Supplementary material for "Universal Scaling of Robust Thermal Hotspot and Ionic Current Enhancement by Focused Ohmic Heating in a Conic Nanopore"

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This document provides information regarding the experimental details about sample preparation and characterization. The geometric measurement results are used in collapsing the experimental data.

In our experiments, the single polymer nanopores were prepared using heavy ion irradiated (Au, 11.4MeV) 12 µm thick foils of polyethylene terephthalate (PET). Asymmetric chemical etching were performed following the procedures in ref.[1] with an etchant solution of 2.5M NaOH and an etch-stopping solution of 1M HCOOH, both in 1:1 MeOH/H2O. We use organic solvent to facilitate the removal of debris and enlarge the cone angle [2]. 1V voltage was applied to detect breakthrough event and slow down etching upon breakthrough. Our nanopipettes and patch pipettes were pulled in a Sutter P-2000 laser puller from borosilicate capillaries with 1.0 mm outer diameter(OD) 0.78 mm inner diameter(ID) and quartz capillaries with 1.0mm OD and 0.5 mm ID, respectively. Pulling parameters: nanopipettes: heat 350, filament 4, velocity 50, delay 225, pull 150; patch pipettes: heat 690, filament 4, velocity 55, delay 132, pull 55 (line 1), heat 750, filament 4, velocity 50, delay 127, pull 55 (line 2). To reduce the effect of surface charge on current measurement all inner surface of glass pipettes are functionalized with N-(3-Triethoxysilylpropyl)gluconamide (Gelest). The pipettes were first treated with Oxygen plasma (Drytek) to activate -OH bonds on surface and then 1µl 0.1% aqueous solution was back filled into the pipette and baked at 120°C for 2 hours to form stable covalent -Si-O-Si- bond. The success of functionalization was verified through rectification ratios of opposite biases which is below 1.05 in all the voltages used for conductance measurement. The elimination of surface charge effect on conductance measurement inside polymer nanopore were achieved by using high ionic strength and validated by rectification ratios below 1.1.

The inner half cone angles of polymer nanopore were estimated based on previous characterization of our asymmetric etching method [2, 3]. Our own measurements of the base side diameter using scanning electron microscope are used to derive the cone angle based on the assumption of a perfect conic geometry. For glass pipettes, our measurements were performed using wide-field microscope images with fluorescent dye solution filling the pipettes. All the images were processed using ImageJ software. The average half cone angles from our measurement were used in the following asymptotic analysis. The inner half cone angles from literature and our measurement are summarized in Table 1.

	polymer nanopore	nanopipette	patch pipette
θ(deg) from literature	2.3±0.3	NA	NA
θ(deg) from measurement	2.6±0.15	2.5±0.3	4.5±0.8

TABLE I: Half inner cone angles θ of the three conic structures. Ref. [2, 3] are used to estimate the half cone angles of polymer nanopore. Scanning electron microscope images of base diameter and wide-field microscopy images of pipettes are used in our own measurement of half cone angle.

Potassium chloride (KCl) solutions of different concentration were used as working electrolyte. Measurement were performed with one Ag/AgCl electrode inserted in tip reservoir acting as working electrode and the other in base reservoir acting as auxiliary/reference electrode. Both electrodes were connected to a Keithley 2636a sourcemeter and the current signal was recorded by a PC with TSP express software (Keithley). Experiments were conducted at 22°C in atmospheric pressure.

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