IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Phase-Field Mechanics of a Porous, Smart Biomedical Material**

Project Number	**IMURA0910**	
Monash Main Supervisor (Name, Email, Phone)	Santiago Badia, santiago.badia@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email, Phone)	NA	
Monash Head of Dept/Centre (Name, Email)	Prof. Kais Hamza, sci-maths-headofschool@monash.edu	*Full name, email*
Monash Department:	Department of Mathematics	
Monash ADGR (Name, Email)	Prof. Peter Betts, peter.betts@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email, Phone)	Alankar Alankar, alankar.alankar@iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email, Phone)	NA	*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Bhalchandra Puranik, head.me@iitb.ac.in	*Full name, email*
IITB Department:	Department of Mechanical Engineering	

Research Clusters: **Research Themes:**

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

The research problem

Actuating smart materials are of prime importance in the biomedical domain due to their applications in heart valves, stents and drug delivery mechanisms etc. In this project we will focus on deformation of a shape memory alloy. In shape memory alloys e.g. NiTi, the shape memory and pseudoelasticity is a result of phase-transformation induced by temperature or deformation. The newly evolved phase interfaces with existing matrix and thus causes stiffening of the overall micro-device. In recent publications we modeled pseudoelasticity in NiTi shape memory alloys using a micromechanics based model. In the present work, we would like to modify the constitutive framework with (1) coupled thermomechanical effects, (2) phase morphology evolution, and (3) strong strain gradients at the interfaces of parent and new phase. Thermomechanical effects capture the dissipation due to plasticity and temperature changes in the environment. Strain gradients address the additional stiffening due to interfacial effects of the second phases. In actuating condition, thermomechanical behavior and phase transformations lead to residual strains in the material leading to failure. This project focuses on development of a robust higher order strain-gradient model for understanding deformation in a smart actuating biomaterial. The effect of interfaces in the numerical approximation of these problems is numerically challenging. An accurate representation of these problems usually requires the use of interface-fitted meshes, which makes the simulation process very expensive and unreliable. Instead, we will develop unfitted finite element techniques that can properly capture those interfaces without the need to generate interface-fitted meshes. These methods use Cartesian (and adaptively refined) meshes combined with integration rules on cut cells. We will also design efficient (non)linear solvers for the resulting discrete systems (preconditioning strategies, line-search algorithms) and implement them in the Gridap parallel finite element framework.

Project aims

1. Develop constitutive framework for actuation of a shape memory material
2. Numerical algorithms for finite deformation in presence of morphology evolution of phases.
3. Validation using test cases available in literature
4. Design use cases that be validated by experiments in subsequent projects

Expected outcomes

1. A constitutive framework for mechanics of a shape memory biomaterial.
2. A simulation tool for phase-field mechanics with interface effects.

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

The project applies Advanced Computational Engineering for Biomedical applications. It falls in the category (1) and (6).

Potential RPC members from IITB and Monash

Tanmay Bhandakkar (expert in Elasticity, tbhanda@iitb.ac.in)
Ricardo Ruiz-Baier (expert in numerical methods for PDEs, ricardo.ruizbaier@monash.edu)

Capabilities and Degrees Required

An ideal candidate should have a BTech or BE or Masters in Mechanical Engineering, Aerospace Engineering, Civil, Mathematics or Physics, with a strong inclination towards advanced mathematics, numerical methods, continuum mechanics, non-linear elasticity and interest in programming. Experience in at least two of the following three criteria is desired: 1. Background in mechanics of materials; 2. Expertise in numerical methods for PDEs (finite element methods); 3. Expertise in programming (Julia, Python, C, C++, Fortran, etc)

Potential Collaborators

Jerome Droniou (expert in numerical methods for PDEs, jerome.droniou@monash.edu)
Ricardo Ruiz-Baier (expert in numerical methods for PDEs, ricardo.ruizbaier@monash.edu)
Raghunath Chellakot (Soft Matter, raghu@phy.iitb.ac.in)
Neela Nataraj (Finite Element Method, neela@math.iitb.ac.in)
We will also look for collaborators in Chemical Engineering or Bio Sciences and Engineering for experimental validations.

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.

Computational Fluid Dynamics and Mechanics, Shape Memory Material, Biomedical Robots, Smart Biomaterials