ABSTRACT: Cholera is caused by vibrio cholera bacteria in water or food. This paper provides the design and simulation of MEMS based biosensor for the detection of vibrio cholera present in the water, which causes cholera using FEM tool. The designed microsensor used the capacitive principle for the detection of bacteria present in the fluids. The MEMS biosensor was designed and optimized based on their sensitivity. Channel model biosensor with distance 2.5um between the electrode and the thickness of the electrode is 1um have high sensitivity than rectangle and triangle based channel. The material used for electrode is aluminum and gold. The flow velocity was also calculated for three channels with bacteria cell.

Keywords: Cholera, Bio-sensor, Capacitance modulation, FEM tool.

1. Introduction

Biosensors are essential gadgets that greatly affect our lives. A considerable lot of the biosensors are being utilized to clinical applications for the finding of the infection [1]. A biosensor utilizes an organic or biochemical locator, which can fluctuate from straightforward proteins and catalysts to entire cells and microorganisms. The biosensors can be grouped as per distinctive plans: the sort of identifier, p. resistant sensors or enzymatic sensors, transduction starting, p. amperometric piezoelectric.

Cholera is a malady of the little stomach related framework caused by vibrio cholerame, gram negative microbes. This is a comma or helix shape that has short of what one turn along its length. A few patients have genuine appearances what's more, some don't have any reactions. The basic sign is that a great deal of water misfortune proceeds for a few days. Issues may likewise happen in the muscles and sanctuaries [2]. Free digestive organs can be extreme to the point that they lead in a couple hours to a serious absence of hydration and electrolyte awkwardness. The absence of hydration can cause the skin getting to be something blue. Manifestations start 2 to 5 days after the microbes enter the body.

In this day and age, the hardware required for research facility testing is costly, cumbersome and takes additional time. The broadly the plate tally test utilized takes 1 to 2 days. PCR (polymerase chain response) is a framework for assessing a short get together of DNA (or RNA) even in tests that contain DNA or RNA minute estimations. PCR is utilized to rehash (assemble) pick DNA or RNA zones. This test keeps going a few hours, in any case it is indulgent (40,000). For nourishment makers, water providers and water purifiers dependably the issue is to have the capacity to identify the nearness of pathogens as quick as conceivable and at the base conceivable focus.

In this paper we have designed three different types of channels one is cylindrical, rectangle and triangle. Comparison of capacitance with and without bacteria cell were performed with two electrode materials namely aluminum and gold.

2. Theory: Mems Based Biosensor Based On Capacitive Principle

The biosensor is a sensor that identifies the nearness of microorganisms, the accompanying isthe capacitive rule [7] in which the biosensor works. We can know the nearness of microscopic organisms by measuring the capacitance with and without microbes. A vibrio cholera bacterium that is the reason for cholera infection is as extreme lethargies or vibrio, so it is outlined as a helix.
The microscopic organisms have been demonstrated as a helix with a dielectric steady of 60 [8]. The dielectric consistent of water is 80. Since the capacitance is straightforwardly relative to the dielectric consistent with the adjustment in the dielectric steady, the capacitance changes. Since water has a higher dielectric consistent, the capacitance of unadulterated water will be more prominent and when microbes are available, the capacitance diminishes.

The capacitance between two electrode plates is defined as

\[ C = \varepsilon_r \varepsilon_0 \frac{A}{D} \]  

where \( C \) is the capacitance in farads,  
\( \varepsilon_r \) = Relative Static Permittivity of material between plates  
\( \varepsilon_0 \) = permittivity of free space (8.85*10^{-12} Farad/m),  
\( D \) = distance between two plates  
\( A \) = Area enclosed between two electrodes.

When the capacitance are in parallel then

\[ C' = \frac{C_1 C_2}{C_1 + C_2} \]  

where \( C_1 \) which represents the capacitance value without bacteria.  
where \( C_2 \) which represents the capacitance value with bacteria cell.

\[ C_2 = \varepsilon_r \varepsilon_0 \frac{A_1}{D} \]  

where \( A_1 \) = area of the helix or area of the V.cholera

\[ A = N \Pi D^2 d \left[ 1 + \left( \frac{P}{\Pi d} \right)^2 \right] \]  

where \( N \) = nub of turns, \( D \) = Major radius(um), \( d \) = Minor radius (um)

3. Device structures

The model-1 represents the cylindrical channel which have the electrode thickness 1um and the gap between the electrodes is 2.5um. The size of V.cholera bacteria is 2um which having the dielectric constant 60 which was present in the water having the dielectric constant 80. The model-2 represents the rectangular channel which have the electrode thickness 1um and the gap between the electrodes is 2.5um. The model-3represents the triangle channel which have the electrode thickness 1um and the gap between the electrodes is 2.5um. The design area is optimized for better sensitivity.

Figure 1. Model-1 cylindrical channel

Figure 2. Model-2 rectangular channel

Figure 3. Model-3 triangular channel
4. Results and Discussion

Table 1- Capacitive value with V.Cholera cell and without the cell which was theoretically calculated

<table>
<thead>
<tr>
<th>Cell count</th>
<th>Cylindrical channel capacitance value</th>
<th>Rectangular channel capacitance value</th>
<th>Triangular channel capacitance value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.14x10^-10</td>
<td>0.16x10^-10</td>
<td>0.15x10^-10</td>
</tr>
<tr>
<td>1 Cell of V.Cholera</td>
<td>8.59x10^-14</td>
<td>9.61x10^-14</td>
<td>1.02x10^-13</td>
</tr>
<tr>
<td>5 Cell of V.Cholera</td>
<td>5.08x10^-14</td>
<td>5.61x10^-14</td>
<td>5.81x10^-14</td>
</tr>
<tr>
<td>10 Cell of V.Cholera</td>
<td>1.90x10^-14</td>
<td>2.06x10^-14</td>
<td>2.11x10^-14</td>
</tr>
<tr>
<td>15 Cell of V.Cholera</td>
<td>1.39x10^-14</td>
<td>1.40x10^-14</td>
<td>1.41x10^-14</td>
</tr>
<tr>
<td>20 Cell of V.Cholera</td>
<td>1.07x10^-14</td>
<td>1.07x10^-14</td>
<td>1.08x10^-14</td>
</tr>
<tr>
<td>25 Cell of V.Cholera</td>
<td>8.69x10^-14</td>
<td>8.72x10^-14</td>
<td>8.75x10^-14</td>
</tr>
</tbody>
</table>

Table 1, shows the capacitance value for 1cell, 5cell, 10cell, 15cell, 20cell, 25cell respectively for three channels having the gap between the electrode is 2.5um and the electrode thickness 1um. The V.Cholera bacteria which was helix or comma shape having N=0.25um, D=0.3um, d=0.1um, and P=0.3 um.

5. Simulate analysis

The electrostatics model uses the equation

\[ \text{Q} = \text{CV} \quad (5) \]

Where C is the equivalent capacitance, V is the voltage applied and Q is the charge developed.

The electrostatic analysis were performed in COMSOL multphysics. The below figures 4,5,6,7,8,9 shows the capacitance value with 1cell and 25 cells with gold electrode having the thickness 1um and the gap between the electrodes was 2.5um.

The cylindrical channel have high sensitivity than rectangle and the triangle channel. The flow velocity was also calculated for the channels with cells.

The figure 10 represents the decrease the capacitance value for different channels. The below fig represents the decrease in the capacitance value of the 3 channels.

The fig 11 represents the flow velocity of different channel with the increase of the bacteria cell.
The rectangular channel have low sensitivity than the cylindrical channel because of low area and having low backward force in it.

The triangular channel have low sensitivity than the rectangular and cylindrical type because it have high backward forces and having large area.
Figure 10. Capacitance value for 25 cells which was decreases with the increase of cells.

Figure 11. Flow velocity with the V. cholera cells.

The sensitivity of the bio-sensor is given by

\[
\text{SENSITIVITY} = \frac{C_1 - C_2}{C_1} \quad (5)
\]

where \(C_1\) = capacitance without bacteria cell  
\(C_2\) = Capacitance with bacteria cell

The sensitivity value is more for cylindrical based channel compare to the rectangle and triangle based channel with the electrode thickness of 1um and the gap between the electrodes is 2.5um.

6. Conclusion

Finally, we have designed MEMS based biosensor using three different models namely cylindrical channel, rectangular channel, triangular channel with the electrode thickness 1um and gap between the electrodes is 2.5um. The capacitance value decreases with the increase of the number of cell. Capacitive based sensor were designed using three different model channels which can detect up to 75 cells. The cylindrical channel will produce high sensitivity when compared to the rest of the channels. The fabrication time taken was nearly 2 hours.

References


