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An Interdigitated Capacitive Sensor to Detect Adulteration

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ABSTRACT

A change in permittivity tends to produce electric field which in turn affects the capacitance values. This technique provides high sensitivity, low hysteresis, and low noise as well as low fabrication cost. Adulteration in that oil affects the health of the human, particularly elderly people is more vulnerable. Mixing of various low grade oil to this edible oil can lead to weight gain, heart problems and other chronic disease. This project intends to detect adulteration in sunflower oil with the help of a MEMS based Interdigitated capacitive sensor. The change in the permittivity of the dielectric will lead to the change in the capacitance in the sensor, that will be a identifying factor in the debasement. COMSOL Multiphysics is used as designing platform in this project.

KEYWORDS: *Interdigitated capacitive sensor, MEMS, dielectric, COMSOL, Adulteration.*

I. INTRODUCTION

As demand for the oil increases adulteration is done with other cheap oils such as palmoil, castoroil. There are many methods to detect adulteration such as specific gravity, refractive index, chemical analysis, tag analysis, Chemometry. Chemometry is used to measure the properties of chemical system by transmitting IR rays. Refractive index is found by penetration of light rays through material. This test requires little sample and consumes less time. Chemical analysis consumes more sample and time, it is carried out in the absence of instrumental analysis. All non tag components present in the substance is found by Tag analysis. Tag analysis detects the amount of adulterated substance present in oil. The expensive oils are replaced by mixing the cheaper oils which contains non-tag components such as fatty acids, diaclglycerols are found by tag analysis. Major adulterations in edible oil and fats are done by mixing cold oil with refined one and replacement of more expensive oils and fats with cheaper one. When the paraffin oil is mixed with sunflower oil, it is not possible to detect the presence of adulterated substance. If the solution is cloudy or sticky, the measurements will be unreliable. It is applicable for cocoa butter. Cooking oil is adulterated with rice bran oil which does not let us to find the adulteration present in the oil. Capacitive sensors have been classified into parallel plate capacitors and Interdigitated Capacitors. While parallel plate capacitors generate sensing as well as actuation with respect to planar electrodes facing each other. The IDT capacitor, as shown in figure 1, has two sets of electrodes kept in the plane parallel to substrate. The Interdigitated fingers are structured like tooth of combs, such a configuration is known as the "comb drive "device. Two sets of fingers are in the same plane and comb fingers are used with the distance of l_0. The length of the finger is denoted as L_c[1] [2].

$C=\xi_r\xi_0 l_0 t/d$

Where

l_0- distance between the comb fingers

t –thickness of the comb fingers

d– distance between the fixed comb finger & Movable comb finger

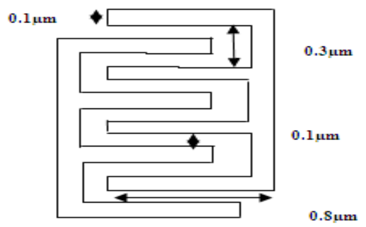


Figure 1: Structure of IDT having length=0.1µm, breadth=0.3µm, thickness=0.1µm and overlapping area =0.8µm

A parallel plate capacitor has two plates parallel to each other. These two plates are not required to be exactly parallel at all time nor are they required to be planar. In parallel plate capacitor, electric field lines are parallel and perpendicular to the plate surfaces in the overlapped region. Electric fields reside outside the boundary of electrode plates. The field lines are three dimensional in nature and should be considered in rigorous design [3] [4].

Two parallel plates can move with respect to each other in two ways, normal displacement or parallel sliding displacement. The parallel plate capacitor is a platform for many sensors. By measuring the capacitance value of a parallel capacitor, one can sense the changes of permittivity, A or d. The permittivity can be changed by temperature and humidity of the capacitor media. The capacitor is used as an actuator in order to measure and detect force as well as displacement. The potential difference applied between the two parallel plates, develops an electrostatic force. The structure of the parallel plate capacitive sensor is shown in figure 2.

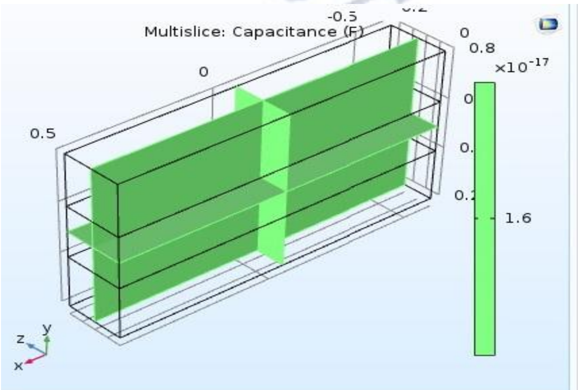


Figure 2: Simulation of parallel plate capacitor

II. Simulation of IDT using COMSOL

COMSOL Multiphysics is an Engineering & Physics tool which performs equation-based modeling in an interface. This software allows to perform modeling and simulation of any physical phenomena. The first step of the simulation includes creating a 2D geometry using the array tools and then extruded to a 3D geometry to perform Mesh analysis and compute the capacitance using Electrostatics Multiphysics.

It is used to simulate a design, test the capacitance and observe the effects on capacitance by changing the parameters, such as dielectric permittivity of materials Figure 3 shows the IDT capacitor with a capacitance value. COMSOL helps to find out the effect of capacitance when permittivity changes. COMSOL proves to be useful in optimizing the design of sensor [7].

The layers represent different materials. The top layer and the bottom layer is a substrate made of Silicon nitride. Silicon nitride is used as a substrate for high reliability. The size of the IDT capacitive sensor is 1.30*1.59µm. The way COMSOL identifies these materials is through a property called 'Dielectric permittivity (Єr) of the material. Sunflower oil is replaced by the dielectric in order to detect the adulteration [5] [6].

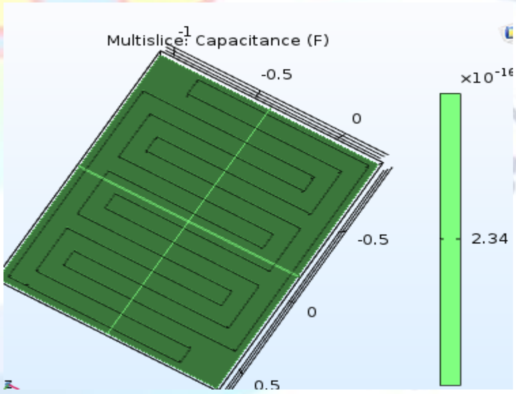


Figure 3: Simulation of IDT

Formula:

THEORETICAL FORMULA TO FIND CAPACITANCE [8]

$$C_{\mu c}= \varepsilon_0(\varepsilon_r+\varepsilon_k)K\left(\sqrt{1-\left(\frac{a}{b}\right)^2}\right)/K(a/b)+ 2\,\varepsilon_0\,\varepsilon_k\frac{t}{a}$$

ε_0 -permittivity in free space

$\varepsilon_r,\varepsilon_k$- dielectric constants of the substrate and dielectric film

K-complete elliptic integral of the first order

a,b- length and breadth of the fingers of IDT

$C_{\mu c}$ – Capacitance of the IDT

III. Results

3.1. Comparison of Parallel plate and IDT Capacitance

Observation:

Difference of capacitance in successive measurements in parallel plate capacitor: $0.06*10^{-17}$ F.

Difference of capacitance in successive measurements in Interdigitated capacitor: $0.8*10^{-16}$ F.

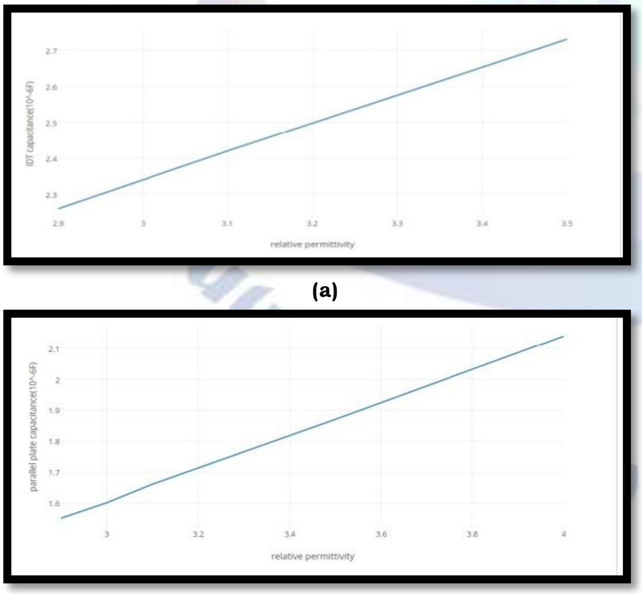
3.2. Discussion:

According to the table 1Interdigitated capacitor has more sensitivity rather than parallel plate capacitor. IDT has more sensitivity and low hysteresis which brings out more preference than parallel plate capacitor.

Table 1

Relative permittivity(ε)	**IDT Capacitance**(10^{-16} F)	**parallel plate capacitance**(10^{-17}F)
2.9	2.26	1.55
3	2.34	1.6
3.5	2.42	1.66
4	2.73	2.14

3.3. Graph



(a)

(b)

Figure 4: (a) Relative Permittivity vs IDT Capacitance (b) Relative permittivity vs Parallel plate capacitance

IV. Conclusion

The simulation of IDT Capacitor and parallel plate capacitor is designed by using COMSOL software. The difference between the IDT and parallel plate capacitance is described in this paper by comparing both the outputs. IDT is preferred which has high sensitivity than parallel plate capacitance. Hardware of this project exhibits, the change of permittivity which tends to change the Capacitance, the obtained capacitance is converted to voltage. The voltage is displayed digitally and tested whether it has been adulterated. The reference value and obtained value is compared in order to detect the presence of adulteration. Capacitive sensor plays a vital role to detect the adulteration. Future work lies in designing pH sensor by using MEMS Technology which displays the pH of the solution directly and reduces the size of apparatus.

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