

SUPPORTING INFORMATION

Fabrication of the planar microelectrode array. The microelectrode array has been fabricated on glass substrate by using photolithography, wet etching and a CMP (chemical mechanical planarization) process. The soda-lime glass is ideally suited for fabricating microfluidic devices due to its low cost, high optical transparency and durability to solvents. Soda-lime glass is a multi-component mixture consisting of mainly SiO₂ and other components like Na₂O, CaO, MgO, and small amounts of Al₂O₃. To remove organic contamination, the glass substrate was first cleaned in Piranha solution (H₂SO₄ : H₂O₂, 4 : 1) for 10 min, then dried by blowing N₂ after a 5 min DI rinse. The dehydration process was carried out by baking the glass on a hot plate at a temperature of 200 °C for 15 min. Next, the Ti (200 Å) and Au (2000 Å) films were deposited respectively on the glass substrate to form microelectrodes by using DC magnetron sputtering (SRN610, Sorona Co., Korea). The microelectrodes were patterned by conventional UV photolithography and wet etching processes. SiO₂ (1.5 μm) was deposited as a passivation layer on the top of the microelectrodes by Plasma-enhanced chemical vapour deposition (PECVD) (Lab80Plus, Oxford, UK) to insulate them. The passivation (oxide) layer is not uniform and step heights could be observed due to the presence of microelectrodes under the layer. To obtain the flat surface of passivation layer, the CMP process was carried out by a CMP polisher (UNIPLA110, Doosan, Korea) with IC1000 (Rohm & Haas, USA) pad. Pad pre-wetting was performed before the start of the polishing. Ex-situ pad conditioning was performed with a 6-inch diamond conditioner (Ehwa Diamond, Korea) for 1 min to maintain uniform removal rate of oxide surface. The polishing was done for 2 min at a slurry flow rate of 500 ml/min at centre and 200 ml/min at edge. Other process parameters were maintained as follows: 120 rpm spindle speed, 10 rpm platen speed, 6 psi wafer pressure, 6 psi R-ring pressure and 5 psi

back pressure. Post CMP cleaning process was conducted to remove the slurry residues in SC1 solution ($\text{NH}_4\text{OH} : \text{H}_2\text{O}_2 : \text{DI water}$, 1 : 1 : 5) for 3 min. After the planarization of the passivation layer, an etch back process was performed to open the second microelectrode by dry etching (AOE, STS, UK) process. Subsequently, all of the embedded microelectrodes were observed by an optical microscope (L150A, Nikon, Japan). Twelve exposed $25 \times 500 \mu\text{m}$ gold electrodes were available. To create the sample well, a casting dish was prepared by using straight tubing glued in the middle of a petri dish. A ratio of PDMS resin 10 g to hardener 1 g were mixed and degassed in a vacuum chamber for 10 minutes. The PDMS mixture was then poured into the casting dish and cured in the oven at $60 \text{ }^\circ\text{C}$ for 1 hour. The PDMS sample well was peeled off from the casting dish and was bonded onto the glass microchip by exposing both PDMS and glass surfaces to O_2 plasma treatment for 12 s at 50 watt with chamber pressure set to 150 mtorr. Both treated surfaces were aligned and attached together once taken out from the chamber. Electrical contact was achieved by using conductive epoxy (CircuitWorks®) to connect the insulated copper wire to the gold pads on the microchip and cured in the oven at $60 \text{ }^\circ\text{C}$ for 30 minutes to ensure proper curing of epoxy.

Supplementary Figure 1. Planar MEA. Alpha-step measurements of the passivation layer were conducted during the fabrication. Prior to the CMP process, **(A)** the step height of passivation layer extends 4314.8 Å. **(B)** Following CMP process, this passivation layer is made planar. **(C)** After the planarization of the passivation layer, an etch back process was performed to open the second microelectrode by dry etching process. The exposed Au had 17nm height by this etch back process, resulting in a relatively planar surface. **(D)** An optical microscope image of the MEA being tested is shown. **(E)** At higher magnification of a single electrode, the two Au layers can be seen. Following etch back, only the 2nd Au layer is exposed, but remains planar with the passivation layer. The electrode size for the active 2nd Au region is 25 × 150 μm. **(F)** This electrode pattern can be represented in a schematic diagram showing a cross-view of the device. The 2nd layer acts as the active regions for electrochemical sensing, while the 1st Au layer provides the electrical connection to the exterior contacts. **(G)** Photograph of the final device, where the electrical connection is carried out by soldering metal wires to the gold connection pads and a PDMS well attached to the gold surface glass using O₂ plasma treatment.

Supplementary Figure 1

