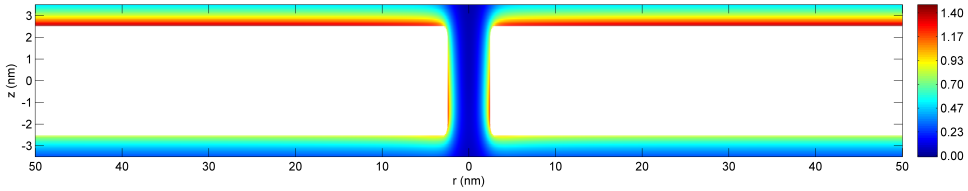
Supplementary material

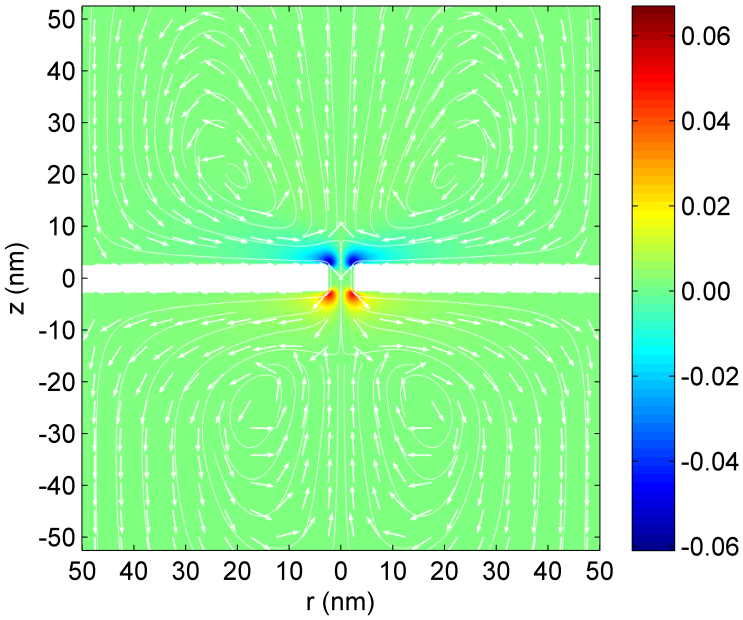
1. More on hydrodynamic characteristics of the nanopore

In the situation where the membrane has fixed charges, its Debye layer is enhanced on one side of the membrane and depleted on the other side by the space charge layer created by the applied field. Depending on the polarity and strength of the applied field, even the sign of the charge in the membranes intrinsic Debye layer could reverse.

For instance, when Σ is negative, what could happen is that at weak ΔV, less Cl^- are brought to EF than defected by Σ. The polarity of space charges along EF should be positive, as shown in Figure 1a. When ΔV is large, on the other hand, more Cl^- are brought to EF by the electric field than deflected by Σ; the polarity of space charges along EF should therefore be negative, as shown in Figure 2a. In other words, different applied field strength will change the polarity of space charges at certain location, thus change the direction of flow. We also show here that at small(e.g. ΔV =0.4 V) or large ΔV(e.g. ΔV =2.0 V), the flow in the bottom rotates in the opposite direction, as the polarity of space charges is reversed (Figure. 1b and 2b). Note that the difference between c_1 and c_2 corresponds to space charge density.

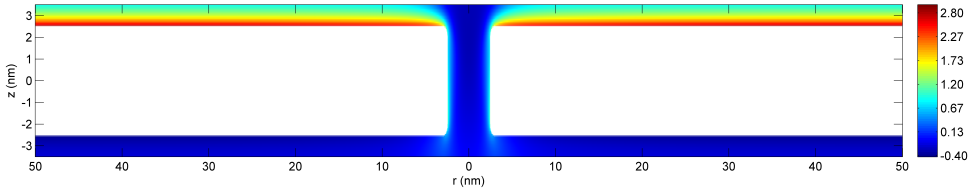


(a) Space charge density when ΔV =0.4 V, positive along EF. Only the Debye layers are shown. The white parts denote the membrane.

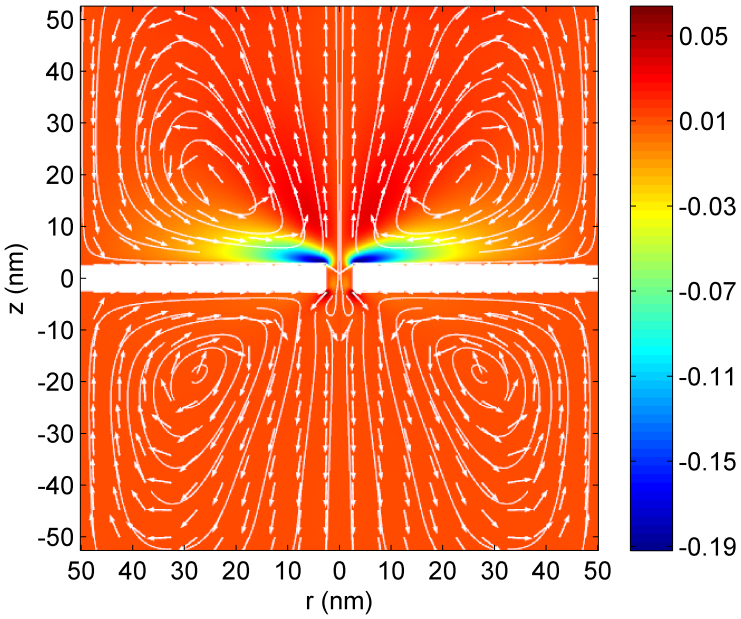


(b) Radial velocity u (colormap) and the direction of flow when ΔV =0.4 V, flowing radial AWAY from the pore along EF.

Figure 1: The space charge distribution $((c_1 - c_2)/c_0)$ and radial velocity u in the nanopore system at ΔV =0.4 V. Here c_0 =0.1M and Σ =-0.01 C/m^2.



(a) Space charge density when ΔV =2.0 V, negative along EF. Only the Debye layers are shown. The white parts denote the membrane.



(b) Radial velocity u (colormap) and the direction of flow when ΔV =2.0 V, flowing radial TOWARDS the pore along EF.

Figure 2: The space charge distribution $((c_1 - c_2)/c_0)$ and radial velocity u in the nanopore system at ΔV =2.0 V. Here c_0 =0.1M and Σ =-0.01 C/m^2.