IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Graphene Coating for Remarkable Corrosion Resistance: Mechanistic Investigation into Degradation and Durability**	
Project Number	**IMURA0791**	
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Research Academy 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. Advanced computational engineering, simulation and manufacture
2. **Infrastructure Engineering**
3. Clean Energy
4. Water
5. **Nanotechnology**
6. Biotechnology and Stem Cell Research
7. Humanities and Social Sciences

The research problem

Define the problem

Corrosion mitigation of common alloys such as mild steel annually costs a developed country ~4% of GDP (i.e., $8b to Australia, $250b to USA). Hence, finding durable corrosion mitigation has immense commercial and social impacts. Graphene, an atomically thin carbon network, has triggered unprecedented research excitement. Its exceptional characteristics include its inertness to even most aggressive chemicals (e.g., HF), excellent impermeability to fluids (even to very small He atoms) and toughness, thus making graphene coating a highly attractive novel approach towards an ideal corrosion resistant coating. The Monash research group (of Raman Singh and Parama Banerjee) has demonstrated an ultrathin graphene layer on bare copper to improve corrosion resistance in sea water by up to two orders of magnitude [1], which is so far possibly the best reported resistance due to graphene coating. Further, this group has very recently demonstrated [2] a considerable durability of corrosion resistance due to graphene coating. Dr Subramaniam's expertise and infrastructure available in his group at IITB for the proposed combined use of Raman spectro-microscopic and electrochemical techniques will hugely enhance the capability for investigation of the mechanistic insight. Metal-passivated graphene will be vibrationally mapped to understand and spatially locate domain boundaries and defect sites. In-situ electrochemical experiments will be carried out and the time-dependent structural changes in the graphene coating will be characterised through micro-Raman spectro-microscopy. This will provide important evidence of the initiation and propagation of the electrochemical corrosion processes. The use of Raman spectroscopy has been established in Dr. Subramaniam's group for developing a fundamental understanding of the structure of nanocarbon materials.[3-6]. The mechanistic understanding of the coating degradation that will be generated through the proposed work will enable development of generic coating characteristics for remarkably durable corrosion resistance of engineering alloys.

[1] RK Singh Raman, PC Banerjee, DE Lobo, H Gullapalli, M Sumandasa, A Kumar, L Choudhary, R Tkacz, PM Ajayan, M Majumder, Protecting Copper from Electrochemical Degradation by Graphene Coating, ***Carbon***, 50 (2012) 4040.

[2] MR Anisur, PC Banerjee, CD Easton, RK Singh Raman, Controlling Hydrogen Environment and Cooling during CVD Graphene Growth on Nickel for Improved Corrosion Resistance, ***Carbon,*** 127 (2018) 131.

[3] V Kalyani, S Mondal, J Saha, C Subramaniam, Electrochemical, top-down nanostructured pseudocapacitive electrode for enhanced specific capacitance and cycling efficiency, Nanoscale, 10 (2018) 3663.

[4] M Moronshing, C Subramaniam, Scalable Approach to Highly Efficient and Rapid Capacitive Deionization with CNT-Thread As Electrodes, ACS Applied Materials and Interfaces 9 (2017) 39907.

[5] P. Rathi, M. K. Jha, K. Hata, C. Subramania, Real-Time, Wearable, Biomechanical Movement Capture of Both Humans and Robots with Metal-Free Electrodes, ACS Omega 2 (2017) 4132.

[6] C. Subramaniam, T. Yamada, K. Kobashi, A. Sekiguchi, D. N Futaba, M. Yumura, K. Hata One hundred fold increase in current carrying capacity in a carbon nanotube–copper composite, Nature Communications, 4 (2013) 2202.

Project aims

Define the aims of the project

With a view to developing the coating characteristics s for remarkably durable corrosion resistance, this project aims to:

1) develop ultra-thin graphene coatings on metals and

2) carry out advanced electrochemical investigation into mechanism of the time-dependent degradation of the coating,.

Expected outcomes

Highlight the expected outcomes of the project

The mechanistic understanding of the degradation of graphene coating during exposure to aggressive environment of seawater.

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.

The mechanistic understanding and molecular origins of electrochemical degradation of graphene coatings will enable optimization of the parameters for developing the generic coating characteristics for remarkably durable corrosion resistance.

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.

For this interdisciplinary yet a highly specialised project, the candidate must possess or have interest in developing a deep interest in nanomaterial and their properties for electrochemical applications such as corrosion. Some demonstrable background will be highly favourable. The selected candidate should possess demonstrated interest in nanomaterial and their electrochemical properties.

The candidate should have Materials Chemistry, Materials Engineering, Chemical Physics or Chemical Engineering degree at Master or a good Honours with reasonable research component, but most important attribute will be a deep interest nanomaterial and their electrochemical properties.

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.

Given the industrial importance of corrosion and its inhibition, potential collaborators would be Tata Steel and Reliance Industries.

Please provide a few key words relating to this project to make it easier for the students to apply.

Graphene, Corrosion Resistance, Electrochemistry, Raman spectroscopy