

Nanopore Array Interactions Weak Dependence On Pore Length

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Abstract

There has been a great amount of interest in nanopores as the basis for sensors and templates for preparation of biomimetic channels as well as model systems to understand transport properties at the nanoscale. The presence of surface charges on the pore walls has been shown to induce ion selectivity as well as enhance ionic conductance compared to uncharged pores. Here, using three-dimensional continuum modeling, we examine the role of length of charged nanopores as well as applied voltage for controlling ion selectivity and ionic conductance of single nanopores and small nanopore arrays. First, we present conditions where the ion current and ion selectivity of nanopores with homogeneous surface charges remain unchanged even if the pore length decreases by a factor of 6. This length-independent conductance is explained through the effect of ion concentration polarization (ICP) that modifies local ionic concentrations not only at the pore entrances but also in the pore in a voltage-dependent manner. We describe how voltage controls ion selectivity of nanopores with different lengths and present conditions when charged nanopores conduct less current than uncharged pores of the same geometrical characteristics. The manuscript provides different measures of the extent of the depletion zone induced by ICP in single pores and nanopore arrays including systems with ionic diodes. The modeling shown here will help design selective nanopores for a variety of applications where single nanopores and nanopore arrays are used

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Figures used in the abstract

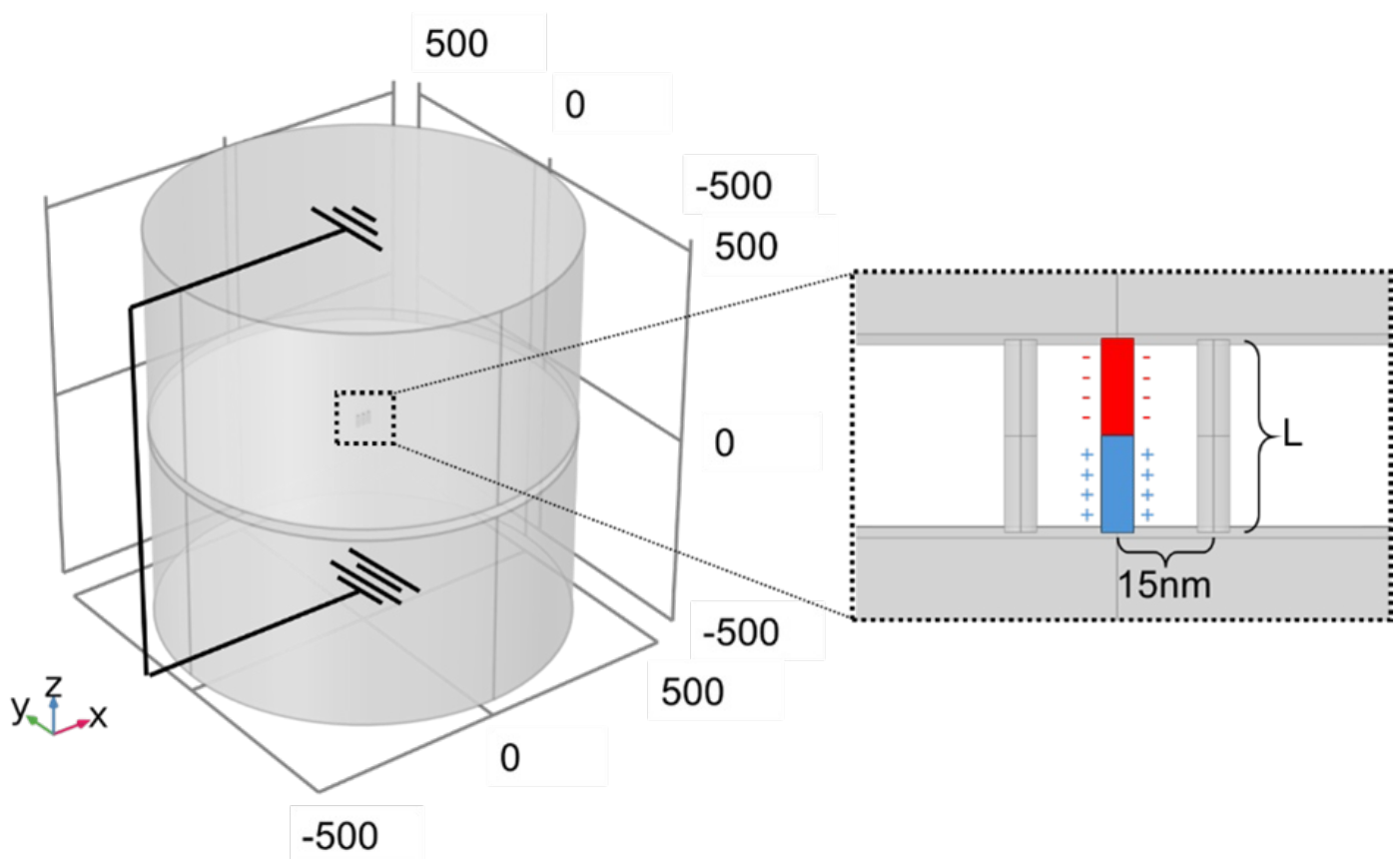


Figure 1 : Scheme 1: Geometrical setup for nanopore array modeling. Cylindrical reservoirs of 0.5 μm radius and 0.5 μm height are connected with a membrane containing a single nanopore or 3-nanopore array with the pore-to-pore distance set to 15 nm. The nanopore dia

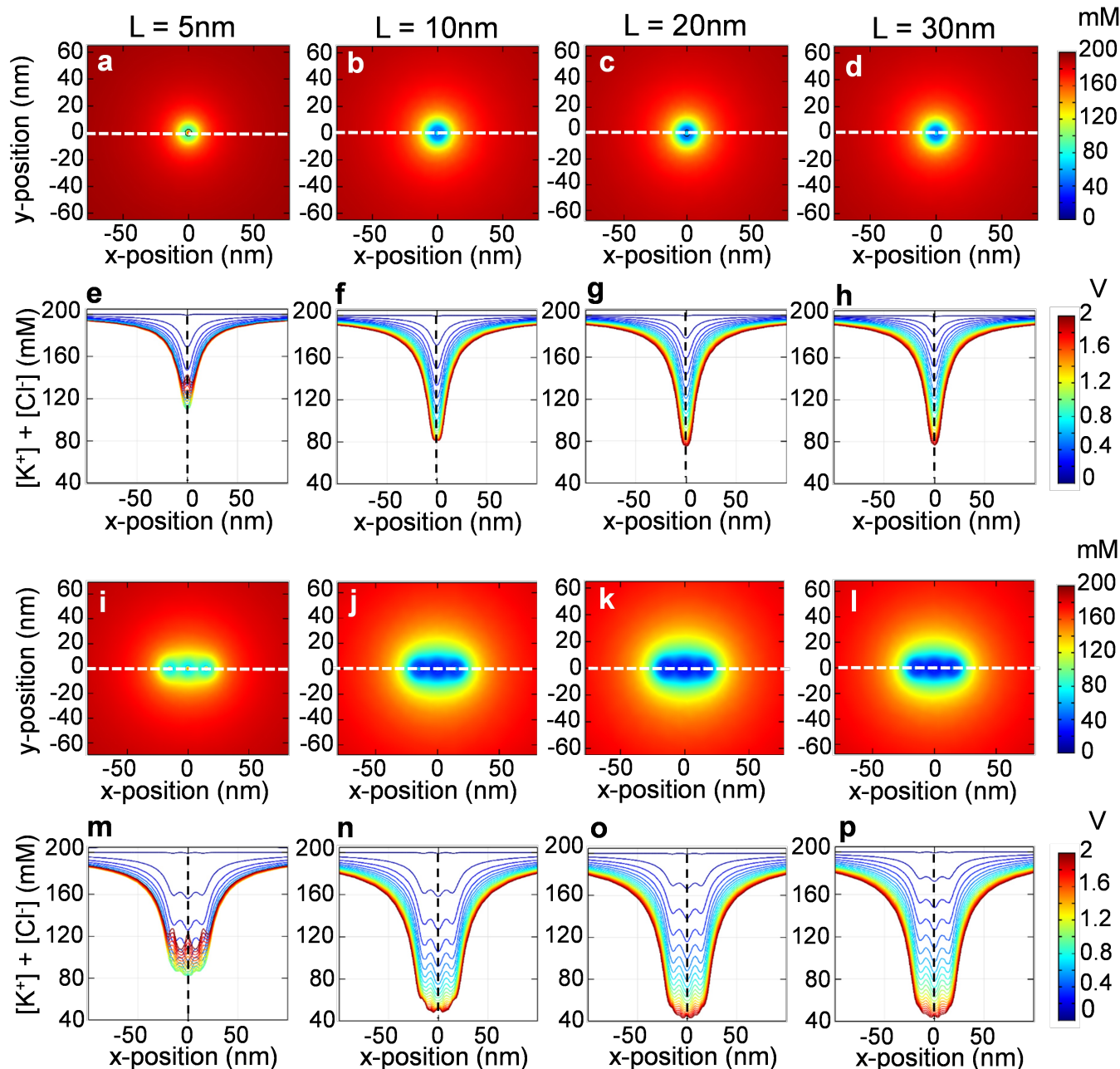


Figure 2 : Figure 1. Ionic depletion caused by ion concentration polarization in single nanopores (a-h) and in nanopore arrays with 3 pores (i-p) in 100 mM bulk KCl concentration as a function of pore length and voltage. Results for 5, 10, 20 and 30 nm long pores are

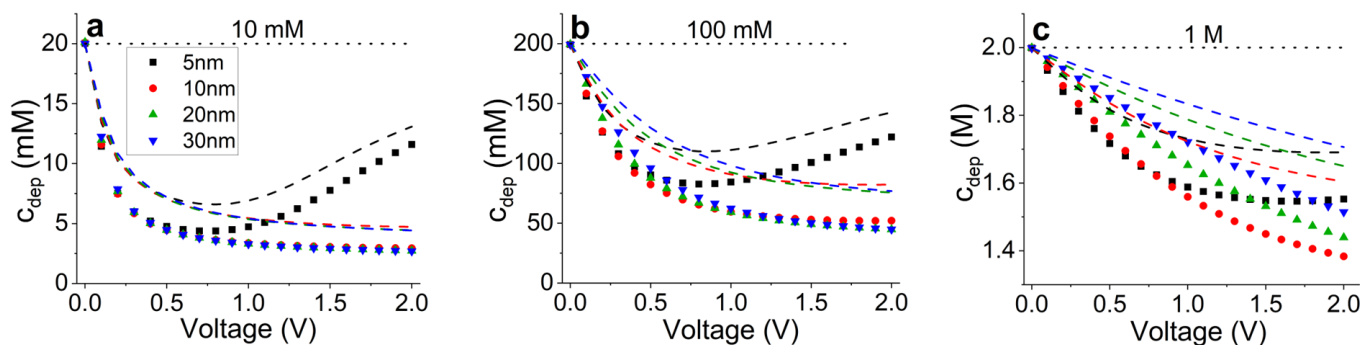


Figure 3 : Figure 2. The total ionic concentration, called c_{dep} , in the middle of single nanopores (dashed lines) and the middle of the center pore in the arrays (symbols) as a function of pore length and voltage. This graph shows concentrations at the vertical dash

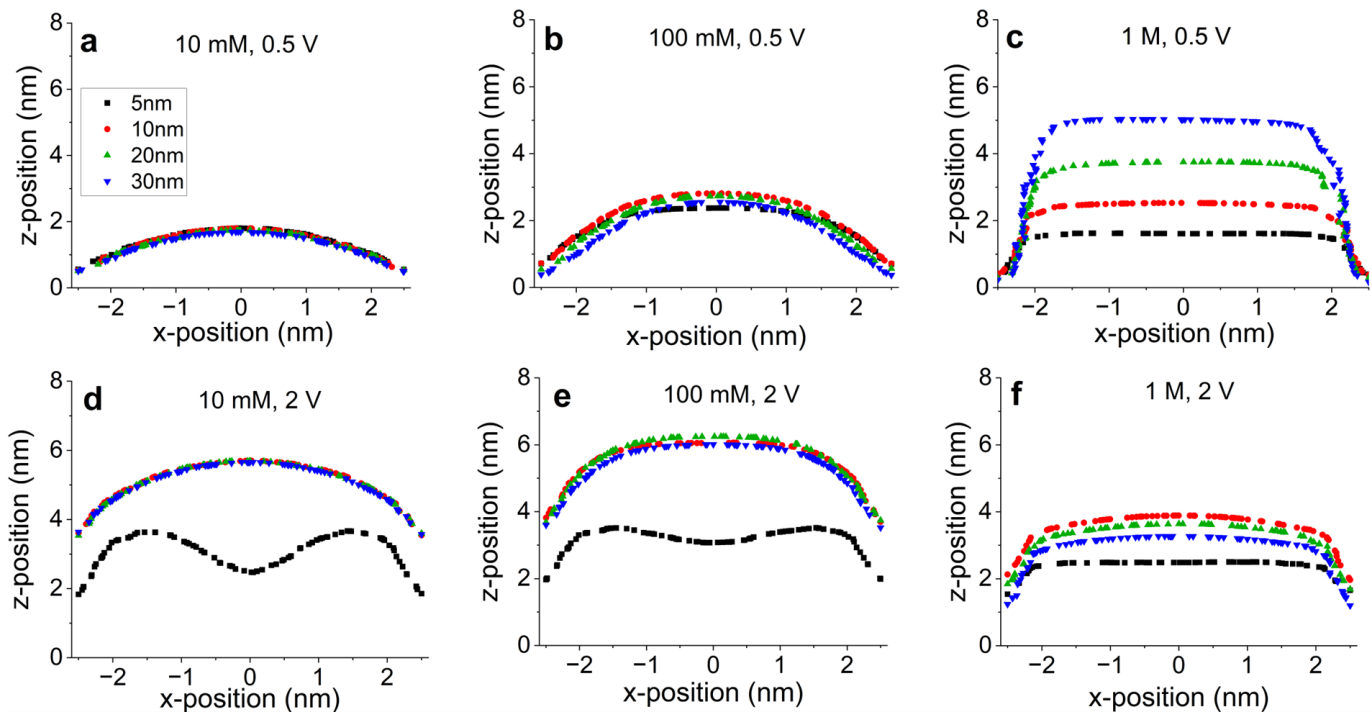


Figure 4 : Figure 5. Contours of the position in the xz -plane inside the pore where the total ionic concentration reaches 95% of the bulk total concentration. $x = 0$ nm indicates the middle of the center pore in 3-nanopore arrays of all lengths. The y -axis indicates