Material optimization of magnetically responsive membranes for tissue testing
(Magnetic Membranes)
ME 498—Spring 2025

Project advisor

Supervision of the project will be conducted by Profs. Craig Goergen (BME), Adrian Buganza (ME/BME), and Andres F. Arrieta (ME).

Project description

There is a need for testing tissues to build material models response models that allow for predicting properties that enable the development of better diagnostic tools and treatments. Actuating on tissues under homeostatic conditions (i.e., under biologically functional conditions) is challenging due to the boundary conditions introduced by systems introducing forces.[1,2] Therefore, biological tissue testing is mostly conducted *ex-vivo*, implying the loss of homeostasis and less relevance material properties. An alternative approach is to develop membranes responsive to remote stimulus such as magnetic fields.[3,4] A key step to achieve this is to design magnetic polymers with tailored microstructures.[5]

This project aims to determine the microstructure design of polymer membranes with magnetically responsive particles to actuate on biological tissues under biologically relevant conditions. Specifically, this implies optimizing the material microstructure by orienting

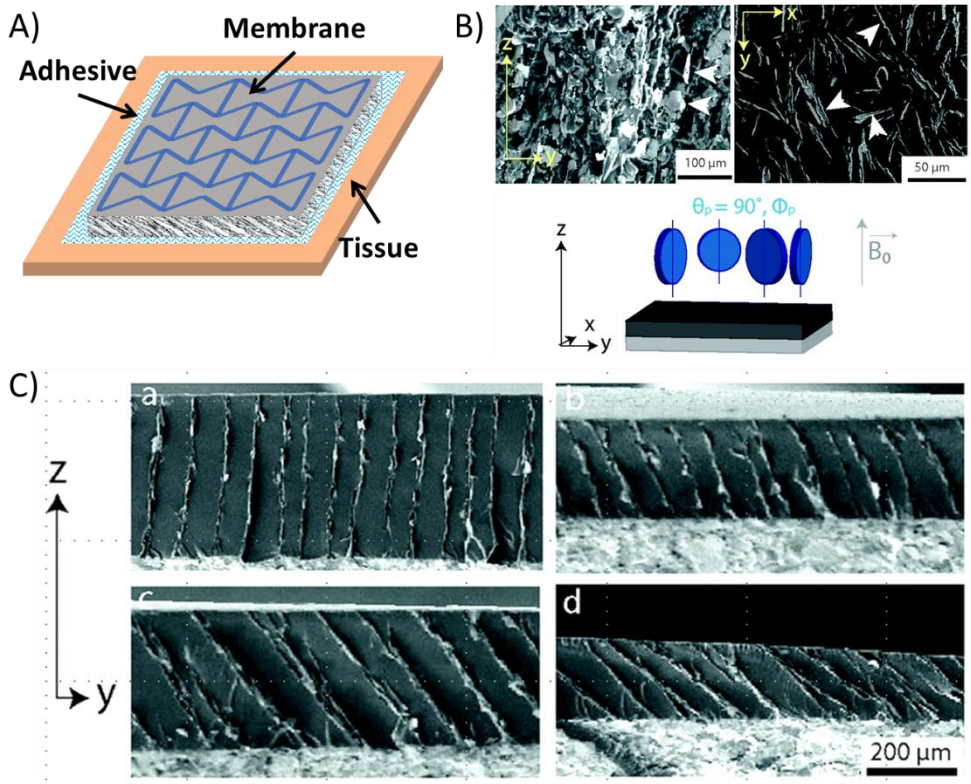

Figure 1: A) Magnetically-responsive membrane glued to biological tissue (bilayer membrane). **B)** Micrograph (left) and optical image (right) of membrane's cross-section showing randomly oriented magnetic particles. **C)** Membrane cross-section with magnetic particles at angles.

magnetically-responsive particles across the cross-section.[5] We will use prior results on modeling of magnetically tailored composites[6,7] and recent results in specific conditions to align particles in across the cross-section in particle reinforced polymers.[8]

Specific tasks & deliverables

The specific task described below can be achieved simultaneously or sequentially as required by the progress and interaction with mentor (Khushal Goparaju) and supervisors (Prof. Arrieta, Buganza, and Goergen)

1. Fabrication tasks
    a. Manufacture and testing of silicone samples as an alternative matrix to substitute PDMS.

    Deliverable for a: *Alternative matrix to PDMS*

    b. Manufacturing samples under different magnet N-S orientations and combination of magnet arrays.
    c. Dog-bone fabrication and biaxial samples for testing purposes at different volume fractions.
    Deliverable for c: *Mechanical response characterization data*
2. Material characterization and testing tasks
    a. Establishing a way to test the samples while applying magnetic field.

    Deliverable: *Test apparatus enabling uniaxial or biaxial testing of membranes under magnetic actuation*

    b. Analysis of the test data to characterize the mechanical response as a function of material properties.
    c. Investigate the effect on the mechanical and magnetic response of different flake orientations with the respect to the out-of-plane membrane axis.

    Deliverable for b-c: *Trends in variations of mechanical response (e.g., elastic modulus, magnetic strain as a function of material microstructure (particle volume fraction, particle/matrix modulus ratio, particle orientation, etc)*
3. Production of a final report, compatible with further presentation as a poster or student paper.

Special project outcomes

1. Familiarization with fabrication of magnetically-responsive materials.
2. Familiarization and execution of material testing protocols for the adhesion and in-plane stretching response of polymeric membranes.
3. Familiarization with magnetic actuation of bilayer membranes.
4. Familiarization with testing of biological tissues.
5. Characterization of material properties that can be used in a mathematical model.

Assessment

The evaluation of the project is based on the successful completion of the above described deliverables. We will use the below shown rubric for the course evaluation.

Criterion	Evaluation Metric	Weight
Creativity	Inventiveness, added intellectual value	0.3
Quality of results	Competences, quality & extend of work	0.3
Work ethics	Work organization, independence, time management	0.1
Literature Analysis	Transferability of results into publications	0.1
Documentation	Form of the report, organization of data, qualtiy of code	0.1
Oral Presentation	Oral presentation	0.1
Sum		

Work policy

Special work techniques need to be observed to ensure efficient and productive results when dealing with research projects. These techniques require the research effort to be conducted in blocks of continuous working sessions. The schedule of these block sessions will be established to accommodate both the student's and supervisor's additional academic commitments, as well as to maximize the resources of the laboratory. It is anticipated that the sessions will be organized to fit periods of at least 4 straight hours, for example, from 9 am to 1 pm three times a week.

_____	_____
Undergraduate Student printed name and signature	Supervisor
Date:	Date:
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References

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