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Development, Analysis and Experimental Findings for Oral Organisms

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Abstract

Researchers' focus has recently been drawn to the link between oral cells and gum disorders, which pose a serious threat to people's overall health as a result of recent advancements in periodontal studies. Complementary Metal Oxide Semiconductors (CMOSs), one of many microfabrication technologies, allow for the creation of inexpensive integrated sensors and circuits for the quick and precise evaluation of living cells that can be used for the early detection and management of periodontal diseases. The CMOS capacitive sensing platform described in this study can be used as an alternative for the investigation of salivary cells, such as oral neutrophils. This platform is made up of two sensing electrodes that are linked to a read-out capacitive circuitry that was created and manufactured on the same chip utilising Austria Mikro Systeme (AMS) 0.35 m CMOS technology.

Keywords: Capacitive sensor • Complementary metal-oxide-semiconductor • Oral epithelial cells • Oral neutrophils

Introduction

In order to monitor the capacitance changes brought on by the presence of saliva cells on top of the chip, a graphical user interface was also created to communicate with the capacitive read-out device and the computer. The experimental and modelling results show the functionality and usefulness of the proposed sensor for monitoring cells in a small volume of 1 L saliva samples due to the broad input dynamic range (IDR) of more than 400 femto farad and high resolution of 416 atto farad. According to these findings, the capacitance of interdigitated electrodes varies according on the hydrophilic adherence of oral cells on the chip. The estimate of the oral cells present in the sample is then provided by these capacitance variations. The simulation and experimentation results in this research establish a new stage for emerging sensing platforms for testing oral samples. Recent investigations on periodontal disease have discovered a connection between gum disorders and illnesses like diabetes, osteoporosis, and HIV. Additionally, it is widely known that people who have advanced osteoporosis are more likely to develop periodontal disease. Additionally, there are data indicating that patients with HIV have higher levels of periodontal-related bacteria. Additionally, those with diseased gums are more likely to develop heart disease due to bacterial infections in the bloodstream. Additionally, current research indicates a connection between gum illnesses and salivary oral cells such Oral Polymorphonuclear Neutrophils. In fact, the measurement and analysis of oral cells can help us better understand the biological processes occurring in saliva and could provide a clearer picture of oral health.

Literature Review

For instance, it has been confirmed that there are four times as many oPMNs in patients with periodontitis as there are in healthy people. The integrity of the oral tissue may suffer if there are too many oPMNs present. Mouth homeostasis may be jeopardised by the production of potent active mediators into the oral cavity. Periodontitis and persistent activation of oral neutrophils may cause injury to the periodontal connective tissue, which results in loss of attachment, alveolar bone loss, and tooth loss. Another illustration is the relationship between oral cavity-derived epithelial cells and oral health. According to recent studies, epithelial cells carry indicators for oral disorders like oral cancer.

There hasn't been a proven sensing system for examining oral cellular activities up to now. Standard techniques used by researchers include flow cytometry and fluorescence microscopy. These procedures require expensive, specialised equipment, a pricey service agreement, and skilled personnel to run it. Their use is therefore limited to laboratories with adequate funding. In this article, we discuss the difficulty of creating a sensing platform employing complementary metal-oxide-semiconductor technology for assessing oral cells. When compared to other sensing technologies, CMOS has provided significant benefits for integrating a single compact chip with millions of high signal-to-noise ratio (SNR), inexpensive, and fast sensors.

Discussion

In these studies, cells are grown on the chip surface, and the sensors rely on the cells' ability to adhere to the substrate as a result of the cell surface protein adhering to the substrate. They have largely been associated with cancer cells, including human ovarian cancer cells, lung carcinoma cells, breast cancer cells, and bacterial cells like E. coli. In this article, we examine the benefits of using a CMOS capacitive sensor to research oral cells. One of the widely used CMOS biosensors for precisely monitoring the capacitance fluctuations at the electrode-sample interface in many cellular assays is the capacitive sensor. They may provide important benefits for researching biological processes like growth. The cells are securely adhered to the surface in these applications.

However, researching oral cells and examining them present certain difficulties. Oral cells, in contrast to the other cells, have relatively poor cultureability. Even though they are in a culture media, they still have less affinity for the surface. Although some attempts have been made to develop oral cells in a media similar to saliva, they have not been entirely effective. The cells suffered apoptosis, perished in less than an hour, and their shape changed in various experiments for cultured neutrophils. The majority of

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periodontal disease testing involved taking samples of normal saline and examining saliva cells without cultivating them. To maintain oral cells alive throughout the studies, it is best to study them in a substance that closely resembles the saliva-like medium.

The measurement outcomes were checked using the hemocytometry cell counting method. The sample was completely mixed at this stage. With 70% ethanol, the hemocytometer was washed and cleaned, then it was left to dry. After being cleaned with 70% ethanol and allowed to dry, the coverslip was put on the hemocytometer counting chamber. In a 1.5 mL Eppendorf tube, 10 m of cells and 90 m of Trypan Blue were combined using a pipette. Then, on a hemocytometer with a coverslip, 10 L of cell suspension was added to the Trypan Blue solution.

Only 1% of saliva is made up of immunoglobulins, protein, mucus, enzymes, salts, and electrolytes like sodium, potassium, calcium, magnesium, bicarbonate, and phosphates. The remaining 99% of saliva is made up of water, along with various cell types like epithelial cells and intact and lysed inflammatory cells, specifically oPMNs. Here, oral cells are extracted from saliva using the common filtration method. Since neutrophils can only be preserved for a brief period of time, the sample is purified physically. Small oral neutrophils must be separated from epithelial cells and salivary debris using microfluidic techniques in order to be monitored by a portable sensor. The purity of the sample has a direct impact on how accurately measurements are taken.

A time-variant offset capacitance that could saturate the sensor's output can be produced by a number of sources, including parasitic effects, systematic errors, ambient influences, and experiment-time offset variation caused by the remnants of the cells. In order to display the concentration of the target cells, the sensor should have a broad IDR. Compared to other reported capacitive sensors, the sensor that is being presented in this work has a wider IDR. The applied calibration-free technique is based on sweeping the reference capacitor, and the IDR of the sensor is configurable. This has made it possible to greatly reduce the consequences of undesirable time-variant offsets. On the other hand, greater accuracy may result from a better sensor resolution [1-5].

Conclusion

This study showed how a wide-IDR, calibration-free CMOS capacitive sensor may be used to track oral cells in saliva samples. The existing parasitic and fringe capacitances were taken into account when modelling the capacitance of the on-chip IDEs numerically. To obtain qualitative information from the sensor response to the biological cells, a COMSOL simulation was run. In terms of sensitivity to changes in the dielectric of additional material on its sensing surface, simulations qualitatively concurred with the experiment and supported the operation of the devices. No cleaning steps were used on the electrodes exposed to the oral cells sample in order to prevent the conditions of the electrodes from being altered after each run. The results of the trials demonstrated that the sensor's sensitivity is reduced by the accumulation of cells after each run. So the cells were taken off the chip surface using a cleaning process. The findings were promising in terms of creating reusable, integrated sensing tools that can pave the way for future quantification and analysis of oral cells, including neutrophils and epithelial cells.

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Conflict of Interest

There are no conflicts of interest by author.

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