3D PRINTED BIODEGRADABLE POLYMER STENT INTEGRATED WITH LC CAPACITIVE PRESSURE SENSOR FOR BLOOD PRESSURE MONITORING

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***Abstract*— In this paper, a hybrid polymer stent composed of PCL and PLA was developed to improve the mechanical properties of a 3D printing-based biodegradable stent. The hybrid stent is integrated with a wireless sensor for real-time monitoring of pressure changes in the blood vessel. In order to obtain uniform thickness of stent struts for enhancing bending flexibility and radial force, 3D printing process was optimized. Obtained hybrid stent thickness is 100 µm. The MEMS-based LC-type wireless capacitive pressure sensor was fabricated using SU-8 based photo-sensitive polymer, and unique microstructures were formed in the sensor to improve the binding strength between the LC sensor and the hybrid stent. The basic experiment was conducted with the different working environment. The resonance frequency changes with applied pressure were consistent as designed values. The radial force of the biodegradable hybrid stent was 0.1 N/m which was met medical requirement and possible for the application range.**

I. INTRODUCTION

Stenting the narrowed cardiovascular vessel to expand the blocked blood vessels is a common method of treating cardiovascular disease. However, re-stenosis of stent is frequently occurred after the stenting procedure. To prevent re-stenosis of stent at the early stage, it is desirable to monitor blood pressure by smart stents that can sense the pressure changes inside of the blood vessels [1]. There are many methods to combination of the stent and LC type pressure sensors such as gluing, bonding, and welding [2]. The biodegradable polymer stents are more likely to develop because they can be completely dissolved and metabolized [3]. However, the mechanical properties of polymer stents, such as radial forces and flexibility, still cannot meet the medical requirements. Regardless of the dependence on the viscosity of the polymer material or the use of biodegradable adhesives to bind the wireless sensor and the polymer stent, there is a problem of insufficient connection strength. More specifically, the separation of the wireless sensor and the polymer stent occurs during the compression and expansion of the stent required during the medical operation. In order to overcome those issues, we have designed and fabricated hybrid stent integrated with MEMS based LC pressure sensor with specific design.

II. DESCRIPTION OF THE RESEARCH

The sensor concept was shown in Fig. 1. LC pressure sensor was fabricated top and bottom layers separately. The top layer was made with a 10 µm thickness of Cu inductor coil and a variable capacitor. The bottom layer is made with a flexible thin capacitor plate and an air cavity to provide deformation space for the flexible capacitor plate. Finally, the top layer and the bottom layers are combined by a thermal bonding process (150°C, 30s). The process flow for sensor fabrication is shown in Fig. 2. the sensor was attached on the shaft which is coated by the PVA sacrificial layer (Fig. 4). During the printing process of the hybrid stent, the molten PCL and PLA materials flow into a connection hole formed in the sensor, hence enhancing the binding strength between the sensor and the stent. After dissolving the PVA sacrificial layer in water, the hybrid stent integrated with the wireless pressure sensor was released from the shaft. (Fig 3.).

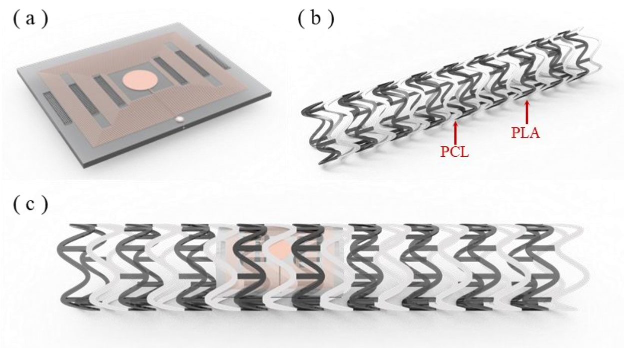

Figure 1. Concept of hybrid polymer stent integrated with LC-type capacitive wireless pressure sensor. (a) LC-type wireless pressure sensor;(b) biodegradable hybrid stent composed by PCL and PLA; (c) combination of smart and stent and pressure sensor

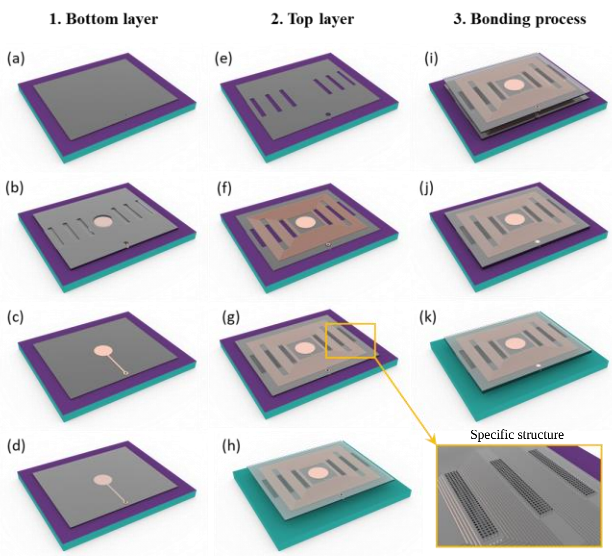

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Figure 2. Fabrication process flow of the MEMS-based wireless sensor; ***1.*** *and* ***2.*** *Is the schematic of bottom and tom layer, respectively;* ***3.*** *Shows the thermal bonding of top and bottom layer.*

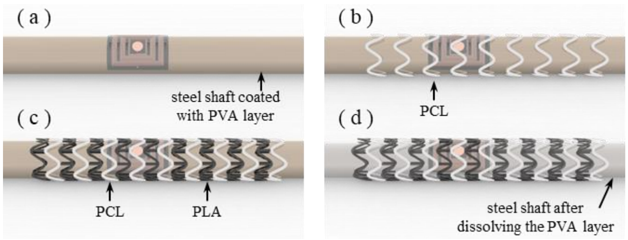

Figure 3. The combination process of wireless sensor and polymer stent. (a) Sensor pasted on shaft; (b)printing first type material; (c) printing second material; (d) Dissolving the PVA sacrificial layer.

III. Experimental Results

Optical and SEM images of the fabricated LC type pressure sensor was shown in Fig.4. The variable capacitor was tested by applying different pressure ranges (Fig. 5a). The variation of the resonance frequency with different pressure was shown in Fig. 5b. The sensitivity of the sensor was 15.19 kHz/mmHg. The printed PCL and PLA hybrid stents with strut width and thickness were 200 mm and 300 mm, respectively, and the obtained radial force was about 0.1 N/m (Fig. 6a, b). The optical images before and after printing the hybrid stent integrated with the pressure sensor are shown in Fig. 6 c, d, respectively. After combining with the stent and applying a pressure of 500 mmHg, the resonance frequency of the sensor changes by 2.92 MHz and 2.44 MHz in air and water, respectively (Fig. 7 a, b). The change in the initial resonance frequency is due to the change of the medium. By changing the voltage so that the pump provides different dynamic pressures, the resonance frequency fluctuation range of the sensor also changes accordingly (Fig. 7 c, d).

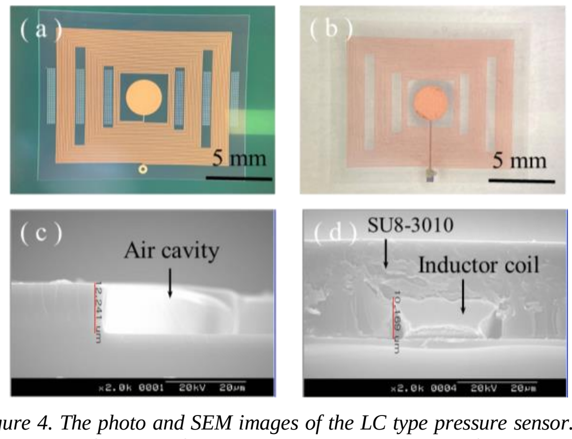

Figure 4. The photo and SEM images of the LC type pressure sensor. (a) and (b) is before and after releasing the pressure sensor from the wafer; (c) and (d) is thickness of the air cavity and inductor, respectively.

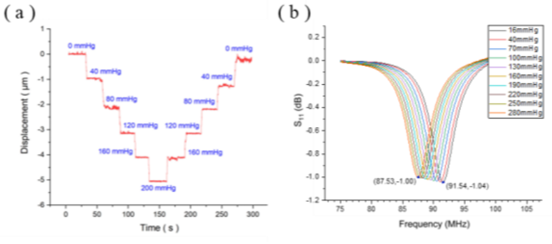

Figure 5. The experiment result of the applied pressure and corresponding changes of the resonance frequency.

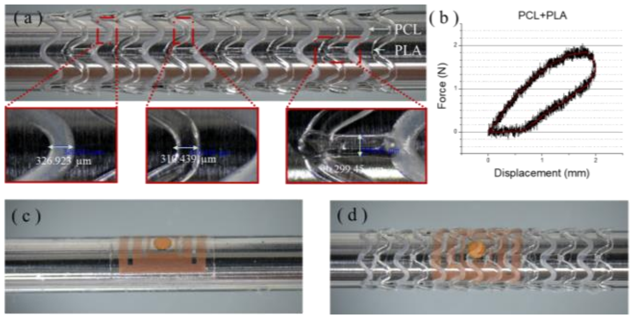

Figure 6: Printing biodegradable polymer stents with different materials (a) PCL/PLA hybrid polymer stent; (b) The radial force of PCL/PLA hybrid polymer stent.; (c)Before printing; (d) Final product inspection.

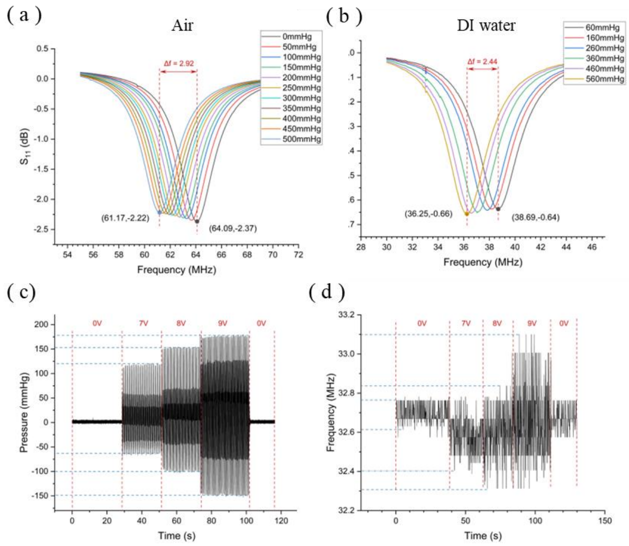

Figure 7. Wireless sensor performance detection after combined with polymer stent. (a) Air; (b) Water; (c) Different pressure value provides by pump; (d) The fluctuation of resonance frequency under different dynamic pressure.

Acknowledgment

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References

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