



Understanding Anomalous Current - Voltage Characteristics in Microchannel-Nanochannel Interconnect Devices

N. R. Aluru, University of Illinois at Urbana-Champaign



Recent experiments revealed nonlinear current–voltage characteristics in a micro–nanochannel integrated system. The current characteristics were found to deviate from the classical–diffusion limited current transport theory, which predicts a saturation of the current density at higher applied voltages with an infinite differential resistance. Using a detailed 2–D nonlinear, nonideal ion–selective model, we capture and explain all the three regions observed in the experiments, by analyzing the behavior of the ionic concentration, near the depletion junction of the micro–nanochannel. Figure 7.6(a) shows the normalized nonlinear current–voltage characteristics in a highly ion–selective nanochannel integrated with a microchannel using our physical model. At low electric

fields (region I in Figure 7.6(a)), the current increases linearly with the applied voltage, following the Ohm’s law. However, beyond the first critical voltage, the current deviates from the Ohmic behavior, but continues to increase with a slope smaller than that of the Ohmic region. This region (II) is often referred to as the limiting resistance region (LRR). Finally, beyond a second critical voltage, the slope of the current increases in comparison to the limiting regime and this region is typically referred to as the overlimiting current region (III). We attribute the limiting resistance region to the predominant propagation of induced space charges towards the microchannel. The overlimiting current characteristics is attributed to the redistribution of the space charges near the micro/nanochannel interface resulting in an anomalous enhancement in the ionic concentration of the electrolyte (predominantly anion concentration) in the induced space charge region (see Figure 7.6(b)).

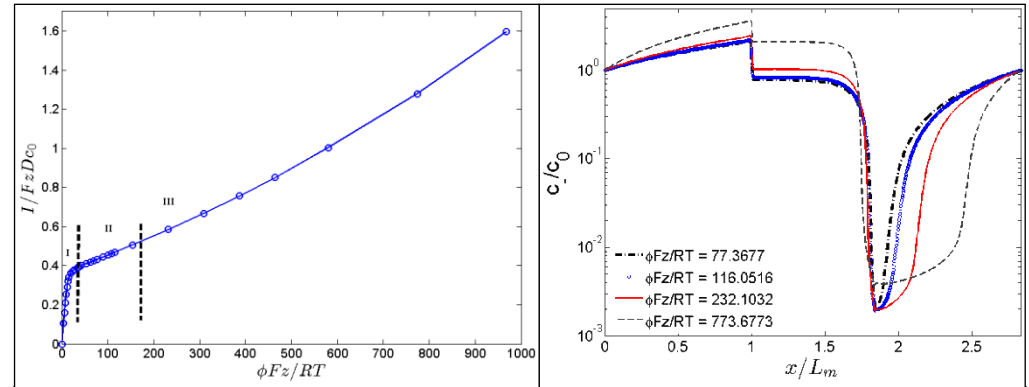


Figure 7.6: (a) Normalized current–voltage characteristics (in magnitude) of a cation–selective nanochannel connected to two microchannels. (b) Normalized concentration of anions (co–ions) along the axial direction for various DC voltages, corresponding to the limiting resistance and overlimiting region.