IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Exciton engineering in atomic monolayers using plasmons	
Project Number	**IMURA0839**	
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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)*	***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

Define the problem

Two dimensional semiconductors have emerged as promising materials for the development of optical sources, owing to their large exciton binding energy and electrostatic tunability of their emission properties. However, the quantum yield of practical devices made out of these materials is still very low on account of nonradiative exciton recombination. Plasmonic nanostructures can enhance the radiative recombination rate due to their small optical mode volume (~50 nm)^3. In this project, using the ideas of plasmonics, we will develop innovative approaches from a fundamental physical and engineering standpoints to significantly enhance the efficiency of these emitters as well as develop practical device realizations of technological relevance.

Project aims

Define the aims of the project

The project would involve four parts:

1) Fabrication / synthesis of gold nanoparticles:

a) Top down approach: EBL here at IIT Bombay & Melbourne Center for Nanotechnology
b) Bottom up approach: Chemical synthesis at Monash

2) 2D Materials / heterostructures

Via mechanical exfoliation of bulk crystal and CVD here at IIT Bombay

3) Optical characterization

a) Raman and photoluminescence here at IIT Bombay
b) Near field optical characterization and time resolved studies of exciton diffusion with and without plasmonic coupling at Monash

4) Simulation and theory

FDTD (Lumerical) and FEM simulations (COMSOL) here at IIT Bombay

Phase 1: IITB
Simulation work for nanocavity design (FDTD via Lumerical)
Beginning of EBL (ebeam lithography) training of the student
Integration of monolayer TMDs with the fabricated nanocavities and optical characterization via Raman and photoluminescence

Phase 2: Monash
EBL is carried out by the student at Melbourne Center for Nanotechnology
Near field and far field characterization of the exciton emission with and without nanostructures
Iterative simulation and redesign via Lumerical based on the characterization results

Phase 3: IITB
Thesis writing and publications

The main objectives of this proposal are:

1) Design and fabricate plasmonic nanocavities
2) Integrate 2D semiconductors (TMD) reproducibly with fabricated plasmonic structures

3) Characterize the resulting emission in the integrated TMD/nanocavity system as a function of various parameters to optimize a low power high efficiency nano optical light source at the visible wavelength.

Expected outcomes

Highlight the expected outcomes of the project

1) Publications in high impact journals: Since this work has many elements of novelty involved, it is possible to publish the results in prestigious journals as well as conferences
2) Develop a fundamental understanding of the channeling of emission from 2D semiconductors into a nanocavity optical mode.
3) Develop technical expertise in nano-optical characterization and functionalization of 2D materials
4) Possible identification of other relevant research problems which can be solved by the synergy of the capabilities of IITB and Monash University.

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

Describe how the project will address the goals of one or more of the 6 Themes listed above.

Nanotechnology:
The project will involve building of optical devices using 2D semiconductors, whose thickness is below a nanometer. We will integrate these nanomaterials with cavities of nanoscale dimension, to build optical sources which will have direct relevance to future information processing and light storage technologies.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Capabilities: Through project or coursework

1) Basic solid state Physics theory (proficient)
2) Optics or basic electrodynamics - theory and experiment (medium)
3) Micro and nanofabrication (some exposure)

Qualifying degrees:

1) MSc. Physics
2) B.E./B.Tech./M.Tech. in Engineering Physics, Chemistry, Electrical Engineering or Materials Science

Strong plus:

1) Some cleanroom experience
2) Exposure to basic optical characterization (microscope / Raman / PL, etc)
3) Exposure to Data analysis in MATLAB or Python

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.

2D Materials, Novel Functional Materials, Photonics, Nanotechnology