# Supplementary Information

## Microelectrochemical Cell Arrays for Whole-cell Currents Recording through Ion Channel Proteins based on Trans-Electroporation Approach

Tianyang Zheng[a,b,*], Gerhard Baaken[c,d], Jan C. Behrends[c], Jürgen Rühe[b]

[a] *State Key Laboratory of Precision Measurement Technology and Instruments, Department of Precision Instrument, Tsinghua University, 100084, Beijing, China*

[b] *Laboratory for Chemistry and Physics of interfaces, Department of Microsystems Engineering (IMTEK), University of Freiburg, Georges-Koehler-Allee 103, D-79110, Freiburg, Germany*

[c] *Laboratory for Membrane Physiology and - Technology, Institute of Physiology, University of Freiburg, Hermann-Herder-Str. 7, D-79104, Freiburg, Germany*

[d] *Ionera Technologies GmbH, Hermann-Herder-Str. 7, D-79104, Freiburg, Germany*

[*] Corresponding author:

Postal address: Dept. of Precision Instrument, Tsinghua Univ., Beijing, China, 100084

Tel: +86-010-62783199

E-mail: zhengty@mail.tsinghua.edu.cn

## Microchip fabrication

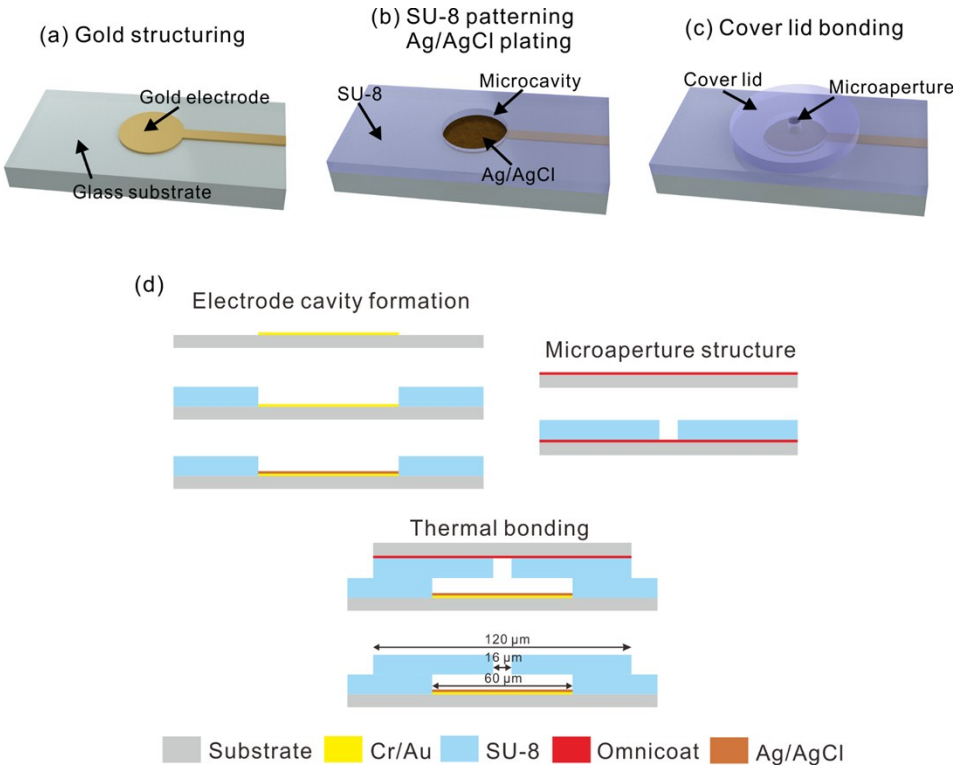


**Figure S1**. Schematics of fabrication processes of the microcavity structure with Ag/AgCl electrode. (a) Gold layer is structured on the glass substrate for the microelectrode array with electron beam evaporation and lift-off processes. (b) The microcavity is generated in a SU-8 film coated on the glass substrate with photolithography process followed by Ag/AgCl layer deposition via DC electrical plating. (c) Cover lid with microaperture bonding to seal the microcavity. (d) Detailed fabrication processes including electrode cavity formation, microaperture structuring and thermal bonding these two structures together. After resolve the Omnicoat layer, the undercut structure is released.

## DEP cell trapping

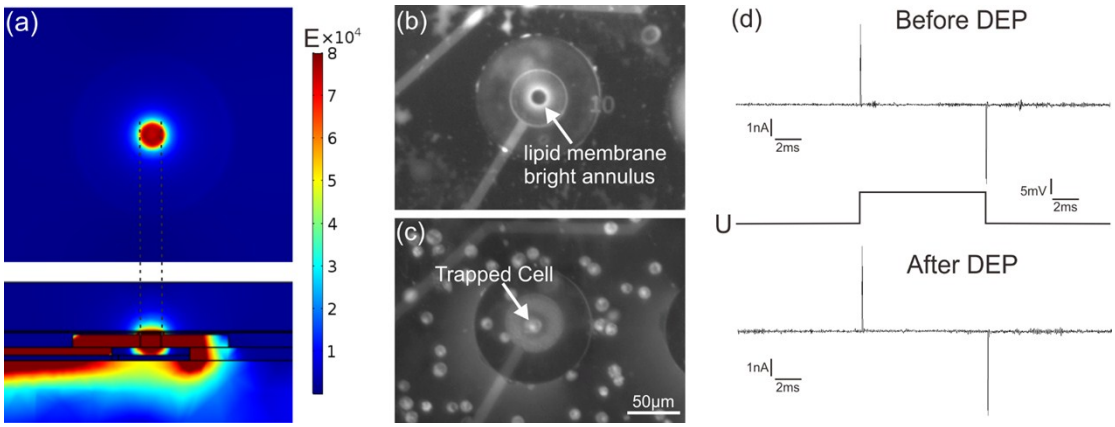


**Figure S2**. Cell trapping using positive dielectrophoresis (pDEP) through a lipid bilayer covering on the microaperture. (a) Simulation result for the electrical filed intensity. The maximum region of the electrical intensity is generated at the microaperture which can trap cells in low conductive solution with pDEP effect. To generate pDEP force, a 4 $V_{pp}$, 10 MHz AC signal is applied to the Ag/AgCl microelectrode through the lipid membrane over the aperture (bright annulus in (b)). After the signal is applied, the cell around the microaperture is trapped to the center (c). The lipid membrane is still intact after the cell trapping, which is confirmed by probing the membrane resistance (d). The sealing resistance is still remained in a high level (appx. 20 GΩ) after cell trapping process corresponding to the prevent of lipid bilayer. The buffer solution is a mixture of 250 mM sucrose solution and patch-clamp test solution (mainly contain 130 mM KCl) at a 5:1 ratio.

**Capacitance of lipid bilayer system**

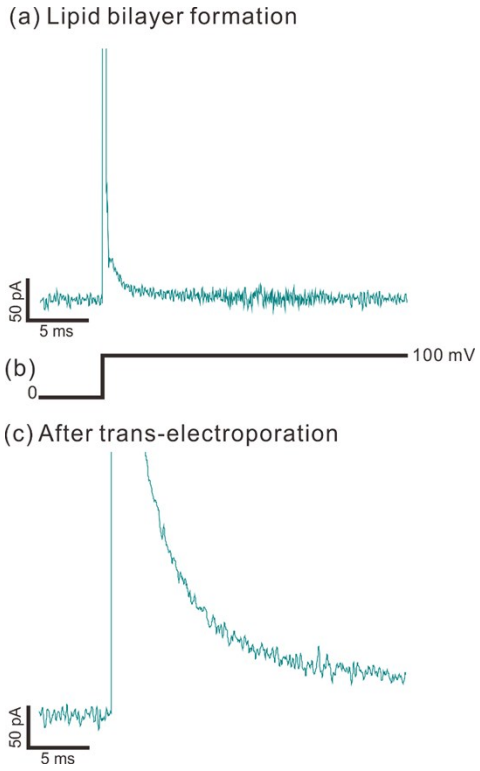


**Figure S3**. Magnified scale of current responses shown in **Figure 3** (a) and (c) at the very first milliseconds when the voltage protocol (100 mV) is applied. (b) is the voltage step from 0 to 100 mV.

## Multi-times current recording

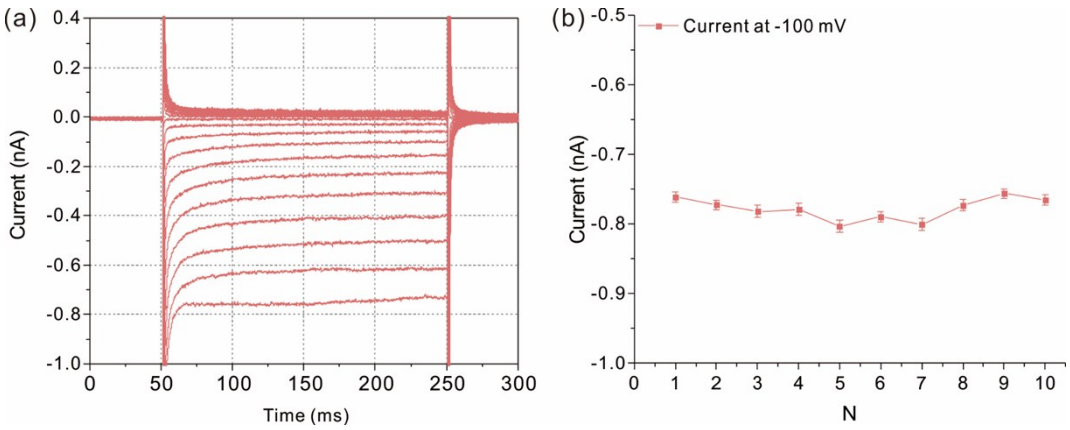


**Figure S4.** Multi-time current recording with the same microelectrode. (a) Current responses of the first test to voltages protocol from -100 mV to 100 mV applied. (b) The mean current values at -100 mV during ten repeated tests which lasts around 1 min. The error bars represent the RMS noises of the current responses at each voltage.

**Electrostability test**

The electrostability and life-time of the Ag/AgCl microelectrode was measured by a voltage-clamp approach in 150 mM KCl aqueous solution. A constant holding voltage with +100 mV from *trans* side was applied between the counter Ag/AgCl wire and one of the microelectrodes. The silver at the microelectrode/electrolyte interface reacted to form a dense AgCl layer. At this point, further charge transfer was maintained only by solid state diffusion of unreacted silver out of the bulk silver electrode, which occurred at a relatively slow rate, thus greatly reducing the microelectrode's conductivity. Accordingly, we defined the life-time of a microelectrode as the time of high conductivity (i.e. during which unreacted silver at the electrode/electrolyte interface could react) which ended when the surface of the electrode was completely covered by AgCl layer. The microelectrodes with longer life-time were referred to be more stable in the ionic current recording.

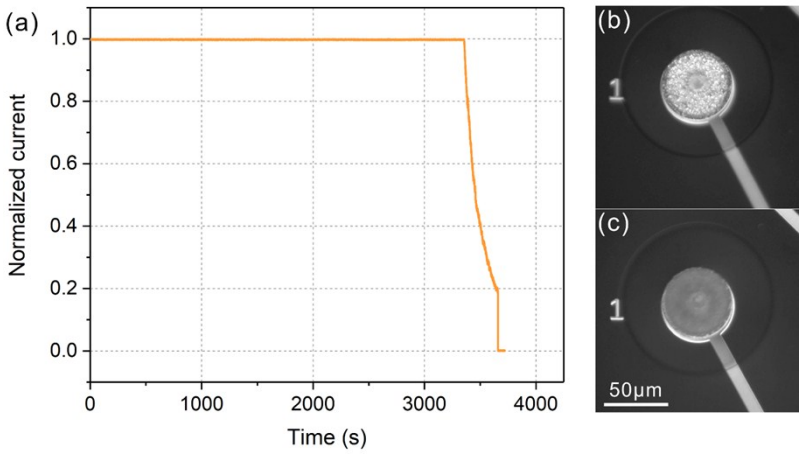


**Figure S5**. (a) Normalized current responses in electrostability tests and the electrode can be stable for more than 1 hour at a 100 mV holding voltage performed with 150 mM KCl solution. Two sizes of electrodes were tested, including 60 μm. (b) and (c) indicate the electrode condition with pure silver deposition and after the stability test.

## Cell current recording without PEG assistance

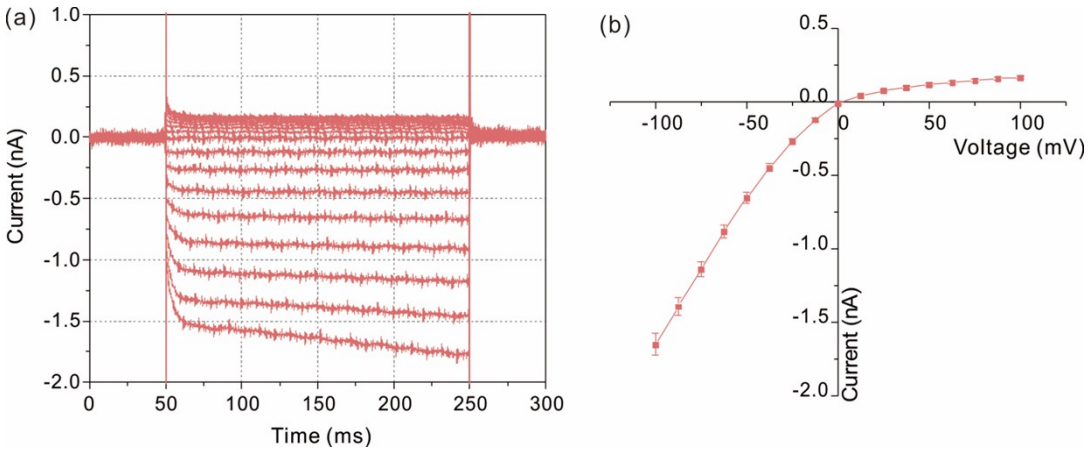


**Figure S6**. Current recording on $K_{ir}$ channel in the case of PEG absence. (a) Current responses to voltages protocol from -100 mV to 100 mV. The rectification behavior of $K_{ir}$ channels is observed. (b) I-V curve from the ionic current responses in (a). The symbols indicate the mean values of the current responses at different voltages and the error bars represent the RMS noises of the current responses at each voltage. Accordingly, the sealing resistance is around 600 MΩ.

## Current recording without cell

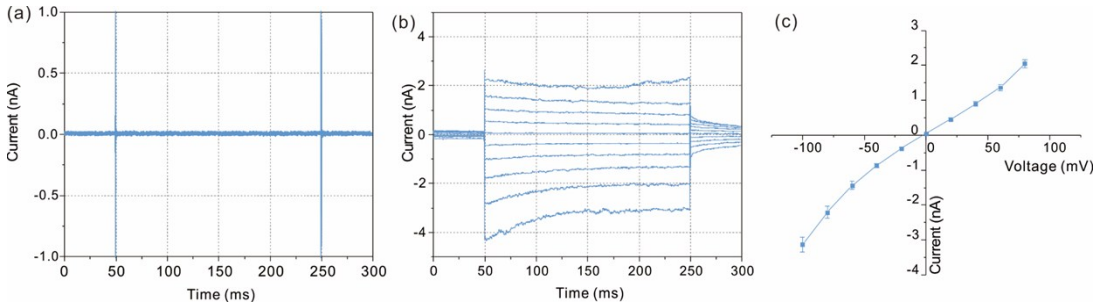


**Figure S7**. Ionic current recording with lipid bilayer electroporation. (a) Painted bilayer provides a robust sealing. Low current responses are recorded at voltages from -100 mV to 100 mV before voltage pulse electroporation. (d) Symmetric current distribution is observed surrounding zero at negative and positive potentials. (c) I-V curve of the current responses. The symbols indicate the average value of the current responses at different voltages. The current increases dramatically both at negative and positive voltages. The error bars represent the RMS noises of the current responses at each voltage.