

논문 No.	Journal Title	First Author	Corresponding Author	Organization
TP-2-15	원형 마이크로 채널에서의 전단 유발 혈전 형성 과정 분석	최지섭	박우태	서울과학기술대학교
TP-2-16	In situ scanning electron microscopy of microparticle grain diffusion on ionic liquid surface	임도현	이원철	한양대학교 ERICA캠퍼스
TP-2-17	Exploring Spiral Microfluidic Channels: Secondary Dean Flow Induction and Micro-Particle Separation via a Progressively Narrowing Upper Channel	배성훈	양성	광주과학기술원
TP-2-18	Magnetically actuated PLGA core-shell-based drug-eluting microsphere for transarterial chemoembolization	김석재	최은표	전남대학교
TP-2-19	Improved Sensitivity of Non-enzymatic Glucose Sensor based on K-doped Co3O4	윤재형	류원형	연세대학교
TP-2-20	PCB-based digital microfluidic platform utilizing acoustically oscillating bubble	김현우	이정민	명지대학교
TP-2-21	Magnetically remote-controlled micromixer for non-invasive drug delivery	채린	이강용	명지대학교
TP-2-22	Development of 3D Printing Process of Cell Culturing Scaffold using Hydrothermally Extracted Marine Polysaccharide	김재호	류원형	연세대학교
TP-2-23	Fabrication of Screen-printed MeHA Microneedle Paper Sensor for Glucose Sensing	김현수	류원형	연세대학교
TP-2-24	Development of miniaturized multi-stimuli-responsive biocompatible soft actuators	남명혜	최은표	전남대학교
TP-2-25	전기 중합을 이용한 분자 각인 고분자 기반의 흰반점 바이러스 검출 센서 개발	윤영란	양성	광주과학기술원
TP-2-26	Acoustic Bubble and Magnetic Liquid Metal-Based Microrobot for Multiphase Drug Manipulation Technology	박지혁	김대근	명지대학교
TP-2-27	Study of a Flexible Probe-type Sensor for Simultaneous Determination of Multi-neurotransmitters	차혜빈	이이재	한국과학기술연구원, 고려대학교
TP-2-28	Liquid atomization and ejection technology in micro-panel gap using acoustic waves	이찬	이정민	명지대학교
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TP-2-33	Micro-/Nanoparticle Separation Combining Multi-physical Fields: Pressure and Temperature	김준호	김태성	울산과학기술원
TP-2-34	높은 민감도 및 선형성을 가지는 다공성 촉각 센서	이재승	김종백	연세대학교
TP-2-35	Hall Sensing 기반의 Auxetic 촉각센서	윤영현	장범진	한양대학교 ERICA캠퍼스
TP-2-36	자성 미세섬모 기반 고범위 압력 센서	서정연	김회준	대구경북과학기술원
TP-2-37	Minimally invasive MEMS thermopile flow sensor for plant sap flow measurement	심재현	임시형	국민대학교
TP-2-38	WSe2-Based Electrothermal Barometric Pressure Sensors for Detecting Subtle Pressure Changes	왕뢰뢰	최정욱	중앙대학교
TP-2-39	A smart piezoresistive pressure sensor based on asymmetric parallelogram cross-sectional channel structure	오별님	김현수	광운대학교
TP-2-40	견고한 전극층과 탄성 접지층을 사용한 차폐형 정전 용량 압력 센서 어레이	이돈호	박인규	한국과학기술원
TP-2-41	플라즈모닉 메타표면을 이용한 맛 분자 현장 검출	이주형	정현호	광주과학기술원

# Investigating the Enhancement of Mechanical Strength in Bioresorbable Smart Scaffolds through Metal-Polymer Series Connections

<sup>1</sup> Wang Lei, <sup>1,2</sup> Nomin-Erdene Oyunbaatar, <sup>1,2</sup> Yunjin Jeong, <sup>3</sup> Dong-Su Kim, <sup>1,2</sup> Dong-Weon Lee \*

<sup>1</sup>) MEMS Nanotechnology Laboratory, School of Mechanical Engineering, Chonnam National University

<sup>2</sup>) Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University

<sup>3</sup>) Energy & Nano Technology Group, Korea Institute of Industrial Technology (KITECH)

E-mail: mems@jnu.ac.kr

## 금속-폴리머의 직렬 연결을 통한 생체흡수성 스마트 스캐폴드의 기계적 강도 향상에 관한 연구

<sup>1</sup> 왕레이, <sup>1,2</sup> 노민, <sup>1,2</sup> 정윤진, <sup>3</sup> 김동수, <sup>1,2</sup> 이동원\*,

<sup>1</sup> 전남대학교 기계공학부 MEMS 나노기술 연구실

<sup>2</sup> 전남대학교 심혈관 환자맞춤형 차세대 정밀의료기술 선도연구센터

<sup>3</sup> 한국생산기술연구원 에너지나노그룹

### Abstract

This article introduces a novel metal-polymer hybrid stent with an integrated elongated wireless pressure sensor, offering improved mechanical support and stable pressure sensing for medical implantation. Traditional bare metal stents (BMS) compromise pressure sensor sensitivity, while biodegradable stents lack sufficient mechanical strength for vascular insertion. Our design, featuring a special metal structure and a polymer component via 3D printing, combines the advantages of both stent types, ensuring robustness and ease of insertion. The stent's elongated pressure sensor is uniquely designed to minimize damage during crimping, enhancing the stability of wireless sensors in medical applications. This innovative hybrid stent presents a promising solution for various medical scenarios, significantly advancing current stent and sensor technology.

**Keywords:** *Hybrid stent; Wireless pressure sensor; Smart stent; 3D Printing in Medical Devices*

### 1. Introduction

To address the global health challenge posed by cardiovascular diseases, particularly coronary artery disease (CAD), this paper explores a novel approach in the field of medical technology. CAD, a leading cause of mortality worldwide, involves the buildup of atheromatous plaques in the arteries, leading to stenosis, reduced blood flow, and the risk of myocardial infarction. A key method to combat this issue is the use of stents, which are cylindrical structures made up of interconnected rings and struts. These stents are designed to be inserted into the affected arteries to restore normal blood flow, offering a minimally invasive alternative to open heart surgery and showing better long-term outcomes.[1]

Initially, stents were made of bare metal and were primarily used in emergency situations following angioplasty. However, the issue of in-stent restenosis, or the re-narrowing of the artery, led to the development of drug-eluting stents (DESs). These DESs have become a standard in percutaneous coronary intervention (PCI),

significantly reducing the rate of restenosis and the need for repeat procedures. [2]

The field of stent research is continually evolving, with diversification in stent designs and materials. This evolution allows for treatments to be tailored to the specific needs of individual patients. One of the recent innovations in this area includes the integration of wireless pressure sensors within the stents. These sensors use changes in capacitance to detect pressure without needing an integrated power source. However, the use of metallic stents can interfere with the function of these sensors. [3] Polymer stents, on the other hand, while they do not interfere with sensor functionality, lack the necessary radial force that is often needed to treat vessel constriction effectively.

One of the challenges with wireless pressure sensors, particularly when using materials like SU-8, is their vulnerability to damage under mechanical stress during the crimping process in PCI. This can compromise the integrity of the sensor, making it a significant challenge that needs to be addressed for the successful integration of reliable sensors in cardiovascular interventions. [4]

In response to these challenges, this paper proposes a groundbreaking hybrid stent that combines the advantages of both metal and polymer stents. This hybrid stent is designed to not only prevent restenosis but also maintain the sensitivity of the integrated sensors. It features a metal-polymer series connection with a wireless pressure sensor. The integration of these elements results in a stent that exhibits enhanced performance in both its primary function as a stent and in its capability to accurately sense pressure. This innovation holds great promise for real-world surgical applications, potentially revolutionizing the way cardiovascular diseases are treated and managed.

### 2. Result and discussion

#### 2.1 Design and fabrication flow of hybrid stent

The metal stent will decrease the sensor signal, the mechanical strength of the polymer support is not enough. The polymer stent

is associated with the limitation of inadequate radial force. The incorporation of metal in the hybrid stent addresses this drawback by providing sufficient radial force. Conversely, the use of metal stents is known to cause reduced sensor sensitivity. However, the combination of a sensor with a polymer component in the hybrid stent overcomes this issue, allowing for optimal sensor sensitivity without the negative impact of the metal component. So, we design the metal-polymer series connection hybrid stent provides sufficient mechanical strength without attenuating the wireless pressure sensor signal, as shown as in figure 1(a). Figure 1(b) depicts the connection mechanism between the metal and polymer components of the hybrid stent. Specifically, a laser cutting process is employed to create a gap in the metal stent, allowing the polymer material to flow in during the subsequent 3D printing process. Once the polymer material has cooled, a robust connection is formed between the metal and polymer components. The fabrication process of the hybrid stent is illustrated in Figure 1(c). Initially, two metal stent parts, each with two gaps, are placed on the shaft. Subsequently, the polymer component of the hybrid stent is 3D printed and allowed to cool. The polymer and metal parts are then firmly bonded together, completing the process of creating the Metal-Polymer Series connection Hybrid Stent.

## 2.2 Combination of stent and sensor

Figure 2 illustrates the intricate integration of a wireless pressure sensor within a polymer stent, showcasing two aspects: (a) a schematic representation of the stent structure with labeled components such as the inductor, capacitor, and connection holes for sensor integration, and (b) a detailed view of the connection structure between the sensor and stent, highlighting the precision engineering required to merge these technologies. This integration is critical for real-time monitoring of blood vessel pressure, potentially improving outcomes in cardiovascular disease treatments. The scale indicators emphasize the miniaturization of the technology, critical for compatibility with human vascular systems.

## 2.3 Phantom system

Figure 3 illustrates the frequency change of a wireless pressure sensor under different water pressures in the Phantom system, combined with different stent types. (a) The image represents the Phantom system used for the experiments. (b-d) The graphs display the frequency change of the sensor at 200, 400, and 600mmHg water pressures when combined with a PCL stent. (e-g) The graphs demonstrate the frequency change of the sensor at the same water pressure levels but when combined with a hybrid stent. The figure provides a comprehensive overview of the frequency variations of the wireless pressure sensor under different water pressure conditions, highlighting the impact of the stent type (PCL or hybrid) on the sensor's performance. This data offers valuable insights into the behavior of the sensor and its compatibility with different stent materials in the Phantom system.

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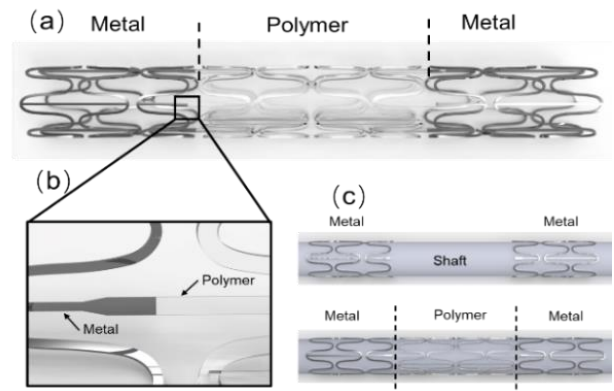


Fig. 1. Metal-Polymer sandwich structure hybrid stent design. (a)Schematic of metal-polymer sandwich structure hybrid stent. (b) Connection structure between metal stent and polymer stent. (c)fabrication flow of hybrid stent.

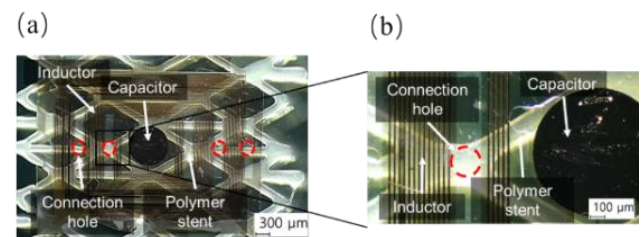


Figure 2. Integration of wireless pressure sensor and polymer stent. (a)schematic of polymer stent integrated with wireless pressure sensor. (b) connection structure between wireless pressure sensor and stent.

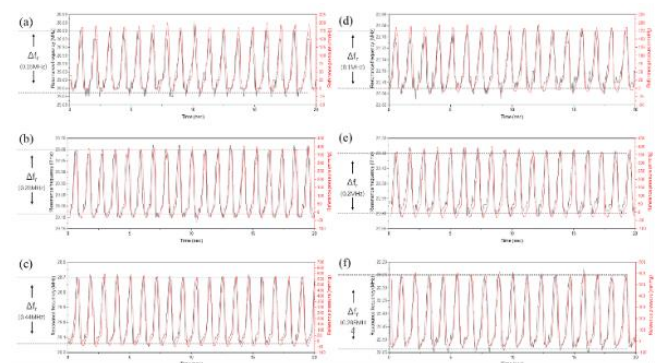


Figure 3. Wireless pressure sensor frequency change under different water pressure in the Phantom system combined with different stent. (a) Phantom system. (b-d) 200/400/600 mmHg in PCL stent. (e-g) 200/400/600 mmHg in hybrid stent.