Video Article

AC Electrokinetic Phenomena Generated by Microelectrode Structures

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Abstract

The field of AC electrokinetics is rapidly growing due to its ability to perform dynamic fluid and particle manipulation on the micro- and nano-scale, which is essential for Lab-on-a-Chip applications. AC electrokinetic phenomena use electric fields to generate forces that act on fluids or suspended particles (including those made of dielectric or biological material) and cause them to move in astonishing ways[1, 2]. Within a single channel, AC electrokinetics can accomplish many essential on-chip operations such as active micro-mixing, particle separation, particle positioning and micro-pattering. A single device may accomplish several of those operations by simply adjusting operating parameters such as frequency or amplitude of the applied voltage. Suitable electric fields can be readily created by micro-electrodes integrated into microchannels. It is clear from the tremendous growth in this field that AC electrokinetics will likely have a profound effect on healthcare diagnostics[3-5], environmental monitoring[6] and homeland security[7].

In general, there are three AC Electrokinetic phenomena (AC electroosmosis, dielectrophoresis and AC electrothermal effect) each with unique dependencies on the operating parameters. A change in these operating parameters can cause one phenomena to become dominant over another, thus changing the particle or fluid behavior.

It is difficult to predict the behavior of particles and fluids due to the complicated physics that underlie AC electrokinetics. It is the goal of this publication to explain the physics and elucidate particle and fluid behavior. Our analysis also covers how to fabricate the electrode structures that generate them, and how to interpret a wide number of experimental observations using several popular device designs. This video article will help scientists and engineers understand these phenomena and may encourage them to start using AC Electrokinetics in their research.

Video Link

The video component of this article can be found at https://www.jove.com/video/813/

Protocol

Fabricating Cr/Au Electrodes on Glass Substrates

Part 1A: Wet Etch Method

*For the highest quality devices, the fabrication process should be performed in a clean room environment or under laminar flow hoods so that dust and other contaminants won't affect the pattern.

1. 2-inch by 4-inch Glass slides are placed in a heated (80°C) Piranha solution (5:7 H_2O_2:H_2SO_4) for 30 minutes to remove contaminants (especially organic) and then rinsed in DI water and dried with compressed air.
2. 20 nm Cr and 200 nm Au are deposited onto the substrates with an electron beam evaporator.
3. Shipley 1827 positive photoresist is deposited on the glass slides with a spincoater (3000 rpm, 1000 rpm/s ramp, 30 second spin time).
4. Substrates are then soft baked for 2 minutes at 100°C.
5. The pattern of the mask is transferred to the photoresist with contact UV exposure for 8.4 seconds for a total of 206 mJ/cm^2.
6. The photoresist is developed in Microposit MF 351:Water (1:3) for 30 seconds with good agitation followed by a DI water rinse.
7. After inspection with a microscope to ensure good development, the substrates are then etched in Au Etchant and Chrome etchant for 15 seconds and 30 seconds respectively with DI washes in between and after.

Part 1B: Alternative Protocol - Lift-off Method

1. 2-inch by 4-inch Glass slides are placed in a heated (80°C) Piranha solution (5:7 $H2O_2$:H_2SO_4) for 30 minutes to remove contaminants (especially organic) and then rinsed in DI water and dried with compressed air.
2. Futurrex NR-7 1500 PY negative photoresist was spincoated onto the substrate (2000 rpm, 1000 rpm/s ramp, 40 second spin time).
3. Substrates were soft baked for 1 minute at 150°C.

4. Contact UV exposure for 21 seconds (400 mJ/cm^2).
5. The substrates were then placed on a hot plate set at 100°C for 1 minute to complete the postbake step.
6. Development was performed for 6 seconds in Futurrex RD6 developer.
7. 30 nm Cr and 200 nm Au are then deposited onto the substrates with an electron beam evaporator.
8. Lift-off is performed by placing the substrates in an acetone ultrasonic bath till the gold was visibly removed and confirmed with microscope observation.

Experimental Setup

Part 2: Microsphere injection and observation

1. PDMS channels (fabrication described elsewhere) are attached to the glass substrate with direct adhesion so that the channel passes over the fabricated electrodes.
2. Approximately 10^7 ml polystyrene microspheres are suspended in either DI water (0.0002 S/m) or a KCl solution (0.05 S/m). They are then injected by placing the tubing inlet in the microsphere solution and applying suction to the outlet with a syringe.
3. The loaded device is then placed on the microscope stage and connected to a signal generator.
4. A time course of frequency settings (1 kHz to 1 MHz) and voltage settings (1 or 2 V) are applied while observations are made with the microscope.

Note: It is important not to raise the voltage too high or allow the frequency to get too low or electrolysis of water will occur. The exact voltage or frequency settings for this to occur are dependant on the electrode design. Our lab guidelines are to avoid frequencies below 500 Hz or voltages above 8 V.

Discussion

In this video, we have shown a wide variety of particle and fluid manipulation behaviors caused by AC electrokinetic phenomena. The electrodes that generate these phenomena are easy to fabricate and can be easily integrated into many other systems. As we have shown, there are numerous applications for the use of AC electrokinetics. The versatility of these devices, as well as the rapid nature of manipulation, makes them particularly attractive. As healthcare and other industries begin to embrace lab-on-a-chip systems, we will likely see the incorporation of AC electrokinetics on those devices as an integral part.

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