

An Indian-Australian research partnership

<b>Project Title:</b>	Simultaneous Effects of Nanostructure and Alloy Composition for Remarkable Oxidation/Corrosion Resistance	
<b>Project Number:</b>	IMURA1005	
Monash Supervisor(s)	Professor Raman Singh Professor Murali Sastry	Full names and titles
Monash Primary Contact:	<a href="mailto:Raman.singh@monash.edu">Raman.singh@monash.edu</a> <a href="mailto:Murali.sastry@monash.edu">Murali.sastry@monash.edu</a>	Email, phone
Monash Head of Department:	Prof Julio Soria <a href="mailto:julio.soria@monash.edu">julio.soria@monash.edu</a>	Full name, email
Monash Department:	Mechanical & Aerospace Engineering	Full name
Monash ADRT:	Assoc Prof Tim Scott, <a href="mailto:Timothy.scott@monash.edu">Timothy.scott@monash.edu</a>	Full name, email
IITB Supervisor(s)	Prof. M.J.N.V. Prasad Professor Vijayshankar Dandapani	Full names and titles
IITB Primary Contact:	Prof. M.J.N.V. Prasad, <a href="mailto:minvprasad@iitb.ac.in">minvprasad@iitb.ac.in</a>	Email, phone
IITB Head of Department:	Prof K Narasimhan	Name, Email,
IITB Department:	Metallurgical Engineering and Materials Science	Full name

## Theme: Nanotechnology

### The research problem

For their unique physico-mechanical properties and exciting industrial applications, nanostructured materials are the most widely investigated materials research topics of recent times. However, oxidation/corrosion of nanocrystalline metallic materials has received limited research attention, even though such materials will often be required to demonstrate acceptable resistance to corrosive environment in most potential applications.

This project is based on the hypothesis that was developed at Prof Raman Singh's group at Monash University, i.e., it may be much easier to develop a protective film on nanocrystalline alloys. This hypothesis has also been validated through research in Prof Singh's group (1,2). This work has shown for the first time that a nanocrystalline Fe-10%Cr alloy provides similar resistance to oxidation at moderately high temperatures as a microcrystalline Fe-20%Cr alloy (that has Cr contents similar to common stainless steels). However, nanocrystalline Fe-Cr alloy has also been found to suffer from poor thermal stability (3), which restricts processing of such alloys at high temperatures. Another, critically important aspect is the well-established and highly beneficial roles of alloying element Al and

that due to the very small additions of rare earths (such as Y, Ce) in remarkably improving oxidation resistance of microcrystalline Fe-Cr alloys. It is hypothesised that such effects (of Al, and rare earth additions) should be far more pronounced in the case of nanocrystalline counterparts of microcrystalline Fe-Cr alloys.

Hence there is a great value in investigation into: (a) identifying the proper alloying additions that could substantially improve thermal stability and hence processability of nanocrystalline Fe-Cr alloys, (b) expected further improvement in oxidation resistance of such alloys, and (c) mechanism of oxidation resistance thorough surface/sub-surface characterisation of the oxidised alloys.

1. R.K. Singh Raman and R. K. Gupta, Oxidation Resistance of Nanocrystalline vis-à-vis Microcrystalline Fe-Cr Alloys, *Corrosion Science*, 51 (2009) 316 - 321.
2. R.K. Singh Raman, R. K. Gupta, Carl C. Koch, Synthesis Challenges and Extraordinary Resistance to Environmental Degradation of Nanocrystalline vis-à-vis Microcrystalline Fe-Cr Alloys, *Philosophical Magazine*, 90 (2010) 3233.
3. R. Gupta, R K Singh Raman and C. C. Koch, Grain Growth Behaviour and Consolidation of Ball Milled Nanocrystalline Fe-10Cr Alloy, *Materials Science and Engineering A*, 494 (2008) 253-56.

### Project aims

The principal aim is the successful development of nanocrystalline alloys with the properties listed below:

1. Syntheses of nanocrystalline Fe-based alloys that can be processed at considerably high temperatures (~1000 °C),
2. Nanocrystalline Fe-based alloys with oxidation and corrosion resistance with much lower alloying contents of Al, Cr and rare earth elements.
3. Thorough surface/sub-surface characterisation of the oxidised alloys, particularly by secondary ion mass spectroscopy (SIMS) and x-ray photoelectron spectroscopy (XPS).

### Expected outcomes

The expected outcomes are:

1. Fabrication of nanocrystalline powders of Fe-Cr alloys with suitable additions of Al and rare earth, by powder metallurgical (ball milling) route,
2. Identifying alloying additions that could substantially increase the temperature of compaction and sintering of the powders, while retaining the nanocrystalline structure,
3. Fabricating Fe-based nanocrystalline alloys with less expensive alloying elements for oxidation resistance (such as Al and Si) than the expensive Cr.
4. Characterization of oxidation (and if time permits, electrochemical corrosion resistance) of the nanocrystalline alloys with their microcrystalline counterparts.
5. Understanding the mechanism of oxidation resistance upon thorough surface/sub-surface characterisation of the oxidised alloys by SIMS, XPS and other techniques.

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

The project is of the Nanotechnology theme, and can lead to development of the next generation inexpensive alloys for corrosion resistance.

### **Potential RPC members** from IITB and Monash

Professor Siddhartha Duttagupta (expert in nanomaterials), IITB  
Dr Parama Banerjee (expert of corrosion), Monash

### **Capabilities and Degrees Required**

The student will need to possess prior training at Bachelors and/or Masters level in Materials/Metallurgical Engineering, Chemical Engineering, Mechanical Engineering or Chemistry/Physics with interest in learning advanced metallurgical engineering aspects of Mechanical Alloying/Ball milling, compaction and sintering, oxidation/corrosion and characterisation by XRD/TEM. XPS, SIMS, FIB, SEM/EDXS.

### **Necessary Courses**

Nanostructured Materials: Processing and Properties, Materials Characterisation, Corrosion

### **Potential Collaborators**

Various industries; we have not contacted yet.

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.

Nanocrystalline structure, Corrosion-resistant alloys