Non Invasive Technique for the Measurement of Glucose Levels in Blood using MEMS Devices

G. V. Sunil Kumar¹, T. Milinda Purna², Dr. V. R. Anitha³
¹²Department of Electronics and Instrumentation Engineering
³Department of Electronics and Communication Engineering
Sree Vidyanikethan Engineering College, A. Rangampet, Tirupati

Abstract— People suffering from diabetics is increasing alarmingly worldwide. They have to check their glucose levels regularly and often self measurement of glucose level is desirable. The most commonly used laboratory diagnostic procedures involve the analysis of cellular and chemical constituents of blood. Blood collecting and analyzing cause stress and pain to the patient. So a noninvasive blood less technique is desirable to relieve the patient from pain and trauma. Also the amount of blood sample required for conventional techniques is more causing further discomfort to the patient. Other biological fluids are utilized for the diagnosis of disease. Saliva offers some distinctive advantages. MEMS sensors require very less amount of sample i.e., in µl. This paper proposes a novel method for the analysis of detecting the glucose level in saliva using microcantilever as a sensor.

Keywords— Blood glucose level, Cantilever, COMSOL Multiphysics, MEMS, Saliva glucose level.

I. INTRODUCTION

A cantilever is one which is fixed at one end and the other end is free to move when it experiences some stress as shown in figure1. A Microcantilever is a device that can be used as physical, chemical or biological sensor by detecting the changes in cantilever bending or vibrational frequency. This deflection of microcantilever changes when a specific mass of an analyte is specifically adsorbed on its surface [1].

Detection of deflection caused by the end of the microcantilever beam is done by a PSD (position sensitive detector), which is an optical position sensor (OPS), that can measure a position of the light spot in one or two dimensions on the sensor surface as shown in the figure 2. The advantage of this detection system is that it is capable of detecting deflection in the sub-nanometer range, but is expensive.

II. MICROCANTILEVER DEFLECTION DETECTION METHODS POSITION SENSITIVE DETECTOR

III. THE PIEZORESISTIVE DEFLECTION DETECTION METHOD

The piezoresistive method involves the embedding of a piezoresistive material near the top surface of the cantilever to record the stress change occurring at the surface of the cantilever.
As the microcantilever deflects, it undergoes a stress change that will apply strain to the piezoresistor, thereby causing a change in resistance that can be measured by electronic means. The advantage of the piezoresistive method is that the readout system can be integrated on the chip. The disadvantage is that the deflection resolution for the piezoresistive readout system is only one nanometer compared with one Angstrom by optical detection method. Another disadvantage with the method is that a piezoresistor has to be embedded in the cantilever. The fabrication of such a cantilever with a composite structure is more complicated. The piezoresistor material in the beam must be localized as close to one surface of the cantilever as possible for maximum sensitivity. The type of doping being used for fabrication of the piezoresistive material is an important factor.

The deflection of the cantilever beam depends upon the dimensions of the beam i.e., length, width, thickness and also depends on various properties of the material like density, young’s modulus etc. used to build the cantilever. The geometric structure of the cantilever beam and also the properties of the material used to construct the cantilever determine the stiffness of the cantilever. Thus the sensitivity of the cantilever beam changes with the change in material and geometry of the cantilever.

IV. OVERVIEW OF NONINVASIVE ANALYSIS

Photometric methods have gained attention as the noninvasive measurement procedure for biological substances. In the past, quantitative determination of blood glucose has been attempted by photometric procedures but clinical applications have not succeeded because the in vivo optical pathways contain various constituents that interfere with the measurement, and the differences in photometric characteristics among sugars is small.

Alternatively, biological screening using body fluids that are obtained noninvasively, such as urine, sweat, lacrime, etc., have long been considered. In particular, a urine glucose screening test is currently in widespread use. However, the success of this screening is limited, since there are individual differences in the excretion threshold of urinary glucose and the test does not indicate hypoglycemia.

Some animal experiments have been conducted to develop a method for determination of the glucose level by using sweat or a suction effusion fluid from the skin, but it remains unclear whether such methods are applicable to human samples.

On the other hand, Shannon, et al. found that Blood Glucose Level is correlated with salivary glucose level Saliva Glucose Level as shown in figure 3. However, there are some reports that deny the presence of such correlation. The correlation between Blood Glucose Level and Saliva Glucose Level has not yet been fully established.

![Figure 3: Relationship between blood glucose levels and saliva glucose levels](image)

An inexpensive, smart, rugged sensors which can be used outside laboratories is possible because of the technological advancements in the area of Micro Electro Mechanical Systems. Biosensor based on microfabricated sequential array systems approach is to use affinity sensors.

A cantilever is coated with selective antigen (probe molecule) which can react only with the respective antibody (target molecule) i.e., glucose in saliva as shown in figure 4. Antibody recognition elements make use of the high sensitivity and specificity of biomolecular antibody-antigen interactions. When the reaction takes place on the surface of the cantilever or when the target molecules are adsorbed on the surface, the cantilever experience deflection. Simulation of such interactions can be done in Comsol Multiphysics software that results in the cantilever displacement to larger extents. The free end is deflected more which is a direct measure of amount of the antigen –antibody interactions.

The piezoresistor which is embedded in the cantilever structure also experience change in length resulting change in resistance or change in resonant frequency. This change in resistance or resonant frequency is calculated which is calibrated in terms of the amount of glucose present in the saliva.
V. SIMULATION RESULTS

A cantilever of length 1000 µm, breadth 100 µm and thickness 10 µm is considered for simulation which is done using COMSOL multiphysics software. The simulation is done for piezoresistive single crystal p type silicon material.

The thickness is varied from 10 to 50 µm and the change in resonant frequency with respect to thickness is observed and plotted. It is observed from the simulation results as shown in table 1, that the resonant frequency of the cantilever increases linearly with the thickness of the cantilever, i.e., when the antigen present in the saliva gets deposited on the surface the cantilever its resonant frequency varies by which the amount of salivary glucose level can be estimated. The relation between thickness of the cantilever and its resonant frequency is shown in figure 5.

The relation between thickness and deflection of the cantilever for a force of 1 N/M² is shown in figures 6-9.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Thickness (µm)</th>
<th>Resonant Frequency (KHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10</td>
<td>12.175</td>
</tr>
<tr>
<td>2.</td>
<td>20</td>
<td>24.354</td>
</tr>
<tr>
<td>3.</td>
<td>30</td>
<td>36.536</td>
</tr>
<tr>
<td>4.</td>
<td>40</td>
<td>48.703</td>
</tr>
<tr>
<td>5.</td>
<td>50</td>
<td>61.160</td>
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<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Thickness (µm)</th>
<th>Displacement (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>30.327</td>
</tr>
<tr>
<td>2.</td>
<td>20</td>
<td>3.790</td>
</tr>
<tr>
<td>3.</td>
<td>30</td>
<td>1.123</td>
</tr>
<tr>
<td>4.</td>
<td>40</td>
<td>0.474</td>
</tr>
</tbody>
</table>

Figure 5: Relation between thickness and resonant frequency.

Figure 6: Deformed shape of the rectangular beam of cantilever when force applied= 1 N/M² and thickness is 10 µm.
VI. CONCLUSION

Microcantilevers can be used as a sensor to sense any specific parameter when it is coated with the respective antigen. The change in resonant frequency with change in thickness can be used to detect the amount of saliva glucose level. Also change in resistance of the material with the change in length due to deflection because of the deposition of mass on the surface of the sensor can also be used to detect glucose level in saliva. Hence the identification of biomarkers for noninvasive detection of diabetes will be of great help to the mankind.

REFERENCES


