IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Tailoring Nanostructured Alloys for Remarkable Oxidation/Corrosion Resistance	
Project Number	IMURA0662 (1)	
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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

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 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 very recent 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 of 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 processabilty 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. Nanocrysalline Fe-based alloys that can be processed at considerably high temperatures (~1000 ^{o}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.

Capabilities and Degrees Required

The student will need the intellectual and infrastructural resource for:

1) *Mechanical Alloying / Ball milling, compaction and sintering and characterisation by XRD/TEM: This will be accomplished at IITM, Chennai, under a collaboration with Prof SR Bakshi.* ***This will be coordinated jointly by Prof S. Parida (IITB) by Prof Raman Singh****.*
2) *Characterization of Nanostructure by XRD and TEM techniques: XRD will be carried out both at IITM and IITB.*
3) *Oxidation will be carried out mainly at IITB. Access to a tubular furnace that can operate up to 900 ^{o}C will be provided. If required,part of these tests can also be run at Monash using existing facility. Electrochemical Corrosion Testing will be carried out at Monas and IIT B.*
4) *Post-oxidation/corrosion Characterization using XPS, SIMS, FIB, SEM/EDXS: These will be carried out primarily at IITB under Prof. S. Parida and Prof Sastry's supervision (and, if required, also at Monash).*