SMART ELECTROPALATOGRAPHY THIN-FILM FLEXIBLE PRESSURE SENSOR ARRAY FOR LINGUISTIC AND MEDICAL APPLICATIONS

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ABSTRACT

A thin-film flexible pressure sensor array based smart electropalatography (EPG) device for linguistic and medical applications is presented. This sensor array is designed to monitor the location, pressure, and duration of tongue contact during speech. A 4 x 4 parallel plate capacitive sensing array consisting of silver nanowire (AgNW) electrodes and a polydimethylsiloxane (PDMS) dielectric layer with a thickness of 350 μm is designed, fabricated, and characterized. Top and bottom active shield ground layers are added to mitigate interference use during sensing. This is one of the first flexible pseudo-palates with a total thickness of less than 500 μm, which would significantly reduce the interruption of airflow during speech thus increasing test accuracy, and enhance the comfort of a wearer compared with a commercially available rigid acrylic based pseudo-palate with a thickness of 1 ~ 2 mm.

KEYWORDS

Electropalatography, Capacitive Pressure Sensor, Active Shielding, Pseudo-Palate

INTRODUCTION

Electropalatography (EPG) is a system that can monitor contacts between the tongue and hard palate during articulation and speech and can be utilized to diagnose speech sound disorder and analyze contact patterns. It can be used to improve speech production for people who are suffering from language and communication difficulties [1, 2]. A pseudo-palate is the main component that consists of a palate with an array of electrodes and is used to detect contact patterns between the tongue and the electrodes. Since the first EPG system was developed in the 1970s at Reading University [3], there were several commercially available EPG devices such as SmartPalate system (CompleteSpeech), LinguaGraph (Rose Medical Solution), and WinEPG (Articulate Instruments Ltd) [4].

An artificially duplicated hard palate with an electrode array is inserted into the mouth and mounted between the tongue and the palate. As most commercially available pseudo-palate devices are made with a resistive sensing mechanism, they can only detect the contact locations. The devices often have a thickness of 2 mm or thicker, and thus speech production during the test can be interfered by the device resulting in producing erroneous test data. Moreover, the customized palate devices for production are expensive, and the clinical therapies and the related research are limited in practice.

In this work, a micromachined thin membrane based smart electropalatography device with an active shielded flexible capacitive pressure sensor array is designed, fabricated, and characterized. A schematic of the proposed EPG device attached to the mouth palate is shown in Fig. 1. The capacitive pressure sensor can not only detect the location of the tongue touching the palate but also tell the pressure values and contact time during speech production and articulation. The measurement results can be used as a biomarker for the early detection of tongue movement related diseases such as concussions, Parkinson's disease (PD), and schizophrenia. Furthermore, a thin and flexible palate structure with a PDMS dielectric layer can reduce the interference of tongue movement and increase the comfort of users. Soft lithography with a stencil mask is used for device fabrication. The batch fabrication process makes it manufacturable, and the production cost can be dramatically decreased, letting the device be disposable with sanitization benefits. An active shielding method is widely used for a proximity sensor to mitigate interference and parasitic capacitances [5]. With the active shielding approach, the parasitic capacitance effects resulting from the measurement environment can be effectively eliminated. The system is further configured to have wireless data readout to realize a smart EPG for the internet of things. The active shielded flexible capacitive pressure sensor is directly applicable for linguistic and medical applications.

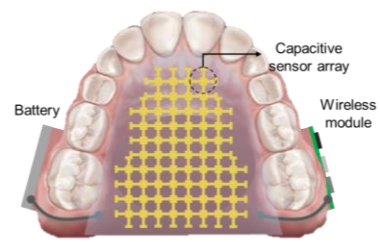

Figure 1: The proposed electropalatography (EPG) device installed on the mouth palate.

FABRICATION

Fig. 2 shows a fabrication process for an active shielded capacitive pressure sensor array. A soft lithography method using soft and flexible PDMS (Sylgard 184 kit, Dow Corning) material is used to micropattern the parallel plate silver nanowire (AgNW 120, ACS Material, LLC) electrodes. First, a silane coated Si wafer is prepared and spin coated with PDMS, where a 10:1 mixture of the prepolymer and the curing agent is used and the AgNW bottom ground layer is spray coated and passivated with a 40 μm thick PDMS layer.

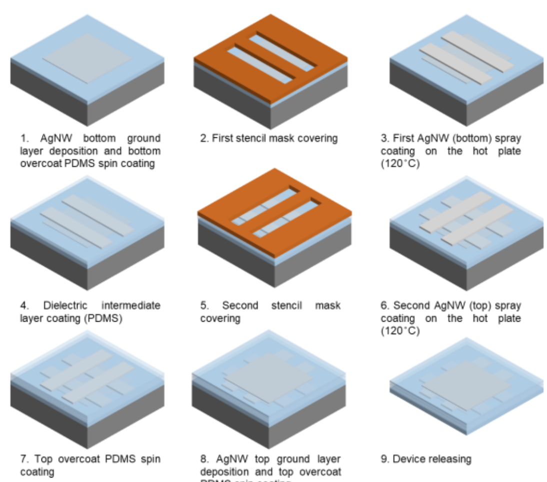

Figure 2: Fabrication process of an active shielding flexible capacitive pressure sensor array.

The first soft lithography is performed with a stencil mask and the

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bottom AgNW electrodes are spray coated with an airbrush (G222, Master Airbrush) having 0.2 mm nozzle size on a hotplate at 120℃. The intermediate PDMS layer mixed in 50:1 (pre-polymer : curing agent) is spin coated at 300 rpm and the second soft lithography is performed to deposit the top AgNW electrodes with the top overcoating passivation layer. Finally, the top AgNW ground layer is spray coated with the thin PDMS layer and the fabricated device is released from the Si wafer.

MEASUREMENT RESULTS

Fig. 3(a) shows a fabricated 4 x 4 active shielding parallel plate capacitive pressure sensor. The overlapped AgNW electrode area is 4 mm^2 with a pitch between sensors of 1 cm and the PDMS intermediate layer is 350 μm thick. The schematic of the measurement setup is described in Fig. 3(b) and the force gauge (Series 5, Mark-10 Corp.) and LCR meter (E4980A, Agilent, Inc.) are used to apply a constant force of 10 N during the capacitive measurement at 1 MHz with 2 V. The ground layers are connected to the power supply (E3630A, Agilent) with a DC voltage of + 2 V and the inset in Fig. 2(b) shows a unit cell design of the parallel plate capacitive pressure sensor and the simple mechanism of the capacitance changing resulting from the gap changing between the top and bottom electrodes due to the applied force on the sensor.

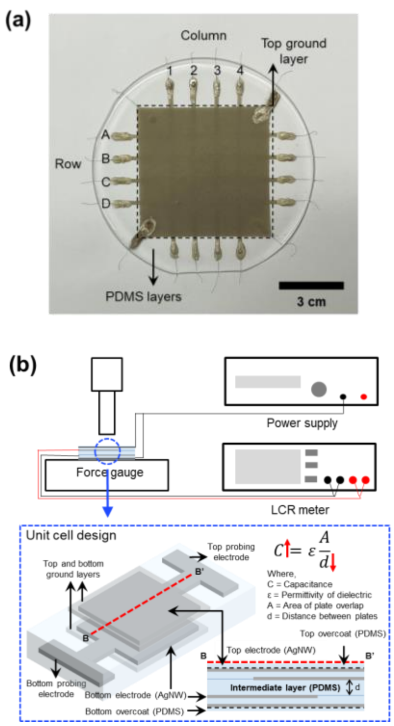

Figure 3: (a) Fabricated 4 x 4 active shielding parallel plate capacitive pressure sensor and (b) measurement setup with the LCR meter, power supply, and the force gauge. (Inset shows a schematic of a unit active shielding capacitive sensor.)

The measurement results of the active shielding case and the non-shielding case are summarized in Fig. 4 left and right, respectively. While reading the capacitance values upon external force to the sensor, one unit sensor (B3) is chosen and monitored without and with active shielding sensors. The non-shielded case shows that all the other sensors are affected by the applied force on the B3 sensor, where ΔC is in the range of 0.82 ~ 1.07 pF, and thus the actual measuring sensor and the neighboring sensors are hardly distinguishable. On the other hand, the active shielding case shows that the parasitic capacitance values are effectively reduced, thus the environmental interference during the measurements can be lowered. The developed active shielding capacitive pressure sensor is well applicable to the smart EPG application.

CONCLUSION

A smart EPG device based on an active shielding flexible capacitive pressure sensor array is successfully fabricated and characterized. A parallel plate flexible capacitive pressure sensor architecture with AgNW electrodes and PDMS intermediate /passivation layers is used. To reduce the parasitic effects during measurement, the active shielding method is applied, and its effectiveness is verified. The fabricated device can be utilized for linguistic and medical applications and contribute to enlarging the research area by not only analyzing the tongue contact patterns but also measuring the tongue pressure during the articulation.

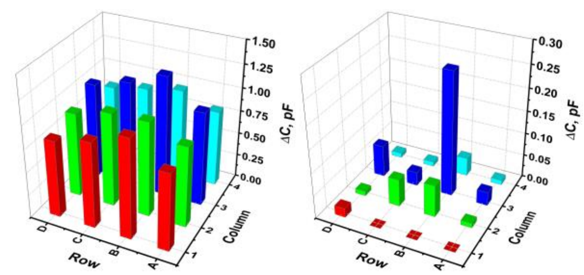

Figure 4: Measurement results of the non-shielded case (Left) and the active shielded case (Right). Sensor B3 is selected, and during the measurement, the parasitic effect is investigated upon the applied force to the sensor. ΔC is the value obtained by subtracting the capacitance values in the non-forced case from the capacitance values in the force applied case in absolute values.

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REFERENCES

[1] A. A. Wrench, "Advances in EPG palate design", *Advances in Speech Language Pathology,* 9.1, 3-12 (2007).
[2] W. Hardcastle,W. Jones,C. Knight,A. Trudgeon & G. Calder, "New developments in electropalatography: A state-of-the-art report", *Clinical Linguistics & Phonetics*, 3.1, 1-38 (1989).
[3] P. J. Roach, and W. J. Hardcastle, "A computer system for the processing of electropalatographic and other articulatory data", *Proceedings of phonetics symposium, university of essex language centre occasional papers*, p. 17 (1976)
[4] S. M. Zin, S. Z. M. Rasib, F. M. Suhaimi, and M. Mariatti, "The technology of tongue and hard palate contact detection: a review", *Biomedical engineering online*, 20(1), 1-19 (2021).
[5] D. Wang, "FDC1004: Basics of capacitive sensing and applications", *Texas Instruments-App. Report,* 12, 1-12 (2014).

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