Enhanced gating effects in sub-nanofluidic channels

Huacheng Zhang[a]*

[a] Chemical and Environmental Engineering, School of Engineering

*Corresponding author: Huacheng.zhang@rmit.edu.au, +61 3 9925 5202

Abstract:

The smart regulation of ion flow in biological ion channels (BICs) is vital to life process. In general, such intelligent BICs possess three main functions: 1) to selective transfer specific ions; 2) to quickly conduct specific ions; and 3) to responsively control the flow of ions. Since the early exploration of potassium (K^+) and sodium (Na^+) channels in 1950s, responsive ions transport (i.e., gating of ion transport) behaviors have been investigated for more than half-century. Taking the first reported voltage-gated ion transport process for example, a gate, the voltage sensor, in BICs detects variation in channel voltage, triggering the opening and the closure of the ion channels. Such BICs have been demonstrated to precisely turn on and off the gate in response to environmental stimuli with extraordinary high gating ratio of up to 10 magnitudes. Inspired by nature, artificial nanofluidic channels have been constructed to intelligently control ions permeation. Since the first artificial ion channels (AICs) for ion gating was reported in 2004, a wide range of AICs have been developed to regulate the flow of ions upon external stimulations (i.e., light, voltage, pH, magnetic field, temperature). In general, these ion nanochannels are constructed with intrinsic or guest functionalities which are responsive to environmental simulations to achieve the opening and closing of the channels. However, gating performances of such nanoscale ion channels are way under those of BICs, due to their relatively larger nanopores ranging from tens to hundreds of nanometres.

Over the past decade, the emerging advanced materials (i.e., 1D nanotubes, 2D nanosheets, and 3D sub-nanopores frameworks) provides a promising tool to fabricate AICs with angstrom-sized pores for efficient ion gating. Recently, our team has fabricated a series of sub-nanofluidic channels based on 3D porous metal-organic frameworks. These sub-nanoscale channels showed enhanced gating effects than nanoscale channels and even replicate gating effect of biological channels, showing great potential for controlled release, biosensing, and separation.

Keywords: Ion channels, gating, nanofluidic, metal-organic framework