Springer Tracts in Additive Manufacturing

Adam Khan M.
Gurpreet Singh
Sarina Sulaiman *Editors*

Challenges and Innovations in 3D Printed Bio-Organs and Their Materials

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The book series aims to recognise the innovative nature of additive manufacturing and all its related processes and materials and applications to present current and future developments. The book series will cover a wide scope, comprising new technologies, processes, methods, materials, hardware and software systems, and applications within the field of additive manufacturing and related topics ranging from data processing (design tools, data formats, numerical simulations), materials and multi-materials, new processes or combination of processes, new testing methods for AM parts, process monitoring, standardization, combination of digital and physical fabrication technologies and direct digital fabrication.

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Thanks to ALMIGHTY
Editors would like to dedicate this book to the Management and Administration Team of Our Institutes.

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Preface

The field of 3D printing and additive manufacturing has witnessed remarkable progress in recent years, particularly in biomedical applications. The ability to design, fabricate, and customize complex biological structures using advanced printing technologies has opened new frontiers in tissue engineering, regenerative medicine, and medical implants. As researchers explore innovative materials and fabrication methods, the potential for 3D printed bio-organs and biomaterials to revolutionize modern medicine has become a focal point of scientific investigation.

This book, *Challenges and Innovations in 3D Printed Bio-Organs and Their Materials*, aims to provide a comprehensive exploration of recent advancements, challenges, and future perspectives in the field of 3D printed bio-organs and biomedical materials. It brings together contributions from leading experts in academia and industry, covering a broad spectrum of topics that address fundamental principles, material developments, biofabrication techniques, and real-world applications of 3D printed organs and implants. The book comprised 16 chapters, each offering an in-depth discussion on various aspects of 3D printing in biomedical science. These chapters highlight the fundamental mechanisms, key challenges, recent innovations, and future directions in the field. It covers a range of critical topics, including biomaterials, antibacterial bioinks, additive manufacturing techniques, tribological and mechanical behavior of biomedical implants, and applications in diabetic care and skin disorders.

This book serves as a valuable resource for researchers, biomedical engineers, clinicians, and students interested in bioprinting, medical implants, and tissue engineering. It offers:

- Fundamentals of 3D Printed Bio-Organs and Tissue Engineering, including the latest materials, methods, and antibacterial bioinks for organ fabrication.
- Advancements in Additive Manufacturing, covering innovations in medical solutions for diabetic patients, 3D printing in diabetes care, and bio-compatible metal implants.

- Tribological and Wear Analysis of Biomedical Materials, focusing on titanium alloys, polymeric materials for skin disorders, and the role of Ti6Al4V alloys in implant development.
- Future Perspectives, addressing the biocompatibility of additive manufacturing processes and the latest trends in soft materials and soft gel applications for artificial organ development.

Chapters 1–5 of the book introduces fundamental concepts of 3D printed organ and tissue engineering, including an overview of the latest biofabrication methods and the role of biomaterials and bioinks in creating functional tissues and organs. The initial chapters explore the potential of 3D printed organ models, their clinical relevance, and the latest innovations in biofabrication. Subsequent Chaps. 6–11 focus on advancements in additive manufacturing for biomedical applications, detailing novel biomaterials, metal implants, and polymer-based solutions for tissue repair and organ regeneration. These chapters also discuss the role of metallic and polymeric materials in the development of bio-compatible implants, emphasizing the importance of biomechanical properties and long-term durability. Chapters 12 and 13 explore the latest developments in 3D printing for diabetic care, including customized insoles, wound healing techniques, and pressure offloading solutions for patients with diabetic foot ulcers. The final chapters (Chaps. 14–16) address emerging trends in the field, including 3D printing of textured Ti6Al4V alloy for enhanced implants, biocompatibility studies, and advances in soft materials and soft gels for artificial organ fabrication. These topics provide valuable insights into the next generation of biomedical devices and implantable structures, emphasizing their clinical implications and translational potential.

We hope that this book inspires further research and innovation in 3D printed bio-organs and biomaterials. We extend our heartfelt gratitude to all the contributors, reviewers, and editorial team members who have played a crucial role in making this book possible. Their expertise and dedication have significantly enriched the content, making this volume a valuable reference for the scientific community.

Srivilliputhur, India — Adam Khan M.
New Delhi, India — Gurpreet Singh
Kuala Lumpur, Malaysia — Sarina Sulaiman

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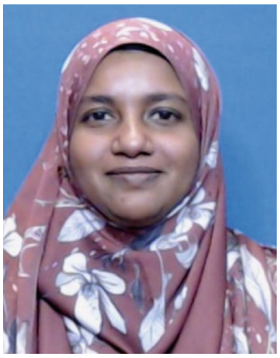
Editors and Contributors

About the Editors

Dr. Adam Khan M. is working as a Professor and Head—Department of Mechanical Engineering, and heading the Centre for Surface Engineering at Kalasalingam Academy of Research and Education, Virudhunagar, India. He completed his Post Doctoral Research from the University of Johannesburg, Doornfontein Campus, Johannesburg, South Africa. He received his Doctoral Degree from the National Institute of Technology, Tiruchirappalli, India, and his Undergraduate and Postgraduate Degrees from Anna University, Chennai, India. His research focus is on material development for different engineering applications. He has developed nickel-based superalloys through a direct laser sintering process for high temperatures. Current his research interest has focused on metal for bio medical engineering and surface sciences. He is working in the invitro analysis on 3D printed and commercial titanium implants; before and after material processing. The research has been placed in track to report the surface quality and cell viability. In addition, the biocompatibility of the same processed materials is studied using simulated body fluids. Recently the research has been more focused to develop the titanium implant material through direct laser sintering process (DMLS) additive-built material and its post processing. Further, the material has been investigated for different property studies, including mechanical strength, surface qualities, corrosion, and oxidation behavior. Beyond his

research, he is serving as a reviewer for more than 30 journals. He also had a chance to serve as Guest Lead Editor for the Journals and Books hosted by SpringerNature, Elsevier, Hindawi and Taylor & Francis publishers. He has published more than one hundred and thirty research articles in the journal of international repute. He has good knowledge of teaching-learning process (outcome-based education) evaluation. Under his supervision, two research scholars have been awarded doctoral degree.

Gurpreet Singh is a Ph.D. scholar at the Centre for Biomedical Engineering, Indian Institute of Technology Delhi, India. He is a recipient of the most prestigious Ph.D. fellowship in India, the Prime Minister's Research Fellowship (PMRF), in the May 2021 cycle. His research interests are soft tissue mechanics, artificial tissues, biomimetics, and computational biomechanics. He is working on the computational modeling of the diabetic foot and its ulceration progression. He is also working on developing artificial human tissue surrogates for injury and disease modeling. Previously, much of his work has been on improving the surface characteristics and bioactivity of metallic biomaterials, with research interests including surface engineering, materials science, biomaterials, and non-conventional machining processes. He worked on the surface modification of metallic biomaterials using electro-discharge machining, where he studied the bioactivity of modified surfaces in terms of wear resistance, corrosion resistance, and other biological responses. He has authored/edited 3 books and contributed 50+ research papers and book chapters to leading international journals and conferences. He is the recipient of the Top Cited Paper Award 2023 for his review article on *Mechanical Properties of Whole-body Soft Human Tissues: A Review* by IOP Publishing and the Research Excellence Travel Award by the Indian Institute of Technology Delhi for this significant research contribution. He also serves as a reviewer for prominent international journals of repute.



Dr. Sarina Sulaiman graduated from University Putra Malaysia (UPM) with a Bachelor of Engineering (Chemical) in 2004 and Master of Science (M.Sc.) in Chemical Engineering. Her M.Sc. research focused on composites and development of brake pad from carbon fiber reinforced phenolic resin. Then, she pursued her Ph.D. and graduated from UM in 2012. Her Ph.D. research was on biodiesel production using reactive extraction. Currently she is an Associate Professor at the Department of Chemical Engineering and Sustainability. Dr. Sarina's research interests include biofuel production, renewable energy technologies, green technology, heterogeneous catalysis, and chemical reaction engineering. She has published over 50 research articles. Her research grants, both as a principal investigator and co-researcher, are valued at over RM 320,000.

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