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DROP STIRRING FLOW UNDER EWOD AND EHD ACTUATION: A NEW STEP TOWARDS BIOLOGICAL SAMPLE PREPARATION

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ABSTRACT

This paper addresses electrically-induced drop mixing. The configuration studied here is typical of electrowetting on dielectrics (EWOD) – based actuation with a drop staying on a hydrophobic dielectric substrate. Application of normal and tangential components of an electric field at and along the interface is found to give rise to an electric surface stress able to pump drop vortices (electrohydrodynamics of Taylor-Melcher type) with a remarkable efficiency.

Keywords: Electrowetting, Electrohydrodynamics, Drop, Mixing

1. INTRODUCTION

Droplets as common carriers for bio-chemical agents have found growing impact in lab-on-a-chips devoted to bio-medical analysis. The basic operations addressed by a droplet-based lab-on-a-chip include generation, motion, coalescence and cutting. ElectroWetting On Dielectrics (EWOD) is a well-known physical mechanism capable of promoting all these digital operations [1, 2, 3]. This paper aims at investigating the abilities of EWOD to perform drop stirring as a new and useful operation.

Purification of biological samples proves to be a process to perform firstly in a digital lab on chip. EWOD could be thought of as the natural physics to use in order to get a fully integrated chain of digital micro-processes including typically centrifugation of a liquid sample. A centrifugation within a drop followed by EWOD-driven cutting could be a good way to purify a liquid sample and to extract target biochemical species. Recent experimental investigations have demonstrated that any EWOD-driven motion of a drop, even if submitted to circular trajectories, is never able to provide the centrifugation level required for purification purposes [4].

2. DROP MIXING AND EHD INTERPRETATION

Quite recently, we have produced a very efficient stirring (velocity~1m/s) within a 1mm-drop submitted to EWOD actuation but staying at rest over isolated electrodes. Different experimental configurations have been studied, especially those which are able to produce stable vortices. A pretty well organised flow is made evident making use of fluorescent DNA strands (figure 2) and hollow glass beads covering drop surface (figures 3, 4). Considering the frequency range of the applied AC voltage (1 KHz, 50V rms), electrohydrodynamics of Taylor-Melcher type (EHD, [5]) is found to be responsible for arising of vortices *via* the tangential component of the jump momentum balance across the drop surface. Considering the Ohmic current is much larger than the displacement current, the only non-vanishing electric charges accumulate to the drop surface provided that the dielectric permittivities of the involved fluids are different (water/air for instance) and that the electric field displays a component normal to the drop surface (Gauss' law, figure 1).

At points of the drop surface where a tangential electric component E_{θ} is made available, the resulting azimuthal Coulombic stress is balanced by a viscous stress. In this way, vortices are pumped within the drop. Depending on the way the drop is located with respect to the underlying electrodes, the EHD-driven flow exhibits either two or four vortices (see focusing of bead tracers on the vortices centres where local pressure is the smallest, figures 3, 4).

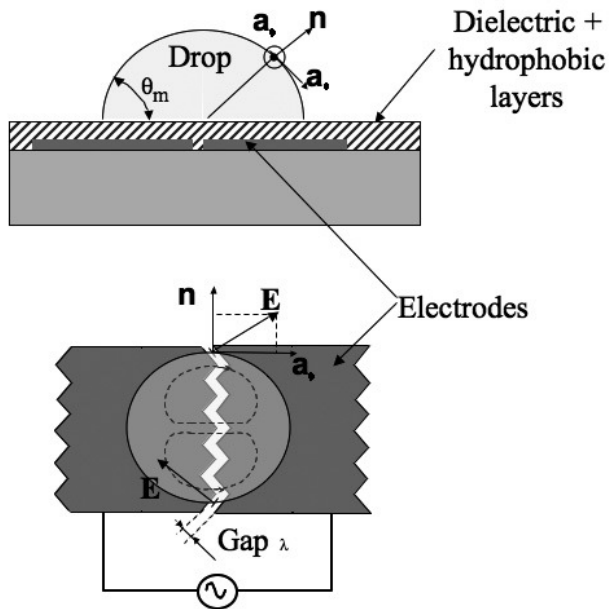


Figure 1: First configuration studied: one water drop staying over stripe electrodes. Side and top views.

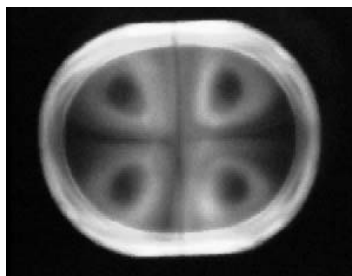


Figure 2: Vortical flow inside the deposited drop as made evident from solubilized labeled DNA strands (see top view in figure 1).

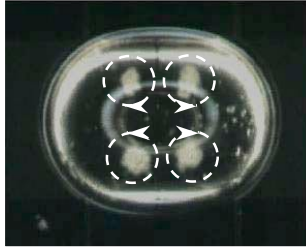


Figure 3: Same vortices made evident from the focusing of hollow glass beads over the drop surface. The water drop is as large as the actuation area.

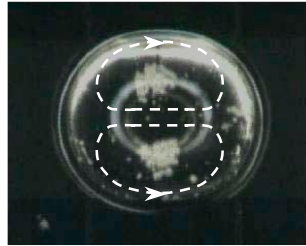


Figure 4. Vortices as made evident from the focusing of hollow glass beads over the drop surface. The drop is smaller than the actuation area (see also attached configuration in figure 1).

A modelling is put forward to predict the EHD-induced flow within a liquid spherical cap. Numerical calculations are performed considering the surface Coulombic stress behaves as a momentum source. The agreement with experimental results is fairly good if a specific constitutive law for the contact line dynamics is introduced [6]. Original geometries of electrodes are suggested in order to enhance drop centrifugation.

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