FLUIGENT
MICROFLUIDICS MADE EASY™

WATER-IN-OIL DROPLETS: POSITION CONTROL WITH LIQUID ELECTRODES

Demonstration of Electrowell-generated on-chip liquid electrodes to replace embedded electrodes

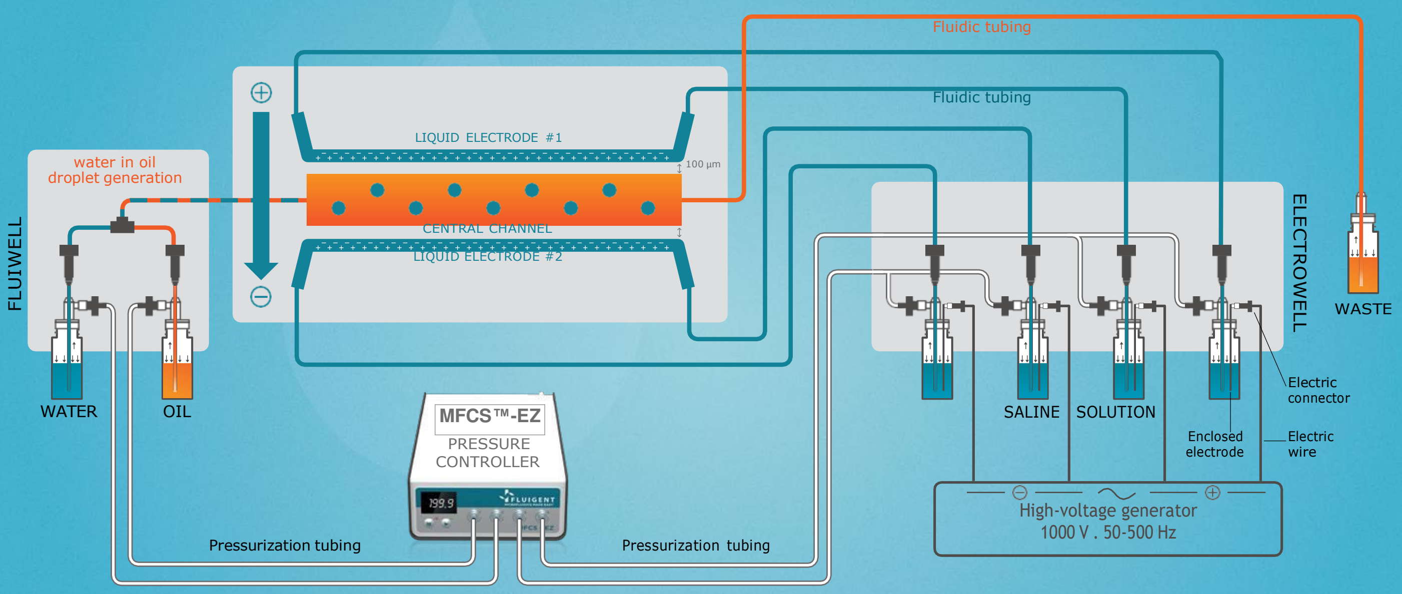

***Figure 1**: Diagram of the droplet manipulation setup with Electrowell-generated liquid electrodes*

INTRODUCTION:
USE OF ELECTRODES IN MICROFLUIDICS

Many microfluidic applications are developed based on concepts relying on electrodes, exploiting the electrical properties of samples to sort or separate them, generate electro-osmotic flows, manipulate particles, perform electrochemical detection... One example of this is electronic paper, where the electrophoretic displacement of titanium dioxide particles in a dark hydrocarbon oil solution allows the formation of a black and white pattern with a high resolution.

Most of the time, this implies complex microfabrication processes to build embedded electrodes inside the microfluidic chip. This can be avoided by the **use of Fluigent's Electrowell device, which combines pressurized fluid reservoirs with a choice of electrodes**. These charged reservoirs can be simultaneously connected to an MFCS™-EZ pressure controller and a high voltage generator in order to generate both a pressure-driven flow and/or an electroosmotic flow in the fluid.

This application note explains how a droplet manipulation setup using embedded conventional indium electrodes could be replaced with a microchip using Electrowell-generated liquid electrodes, with a simpler design that provides enhanced performance.

MATERIAL USED
TO CONTROL FLOWS

PRODUCTS	NAME & USE
	**MFCS™-EZ** Microfluidic pressure pump to generate fast and pulseless fluid movement (1 bar).
	**ELECTROWELL** Microfluidic accessory to create an electric field inside a microchannel while pressurizing the samples.
	**FLUIWELL (1C & 4C)** Reservoirs (2ml and 15ml) for cell samples and buffers.

APPLICATION:
WATER-IN-OIL DROPLETS POSITION CONTROL WITH THE ELECTROWELL

The initial setup uses two embedded indium wires running outside a central channel where water-in-oil droplets flow. When the right voltages are applied on the electrodes, **a transverse electric field is created across the droplets channel**, changing their position within the channel. To fabricate the electrodes, indium is cast inside special channels on the chip: this is a complex step with a high risk of irreversibly deteriorating the chip.

In the Electrowell setup, **the indium electrodes are replaced with liquid electrodes by filling the side channels with a conductive solution** (water solution saturated with salts) instead of indium. The diagram of the Electrowell setup is shown in Figure 1 on cover.

Standard MFCS™-EZ-pressurized reservoirs (Fluiwell) of oil and water are connected to a T-junction upstream of the chip, were the droplets are generated (2 to 3 droplets per second) before flowing through the central channel. The water contains carbon black pigments that make the droplets behave as electric dipoles. **Electrowell reservoirs of conductive solution with platinum enclosed electrodes are connected to the side channels**. They are firstly pressurized with the MFCS™-EZ in order to fill in the side channels with salted water.

Then, **an alternating current is applied on the Electrowell reservoir-enclosed electrodes**: the top side channel becomes positively charged while the bottom side channel becomes negatively charged, generating a transverse potential difference across the central channel (cf. Figure 1 on cover). **A continuous low pressure of 100 mbar is applied on the inlet reservoirs of the liquid electrodes** to maintain a low flow-rate in the liquid electrode channels.

The electric field resulting from the induced potential difference between the two liquid electrodes triggers a spatial reorganization of the droplets within the central channel. When the electric field is applied, the first dipole droplets are attracted towards one liquid electrode or the other, the intensity of the attraction increasing all the more that the droplets get further from the centre of the channel. The displacement of the droplets furthermore generates a perturbation of the hydrodynamic flow that impacts the following droplets. **This perturbation of the flow, along with the potential difference effect and the droplet generation frequency, is at the origin of the rearrangement of the droplets in the central channel**. This is the same phenomenon as already characterized in the indium electrode microchip.

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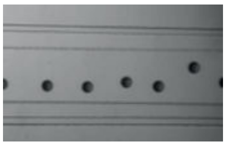
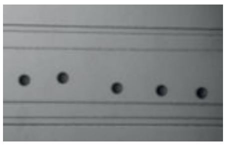
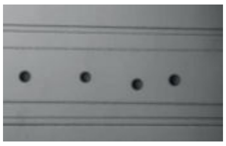
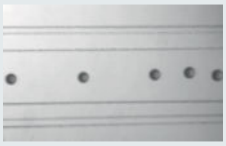
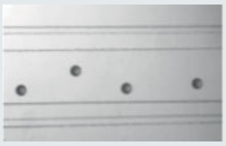
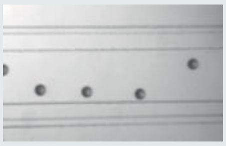
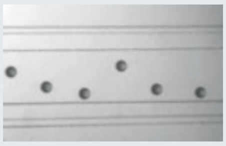
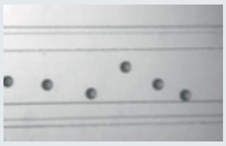
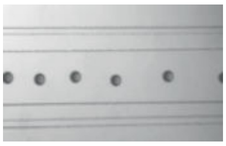
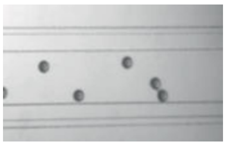
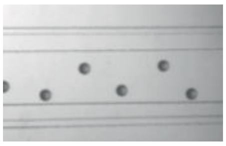
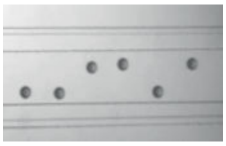
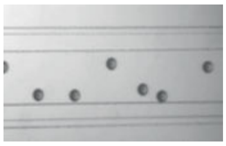
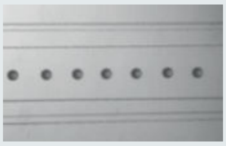
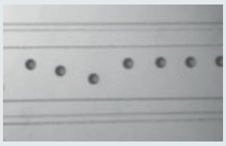
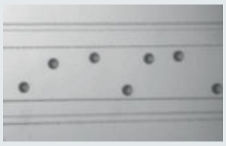
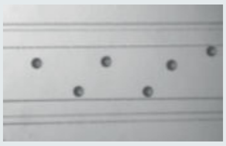
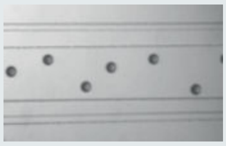
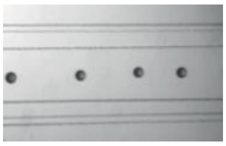
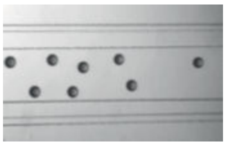
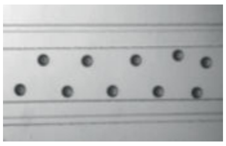
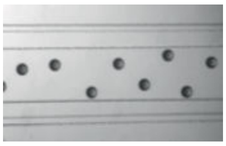
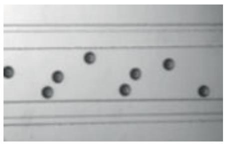
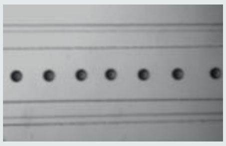
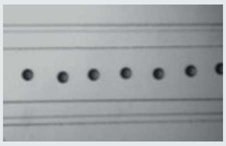
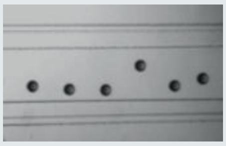
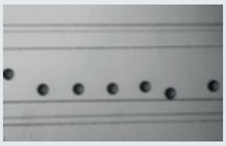
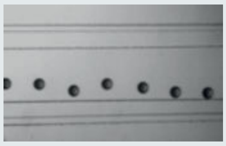
0.1 Hz					
0.5 Hz					
1 Hz					
5 Hz					
10 Hz					
50 Hz					

Table 1*: Characterization of the droplets reorganization in the Electrowell setup at different frequencies*

The droplets response with the Electrowell setup is then characterized with pictures taken at different voltage frequencies, for an alternating voltage of ±500V. The voltage is chosen alternative in order to avoid a saturation of the charges and the subsequent electric field screening that would impair the phenomenon of interest. In addition the voltage is chosen high because of the decrease of potential within the PDMS between the liquid electrode and the working channel. The results are shown in Table 1, the first column showing the initial droplets configuration (no electric field).

The electric field produced by the liquid electrodes generated with the Electrowell triggers an effective displacement of the droplets within the central channel, which can be observed for different voltage frequencies. We see optimum conditions are in the region of 10 Hz.

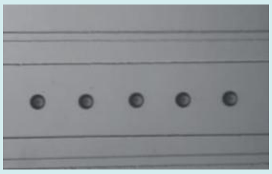
The next step of this experiment is the creation of Janus droplets, droplets with two faces, one black and one white. The polarization of these droplets will allow the display of a black and white pattern that will be more rapid than the current system.

CONCLUSION

The Electrowell enables one to apply a simultaneous pressure and voltage to a liquid and induce a flow inside a microfluidic system. It imposes a difference of potential at the terminal of a microfluidic system to create an electric field that initiates the displacement of droplets. It can functionally replace traditional embedded electrodes, simplifying the user's operation while maintaining the same behavior and performances of the experiment.

Source	Equipment	Reagents/consumables
Fluigent	MFCS™-EZ 4C (345 mbars) with OxyGEN software	Fittings and tubing
Fluigent	Electrowell	Disposable vials
Watson Smith	Air regulator	¼'' Tygon tubing
Leica	Microscope	
MMN Laboratory		Microfluidic chip
Sigma aldrich		Mineral oil , Carbon black pigments, Span 80

MORE INFORMATION



See video on YouTube:
http://www.youtube.com/watch?v=5dPNzAh4tg0

ACKNOWLEDGEMENTS & REFERENCES

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