IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Photothermal DNA-lipid nanoparticles for medical diagnostics applications**	
Project Number	**IMURA1282**	
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IITB Department:	Department of Physics	

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

There is an inadequate sensitivity, efficiency, and stability of existing biosensors for diagnose of disorders. Current methods struggle to perform reliably in complex biological environments due to complex and unstable behaviour. Some of the challenges include limited sensitivity in current sensing technologies, inefficiency of photothermal conversion, insufficient understanding of membrane-nanostructure interactions and lack of functionalization strategies.

The proposed solution involves developing biomimetic photothermal sensors using novel porous-gold nanorods (PGNRs) encapsulated within liposomes, further functionalized by DNA for biomarker detection. This innovative approach leverages the high photothermal conversion efficiency of PGNRs to enhance detection capabilities in complex environments. By functionalizing the biomimetic shell with specific sensing biomolecules-DNA, we aim to create sensors that respond effectively to target analytes. Furthermore, in-depth studies on the interaction between the sensors and cell membranes will optimize design parameters. This integration of advanced nanostructures and biomimetic principles represents a significant innovation, potentially transforming biosensing applications with improved sensitivity, stability, and biocompatibility.

Project aims

Rapid and ultra-sensitive detection of biomolecules is essential for breakthroughs in medical diagnostics and environmental monitoring. In this project, we aim to develop a next-generation biosensor that combines liposomes, DNA probes, and photothermal nanoparticles into a single, integrated platform powered by photothermal detection. Photothermal nanoparticles such as gold nanorods or other plasmonic materials will be employed for their exceptional ability to convert light into heat, thereby enhancing the detection signal upon optical irradiation. Liposomes will function as intelligent carriers, encapsulating signal molecules or amplification agents and releasing them only in the presence of the target analyte. DNA probes will serve as precise recognition elements, capable of detecting specific sequences or biomolecules through nucleic acid hybridization or aptamer-based interactions. The fabrication strategy involves immobilizing DNA probes onto the surfaces of nanoparticle-encapsulated liposomes. When the target analyte binds to the DNA probe, a synergistic cascade is initiated: hybridization is followed by a localized temperature increase generated by the photothermal nanoparticles under light excitation. This approach significantly enhances both sensitivity and specificity, enabling detection through precise temperature measurements.

To ensure structural integrity and optimal architecture of the biosensor components, comprehensive characterization will be conducted using Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM) for imaging and assessing the morphology and spatial organization of nanoparticles and liposome-DNA assemblies. X-ray scattering techniques will provide additional insight into the nanoscale structural features and assembly behavior within the sensor matrix, confirming successful integration and monitoring any structural changes throughout the fabrication process. By introducing these rigorous characterization methods, the biosensor design ensures high sensitivity, selectivity, and multiplex capability with precise control over nano-architecture. To demonstrate feasibility, proof-of-concept experiments will be conducted to detect biomarkers associated with infectious diseases such as tuberculosis. This multidisciplinary approach positions the proposed biosensor for significant advances in point-of-care diagnostics, and real-time environmental analysis, thereby enhancing the reliability and versatility of photothermal biosensing technologies.

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

Prof. Sunita, IITB supervisor, has extensive experience in the synthesis and assembly of photothermal particles. A patent has been acquired in this domain. She has worked on DNA- and nanoparticle-based nanoarchitectures and has published several papers in peer-reviewed journals in this domain. Prof. Leonie possesses wide-ranging expertise in liposome-based nanostructures and has also worked extensively on drug-delivery applications of nanoparticles. Her expertise will be crucial to the success of the project.

The two PIs bring complementary skills essential for the project's objectives. For characterization, Prof. Sunita contributes expertise in X-ray scattering-based structural analysis, while Prof. Leonie specializes in optical microscopy-based measurements in addition to X-ray scattering. Together, their combined knowledge will be instrumental in ensuring the project's success.

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

At IITB, the student will focus on the synthesis and characterization of photothermal nanostructures. This will include detailed work on encapsulating photothermal nanoparticles within liposomes, functionalizing them with DNA, and characterizing the resulting constructs using scattering and microscopy techniques. Experimental will be performed to characterize stimuli based photothermal response of these structures.

At Monash, the student will carry out experiments to characterize these nanostructures using synchrotron-based X-ray scattering measurements. Additional experiments will be conducted to evaluate the sensing efficiency of the nanostructures for various biomarkers. Further studies will focus on advancing their application for diagnostic purposes.

Expected outcomes

The project seeks to deepen the fundamental understanding of interactions between photothermal nanoparticles and biomimetic membranes. Through detailed experiments, we aim to identify critical design parameters for creating efficient nanostructures featuring porous architectures within DNA-functionalized liposomes for sensing and diagnostic applications. The ultimate goal is to develop advanced biomimetic photothermal sensors based on porous gold nanorods, engineered for high sensitivity, stability, and biocompatibility. These sensors will be optimized for biomedical diagnostics and rigorously characterized and tested to ensure reliable performance in complex biological environments.

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

The nanostructures developed in Prof. Srivastava's lab demonstrate state-of-the-art photothermal efficiency. Integrating these nanostructures with liposomes is expected to enable early diagnostics through stimuli-responsive photothermal sensing. Furthermore, the combined incorporation of liposomes and DNA with photothermal nanostructures is anticipated to yield smart materials with promising applications in the health sciences.

How well the IITB and the Monash supervisor(s) know each other

Their collaboration began during a visit by IITB delegates to Monash, where the initial idea evolved into a project proposal. The IITB and Monash supervisors have known each other for the past three years. Prof. Leonie has also served as an RPC member for one of the students in Prof. Srivastava's group, leading to regular interactions between the two research groups.

Potential RPCs from IITB and Monash

Prof. Venkat Gundabala and Prof. Rajdip Bandyopadhyay (IITB)

Prof. Sushil Dhital and Prof. Hsin-Hui Shen (Monash)

Capabilities and Degrees Required

M.Tech Biotechnology, M.Tech Nanoscience and Nanotechnology , B.Tech Bioscience and Bioengineering, M.Sc in Physics/Material Science, M.Tech/B.Tech in Chemical 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)

Soft Matter Physics, Analytical techniques in experimental physics and Microscopy Methods

Potential Collaborators : NA

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.

K**eywords** relating to this project to make it easier for the students to apply.

Self-assembly, Phothermal, Liposomes, DNA, Biosensing