF dominates DNA transport. (b) The y-component fluid velocity within the nanopore shows a similar profile between +0.3 V and –0.3 V. The similar velocity profile indicates the different flux density is due to the different DNA concentration when applying ±0.3 V. (c) The IV curve shows a rectification ratio of 1.075 at 0.4 V. The pore and top surface charge is +15 mC/m^2, the bottom surface charge is -30 mC/m^2.

Supplementary Tables

Table S1 Summarization of the parameters used in the numerical simulation.

Parameter	Meaning	Value	Unit
N_A	Avogadro constant	6.022 e23	$1/\mathrm{mol}$
e	Elementary charge	1.6 e-19	C
ε_0	Vacuum permittivity	8.85 e-12	F/m
ε_r	Relative permittivity	78	1
σ	Surface charge density	Variable	mC/m^2
V_0	Bias Voltage	Variable	V
C_{ion}	Ions concentration	1	M
$C_{molecule}$	Molecule concentration	100	pM
T	Temperature	300	K
D_{Cl}	Diffusivity of Cl^-	2.03 e-9	m^2/s
D_K	Diffusivity of K^+	1.96 e-9	m^2/s
D_{DNA}	Diffusivity of DNA	2.1 e-12	m^2/s
μ_{Cl}	Electrophoretic mobility of Cl^-	7.85 e-08	m^2/Vs
μ_K	Electrophoretic mobility of K^+	7.58 e-08	m^2/Vs
μ_{DNA}	Electrophoretic mobility of DNA	8 e-8	m^2/Vs
J_{ion}	Ions Flux	Variable	$\mathrm{mol}/(\mathrm{m}^2\ s)$
$J_{molecule}$	Molecule Flux	Variable	$\mathrm{mol}/(\mathrm{m}^2\ s)$
ν	Fluid viscosity	Variable	$Pa.s$
p	Fluid pressure	Variable	Pa
u	Fluid velocity	Variable	m/s