

논문 No.	Journal Title	First Author	Corresponding Author	Organization
TP-2-42	아이웨어 적용을 위한 플렉서블 멀티레이어 피부 건강상태 모니터링 플랫폼	송영환	김민구	인하대학교
TP-2-43	Ga2O3/Ti3C2Tx MXene 복합체 기반의 실온 암모니아 센서	차고은	박종성	경북대학교
TP-2-44	Development of a detection sensor based on lateral flow immunoassay for monitoring vancomycin in whole blood	정유경	양성	광주과학기술원
TP-2-45	Electrically tunable superradiant plasmonic nanocomposite	김현민	정현호	광주과학기술원
TP-2-46	Active Chiral Plasmonic Metasurface	김주환	정현호	광주과학기술원
TP-2-47	Research on Improving Fiber-Type Energy Storage Devices for Wearable Devices	이수범	안건형	경상국립대학교
TP-2-48	Fabrication of On-chip Microsupercapacitors based on Laser Lithography Process	권순근	안준형	한국기계연구원
TP-2-49	All Nanofibrous Triboelectric Nanogenerator-Based Self-Powered Pressure Sensor	Omar Faruk	박재영	광운대학교
TP-2-50	Enhanced Underwater Mechanical Sensing Using a Flexible Triboelectric Nanogenerator: A Combination of PVDF/Zn-Cr Layered Double Hydroxide Polymer Composite and Nylon 11 Nanofibers	비스와짓마한티	이동원	전남대학교
TP-2-51	차량 진동에너지 수확을 위한 코일진동형 전자기유도 에너지 하베스터	권대성	김현수	현대자동차
TP-2-52	불규칙 곡률반경 및 물체 형상 감지를 위한 프린팅 기반 소프트 압력센서 어레이	장재환	김민구	인하대학교
TP-2-53	다양한 형태의 감각기반 유저 인터페이스를 이용한 유아의 행동 패턴 감지 및 발달 특성 분석	이상민	김민구	인하대학교
TP-2-54	Development of a Soft and Flexible Wearable Temperature Sensor based on a Temperature-sensitive Composite Mixed with NiO Nanoparticles and C-PDMS	박세영	서민호	부산대학교
TP-2-55	Direct Writing Liquid Metal Inverse Patterning on Paper	김우찬	김대영	명지대학교
TP-2-56	Development of a mesh-type flexible electrode array for parallel recording of electrophysiological signals and fluorescence images	은종희	추남선	한국뇌연구원
TP-2-57	Enhanced Backflow Prevention in Microfluidic Check Valve through 3D Dome-shaped Valve Disk	마운호	황용하	고려대학교학과
TP-2-58	잉크젯 공정과 반응성 은 잉크를 활용한 면직물 기반 전극 제작 및 웨어러블 디바이스로의 활용	허보용	김종백	연세대학교
TP-2-59	Biologically-inspired microlens array camera for ultrafast and low-light imaging	김현경	정기훈	한국과학기술원

Poster Session 3 (FP-3)				3월 29일 금요일 08:50~10:20
논문 No.	Journal Title	First Author	Corresponding Author	Organization
FP-3-01	이중 열분해 공정을 이용한 고재현성 공중부유형 탄소 1D 나노 구조체 제조 기법	곽종현	신흥주	울산과학기술원
FP-3-02	Piezoelectric micro-jet devices with interdigitated electrode system	허근영	이병철	한국과학기술연구원
FP-3-03	롤투롤 인쇄된 유연 플라스모닉 메타표면	마지영	정현호	광주과학기술원
FP-3-04	Ice mold-assisted bidirectional freeze-casting of patterned aerogels for highly ordered porous structures	휘디엔홍	최정욱	중앙대학교
FP-3-05	Cyclic Olefin Copolymer(COC)기반의 유연하고 투명한 신경 전극 어레이의 제작	서윤	정준수	부산대학교
FP-3-06	전력반도체 모듈 역설계 및 고장 분석을 위한 실리콘 젤 제거	이규석	마병진	한국전자기술연구원

PCL/PLA-based Bioresorbable Polymer Stent integrated Wireless Sensor for Real-Time Monitoring of Cardiovascular Pressure

¹Jinliang wei, ¹Nomin-Eedene Oyunbaatar, ¹Yun-jin Jeong, ²Dong-Su Kim, ^{1,3}Dong-weon Lee*

¹MEMS Nanotechnology Laboratory, School of Mechanical Engineering, Chonnam National University

² Energy & Nano Technology Group, Korea Institute of Industrial Technology (KITECH)

³Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University

E-mail: mems@jnu.ac.kr

실시간 심혈관 압력 모니터링을 위한 무선 센서가 내장된 PCL/PLA 기반 생체흡수성 스텐트

¹웨이 진량, ¹노민, ¹정윤진, ²김동수, ^{1,3}이동원*

¹ 전남대학교 기계공학부 MEMS 나노기술 연구실

² 한국생산기술연구원 에너지나노그룹

³ 전남대학교 심혈관 환자맞춤형 차세대 정밀의료기술 선도연구센터

Abstract

Using cardiovascular stents to support the blocked part to restore blood flow is currently the mainstream treatment method for cardiovascular diseases. Bare metal stents (BMS) or drug-eluted stents (DES) have caused a series of complications because they cannot be removed after implantation. Therefore, we proposed a hybrid biodegradable polymer (HBS) stent based on PCL and PLA materials. Taking full advantage of the different physical properties of these two materials, the HBS T has both sufficient radial support and axial flexibility. The Wireless pressure sensor is made using MEMS technology. When restenosis occurs, changes in intravascular pressure cause the deformation of the capacitive sensing element, which is detected in the form of a resonance frequency shift. The two are connected through a unique mechanical structure to ensure the strength of the connection between the two. The excellent performance of the proposed smart stent highlights its potential for medical purposes.

Keywords: *Bioresorbable vascular scaffold, Pressure sensor, Smart stent, Restenosis*

1. Introduction

In the treatment of cardiovascular diseases, the insertion of stents into constricted cardiovascular vessels is a prevalent technique to alleviate obstructions. However, the phenomenon of stent restenosis, a recurring narrowing post-stent placement, is a notable complication. Emerging research is increasingly focusing on biodegradable polymer scaffolds, which offer the advantage of complete dissolution and metabolism in the body [1]. Despite this, current polymer stents face challenges in meeting clinical standards for mechanical properties, including radial strength and flexibility.

To proactively address stent restenosis, it is essential to monitor blood pressure within the vessels. This is achievable through 'smart stents' equipped with sensors capable of detecting intravascular pressure fluctuations [2]. Various methods, such as adhesion, bonding, and welding, have been explored for integrating LC-type pressure sensors with the stent framework [3]. However, both strategies, whether utilizing polymer material viscosity or

biodegradable adhesives for affixing wireless sensors to the polymer scaffolds, encounter issues with connection strength. Particularly, the detachment of the wireless sensor from the polymer stent is a concern during the compression and expansion phases inherent in medical procedures.

To surmount these challenges, our team has developed a Hybrid Biodegradable Polymer Stent (HBS) composed of Polycaprolactone (PCL) and Polylactic Acid (PLA). This HBS is specifically engineered to balance radial force and bending flexibility. Additionally, we have innovated a unique design for the connection structure of the wireless pressure sensor, ensuring a robust mechanical bond between the sensor and the HBS. This design aims to establish a secure and enduring connection, essential for the effective functioning of the stent in clinical applications."

2. Material and method

The fabrication of the LC wireless pressure sensor is divided into two main parts: the top layer and the bottom layer. The top layer consists of an inductor coil and a capacitor plate. Using silicon dioxide as a substrate, a 10 μm thick SU8 2002 layer is made on top. Then 10 μm thick inductor and capacitor plates are formed by electroplating and finally packaged with SU8 3010. The production of the bottom layer is similar to the above process, but the capacitor plate is formed by metal etching, and the insulating layer is formed with SU8 2002. Finally, the air cavity is formed with PermiNex. The two are combined through thermal bonding technology to form a wireless pressure sensor.

The structural design of the stent used in this study is divided into two parts: the corrugated ring and the connector. The corrugated ring is the main part that provides the radial force. The connector is used to connect the two adjacent rings, and the performance of this part will dominate the bending flexibility of the stent. The application of 3D printing technology allows us to freely define materials at different locations. Print PCL material with a lower melting point and PLA material with a higher melting point in sequence. The intersection of the two will form a communion that will unite them together. Before printing HBS, use the adhesiveness of PVA to paste the wireless pressure sensor h onto

the shaft. At this time, during the HBS printing process, the molten polymer material will flow into it to form a mechanical structural connection. At this time, the smart stent we designed can be obtained by dissolving the PVA sacrificial layer.

3. Result and discussion

An optical image showing the fabricated wireless pressure sensor after peeling it off a silicon wafer is shown in Figure 1a. The dimensions of the wireless pressure sensor are 7.4mm long and 6mm wide. Another important structure is the connection hole that is mechanically connected to the polymer scaffold, which is located on the centerline of the wireless pressure sensor (Figure 1b).

To examine the membrane's response to external pressure changes, the internal pressure of the vacuum chamber was increased to 200 mmHg and then returned to 0 mmHg pressure at the same rate. The laser vibrometer records the deformation of the film center as the pressure changes in real-time. The relationship between pressure changes and membrane deformation is shown in Figure 2a. We will gradually increase the ambient temperature to room temperature. The experimental results show that the sensor can work stably at different temperatures, as shown in Figure 2b, which illustrates the stability of the wireless pressure sensor. Resonant frequency changes of wireless pressure sensors were recorded via VNA. When the external pressure increases from 0 mmHg to 250 mmHg, the resonant frequency of the wireless pressure sensor attenuates from 88.10 MHz to 84.80 MHz, as shown in Figure 3c. The sensitivity of the wireless pressure sensor is calculated to be 13.2 kHz/mmHg, as shown in Figure 2c. The distance between the wireless pressure sensor and the external readout antenna is varied by a high-precision Z-axis moving platform, and the resonant frequency signal is recorded using a VNA. When the distance is increased to 24 mm, a clear resonance frequency signal can still be read, as shown in Figure 2d. The fabricated smart stent was reduced in diameter from 3 mm to 2 mm through a crimping device (Figure 3a-b), and then expanded to the initial 3 mm through a balloon catheter (Figure 3c). After the crimping and expansion process, the smart stent still maintains a complete structure, and the side view shows that the wireless pressure sensor maintains a tight fit with the PCL/PLA HBS (Figure 3d). These experimental results show that we have achieved a reliable combination of wireless pressure sensors and polymer scaffolds.

4. Conclusion

In summary, we proposed a novel hybrid smart stent for potential cardiovascular applications. The use of hybrid materials in combination for printing the stent overcomes the limitations of a single material and enhances its bending flexibility while ensuring radial force. The basic experiment conducted with the fabricated smart stent demonstrated that the change in the resonant frequency according to pressure was highly consistent with the design value. The excellent performance of the proposed smart stent highlights its potential for medical purposes.

Acknowledgments

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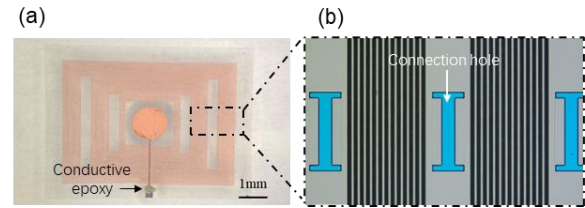


Fig. 1. (a) Optical image showing a panoramic view of the fabricated LC pressure sensor. (b) Optical images show details of the connection structure

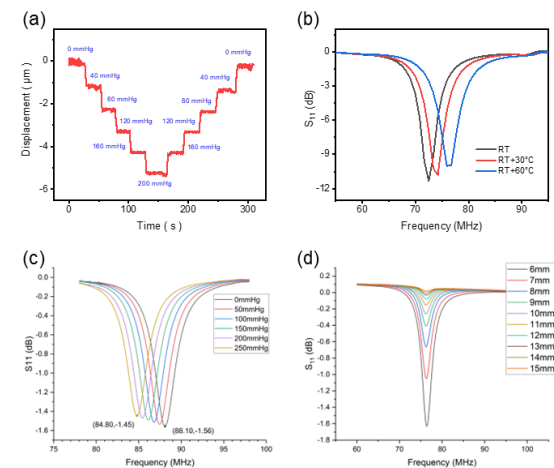


Fig. 2. (a) The theoretical deformation of the membrane when an external pressure of 0mmHg to 250mmHg is applied. (b) Effect of temperature on the resonant frequency. (c) The plot shows the resonance frequency shift of LC pressure when an external pressure of 0 mmHg to 250 mmHg is applied. (d) S11 of the fabricated LC pressure sensor when the external antenna distance is varied from 0 to 5 mm.

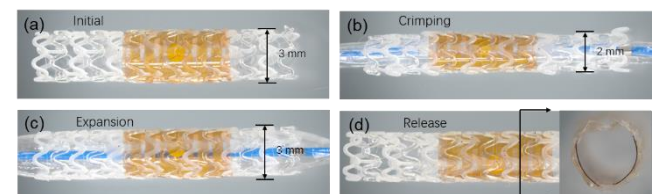


Fig. 3. Crimping and expansion experiments were conducted by combining a wireless pressure sensor with a 3D-printed hybrid polymer stent to verify the strength of the connection between the wireless pressure sensor and the hybrid polymer stent through the mechanical structure.