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Glucose Level Detection based on Capacitive Dielectric Sensing by Micro-fabricated Resonator

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Abstract

The paper presents the novel concept of glucose detection in the blood sample by using the micro-fabricated resonator. The variation in the glucose concentration was modeled for the frequency shift variation and ultimately the result validates the detection of diabetes in the deionized water glucose solution. The resonator resonates at a bare resonator frequency of 10.82 GHz. The finding supports the development of resonance-based sensing with an excellent sensitivity of 3.4 MHz per 1 mg dl^{-1} change in glucose level, a detection limit of 12.33 mg dl^{-1}, and a limit of quantitation of 38.36 mg dl^{-1}.

Keywords: *Glucose sensor; capacitor; dielectric; microfabrication; resonator.*

1. INTRODUCTION

The level of glucose in the blood is a vital biomarker for the detection of diabetes disease. Depending on the level of glucose there are two types of diabetes. The American Diabetes Association recommends a fasting plasma glucose level of 70 –130 mg dl^{-1}for the normal person. If the glucose level is between 60 – 68 mg dl^{-1}, then the condition is called hypoglycemia. If the glucose level is above 240 mg dl^{-1}, it is called hyperglycemia [1]. There are several concepts proposed for the detection of glucose from the microfluidics to radio frequency detection. This works demonstrate an innovative, ultra-sensitive, reusable and portable RF (Radio Frequency) resonator based biosensor for real-time and label-free detection of the glucose level in the deionized water glucose solution. The proposed biosensor resonating at 10.81 GHz used microfabrication called integrated passive device (IPD) technology on a gallium arsenide substrate [2-4]. The proposed technology becomes handy when combined with the wireless system for the telemedicine [5].

2. DESIGN AND FABRICATION

The resonator was fabricated using IPD technology, implementing the cavity like structure called an air - bridge. The fabricated air-bridge used as a capacitive sensor for the detection and improves the sensitivity. The fabrication of the device started with the silicon nitride (SiNx, 200 nm) passivation layer, which was first deposited over a gallium arsenide (GaAs, 400 μm) substrate using plasma enhanced chemical vapor

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deposition [6-8]. Finally, the broken coil path around the metal beeline for the resonator was implemented for the design of the air-bridge structure as shown in Fig. 1.

3. RESULT AND DISCUSSION

This developed biosensor resulted in a good dynamic performance for the deionized water glucose concentration from 50 mg dl^{-1} to 250 mg dl^{-1}. The shift in the resonance frequency caused by the different concentration of the glucose level present in the blood for five different samples was demonstrated as shown in Fig. 1. The featured characteristics based on the resonance concept was critically analyzed by capacitor, inductor, and resistor. The finding support the development of resonance-based sensing with an excellent sensitivity of 3.4 MHz per 1 mg dl^{-1}change in glucose level, a detection limit of 12.33 mg dl^{-1}, and a limit of quantitation of 38.36 mg dl^{-1}.

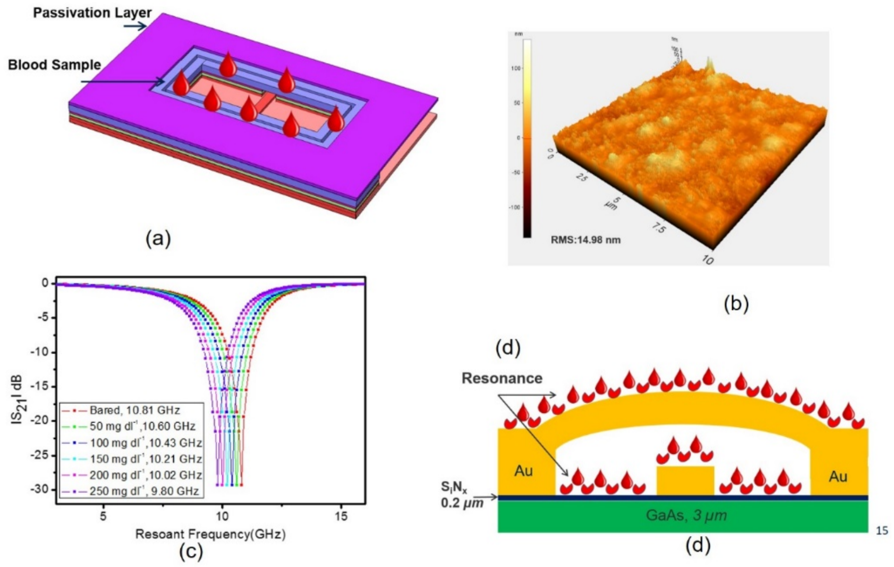

Figure 1. Schematic diagram showing. (a) Device for glucose sensing. (b) Analytical diagram showing the sensing procedure (c) Resonance based on capacitive sensing. (d) AFM characterization of the Au-surface of the biosensor after pouring of deionized water glucose solution, and (e) Final characterization of the device showing the resonance shifting for the different glucose concentration.

4. CONCLUSION

The studied biosensor provided a rapid response for each of the glucose concentration within the linear calibration ranges of 50 to 250 mg dl^{-1}, with the correlation coefficient of 0.9983. The proposed device produces excellent reusability for a different sample of the deionized water glucose solution. The concept can be applied for the real-time detection of glucose level in the human serum of diabetes patients for the point of care testing (POCT).

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