IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Understanding evaporative assembly mechanism of nanoscale materials and exploring assembly structure for optical applications	
Project Number	**IMURA0998**	
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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*

The research problem

Evaporative self-assembly is a simple yet effective bottom-up approach to obtain ordered nanostructure assembly on solid surface. The evaporation of a liquid droplet with colloidal dispersion based on the basic theory of fluid flow, phenomenologically seems to be a rather simple problem however the role of the nanoscale interactions that effects the microstructure are yet far reaching and complex scientific problem.

Previous reports have discussed several ways to modulate the deposition patterns by manipulating internally generated fluid flow patterns, interactions, drying conditions, physicochemical properties of solutes, solvents and substrates. Our work based on evaporative assembly of DNA coated nanoparticle (DNA-NPs) on hydrophilic substrates reveals the formation of tunable nanostructures via stick-slip motion, a phenomenon usually expected to occurs in case hydrophobic substrates via periodic pinning-depinning of the droplets. These results indicate that the nanoparticle-substrate interactions predominately govern the drying profile and the deposition pattern. The assembly length scale is of the order of few 10's of nanometre which not possible to be achieved by conventional lithography techniques. The ongoing experiments in our group on CTAB coated gold-NRs (GNRs) reveals a different mechanism of pattern formation due to the presence of surface-active components in nanoparticle suspension. The dried pattern consists of a coffee ring structure that primarily exhibits three different regions of assembly: the exterior of the droplet, consists of a small cluster like arrays of GNRs, followed by a usual coffee ring-like deposit. This is preceded by the formation of a depletion zone, after which the random deposition of the NRs was found at the central region of the droplet deposits.

From the existing literature and the ongoing experiments in our group it is evident that the fundamental understanding of the nanoscale interactions is essential to tailor the evaporation driven patterning on solid substrates. The current research proposal is aimed at understanding the role of nanoscale interactions such as substrate-nanoparticle, surfactant and shape of the nanoparticles, altering variety of transport phenomena, length-scales and time scales at the microscopic level that effects the pattern formation at the macroscopic length scale. To the best of our knowledge the majority of the existing studies has primarily focused on colloidal particles of the micrometre length scale. Our assembly studies are based on using functional nanoparticle in the size range of 2nm-50nm which can further be used for designing of application-based system e.g. template to grow hierarchical structure and create metamaterials. The research in our group focuses at understanding the nanoscale forces for controlled and tunable pattern formation in the nanometre length scale, which we envision shall serve as an alternate to nanolithography technique.

Project aims

- Understand the role of nanoscale interactions in pattern formation and develop assembly methods for nanostructure creation using functional nanoparticles. The evaporative self-assembly method is cost effective and allows creation of ordered structure at few nm's of length scale, a regime not achievable by conventional lithography methods. We shall perform measurements to correlate the different stages of the drying profile with the structural assembly.
- Our paper on the formation of dual scale nanostructures of DNA functionalized nanoparticles [1] via stick-slip motion on hydrophilic substrate, reveals the importance of nanoscale interaction for tunable surface morphology. Future plan is to explore the highly ordered DNA-NP structures for optical application, biomolecule sensing and device application.
- Create ordered structure with tunable length to be used as a template for growth

of hierarchical structures. The goal is to achieve control over the ordered assembly and investigate its usability for creation of metamaterials.

- Our paper on functional gold nanorod structures [2] reveals SERS signal enhancement of Rhodamine B analyte, by factor of ~ 7.6 x10^5 and detection limit to concentration as low as 10^{-8} M has been achieved using the ordered arrays of gold nanorods as substrates. We plan to extend our studies on the AuNR assembly for fabrication of optical sensors and other application-based studies. For these studies we plan to explore assembly of the hybrids system of functional nanoparticles which are also optically sensitive such as binary mixture of silver nanoparticles and gold nanorods.

Expected outcomes

- Use of DNA-Nanoparticle assembly for biomolecule detection and applications.
- Understanding of plasmonic application of ordered functional structures of nanoparticles such gold nanoparticles , gold nanorods, silver particles.
- Demonstrating the usability of structures obatined from evaporative methods for template driven growth of higher structures.
- Fundamental understanding of the nanoscale interaction evaporation driven self-assembly mechanism.

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

Material Science/Engineering (including Nano, Metallurgy) : Our project based on studying the self-assembly methods for creation of long range ordered structures aligns with the goal of **material science and nanomaterial engineering.**

Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng : The proposed optical and plasmonic applications based studies of the evaporative nanostructures comes under the preview of the defined goal of studies related to **optics and photonics.**

Smart Materials: Our vision to explore the nanostructured for biosensing applications shall throw insights and provide inputs towards the applicability of these functional nanostructure materials for creation of biosensing devices which will be a step forward towards using structured nanomaterials as **smart materials.**

Potential RPCs from IITB and Monash

Prof. Dinesh Kabra (Physics, IITB) : Prof. Kabra has expertise in the area of semi-conductor research and optical studies. He will be suited to judge the research progress of the student.

Prof. Rajneesh Bharadwaj (Mechanical Eng): Prof. Rajneesh has expertise in studying evaporative assembly mechanism.

Prof Wenlong Chen (Chemical Eng): Prof Chen has expertise in biosensing, biomedical applications and plasmonics.

Capabilities and Degrees Required

MSc : Physics, Material Science, nanomaterials
M.Tech : Chemical Eng, Mechanical Eng, Nanoscience, Nanotechnology,
B.Tech : Physics, Material Science, Chemical Eng, Mechanical Engineering

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)

- *Condense Matter Physics*
- *Introduction to Nanoscience and Nanotechnology*
- *Optical properties of nanoscale materials*

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.

- Professor Sudha Mokkapati, Materials Engineering, 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
Nanotechnology,nanoscience
Optics, Photonics
Materials Chemistry/Science