# 3D Bioprinting and Biofabrication Technologies and Their Applications

From 9th to 14st December 2019

**About the Workshop:**

Bioprinting is an additive biomanufacturing process where biomaterials, cells and bioactive factors are combined in the form of bioink and printed in a layer-by-layer manner to create tissue-like structures. Based upon the operation, this technology can be classified into three major categories, inkjet-based, extrusion-based, and laser-assisted bioprinting. Applications of 3D bioprinting, both actual and potential, can be categorized into several broad classes, including: tissue and organ fabrication; creation of customized prosthesis, and implants; development of anatomical and surgical models; construction of in vitro tissue/organ/cancer model and pharmaceutical research involving drug dosage forms, delivery, and discovery. The application of 3D bioprinting in medicine brings in many benefits, including the customization and personalization of medical products, drugs, and equipment; cost-effectiveness; increased productivity; the democratization of design and manufacturing; and enhanced collaboration. However, it should be cautioned that outstanding scientific and regulatory challenges remain and the most transformative applications for this technology are yet to be fully realized. All the aspects of this field will be covered in this workshop with interactive lectures from experts, both from engineering and medicals backgrounds and with few hands on sessions.

This workshop is designed for biomedical, biotechnology, mechanical, material scientists to learn about 3D printing technologies, design aspects, medical applications, and critical issues related to these topics. We hope that the workshop will benefit faculty and researchers from Mechanical Engineering, Materials Science and Engineering, Biomedical Engineering, Biotechnology, Chemical Engineering, and other related domains.

**Topics covered:**

The six-day workshop provides an overview of:

Introduction to 3D Bioprinting; Introduction to CAD; Introduction to Various 3D Bioprinting Technologies; Emergence of 3D Printed Implants; Biomaterials for 3D bioprinting; Material Design and Processing; Application of 3D Printing for Different Medical Applications, like Dentistry, Customized Implants and Prostheses, Anatomical Models for Surgical Preparation; Custom 3D-Printed Dosage Forms and Drug Delivery Devices; Ethical Issues related to 3D Printing for Medical Applications; Hands On Sessions On Various 3D Printing Techniques Like FDM, SLA, Extrusion-Based, and Bioprinting technologies; Printing 3D Structures For Medical Applications.

**Intended participants:**

Faculty members and Students from academic institutes; Personnel from R&D organizations; Personnel from related industries. We hope that the workshop will benefit faculty and researchers from Mechanical Engineering, Materials Science & Engineering, Biomedical Engineering, Biotechnology, Chemical Engineering, and other related domains.

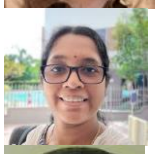
**Registration:**

For TEQIP participants, registration is free, and accommodation and food are provided as per TEQIP norm. For Non-TEQIP participants, registration fee is there; only lunch and tea are complimentary.

# Brief Profile of Speakers

***Dr. Subha Narayan Rath*** is an Associate professor in Department of Biomedical Engineering at IIT Hyderabad. He has completed Ph.D. from Division of Bioengineering at National University of Singapore (NUS) and Post-doctoral from Department of Plastic & Hand Surgery, University, Hospital of Erlangen, Germany. His research expertise is on Stem Cells and Tissue Engineering.

***Dr. S. Suryakumar*** is an Associate professor in Department of Mechanical and Aerospace Engineering at IIT Hyderabad. He has completed PhD from IIT Bombay. His research interests are Additive Manufacturing of Metallic Objects, Fabrication of Functionally Gradient Objects through Additive Manufacturing, Design for Additive Manufacturing, Medical Applications of AM, Data formats for Heterogeneous objects (i.e., gradient objects).



***Dr. Suhanya Duraiswamy*** is an Assistant professor in Department of Chemical Engineering at IIT Hyderabad. Her research interests include microfluidics and Lab on chip technology. She uses microfluidic principles to understand cells separation and manipulation.

***Dr. Subhradeep Chatterjee*** is an Assistant professor in Department of Materials Science & Metallurgical Engineering at IIT Hyderabad. He obtained PhD from IISc Bangalore. His research interest is related to Welding Metallurgy, Transmission Electron Microscopy, Diffraction, Thermal Analysis, Phase Field Models, Finite Element and Finte Volume Methods.

***Dr. Omkar Prasad*** is an Assistant professor in Department of Design at IIT Hyderabad. He obtained his PhD from Indian Institute of Science, Bangalore. Some of his Research Highlights are Development of desktop based virtual environment for 3D sketching, Development of sketching application for Touch Screen Tablets, Development of sketch enabled collaborative conceptual design system.

***Dr. Madhumohan Rao*** is working as a scientist at Nizam Institute of Medical Sciences, Hyderabad. He has vast experiences in genomics and proteomics study of the organoids, single cells, cell-laden constructs. He delivered a lecture on validation of 3D bioprinted tissues/organs, which is a very pertinent topic for 3D bioprinted tissues and organs to evaluate their potential for transplantation and as models for drug discovery.

***Dr. Aditya Mohan Alwala*** is a Maxillofacial surgeon working in MNR Medical College and Hospital. He is an active user of 3D printing technology for maxillofacial reconstruction. He developed a patent pending TMJ joint and implanted on a patient successfully. The patient is doing fine even after 12 months.

***Dr. Ananya Barui*** is an Asst. Professor in the Center of Healthcare Science and Technology at IIEST, Shibpur, Kolkata. Her research interest includes biomedical imaging and stem cell research. She has developed a novel method for isolating and culture of MSCs from umbilical cord tissue. She has published extensively in Stem cell and Regenerative Medicine field.

***Dr. Pallab Datta*** is an Assistant Professor in the Center of Healthcare Science and Technology at IIEST, Shibpur, Kolkata. He has over 5 years of experiences in 3D Bioprinting and Tissue Engineering and has published extensively in this area.

***Dr. Falguni Pati*** is an Assistant professor in Department of Biomedical Engineering at IIT Hyderabad. He has completed his PhD from IIT Kharagpur and done postdoc in POSTECH, South Korea and KTH, Sweden. His research interest are 3D Bioprinting, Tissue Engineering, and Regenerative Medicine.

**Course Co-ordinator**

Dr. Falguni Pati

Dept. of Biomedical Engineering,

IIT Hyderabad

Phone No. 040-2301-6140

# Schedule

**Day 1 (9th December, Monday)**

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| 9:00-9:45 | Registration | | Outside C-LH-3 |
| 9:45-10:00 | Inauguration | | C-LH-3 |
| 10:00-11:30 | Tutorial-I: Introduction to 3D Printing and Bioprinting | Dr. Falguni Pati, IITH | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45-13:15 | Tutorial-2: 3D Bioprinting for Biomedical Applications | Dr. Subha Narayan Rath, IITH | C-LH-3 |
| 13:15-14:15 | Lunch Break | | |
| 14:30-17:30 | Hands-on-Session 1: FDM based 3D Printing | Dr. Falguni Pati, IITH | Lab |

**Day 2 (10th December, Tuesday)**

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| 10:00-11:30 | Tutorial-3: Design Aspects in 3D Printing | Dr. Omkar Prasad, IITH | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45-13:15 | Keynote Lecture-I: Validation of 3D Bioprinted Tissues and Organs | Dr. Madhumohan Rao, NIMS | C-LH-3 |
| 13:15–14:30 | Lunch Break | | |
| 14:30-17:30 | Hands-on-Session 2: SLA based 3D printing | Dr. Falguni Pati, IITH | Lab |

**Day 3 (11th December, Wednesday)**

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| 10:00-11:30 | Tutorial-4: Introduction To CAD and its Use for Medical Design | Dr. S. Suryakumar, IITH | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45-13:15 | Tutorial -5: 3D Bioprinting in Nanomedicine | Dr. Aravind Kumar Rengan, IITH | C-LH-3 |
| 13:15–14:30 | Lunch Break | | |
| 14:30-17:30 | Hands-on-Session 3: Extrusion-based 3D printing | Dr. Falguni Pati, IITH | Lab |

**Day 4 (12th December, Thursday)**

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| 10:00-11:30 | Tutorial -6: Metallic Materials and Designing for 3D Printed Implants | Dr. Subhradeep Chatterjee, IITH | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45-13:15 | Tutorial -7: In Vitro and In Vivo evaluation of Biofabricated Tissues and Organs | Dr. Subha Narayan Rath, IITH | C-LH-3 |

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| 13:15–14:30 | Lunch Break | | |
| 14:30-17:30 | Hands-on-Session 4: Preparation of Bioink | Dr. Falguni Pati, IITH | Lab |

**Day 5 (13th December, Friday)**

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| 10:00-11:30 | Tutorial -8: Microfluidics for Biological Application | Dr. Suhanya Duraiswamy, IITH | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45–13:15 | Keynote Lecture-II: 3D Printing in Dentistry and Maxillofacial Surgery | Dr. Aditya Mohan Alwala (Oral and Maxillofacial Surgeon) | C-LH-3 |
| 13:15–14:30 | Lunch Break | | |
| 14:30-17:30 | Hands-on-Session 5: 3D Bioprinting | Dr. Falguni Pati | Lab |

**Day 6 (14th December, Saturday)**

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| 10:00-11:30 | Keynote Lecture-III: Improvising cell-material interactions with bio- and nano-fabrication techniques for tissue engineering and drug delivery | Dr. Pallab Datta, IIEST | C-LH-3 |
| 11:30-11:45 | Tea-Break | | |
| 11:45–13:15 | Keynote Lecture-IV: Minimally invasive stem cell isolation techniques and clinical features of early cancer transformations as necessary aids for varied biofabrication research | Dr. Ananya Barui, IIEST | C-LH-3 |
| 13:15–14:30 | Lunch Break | | |
| 14:30–16:00 | Tutorial -9: Prospects and Applications of 3D Printing and Bioprinting | Dr. Falguni Pati, IITH | C-LH-3 |
| 16:00-17:30 | Quiz and Concluding Remarks | Dr. Falguni Pati, IITH | C-LH-3 |
| 17:30-18:00 | Feedback collection, Photo Session and High Tea | | |

# Overview of Tutorials and Hands-on-Sessions

## Day 1

**Tutorial 1:** The technical sessions started with the tutorial by Dr. Falguni Pati, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. Dr. Pati introduced the topic "3D Printing and 3D Bioprinting" and explained in detail about various 3D printing technologies, their mechanism of action, operation, and different process parameter with suitable examples. He also showed some exciting videos of 3D printing technologies.
**Tutorial 2:** The second tutorial was on "An Overview of 3D Bioprinting in Medicine", which as delivered by Dr. Subha Narayan Rath, Associate Professor, Department of Biomedical Engineering at IIT Hyderabad. He discussed in great detail about various applications of 3D bioprinting in medicine with appropriate examples and case studies.
**Hands-on-Session 1:** The first hands-on-session was conducted by Dr. Falguni Pati. This focus of this session was to demonstrate FDM-based 3D Printing techniques. The session started with introducing FDM-based 3D printing techniques and explaining in detail about the various components of 3D printer and its operation. Candidates also witnessed 3D printing operation by printing a 3D object.

## Day 2

**Tutorial 3:** The first tutorial of day 2 was on "Design Aspects for 3D Printing", which was delivered by Dr. Omkar Prasad, Assistant Professor, Department of Design at IIT Hyderabad. He discussed in great detail about several design aspects of 3D printing with appropriate examples and case studies. He also discussed the potential applications of 3D printing in daily life in future.
**Keynote Lecture-I:** The first keynote lecture of day 2 was delivered by Dr Madhumohan Rao from NIMS, Hyderabad. He introduced the topic of genimocs and proteomics and their importance for characterizing the bioprinted tissues and organs.
**Hands-on-Session 2:** The hands-on-session at Day 2 was focused on SLA-based 3D printing, which was conducted by Dr. Falguni Pati, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. Dr. Pati demonstrated SLA-based 3D Printing techniques, with explaining different components of the 3D printer, Formlab 2, its operation and various process parameters. He also showed the printing operation starting with making a CAD file, conversion into stl. format and loading the same to the Preform software, which is the default software for the printer. Followed by that, participants witnessed printing of a 3D object by SLA 3D printer and post-printing operations.

## Day 3

**Tutorial 4:** The technical sessions at Day 3 started with the tutorial "Introduction To CAD and its Use for Medical Design" by Dr. S. Suryakumar, Associate Professor, Department of Mechanical and Aerospace Engineering at IIT Hyderabad. Dr. Suryakumar introduced the topic "CAD and Medical Design" and explained in detail about the various aspects of Medical Design with suitable examples. He demonstrated the usefulness of MIMICS software for medical modelling.
**Tutorial 5:** The second tutorial of the day 3 started with the tutorial by Dr. Aravind Kumar Rengan, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. Dr. Rengan introduced the topic "3D Printing in Nanomedicine" and explained in detail about various aspects of this topic with suitable examples.

**Hands-on-Session 3:** The hands-on-session at Day 3 was focused on extrusion-based 3D bioprinting, which was conducted by Dr. Falguni Pati. Dr Pati demonstrated extrusion-based 3D bioprinting, optimization of process parameters, software handling and usage, printing small structure with Biobot 3D printer.

## Day 4

**Tutorial 6:** The technical sessions started with the tutorial by Dr. Subhradeep Chatterjee, Assistant Professor, Department of Metallurgical and Materials Engineering at IITH on "Materials and Designing for 3D Printed Metallic Implants". This lecture was focused on various aspects of materials design and process for 3D printing of metallic structure for medical applications with suitable examples.

**Tutorial 7:** The second tutorial was on "*In Vitro* and *In Vivo* evaluation of Biofabricated Tissues and Organs", by Dr. Subha Narayan Rath, Associate Professor, Department of Biomedical Engineering at IIT Hyderabad. He discussed in great detail about several aspects of *in vitro* and *in vivo* evaluation of biofabricated tissues and organs.

**Hands-on-Session 4:** The hands-on-session at Day 4 was conducted by Dr. Falguni Pati. This focus of this session was to demonstrate development of bioink formulation encapsulating cells. The session started with providing an overview of cell culture protocols and preparation of cell suspension for preparation of bioink, where cell detachment, cell counting, cell encapsulation in prepared hydrogel were demonstrated.

## Day 5

**Tutorial 8:** The technical sessions started with a tutorial on Microfluidics for Biological Application, which was delivered by Dr. Suhanya Duraiswamy, IITH. She explained in great detail about the various microfluidic technologies and their application in biofabrication starting from lab on chip to bioreactors.

**Keynote Lecture-II:** The Keynote Lecture-III was on "3D Printing in Dentistry and Maxillofacial Surgery", which as delivered by Dr. Aditya Mohan Alwala, Oral and Maxillofacial Surgeon, MNR Hospital, Hyderabad. He discussed in great detail about various applications of 3D printing for Maxillofacial reconstruction with appropriate examples and case studies.

**Hands-on-Session 5:** The hands-on-session at Day 5 was conducted by Dr. Falguni Pati, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. This focus of this session was to demonstrate 3D Bioprinting. The session started with providing an overview of 3D bioprinting process and various steps involved there. Candidates also experienced bioprinting with alginate bioink by a EnvisionTec 3D bioprinter.

## Day 6

**Keynote Lecture-III:** The technical sessions started with a keynote lecture on Improvising cell-material interactions with bio- and nano-fabrication techniques for tissue engineering and drug delivery, which was delivered by Dr. Pallab Datta, Assistant Professor, the Center of Healthcare Science and Technology at IIEST, Shibpur, Kolkata. Dr. Datta introduced the topic and explained in detail about various cell-materials interaction, manipulation of cells for 3D bioprinting.

**Keynote Lecture-IV:** The second technical sessions started with another keynote lecture on Minimally invasive stem cell isolation techniques and clinical features of early cancer transformations as necessary aids for varied biofabrication research, which was delivered by Dr.

Ananya Barui, Assistant Professor, the Center of Healthcare Science and Technology at IIEST, Shibpur, Kolkata. Dr. Barui introduced the topic and explained in detail about how to use stem cells form different origin and their applicationfor 3D bioprinting.

**Tutorial -9:** The tutorial session post lunch was on “Prospects and Applications of 3D Printing and Bioprinting”, which as delivered by Dr. Falguni Pati, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. He discussed in great detail about prospects and recent trends in 3D bioprinting for development of tissue and organs and how customized solution can be provided to the needful patients.

**Session 10: Quiz and Concluding Remarks:** The next session was conducted by Dr. Falguni Pati, Assistant Professor, Department of Biomedical Engineering at IIT Hyderabad. This session was focused on quiz on the overall program. The session was ended with a concluding remarks by him on the 3D bioprinting techniques and on overall program.

**Feedback collection:** The final session was focused on participant’s feedback collection, where participants expressed their opinion and remarks about the workshop. Followed by the Certificate distribution for the course is carried out and a photo session was conducted.

Dr. Falguni Pati
Workshop Faculty Coordinator, IIT Hyderabad



***Session 1:*** This session focused on an introduction to solid mechanics from a variational calculus perspective. Various