IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Wear, corrosion and oxidation behaviour of electrodeposited multi-layered Fe-Ni and compositionally graded Fe-Al coatings**	
Project Number	**IMURA0767**	
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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

Hard-chrome coatings are extensively applied to steels to protect the surface from extreme mechanical wear and to enhance the corrosion resistance concurrently. The detrimental effects of using Cr (VI) (generated during the coating process) on human health and environment has raised serious concerns in the recent past. This has led to the restriction of its usage in some countries. Hence there is a pressing need for finding a suitable replacement of chrome coatings.

Nanocrystalline materials (nc) with grain sizes in the range of 1-100 nm offer excellent hardness and strength as compared to their coarse-grained counterparts due to their remarkably greater grain boundary area. They are potential materials as wear resistance coatings. However, they may exhibit inferior corrosion and oxidation resistance which is a major drawback. The minimum lattice mismatch between steel substrate and nc Fe coating is a major advantage over other nc metal coatings. Our recent efforts[1] to enhance the corrosion resistance of nc Fe without compromising the wear resistance by alloying with noble elements like Ni has proved to be fruitful. Further, our other recent study[2] demonstrated enhancement in mechanical properties by codepositing Al nanoparticles in Ni matrix.

The present study is aimed at establishing nc Fe based wear resistant coatings as an alternative to hard-chrome coatings. The corrosion and oxidation resistance problems shall be addressed by investigating the following approaches of noble metal alloying through pulsed electrodeposition route:

(i) Non-equilibrium solid solution of Fe-Ni: Coatings with multi-layers of nc Fe-Ni with increasing Ni content at regular thickness intervals from substrate-coating interface.

(ii) Nanocomposite of Al nanoparticles in Fe matrix: Compositionally graded nc Fe-Al composite coatings with increasing Al nanoparticles (<100 nm) codeposition content from substrate-coating interface.

[1] D.V. Kumar, S. Ayyagari, M.J.N.V. Prasad, “Mechanical characteristics and electrochemical behaviour of electrodeposited nanocrystalline iron and iron-nickel alloy,” Materials Chemistry and Physics 201 (2017) 26-34.

[2] Sumit Chhangani, M.J.N.V. Prasad, “Microstructure, texture and tensile behavior of pulsed electrodeposited Ni–Al composites produced using organic additive-free sulfamate bath loaded with Al nanoparticles,” Materials Characterization 136 (2018) 247-256.

Project aims

Define the aims of the project

- Establishing pulsed electrodeposition technique to synthesize multi-layered Fe-Ni and compositionally graded Fe-Al composite coatings with increasing Ni and Al concentrations, respectively from the substrate-coating interface.
- Study wear resistance of the as-deposited coatings as a function of concentration of the alloying element and particles by using pin-on-disc apparatus and nano-scratch tester.

- Detailed evaluation of corrosion resistance of the as-deposited coatings with respect to the concentration of the alloying element using potentiodynamic polarization and impedance spectroscope techniques.
- The general service temperatures of hard coatings is ~400 ºC. Hence detailed low temperature oxidation studies (<570 ºC) of the deposited Fe-Ni and Fe-Al coatings will be carried out using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) techniques.
- To develop a coating with optimized combination of wear, corrosion and oxidation resistant which can be a possible replacement of the hard-chrome coatings.

Expected outcomes

Highlight the expected outcomes of the project

- The present project is aimed at synthesizing a strong adherent wear and corrosion resistant coating for steels using pulsed electrodeposition. Hence the primary outcome of this work is a standardized pulsed electrodeposition method for obtaining thick coatings of the following:
  - Multi-layers of nc Fe-Ni with customizable variation of Ni concentration
  - Compositionally graded nc Fe-Al composite coatings with varying distribution of Al nanoparticles across the thickness
- Detailed evaluation of the wear reistance with all the relevant possible concentrations of the alloying elements in the coatings
- Validation of the effect of alloying element in non-equilibrium solid solution (Fe-Ni) and composite (Fe-Al) form on the corrosion resistance
- Detailed study on the thermal stability (<570 ºC) of the coatings to evaluate the oxidation resistance and ascertain the possible phase transformations
- The work is targetted at designing and synthesizing an alloy coating that can be a possible replacement of the conventional hard-chrome caotings with optimized wear, corrosion and oxidation resistance

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 project fits two themes, nanotechnology (as the study involves nanostructured materials) and infrastructure engineering (as the project deals with mechanical, corrosion and oxidation behaviour of the coatings).

The present study is an attempt to find a possible replacement for the hard-chrome coating, which is an integral part of various structural components used in infrastructure engineering. The adaptation of nanocrystalline materials in amalgamation with solid solution and composite alloying to achieve the set objective is a novel approach in nanotechnology.

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.

The candidate should have a B.E/B.Tech equivalent degree in Metallurgical or Materials Engineering and M.E/M.Tech equivalent degree in Materials Science, Physical Metallurgy or Corrosion Engineering related specializations with deep interest in electrochemistry, wear, corrosion and oxidation behaviour of 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.

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

Hard coatings, electrodeposition, wear, corrosion, oxidation