Design and Development of Microfluidic Based Dielectric Sensor for Biomedical Application

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***Abstract*— A microfluidic device capable of sensing even minute capacitive change is proposed. Purpose of the developed device is fluid concentration identification and characterization on the basis of the dielectric permittivity. A microchannel, realized on Silicon layer, below a sensing capacitor formed by electrodes sputter printed on a glass substrate. Fluids inside the microchannel affects the capacitance that is measured by a standard electronic interface system. Experimental results obtained for different fluids injected in the microchannel demonstrate the ability of the system to differentiate the fluids and estimate their dielectric permittivity both as pure samples and as mixtures at varying concentration of solute fractions. This makes the device a promising building block for fluid mixing monitoring in microfluidic systems.**

Keywords— Microfluidic devices, capacitive sensing, dielectric.

I. INTRODUCTION

Recent research on microfluidic based device for chemical and biological application has gain enough attraction [1-2]. These devices can be made of one or more channel where the desired fluid or tissue sample [3] can be manipulated for analysis. The functionality of working of such devices offers great advantage which require very small quantities of samples, i.e., in the order of 10^{-6} to 10^{-12} l, which makes it a ultimate choice for biological or chemical analysis of expensive materials and where multiple sample analysis is required for cross-checking purpose [4-5]. Moreover, various processing elements can be integrated within the same device making it multi-purpose devices capable of analyzing small dimensions and offers reduced analysis time. Exploiting the micrometric volume requirement for signal analysis these device offers future solution in the chemical and biological analysis of expensive material and on filed measurement[6].

The present study is mainly focussed on microfluidic based device with an aim to classify and characterize fluids even with a minor change in the dielectric behaviour. This is obtained by means of a capacitive measurement taken from the electrodes sputter coated on to a glass top isolated form the direct contact of the test fluid. The dielectric permittivity of different fluids or mixtures affects the capacitance of the electrode [7], which is the parameters being mesaured in our case to estimate the dielectric constant of different fluids. For the mathematical analysis of the above described physical situation, the following major assumptions are made: (a) the fluid motion is Newtonian and laminar; (b) the input effects are ignored; (c) the contact angle is static; (d) the flow action can be roughly modeled as one-dimensional; and (e) the gravity effects are neglected.Under these assumptions, the fluid flow is modele d mathematically by using appropriate governing equations and boundary conditions and the explanataion are published in previous work [8]

II. DEVICE FABRICATION

Fluidic channel wall material selection plays a significant role in passive pumping in micro / nano fluidics. Therefore, SiO_2 being hydrophilic in nature is selected as the fluidic wall material of the channel. The micro-fluidic device has a channel width (W) of 500 µm, length (L) of 2 cm, height (H) of 30µm and reservoir diameter of 4mm (Fig.1). Initially the Silicon Wafer lithography is carried out for the realization of the fluidic channels followed by 0.2 µm SiO_2 using 1050°C heat oxidation. Using TMAH solution at 80° C for 1 h 30 µm Si is etched followed by SiO_2 etching using BOE.

Thermal oxidation is performed after Si etching to create the hydrophilic channel. Backside electrode patterning using rear side alignment (BSA) on silicon wafer is conducted using second lithography accompanied by 2000/200Å sputtering of Gold / Titanium (Au/Ti). In next stage the glass lithography is carried out followed by Au electrode pattern by 2000/200Å Au/Ti sputtering. Followed by anodic bonding of glass- silicon to realize the final device. Fig 1 shows the schematic of the device

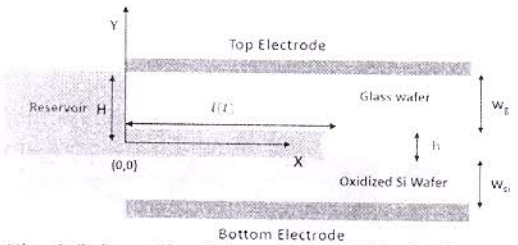

Fig. 1 Schematic of the microfluidic device.

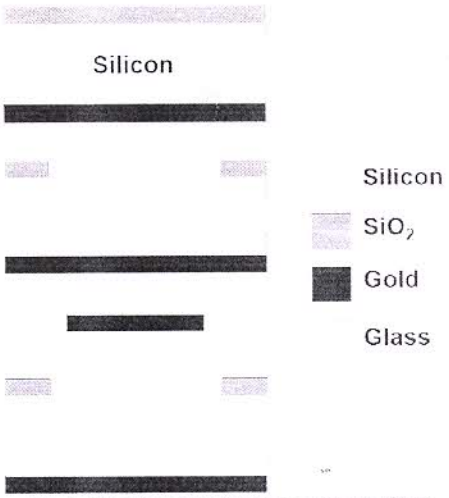

Fig 2. Device fabrication process flow.

The device testing arrangement is shown in Fig.3

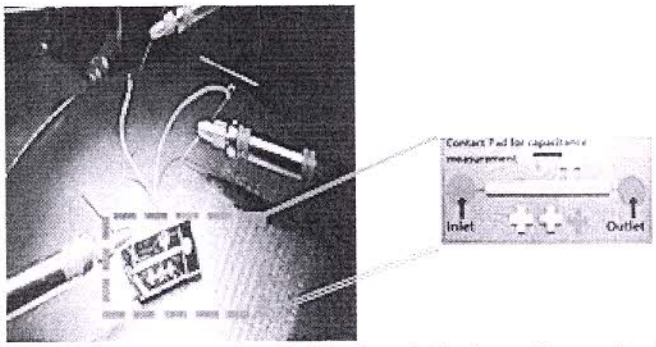

Fig. 3 Developed microfluidic based device with standard system.

III. RESULTS AND DISCUSIONS

The device response has been recorded using standard capacitance measurement unit (table-top) with built in readout. The sample used for sensing the capability of the device are prepared by CSIR-IICB, Kolkata.

Three types of sample are used for the measurement.

1. Blood serum sample
2. Blood serum sample with 10 microliters volume of gold nanoparticles with average size of 40 nm
3. Blood serum sample with 20 microliters volume of gold nanoparticles with average size of 40 nm

From Fig 4. It is evident that the dielectric based bio-chip is capable of measuring even a small change in the concentration of the sample condition. It can further be noted that before introducing the serum sample to the bio chip the base capacitance value is ~4.5 pF, after the introduction of the serum to the system the capacitance value touches a saturated value of ~5.3 pF. The same device is then thoroughly cleaned using acetone and then dried using nitrogen gas. The device is then examined for the sample with a known concentration of 10 µl. volume of gold nanoparticle (Au NP) of average size of 40 nm (spherical balls) per 200 µl. of serum sample. Maintaining the base capacitance value at ~4.5 pF. The change in the sample condition changes the capacitance value and a drop in the capacitance value is observed compared to serum sample. Similarly, when the sample condition is further changed i.e., concentration of 20 µl. volume of gold nanoparticle of average size of 40 nm (spherical balls) per 200 µl. of serum sample.

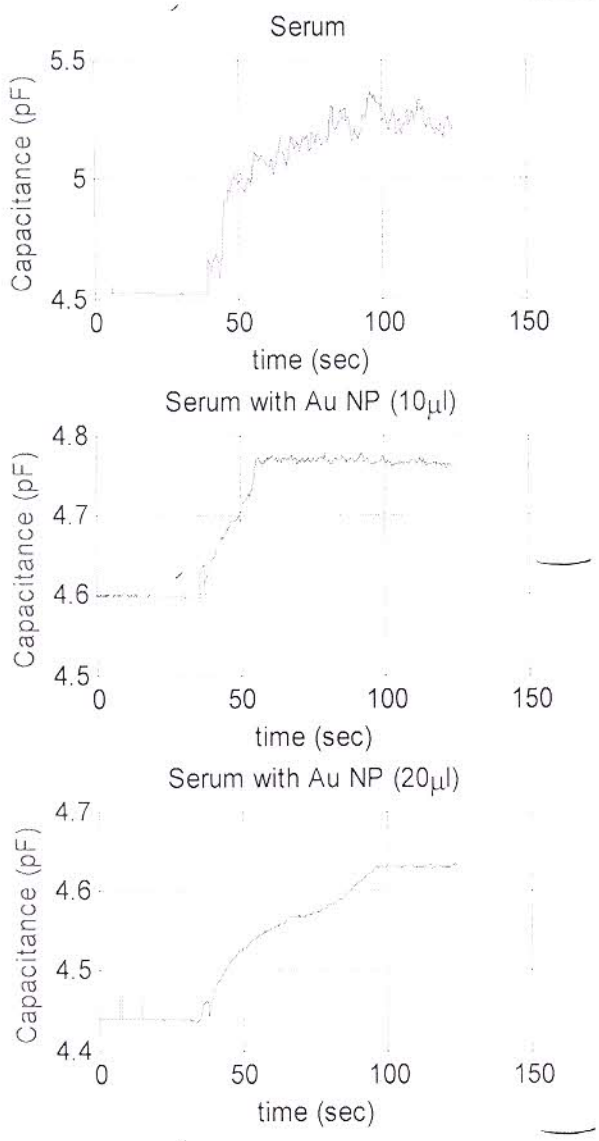

Fig. 4 Capacitance response in three different sample condition.

In this case also prior introducing the sample into the bio-chip the base capacitance matched the earlier recorded base value (~4.5 pF) and after introduction of the modified sample the capacitance value further drops and the value reaches ~4.65 pF compared to the one recorded with serum (~5.3pF). Graphical representation of the capacitance values with air, with serum sample and with serum sample with nanoparticles is shown in Fig 5.

Table 1. Shows the value of capacitance variation of the three samples as well the estimation of dielectric constant for the serum and gold nanoparticles mixed serum samples. Throughout the test it is worth mentioning that the rise in the value of capacitance before saturating signifies fill time of the device.

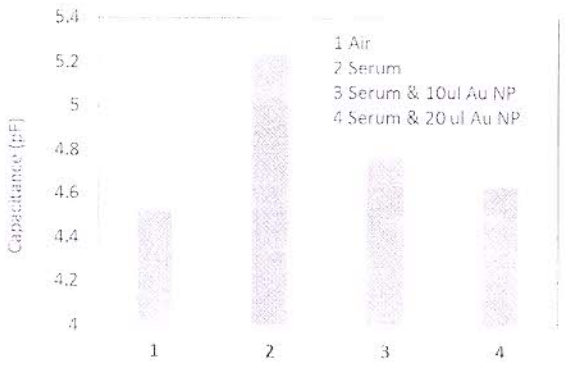

Fig. 5 Capacitance values for serum and serum-Au-NP compositions with respect the capacitance in Air

Table 1. Shows the Capacitance and dielectric change measurement of the three samples.

Sample	Capacitance change (pF)
Serum	~0.715
Serum (200 µL) with 10 µL, Au-NP	~0.250
Serum (200 µL) with 20 µL, Au-NP	~0.107

CONCLUSISON

The microfluidic based device is capable of detecting small change in the sample condition and is capable of producing repeated results with almost no offset value. The developed device may offer huge potential for bio medical application where the sample concentration change can be predicted with greater accuracy.

ACKNOWLEDGMENT

Authors would like to acknowledge Director CSIR-CEERI for his guidance and encouragement. Authors are also thankful to CSIR health mission project HCP0012 for providing financial support. The authors also acknowledge Dr. Subhojeet Biswas and Dr. Surjit Ghosh of CSIR-IICB Kolkata for providing the serum sample.

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