

Advanced Biomanufacturing Technologies for Micro-physiological Systems

Min Kyeong Kim^{1,24}, Jungbin Yoon^{2,24}, Dohui Kim^{2,24}, Jongmin Kim^{2,24}, Jae-Seok Kim³, Gyugang Go^{4,5}, Junhyeok Song^{4,5}, Seunghun Son⁶, Kyungdeok Park⁶, Jooyoung Lee⁷, Donghan Lee⁸, Sumin Cho⁸, Wonseok Choi⁹, Jaehong Min¹⁰, Young-Sam Cho^{11,12,13}, Seung-Jae Lee^{11,12,13}, Hee-Gyeong Yi^{14,15}, Andrew Choi^{4,5}, Seunggyu Jeon⁶, Hyungseok Lee^{7,16}, Dongwhi Choi⁸, Sungmin Han^{8,17,18}, Jihoon Ko¹⁰, Dong-woo Cho^{2, #}, Dong Sung Kim^{2,19,20,21, #}, Jinah Jang^{2,21,22,23, #}, and Hyun-Wook Kang^{1, #}

¹Department of Biomedical Engineering, Ulsan National Institute of Science and Technology, 50, UNIST-gil, Ulsu-gun, 44919, Ulsan, South Korea.

²Department of Mechanical Engineering, Pohang University of Science and Technology (POSTECH), 77, Cheongam-ro, Nam-gu, 37673, Pohang, South Korea

³Department of Mechanical Engineering, Wonkwang University, 460, Iksandae-ro, Iksan, 54538, Jeonbuk-do, Republic of Korea.

⁴Department of Mechanical Design and Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul, 04763, Republic of Korea

⁵Department of Mechanical Engineering, BK21 FOUR ERICA-ACE Center, Hanyang University, 55 Hanyangdaehak-ro, Sangnok-gu, Ansan, 15588, Republic of Korea

⁶Department of Bionic Machinery, KIMM Institute of AI Robot, Korea Institute of Machinery and Materials (KIMM), 156 Gajeongbuk-Ro, Yuseong-Gu, 34103, Daejeon, Republic of Korea.

⁷Department of Smart Health Science and Technology, Kangwon National University (KNU), Chuncheon 24341, Republic of Korea

⁸Department of Mechanical Engineering (Integrated Engineering Program), Kyung Hee University, 1732 Deogyong-daero, Yongin, Gyeonggi 17104, South Korea

⁹Bionics Research Center, Korea Institute of Science and Technology (KIST), Seongbuk-gu, 02792, Seoul, Republic of Korea

¹⁰Department of BioNano Technology, Gachon University, Seongnam-si, Gyeonggi-do 13120, Republic of Korea

¹¹Division of Mechanical Engineering, Wonkwang University, 460, Iksandae-ro, Iksan, 54538, Jeonbuk-do, Republic of Korea.

¹²MECHABIO Group, Wonkwang University, 460, Iksandae-ro, Iksan, 54538, Jeonbuk-do, Republic of Korea.

¹³Advanced Bio-Convergence Research Center, Wonkwang University, 460, Iksandae-ro, Iksan, 54538, Jeonbuk-do, Republic of Korea.

¹⁴Department of Convergence Biosystems Engineering, College of Agriculture and Life Sciences (CALS), Chonnam National University, 77, Yongbong-ro, 61186, Gwangju, South Korea

¹⁵Institute for Biomedical Science, Chonnam National University Hwasun Hospital, 322, Seoyang-ro, Hwasun-gun, 58128, Jeollanam-do, South Korea

¹⁶Department of Mechanical and Biomedical, Mechatronics Engineering, Kangwon National University (KNU), Chuncheon 24341, Republic of Korea

¹⁷KHU-KIST Department of Converging Science and Technology, Kyung Hee University, Dongdaemun-gu, 02447, Seoul, Republic of Korea

¹⁸Division of Bio-Medical Science & Technology, Korea Institute of Science and Technology School, Seongbuk-gu, 02792, Seoul, Republic of Korea

¹⁹Department of Chemical Engineering, Pohang University of Science and Technology (POSTECH), 77 Cheongam-ro Nam-gu, Pohang, 37673, Republic of Korea

²⁰School of Interdisciplinary Bioscience and Bioengineering, Pohang University of Science and Technology (POSTECH), 77 Cheongam-ro Nam-gu, Pohang, 37673, Republic of Korea

²¹Institute for Convergence Research and Education in Advanced Technology, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul, 03722, Republic of Korea

²²Department of Convergence IT Engineering, Pohang University of Science and Technology (POSTECH), 77, Cheongam-ro, Nam-gu, 37673, Pohang, South Korea

²³School of Interdisciplinary Bioscience and Bioengineering, Pohang University of Science and Technology (POSTECH), 77, Cheongam-ro, Nam-gu, 37673, Pohang, South Korea

²⁴These authors contributed equally to this work.

Corresponding Author / E-mail: dwcho@postech.ac.kr, smkds@postech.ac.kr, jinahjang@postech.ac.kr, hkang@unist.ac.kr

KEYWORDS: Microphysiological systems, Biomanufacturing, Organ-on-a-chip, Bioprinting

Advanced biomanufacturing technologies are rapidly transforming the development of microphysiological systems (MPS), which serve as sophisticated in vitro platforms to model human organ structure and function with high fidelity. This review highlights cutting-edge biofabrication strategies, including 3D bioprinting technologies (such as inkjet, extrusion-based, digital light processing, stereolithography, and laser direct writing), microfluidics, modular tissue engineering, and electrohydrodynamic manufacturing that enable precise fabrication of complex, multicellular, and physiologically relevant tissue models. The integration of microfluidic systems enhances MPS by supporting dynamic perfusion, mechanical stimulation, and real-time monitoring, while modular approaches such as cell spheroid, organoid, and cell sheet assembly facilitate scalable and reproducible tissue engineering. Electrohydrodynamic techniques like electrospraying and melt electrowriting are emphasized for their ability to fabricate nanostructured scaffolds that closely mimic native extracellular matrix properties. This review also examines the selection and application of biomaterials, ranging from natural and synthetic polymers to hybrid composites and stimuli responsive hydrogels, that underpin the structural and functional integrity of MPS. Finally, the broad applications of advanced biomanufactured MPS in drug screening, toxicology, disease modeling, and regenerative medicine are discussed, emphasizing their potential to reduce reliance on animal models and accelerate biomedical discoveries toward clinical translation. The convergence of real-time sensing, smart materials, and modular design principles is identified as a key driver for the next generation of physiologically relevant and patient specific in vitro models.



Min Kyeong Kim received the Ph.D. degree from the Department of Biomedical Engineering, Ulsan National Institute of Science and Technology (UNIST) in 2021. Since 2024, she has been working as a postdoctoral researcher in the Department of Biomedical Engineering. Her current research interests include 3D bioprinting-based tissue engineering and regeneration, biomaterials, and organ-on-a-chip.



Jungbin Yoon received the Ph.D. degree in Biological Sciences from Seoul National University in 2019. Since 2023, she has been serving as a Research Assistant Professor in the Department of Mechanical Engineering at Pohang University of Science and Technology (POSTECH). Her current research focuses on kidney-centered 3D bioprinting-based multiorgan-on-a-chip modeling for complex disease studies. She is also developing real-time monitoring strategies of in vitro organ functions to advance innovative and functional multiorgan-on-a-chip platforms.



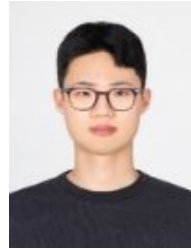
Dohui Kim received the Ph.D. degree from the Department of Mechanical Engineering, Pohang University of Science and Technology (POSTECH) in 2025. Her current research interests include organoid manufacturing using nano/microfabrication techniques and the application of machine learning for process optimization.



Jongmin Kim received the Ph.D. degree from the Department of Mechanical Engineering, Pohang University of Science and Technology (POSTECH) in 2022. Since 2023, he has been working as a Research Professor in the Department of Mechanical Engineering. He is conducting the research in 3D cell printing based in vitro ocular models.



Jae-Seok Kim received the M.S. degree from the Department of Mechanical Engineering, Wonkwang University in 2022. Since 2022, he has been pursuing the Ph.D. degree in the Department of Mechanical Engineering, Wonkwang University. His current research interests include 3D bioprinting, tissue engineering, and bioreactors.



Gyugang Go is currently a Ph.D. student in the Department of Mechanical Design Engineering at Hanyang University. He received a B.S. degree from Hanyang University in 2023. His research focuses on biomedical image analysis and quantitative pattern assessment.



Junhyeok Song started his academic studies in the field of mechanical engineering and received his B.S. degree from the Hanyang University in 2024. And, he is currently a **M.S. student** in the Department of Mechanical Design and Engineering in Hanyang University. His research focuses on biomedical imaging, monitoring.



Seunghun Son received the Ph.D. degree in Mechatronics Engineering from Chungnam National University, Daejeon, Korea, in 2025. He is currently a postdoctoral researcher at the Korea Institute of Machinery and Materials (KIMM), where he conducts research on tubular tissue bioprinting.



Kyungdeok Park received the M.S. degree from the Department of Polymer Engineering, Chungnam National University in 2024. Since 2024, he has been working as a researcher at the Korea Institute of Machinery and Materials (KIMM). His current research interests include 3D bioprinting, Deep learning-based cell image analysis.



Jooyoung Lee received the M.S. degree in Smart Health Science and Technology from Kangwon National University (KNU), Chuncheon, Republic of Korea, in 2023. Since 2023, she has been pursuing the Ph.D. degree in Smart Health Science and Technology at KNU. Her current research interests include 3D bioprinting and organ-on-a-chip.



triboelectricity and its application.

Donghan Lee is currently pursuing a Ph.D. candidate under the supervision of Prof. Dongwhi Choi, Kyung Hee University. He started his academic studies in the field of Mechanical Engineering and received B.S. and M.S. degree from Kyung Hee University, South Korea. His research interest is based on mechanical design for effective energy harvesting using



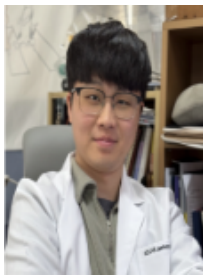
powered sensors and hybridization of the energy harvester.

Sumin Cho received his Ph.D. degree from Kyung Hee University in 2024. He started his academic studies in the field of Mechanical Engineering and received B.S. and M.S. degree from Kyung Hee University, South Korea. His research interest is based on biomechanical energy harvesting and its applications of self-



applications, including ultrasound-assisted drug delivery systems, mechanical tissue ablation via histotripsy, and acoustic holography for ultrasound field modulation.

Wonseok Choi received his B.S. and Ph.D. degrees in Biomedical Engineering from Yonsei University in 2019 and 2024, respectively. He is currently a postdoctoral researcher at the Bionics Research Center, Korea Institute of Science and Technology (KIST). His research interests encompass a broad range of biomedical ultrasound



Jachong Min is a Master's student in the Department of Bionano Technology at Gachon University. His research focuses on developing microfluidic-based 3D vascular networks using endothelial cells from various sources to better understand vascular structure and function, and to evaluate the efficacy of candidate drugs.



Young-Sam Cho received the Ph.D. degree from the Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST) in 2004. Since 2008, he has been working as a professor in the Division of Mechanical Engineering, Wonkwang University. His current research interests include 3D/4D

printing, tissue engineering, bone-on-a-chip, bone-mimic ex-vivo system, and mechano-bactericidal surfaces.



Seung-Jae Lee received the Ph.D. degree from the Pohang University of Science and Technology (POSTECH) in 2007. Since 2011, he has been working as a professor in the Division of Mechanical Engineering, Wonkwang University. His current research interests include 3D bioprinting, tissue engineering, and bioreactors.



Hee-Gyeong Yi is an Associate Professor in the Department of Convergence Biosystems Engineering, Chonnam National University. Her research interest is microphysiological system engineering, bioprinting, biomechanical engineering, tissue engineering, and regenerative medicine.



After receiving his Ph.D. in 2021, he joined the Brain Science Institute of Korea Institute of Science and Technology (KIST) in 2022. And, he is currently an assistant professor at the Department of Mechanical Design and Engineering in Hanyang University. His research topic covers micro/nano polymer fabrication and its utilization in the fields of lab-on-a-chip, soft robotics, tissue engineering, and regenerative medicine.

Andrew Choi started his academic studies in the field of mechanical engineering and received his B.S. degree from the Georgia Institute of Technology in 2013. Thereafter, he received his Ph.D. from the School of Mechanical Engineering at Pohang University of Science and Technology while working as a technical research personnel.



Seunggyu Jeon received his Ph.D. degree in Biomedical Engineering from the Ulsan National Institute of Science and Technology (UNIST), Ulsan, Korea, in 2023. He is currently a senior researcher in the Department of Bionic Machinery at the Korea Institute of Machinery and Materials (KIMM). His research focuses

on bioautomation and bioprinting technology.

Hyungseok Lee received the Ph.D. degree from POSTECH, Republic of Korea. Since 2024, he has been working as an associate professor in the Department of Mechanical and Biomedical, Mechatronics Engineering at Kangwon National University (KNU). His current research interests include 3D printing, bioprinting,

manufacturing, and biomedical engineering.



Dongwhi Choi is a professor in Department of Mechanical Engineering, Kyung Hee University, South Korea. He received his Ph.D. degree from Pohang University of Science and Technology (POSTECH) in 2016, by developing the platforms for utilization of liquid-solid contact electrification. His research is based on development of contact electrification based functional self-powered electronic devices fabricated by multi-scale advanced materials processing.



Sungmin Han received his Ph.D. degree in Biomedical Engineering Science from Korea University in 2017. He is currently a principal research scientist at the Bionics Research Center, Korea Institute of Science and Technology (KIST). He also serves as an associate professor in the Division of Bio-Medical Science and Technology at the University of Science and Technology (UST) and at the KHU-KIST Department of Converging Science and Technology, Kyung Hee University. His research interests include a wide range of biomedical applications, such as biosignal processing, biomechanics, gait analysis, ultrasound stimulation, rehabilitation engineering, virtual reality-based rehabilitation, and healthcare technologies.



Jihoon Ko is an Assistant Professor in the Department of Bionano Technology at Gachon University, where he began his faculty position in 2023. He earned his Ph.D. in Mechanical Engineering from Seoul National University in 2021. His research focuses on microfluidics, organ-on-a-chip systems, and AI-powered analysis for high-throughput drug screening and disease modeling.



Dong-Woo Cho received the Ph.D. degree in Mechanical Engineering from the University of Wisconsin-Madison, in 1986. Since 1986, he has been a Professor with the Department of Mechanical Engineering, Pohang University of Science and Technology. He is currently the Director of the Center for Rapid Prototyping-Based 3D Tissue/Organ Printing. His research interests include 3D microfabrication based on 3D-printing technology, its applications in tissue engineering, more generally bio-related fabrication, tissue/organ printing technology, and developing high-performance bio-inks.



Dong Sung Kim is the Mueunjae Chair Professor in the Department of Mechanical Engineering at Pohang University of Science and Technology (POSTECH), and a member of the Young Korean Academy of Science and Technology (Y-KAST). His primary research interests focus on micro- and nano-manufacturing processes, including advanced electrospinning techniques and multi-scale precision forming and shaping of polymers and hydrogels. Recently, his work has expanded to include innovations such as nanofiber membrane-based organ-on-a-chip systems, advanced organoid/spheroid culture platforms, and studies on tissue wrinkle/folding.



Jinah Jang is the Mueunjae Chair Professor at Pohang University of Science and Technology (POSTECH), where she holds joint appointments in Mechanical Engineering, Convergence IT Engineering, Life Science, and the School of Interdisciplinary Bioscience and Bioengineering. She also directs the Center for 3D Organ Printing and Stem Cells and leads the Biofabrication Technology Laboratory. She earned her Ph.D. in Biomedical Engineering from POSTECH in 2015 and completed postdoctoral training at POSTECH and the University of Washington. Since joining the faculty in 2017, she has pioneered advances in 3D bioprinting technologies, decellularized extracellular matrix (dECM) bioinks, and stem cell-based regenerative platforms, as well as organ- and disease-on-a-chip models for translational medicine.



Hyun-Wook Kang received the Ph.D. degree in the School of Mechanical Engineering, Pohang University of Science and Technology (POSTECH) in 2009. Since 2015, he has been a professor in the Department of Biomedical Engineering, Ulsan National Institute of Science and Technology (UNIST). His current research interests include 3D bioprinting-based tissue engineering and its applications in regenerative medicine, artificial tissue/disease models, and organ-on-a-chip.