Supplementary Material (ESI) for Lab on a Chip

Formation of Artificial Lipid Bilayers using Droplet Dielectrophoresis

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- **Supplementary Information**
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SUPPLEMENTARY INFORMATION

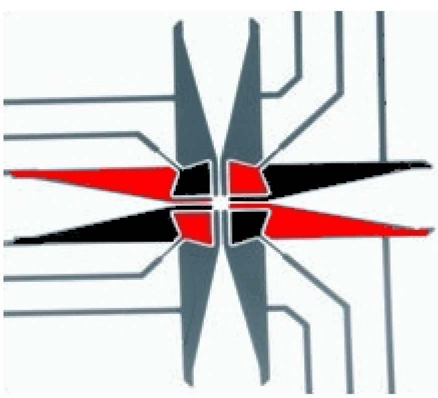
Device Microfabrication

Devices for were fabricated on 6” glass wafers. The electrode structures were created from an evaporated Ti/Pt layer (10/200 nm thick) that was patterned by ion-beam milling. Electrode fabrication and wafer dicing was carried out by Philips (MiPlaza, Eindhoven, The Netherlands).

Before use, a device was cleaned with acetone and isopropanol (IPA) and baked on hotplate at 150°C for 15 minutes to remove adsorbed water from the surface. It was then spin coated with TI Prime adhesion promoter (MicroChem Corp., USA) at 3000 rpm for 20 s, and baked at 120°C for 2 minutes on a hotplate. Two layers of SU8 2000.5 (MicroChem Corp., USA) were then deposited by spin coating a 14% cyclopentanone solution at 6000 rpm for 30 s, followed by soft-baking on a hot plate at 105°C for 1 min. The device was then exposed to UV light (broadband source with IR filter) for 1 min and post-baked at 125°C for 60 s. This produced a 0.7 μm thick SU8 layer as confirmed using a profilometer. Lastly, a plastic reservoir was glued onto the surface of the device to contain the lipid-decane solution.

Electrical Parameters

When applying a potential to both the inner electrode (2-2’ and 3-3’) and outer electrode (1-1’ and 4-4’) pairs, the configuration employed was:



Red: 12 V_{rms}
Black: 0 V

The voltage required to move a droplet was frequency-dependent. Over the frequency range from 100 Hz to 1 MHz, it was found that the lowest voltages required for droplet movement was in the range 1-10 kHz and a value of 2 kHz was chosen for all experiments. Droplet velocity is in the range of mm s^{-1} and varies as a function of the voltage square.

3-Droplet Network Formation

To form a 3-droplet network, a voltage (12 V at 2 kHz) was first applied to the top (5-5’) and inner electrode (2-2’ and 3-3’) pairs and subsequently only to the inner electrodes to position the central droplet in the middle of the device. A voltage was then applied to the outer electrode pairs (1-1' and 4-4') to move the outer droplets towards the central droplet. Before they contacted, the voltage was temporarily switched off and Ag|AgCl electrodes were inserted into the outer droplets. The voltage was then re-applied and the droplets moved into contact. At this point, two BLMs formed at the droplet-droplet interfaces, BLM formation was confirmed by recording gramicidin ion-channel.

Electric Field Simulations

The electric field produced by the electrodes was simulated using Comsol Multi-Physics finite element software. The Laplace equation was solved to give the potential, the electric field and the Maxwell stress tensor calculated with a droplet of fixed dimensions on the dielectric layer. The permittivity of the decane was set to 2 with zero conductivity and the droplet conductivity was set to 1 S m^{-1}. The system was simulated for four different configurations, as in Supplementary Figure 1 (rhs). The simulation shows the magnitude of the Maxwell stress tensor over the droplet surface, plotted along the *y-z* plane for each configuration:

(a) droplet at start position, voltage applied to both pairs of electrodes;
(b) droplet moves to end of wedge shaped electrodes, voltage applied to both pairs of electrodes;
(c) droplet moves to rest position on the inner electrode pair, voltage applied to both pairs of electrodes;
(d) field configuration for moving droplet backwards, voltage applied only to outer pairs of electrodes.

The scale is the magnitude of the stress tensor (N m^{-2}) and the simulations show the imbalance in pressure and therefore the direction in which the droplet moves. The stress distribution is only significant close to the interface between the droplet and the dielectric layer, therefore the top hemisphere has been omitted. The integral of the stress tensor over the droplet surface shows that the force is in the order of nN.

Fig. 1 ***Simulation of the Maxwell Stress Tensor***

Shows the magnitude of the Maxwell stress tensor over the droplet surface, plotted along the *y-z* plane, for four different droplet positions with two different electrode configurations (a potential applied to both the inner and outer electrodes (a-c) and to the outer electrodes only (d)). In this simulation (a-b-c-d) only the stress tensor in the droplet is shown: the view is not a cross section of the droplet, instead it is a projection of the outer surface of the droplet from the *y-z* plane. Only the bottom half of the droplet is shown, because the stress tensor field is negligible in the upper half. As the droplet moves along the electrodes, the stress tensor changes: (a-b) droplet moves towards the centre; (c) no net force exerted on the droplet (no droplet movement); (d) droplet moves outwards.

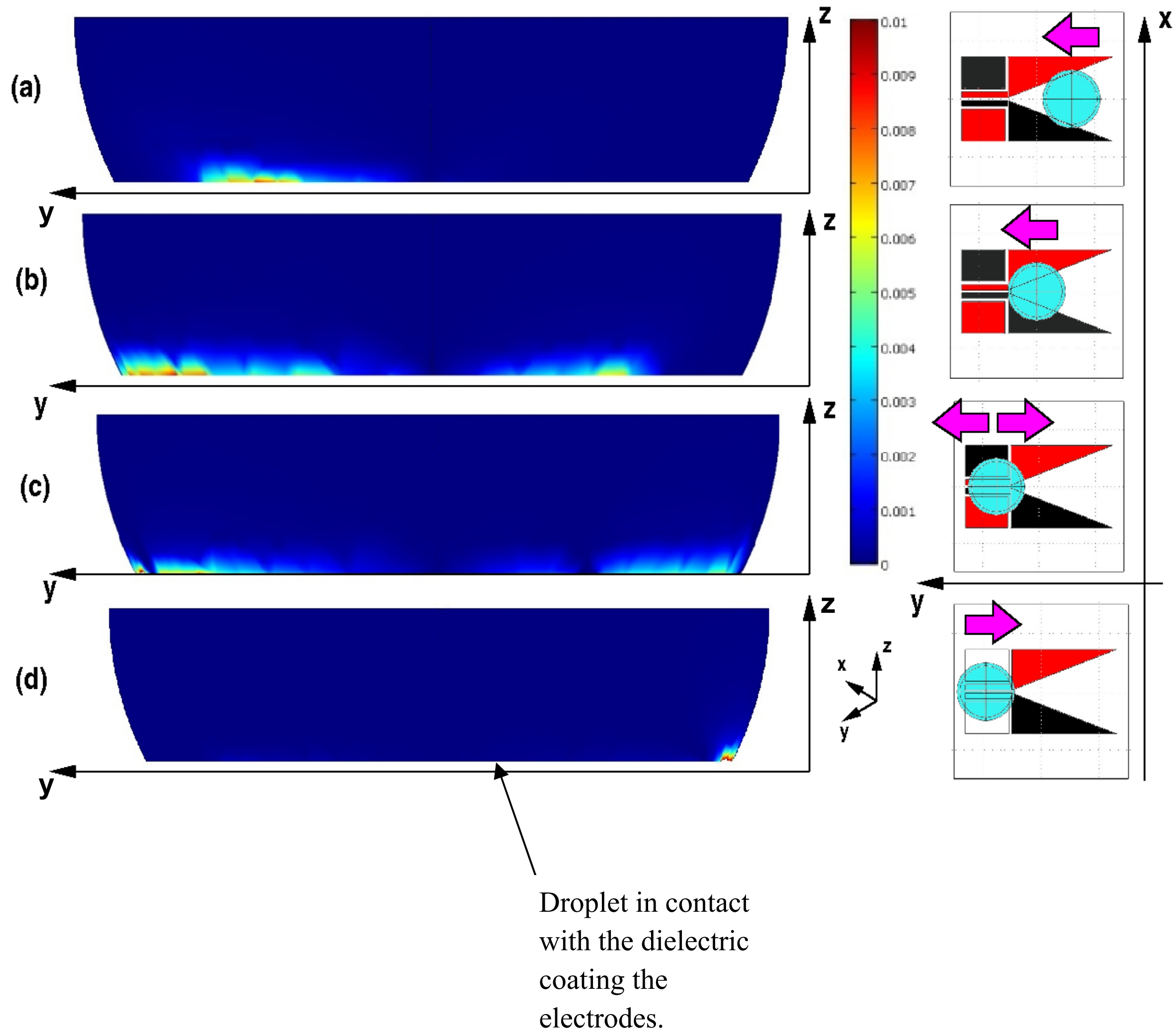


Fig. 2 ***The lifetime of a BLM***

A capacitance trace showing the lifetime of a BLM. After approximately 20 h, the capacitance begins to drops sharply as the BLM shrinks.

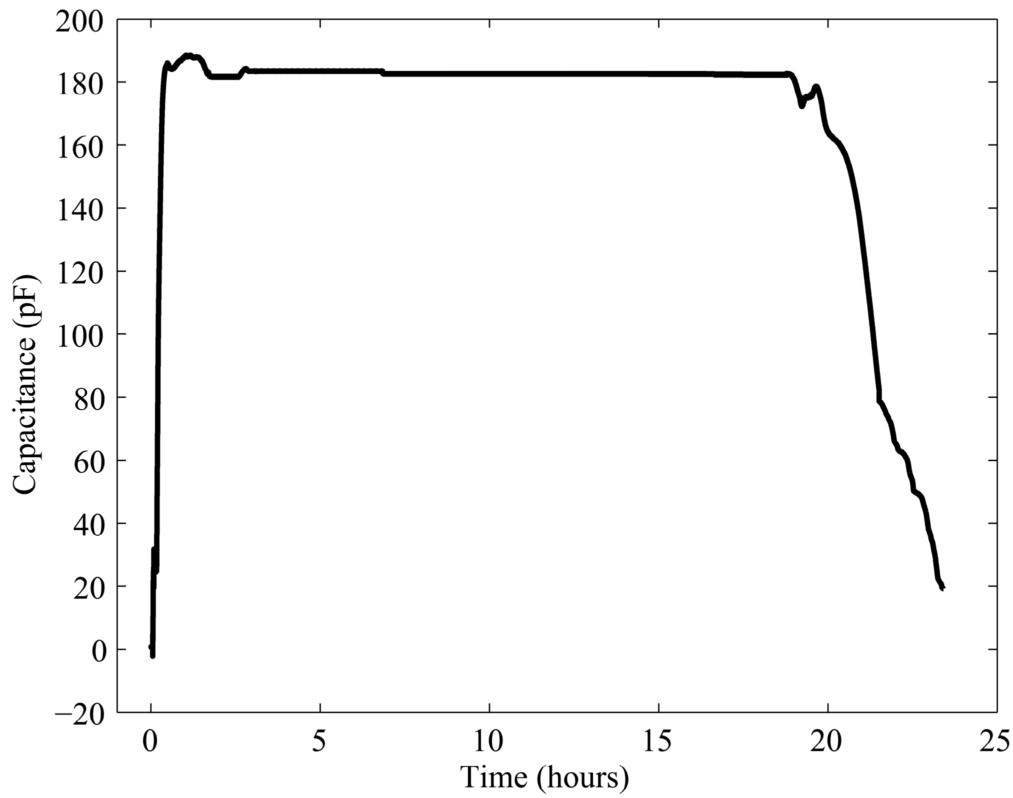
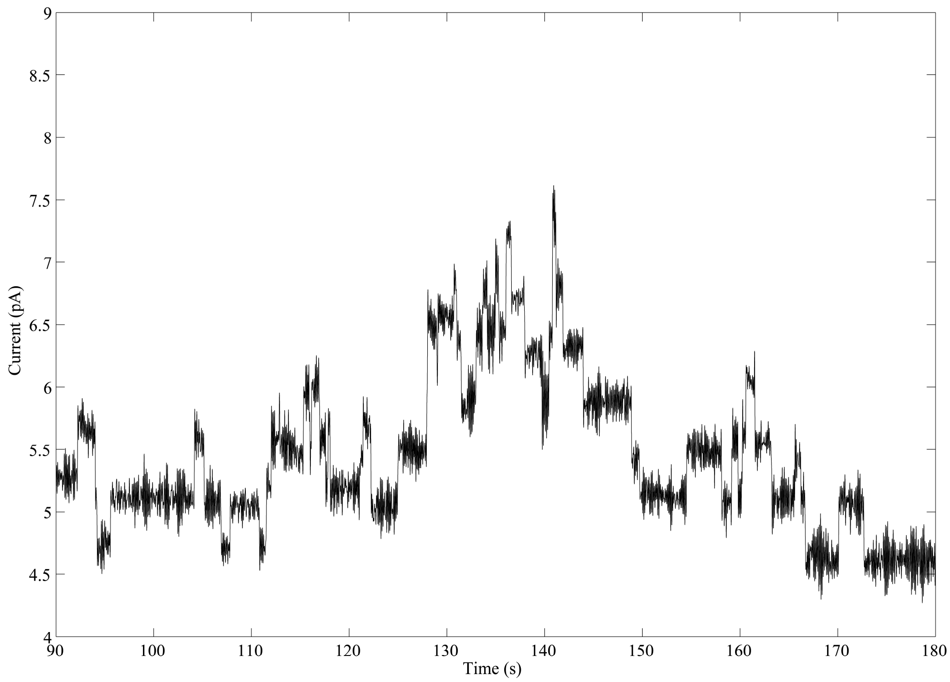


Fig. 3 ***Gramicidin recording from a 3-droplet network***

A recording of gramicidin activity where the Ag|AgCl electrodes were immersed in the outer two droplets of three droplet chain. The potential applied was 75 mV.



Video 1 ***The formation of a BLM***

A movie showing the two stages of the BLM formation process: the initial inward droplet movement and (following electrode insertion) the bringing into contact of the two droplets.

Video 2 ***The disassembly and reformation of a BLM***

A movie showing the formation and subsequent disassembly of a BLM, repeated twice. The movie has a speed of x4.

Video 3 ***Electrical breakdown of a BLM***

At approximately 6 s, a potential large enough to cause electrical breakdown of the BLM is applied (300 mV). This causes the droplets to merge and the buffer solutions to mix by diffusion (the colour of the solution over the gap between the central electrodes can be seen to change as diffusive mixing proceeds).