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P11-04 **Uncertainty evaluation of KRISS-AG-1 and toward improving the uncertainty**
 Sang-Bum Lee^{1),†}, Taeg Yong Kwon¹⁾, Sang Eon Park¹⁾, Sangwon Seo¹⁾, Sang Lok Lee^{1),2)}, Hyun-Gue Hong¹⁾, Jae Hoon Lee¹⁾, Young-Ho Park¹⁾, Seji Kang¹⁾, Meung Ho Seo¹⁾, and Hyun Gyung Lee¹⁾
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²⁾*Department of Physics, Chonnam National University* 373

P12. Multidisciplinary

P12-01 **A Study on the Inspection, Analysis and Evaluation of Carbon Fiber Filament Yarn & Tow using Multi-Channel Eddy Current Sensor**
 Joonho Bae^{1),†}, Jongik Lee¹⁾, Hyewon Park¹⁾, Jihun Moon²⁾, and Seonghun Kwak²⁾
¹⁾*K-albatross Co., Ltd*, ²⁾*Gyeongbuk Hybrid Technology Institute* 377

P12-02 **UV detecting characteristics of GaN/Ga₂O₃ p-n junction**
 Yukyung Kim¹⁾, Mankyung Kim¹⁾, Kwang Hyeon Baik³⁾, and Soohwan Jang^{1),2),†}
¹⁾*Department of Chemical Engineering, Dankook University*, ²⁾*Convergence Semiconductor Research Center, Dankook University*, ³⁾*Department of Materials Science and Engineering, Hongik University* 378

P12-03 **Anomaly Detection via Typicality and Atypicality for Military Application**
 Sehong Oh¹⁾, Jongsung Park²⁾, and Youngsam Yoon^{3),†}
¹⁾*Department of AI and Data Science, Korea Military Academy*, ²⁾*Department of Precision Mechanical Engineering, Kyungpook National University*, ³⁾*Department of Electrical Engineering, Korea Military Academy* 379

P12-04 **Power divider design applicable to beamforming system**
 Woojin Yun¹⁾, Gapseop Sim^{1),2)}, Kilsun Roh¹⁾, Changhee Han¹⁾, and Choul-Young Kim^{2),†}
¹⁾*National Nanofab Center*, ²⁾*Department of Electrical Engineering, Chungnam National University* 381

P12-05 **Approaches for Cardiomyocyte Maturation and Drug Toxicity Assessment through Mechanical Stimulation and AgNW Integration**
 Jongyun Kim¹⁾ and Dong-Weon Lee^{1),2),†}
¹⁾*School of Mechanical Engineering, Chonnam National University*,
²⁾*Center for Next-generation Sensor Research and Development, Chonnam National University* 382

P12-06 **3D-printed stent using biodegradable PCL composite infused with contrast agents for enhanced radiopacity**
 Yun-Jin Jeong^{1),2)}, Byeongjun Choi³⁾, Seokjae Kim²⁾, Juyeong Jo^{1),4)}, Arunkumar Shanmugasundaram^{1),2)}, Hyungwoo Kim³⁾, Eunpyo Choi^{1),4)}, and Dong-Weon Lee^{1),2),5),†}
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3D-printed stent using biodegradable PCL composite infused with contrast agents for enhanced radiopacity

Yun-Jin Jeong^{1),2)}, Byeongjun Choi³⁾, Seokjae Kim²⁾, Juyeong Jo^{1),4)}, Arunkumar Shanmugasundaram^{1),2)},
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Abstract

Continuous in vivo observation of polymer-derived biodegradable stents (BDSs) is important for their efficacious interventions in cardiovascular applications. However, the inherent non-radiopacity of BDSs presents substantive impediments in assiduously observing patient trajectories. Herein, we propose a biodegradable contrast medium which is synthesized by conjugating 2,3,5-triodobenzoic acid (TIB) with polycaprolactone diol (PCL-diol). The subsequent PCL-TIB is amalgamated with polycaprolactone (PCL) to prepare a polymer framework apt for stent fabrication via additive manufacturing methodologies. The mechanical resilience of the resultant BDSs is appraised via exhaustive evaluations, evidencing their capacity to counter external perturbations and maintain their architectural coherence. Cell viability tests on human umbilical vein endothelial cells (HUVECs) indicate a viability surpassing 90% relative to a control cohort, highlighting the superior biocompatibility and minimal cytotoxicity of the engineered BDSs. Moreover, in vivo radiographic assessment of the BDSs, inclusive of those laden with iohexol, showcased a decline in radiopacity post 7 days, culminating in an indiscernible radiopacity post 9 days. Conversely, BDSs fortified with the proposed degradable contrast medium sustained their radiographic visibility for an interval extending to 40 days. Owing to the excellent biocompatibility and extended radiopacity, the proposed BDSs can be used to address diverse cardiovascular ailments.

Keywords: 3D printing, Biodegradable contrast agent, Radiopacity, Bioresorbable stent

Acknowledgement

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Material characterization and 3D printer fabrication

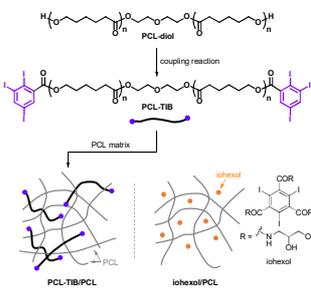


Fig. 1. Schematic illustrates the preparation process flow of the PCL-TIB/PCL hybrid composite and a control iohexol/PCL composite.

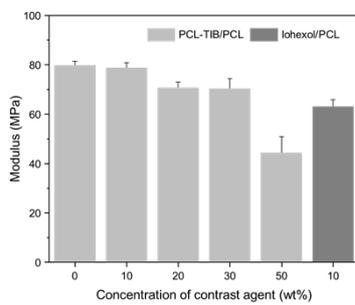


Fig. 2. Change in elastic modulus of the PCL-TIB/PCL hybrid composite according to the weight percentages of the PCL-TIB contrast agent.

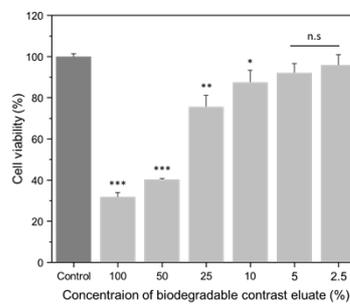


Fig. 3. Cell viability measurements of HUVECs cultured with PCL-TIB contrast agent eluate with different concentration.

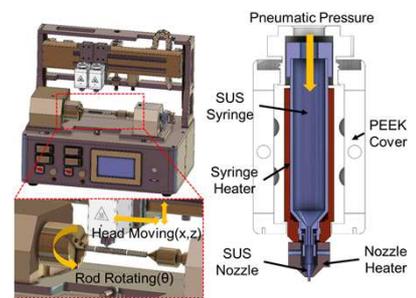


Fig. 4. Schematic diagram of an FDM-type 3D printer for manufacturing biodegradable stents

Characterization of biodegradable stent with contrast medium

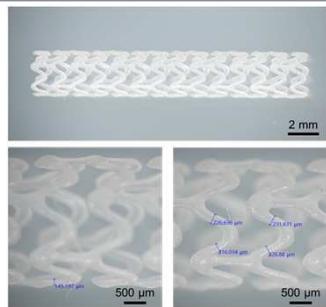


Fig. 5. Optical image of PCL stent with integrated biodegradable contrast agent

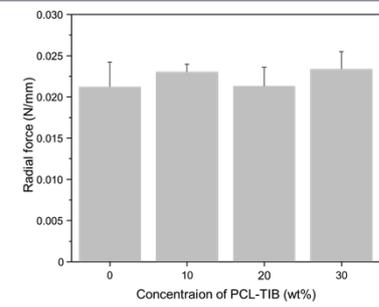


Fig. 6. Bar plots illustrating the radial force exerted by the fabricated BDSs at different concentrations of functional additives.

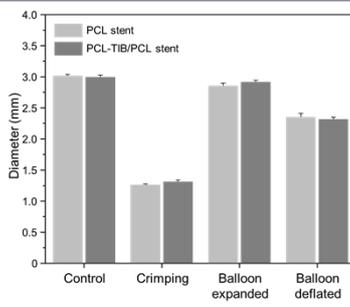


Fig. 7. Bar plots demonstrating the diameter of the fabricated BDSs comparing bare stents with BDSs incorporating 30 wt% of the PCL-TIB.

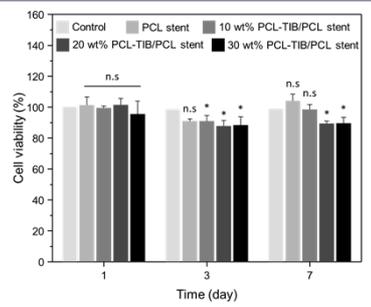


Fig. 8. Cytotoxicity analysis of the fabricated biodegradable stents at different concentration of contrast medium.

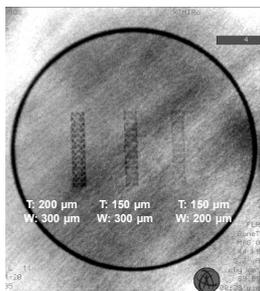


Fig. 9. Visibility of the PCL-TIB/PCL stent under real-time x-ray for in vitro.

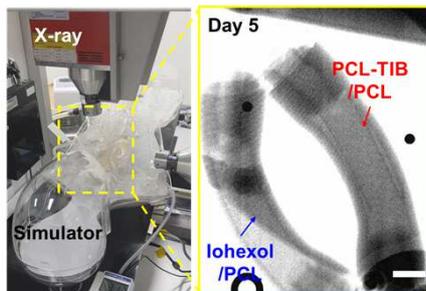


Fig.10. Prolonged x-ray visibility of stents based on 30 wt% PCL-TIB/PCL and 10 wt% iohexol/PCL in the endovascular evaluator.

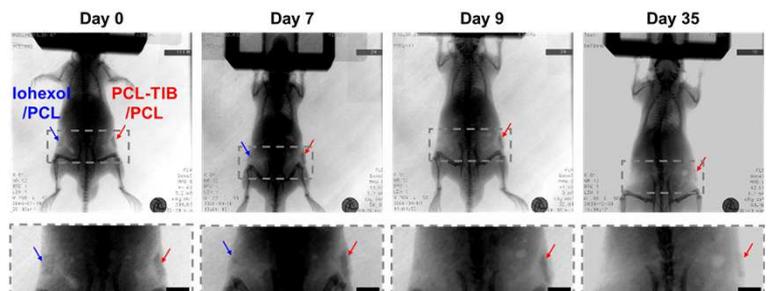


Fig. 11. In vivo prolonged x-ray visibility of stents based on 30 wt% PCL-TIB/PCL and 10 wt% iohexol/PCL

Conclusion

The aim of this study was to enhance the X-ray visibility and duration of biodegradable polymer stents. To achieve this, a biodegradable contrast medium incorporated PCL composites were synthesized. Subsequently, a stent structure was fabricated 3D printing technology. The PCL composite-based biodegradable stent exhibited no alterations in mechanical stiffness owing to the incorporation of the contrast agent. Furthermore, cell viability analysis using human umbilical vein endothelial cells (HUVECs) demonstrated that over 90% of cells survived, thus confirming biocompatibility. Notably, X-ray visibility persisted for more than 50 days, enabling monitoring post endovascular stent implantation and surgery. Consequently, the PCL composite-based biodegradable stent, featuring the proposed contrast medium, is anticipated to possess significant medical applicability.

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