Negative Differential Resistance in a Nanopore Under Salt Gradient: Models of Surface Charge Effect

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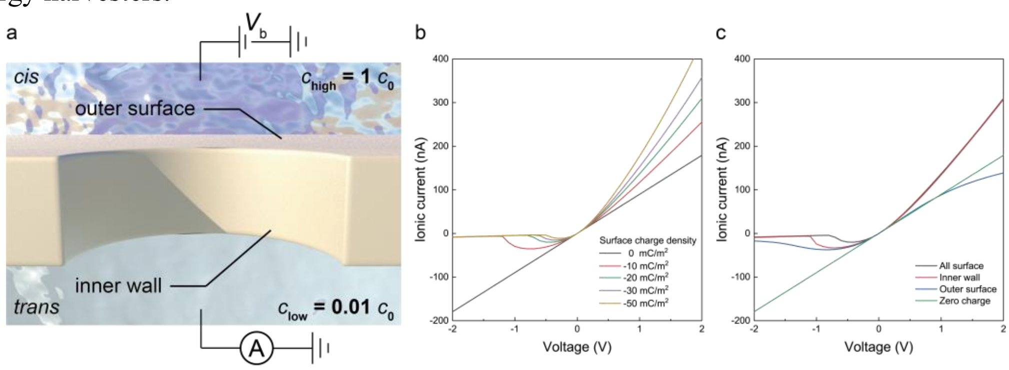
Nanopore technology has been widely used in various bioanalytical applications because of the high spatial sensitivity and simple mechanism. Recently, ionic current rectification (ICR) and negative differential resistance (NDR) were reported for salt-gradient-biased solid-state nanopores showing the potential usage as nanofluidic diodes[1] and memristors.[2] The unique electric characteristics of ICR and NDR presenting asymmetric ion transport is based on the electrical double layers on the charged surface and the associated electroosmotic flow (EOF). In this study, we explored the roles of wall surface charge on the distinct ion transport properties. We performed finite element simulations by solving Poisson-Nernst-Planck and Navier-Stokes equations under different conditions: (i) all surface is charged; (ii) only inner wall is charged; (iii) only pore wall is charged. Those charged patterns were elucidated to change the current-voltage characteristics. Through this method, we show how NDR of low-aspect-ratio nanopore with 50-nm thick SiN_x membrane with salt gradient can be tuned by controlling two important factors: surface charged destiny and it's charged pattern.

In experimental section, a model of 300 nm-diameter and 50 nm-thick membrane under the cis-to-trans ion concentration ratio of 100, is considering in the simulations: charged boundary surface on the outer surface and inner wall are shown in Fig. 1a. When changing the values of surface charge density in the case of (i), simulated current-voltage curves show that nanopore behaves as an ohmic resistor (0 mC/m^2, black curve) and NDR occurs at higher charge density (Fig. 1b). On the other hand, examining the four different regions of the charged surface area, only the case of (i) showed NDR behavior (Fig. 1c). These findings provide a new approach to build nanofluidic devices in many fields such as iontronics, nanosensors, and energy harvesters.



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