IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

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| **Project Title:** | **Role of local order in the mechanical properties of disordered, anisotropic colloidal particle assemblies and nanocomposites** | |
| **Project Number** | **IMURA1052** | |
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| **IITB Department**: | Chemical Engineering | |

## Research Clusters: Research Themes:

| **Highlight which of the Academy's CLUSTERS this project will address?** *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)* | | **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 | *Material Science/Engineering (including Nano, Metallurgy)* | 2 | *Nanotechnology* |
| | | 3 | *Circular Economy* |
| | | 5 | *Clean Energy* |
| | | 6 | *Smart Materials* |
| | | 7 | *Sustainable Societies* |

## The research problem

Advances in materials chemistry have made it possible to synthesize colloidal nanoparticles with exceptional control over size and shape distribution and over interparticle interactions. Such control affords functional designer nanoparticles with important technological applications. Colloidal assemblies and nanocomposites are an important class of functional materials that often have intriguing and highly-tuneable mechanical, viscoelastic and optical properties. They have very interesting and complex phase behaviour and can assemble, or solidify in either ordered or disordered forms by tuning particle shape, interactions, density or other condition (templating, centrifuging). Due to this natural functionality, they have a multitude of important technological applications in energy and environmental materials, personal care products, catalysis and other industrial processes, as well as emerging fields such as nanomedicine and theranostics. In recent years, there has been growing interest in studying colloids and their assemblies as models for molecular systems since such investigations are often more tractable than studying molecular systems. In particular, studying the colloidal glass transition has already provided important clues to advance our understanding of the glass transition. In the past three decades, there has been an explosion of research activity leading to ever-finer control of nanoparticle composition, shape, interaction (attractive, repulsive, sticky, patchy), templating and thus phase selection. Despite this, fundamental understanding of the role of disorder and the large variety of local environments on the bulk properties remains to be developed. This represents a critical impediment to further engineering and designing of these unique functional materials. While there have several studies that have focused on the glass transition of spherical colloids, there are relatively few studies of anisotropic systems. However, anisotropic building blocks and their disordered, glassy assemblies are not uncommon in nature. This project proposes to combine the advances in colloidal nanoparticle synthesis with advanced X-ray tools to investigate local ordering in assemblies of anisotropic colloidal entities.

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## Project aims

This project aims to use a novel method developed by the Monash supervisors of scanning micro-beam small angle x-ray scattering to make strong links between local particle arrangements in disordered, anisotropic colloidal particle assemblies and nanocomposites and observed global mechanical properties. A range of materials will be studied with varying parameters (particle anisotropy, interactions, filler type). Particles will be assembled by allowing them to settle or by the ice-templating technique, developed by the IITB group. In situ deformation x-ray scattering studies at the Australian Synchrotron will be used to understand changes to local order with loading. A range of bulk characterisations on the materials will be performed (mechanical, optical) and also supporting measurements employing electron microscopes.

## How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

Amelia Liu is a physicist, and expert on disordered materials and new diffraction-based methods to understand local order in these challenging materials. Rico Tabor is a physical chemist with expertise in colloidal chemistry and also x-ray and neutron scattering. The Monash Science Faculty supervisors have a history of successful collaboration and many co-authored articles (Sci. Adv. 2022, Proc. Natl. Acad. Sci 2017, Phys. Rev. Lett. 2016).

Guruswamy Kumaraswamy is a chemical engineer at IITB with interests in soft matter in general. His group has worked with polymers and polymer phase transitions, amphiphiles and nanocomposites. Most projects in the group have a strong experimental component, and we use rheology, microscopy, spectroscopy and scattering to understand structure-property relations in soft materials. We have a strong track record of collaborations with academic groups (including with the group of Prof Prabhakar Ranganathan at Monash University) as well as with industry.

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

The student will prepare materials and their assemblies and perform bulk characterisation at IITB. They will then visit Monash for x-ray scattering experiments, supporting modelling work and electron microscopy analysis.

## Expected outcomes

The project expects to make strong connections between local order and bulk properties in disordered, anisotropic colloidal particle assemblies and nanocomposites. The effect of different parameters (particle anisotropy, interactions, filler type) will be elucidated.

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

The project will address the goal of “Smart Materials” by uncovering the role of structure in mechanical properties for disordered, anisotropic colloidal particle assemblies and nanocomposites. This will facilitate further design of this important class of functional materials.

## Potential RPCs from IITB and Monash

Tim Petersen (Monash Centre for Electron Microscopy)
Sunita Srivastava (Physics, IITB)
Rajdip Bandyopadhyay (Chemical Engineering, IITB)
Mithun Chowdhury (MSME, IITB)

## Capabilities and Degrees Required

Science (Physics/Physical Chemistry) or Engineering (Chemical, Mechanical, Materials)
High-level programming for data analysis
Sound understanding of diffraction, chemistry and physics of colloids

## 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)*

CL 602 Mathematical and Statistical Methods in Chemical Engineering
CL 607 Advanced Thermodynamics
CL 613 Special Topics in Complex Fluids OR CL 651 Rheology of Complex Fluids OR

## 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.*

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.

**Nanotechnology,nanoscience**
**Materials Chemistry/Science**