IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Multi-material 3D printing of biodegradable smart materials**	
Project Number	**IMURA1070**	
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IITB Department:	Mechanical Engineering	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
*(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	***Math, CFD, Modelling, Manufacturing***
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1	*Artificial Intelligence and Advanced Computational Modelling*
2	*Circular Economy*
3	*Clean Energy*
4	***Health Sciences***
5	***Smart Materials***
6	*Sustainable Societies*
7	*Infrastructure*

The research problem

Define the problem

Multifunctional composites with a single design may accomplish multiple functional tasks, including sensing, actuation, weight carrying, and locomotion. Due to their unique features, smart surfaces, deployable structures, and active metamaterials have found extensive use in biomedical applications for drug delivery, stent deployment, smart implant etc. However, the fabrication of these functional task materials is complicated by traditional manufacturing practices.

3D printing has emerged as an appealing industrial method for the high-resolution manufacture of complicated geometries on demand. Moreover, when paired with smart or active materials, an innovative paradigm known as 4D printing could be used to produce multifunctional composites that intelligently adapt to their surroundings by modifying their structure, functionality, or qualities in response to certain stimuli such as heat, magnetic field, Ph change, UV light, etc. Traditional 4D-printed structures depend on single smart materials such as shape memory polymers, hydrogels, or elastomers, however when used alone, they often have limits. Hydrogel and elastomers, for instance, may achieve reversible form changes, but they cannot give the desired mechanical qualities, such as high stiffness, needed for many applications. 4D-printed composite consisting of an elastomers and an SMP that can perform not only huge, quick, reversible shape changes, but also controllable shape changes while preserving required mechanical stiffness in the actuated state. However, the multi-material 3D printing of these composites and biodegradable properties are still challenging. The control of shape memory effect during degradation is a complex problem.

The proposal seeks to develop new generation multi material shape memory biodegradable materials using multi-material 3D printing. The key idea is to print thermoplastic and thermoset materials as functional graded along with shape memory elements such as Iron oxide to possess multi shape memory and to attain this property with biodegradation and mechanical properties. The development of Multiphysics model to predict the shape memory effect with heat and magnetic field stimuli will be customized the design of the prints as desired. The research outcome would enable the control of shape memory effect with biodegradable materials by multi material printing of customized structure.

Project aims

Define the aims of the project

The overreaching goal of this project is to develop multi-material printed biodegradable shape memory materials with tailored properties. Specifically, the projects aim to

(a) Development of multi material printing setup and 3D printing slurries.

(b) Develop an understanding of process parameters to control multi material 3D printing. Study of mechanical, biodegradable, shape memory and biocompatible properties of the printed parts.

(c) Development of Multiphysics model to predict the shape memory effect of the virgin multilateral structure and structure degraded over the time.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

Student will get chance to learn different set of skills by achieving research milestones at IITB and Monash.

#	Milestone	Deliverable	Timeline	Place
A	Literature review and preliminary experimentation	Understanding of different physical phenomena, Process maps, and associated key process parameters in multi material printing, biodegradable and smart materials.	June 2023 – June 2024	At IITB
B	Process parameter studies and optimization to print multi-material structures	3D printing of multi materials will be conducted to print heat and magnetic field stimuli-based shape memory polymers. Process parameters will be studied and optimized to minimize the porosity and to improve inter-material bonding.	July 2024- June 2025	At IITB
C	Mechanical, Biodegradable and shape memory characterization	Tensile properties will be studied of multi material printed parts using temperature chamber at 37^{o}C. Biodegradable studies will be carried out by static and dynamic immersion test. Shape memory effect by heat and magnetic field will be studied.	Jan 2025 – Dec 2025	At IITB
D	Simulation studies to predict shape memory effect	Simulation models will be developed to predict the heat and magnetic field stimuli-based shape memory effect. Multiphysics model will be developed to predict change in mechanical and shape memory properties along with degradation	Jan 2026 Dec 2026	At Monash

		time.		
E	Case studies to fabricate multi material shape memory structures for biomedical applications	Custom shape such as actuators, scaffolds will be designed as per the simulations. The desired shapes will be fabricated using 3D printing and experiments of mechanical, biodegradable and shape memory studies will be carried out for the validation.	Jan 2027 – June 2027	At IITB
F	Thesis Writing and Publications	To understand the technical writing skills for publishing high IF journal paper and conference papers. Journal and conference papers writing will be completed after each Milestone. Thesis for submission will be written in the last year of PhD.	Jan 2027 – June 2027	At IITB

Expected outcomes

Highlight the expected outcomes of the project

(a) Development of multi material printing setup by upgrading the traditional polymer 3D printing machine using dispensing system units and to fabricate 3D printing slurries of pure polylactic acid (PLA), poly (D,L-lactide-co-trimethylene carbonate) (PLMC) and PLA-Fe_3O_4 by mixing with suitable solvents.

(b) Develop an understanding of process parameters to control multi material 3D printing using three different nozzles on the responses such porosity, geometric deviation, and material joining.

(c) Study of mechanical, biodegradable, shape memory and biocompatible properties of complex shapes such as actuators, scaffolds, etc. fabricated using multi-material 3d printing.

(d) Development of Multiphysics model to predict the shape memory effect of multi material parts with heat and magnetic field stimulus. Design customized shape with multi material by developed model for tubular scaffold with controlled shape change and validate results by fabricating and testing the samples.

(e) Development of Multiphysics model to predict change in shape memory effect and mechanical properties with degradation over the time.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

The primary outcome of this project is the fabrication of multi-material biodegradable shape memory materials by developing multi-material 3D printing machine. Parts manufactured from this process have diverse applications in drug deliveries, stent deployment, smart implants, etc. Thus, it is believed that this research will contribute to addressing the current and future needs in manufacturing of shape memory smart materials for healthcare applications.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

From IITB:

Prof. Parag Bhargav, Metallurgical Engineering and Materials Science Department

Prof. Bhargav has rich experience in materials from last 15 years at IITB. His research areas are material science, polymer processing, etc.

Prof. Soham Mujumdar, Mechanical Engineering Department

Prof. Mujumdar is working in manufacturing from last 5 years. His interest areas are additive manufacturing, manufacturing processes, materials, etc.

From Monash:

Professor Neil Cameron. Materials Science and Engineering,

Professor Neil is the head of Materials Science and Engineering at Monash University. He is working in the area of polymers and are expert in 3D printing functional materials.

A/Prof Chao Chen, Mechanical Engineering Department.

Professor Chao is an expert in the area of robotics and soft robotics. He has expertise using soft functional materials for a wide range of robotics applications.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

The student needs to have good analytical and programming skills, background in computational mechanics, material characterization, polymers, additive manufacturing, manufacturing processes and analysis etc.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Courses at Mechanical Department

ME 800 Additive Manufacturing: Design, processes, and inspection

ME 679 Micromechanics of Composites
ME 756 Numerical Modelling of Manufacturing Processes
ME 789 Computational Tools for Process Modelling

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Dr. Yunlong Tang and Prof. Aijun Huang from Monash University

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Novel Functional Materials, Bio Medical Engineering, modelling and simulation, smart manufacturing, Miscellaneous/uncategorizeds