Sensitivity Optimization of Microfluidic Capacitance Sensors

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Abstract

Introduction:
Recently, the concept of lab on a chip has been gaining popularity, considering the many advantages it offers for applications such as point of care diagnostics, drug delivery and chemistry . Main features of this technology are reduced costs, ease of use for home care applications, faster assays and higher sensitivity [1]. The whole process of using lab on a chip can be divided into sample preparation, mixing, reaction, and characterization steps. All of these processes are performed on fluids present in microfluidic channels, and need to be suited for such channels.

As a part of the characterization process, more often it is required to measure dielectric constant of the fluid. It's important to perform this measurement on the chip itself to avoid any interaction with the macro world [2]. For this purpose it is necessary to develop a sensor whose size is compatible with microfluidic channel, is sensitive, and can be easily integrated. Such sensors have been reported earlier [3]. Figure 1 shows a simple structure of the sensor based on the concept of variation of fringing electric field arising out of a capacitor having co-planar plates.

The research presented in this paper studies effect of all the parameters influencing sensitivity of such a sensor and ultimately optimizes the dimensions to maximize the sensitivity.

Use of COMSOL Multiphysics:
First, a list of parameters associated to the fabrication procedure and sensitivity control are enumerated. These parameters, abbreviated, are shown in Figure 2. The geometry of the device is parametrized and built using the aforementioned five variables. AC/DC module in COMSOL was used to define the boundary value problem, the dielectric constants of the materials (PDMS is Polydimethylsiloxane, an elastomer)

Results:
Graphs of voltage along x and y directions were obtained, and the effect of the channel on electric field lines (perpendicular to equipotential contours) could be observed in Figure 3. From this solution of voltage, we obtain the capacitance of the system. The figure of merit for a configuration is taken as the percentage change in capacitance when a dielectric of constant 50 is present in the channel, and when the channel is filled with air.Varying the parameters one by one, this figure of merit was plotted as a function of the parameter as seen in Figure 4. 3D graphs of

voltage when interdigitated electrodes are present were also obtained.

Conclusions:
We have shown that the dependence of the figure of merit on certain parameters is not monotonic and hence can be maximized at a certain value of a parameter [Figure 4]. Given certain constraints, such as an already existing microfluidic channel in PDMS, we can design electrodes that will maximize the figure of merit, i.e. change in the capacitor due to change in the dielectric constant of fluid flowing in the channel. The effect of interdigitated electrodes on the figure of merit of the configuration was checked and some rules for design of such electrodes have been proposed.

Reference

[1] Darwin R. Reyes et al., Anal. Chem., 74, 2623-2636 (2002)

[2] Liyu Liu et al. Biomicrofluidics 2, 034103 (2008)

[3] M. Demori et al. Sensors and Actuators A, 172, 212– 219 (2011)

Figures used in the abstract

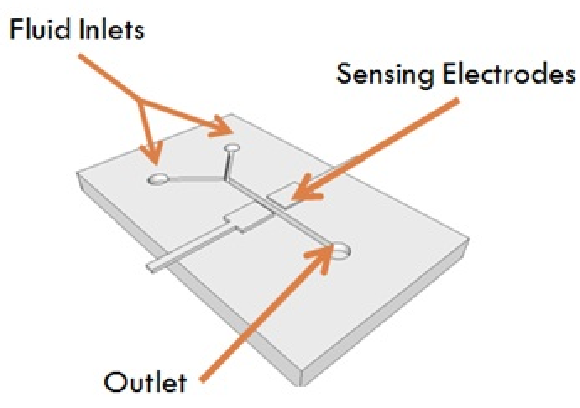

Figure 1: Structure of microfluidic sensor

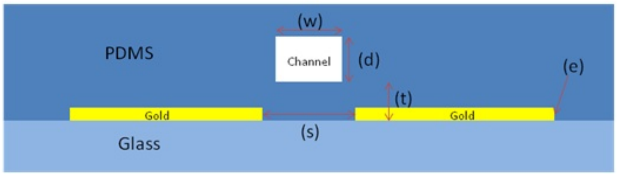

Figure 2: Geometrical parameters of the sensor

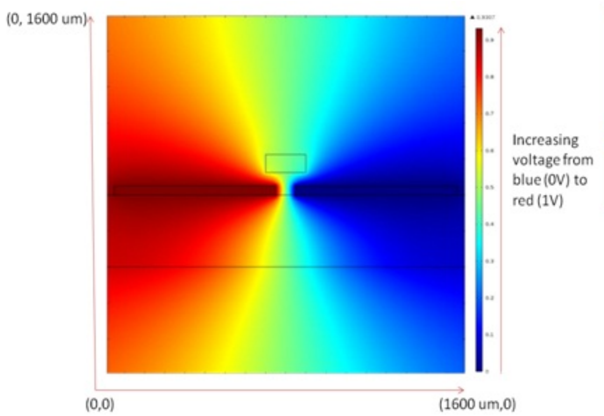

Figure 3: 2D electric potential graph of cross-section

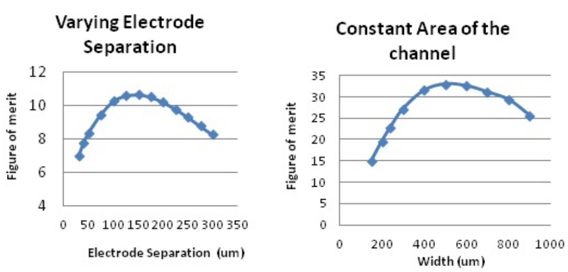

Figure 4: Trends on variation of parameters