

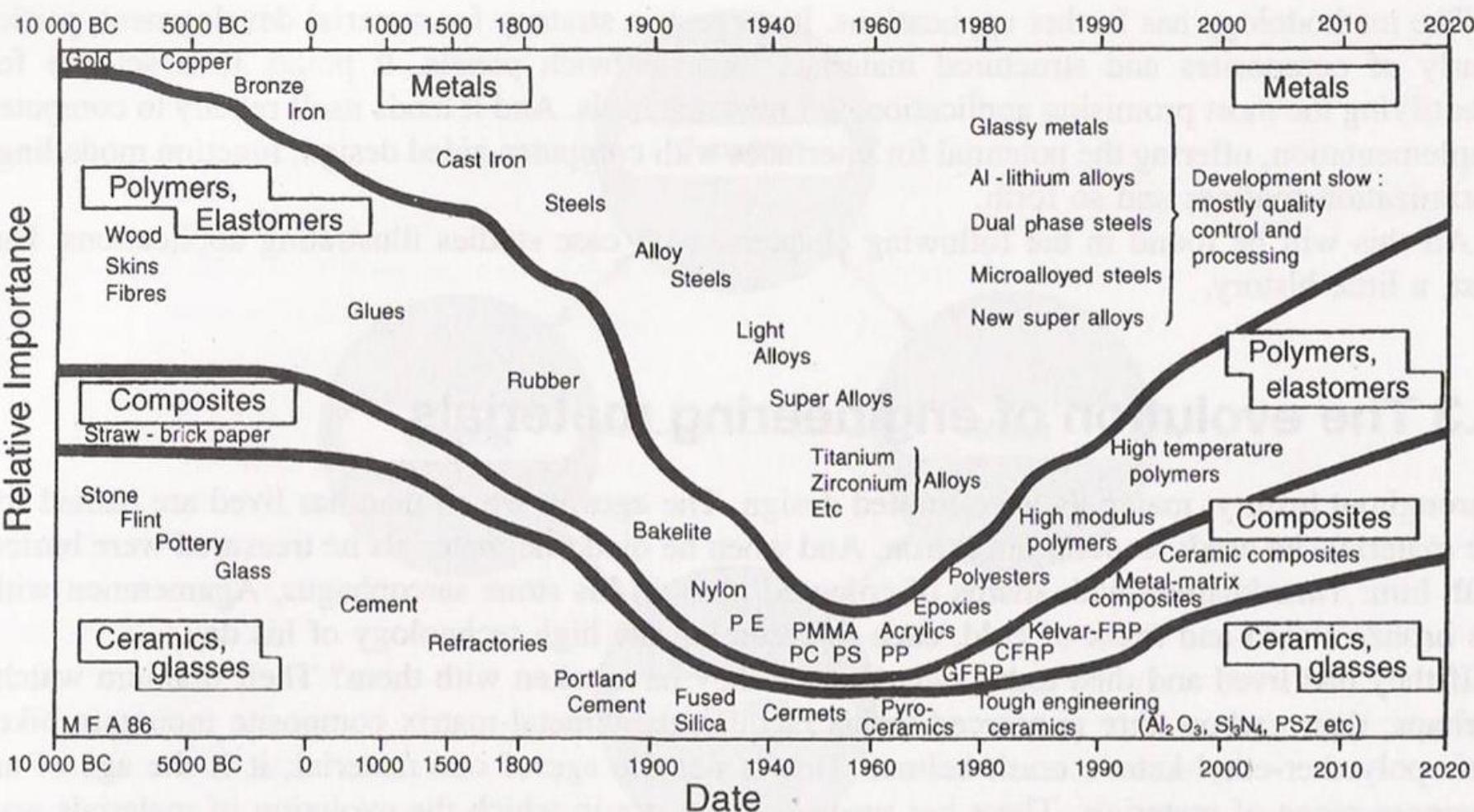
Role of Advanced Materials in Transforming India into a Global Leader

B.S. Murty

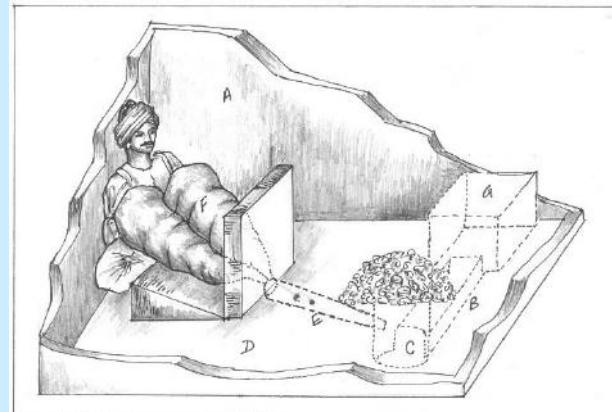
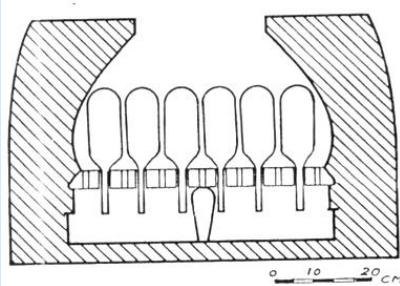


**Department of Metallurgical and Materials Engineering
Indian Institute of Technology Madras
murty@iitm.ac.in**

Use of Materials over ages



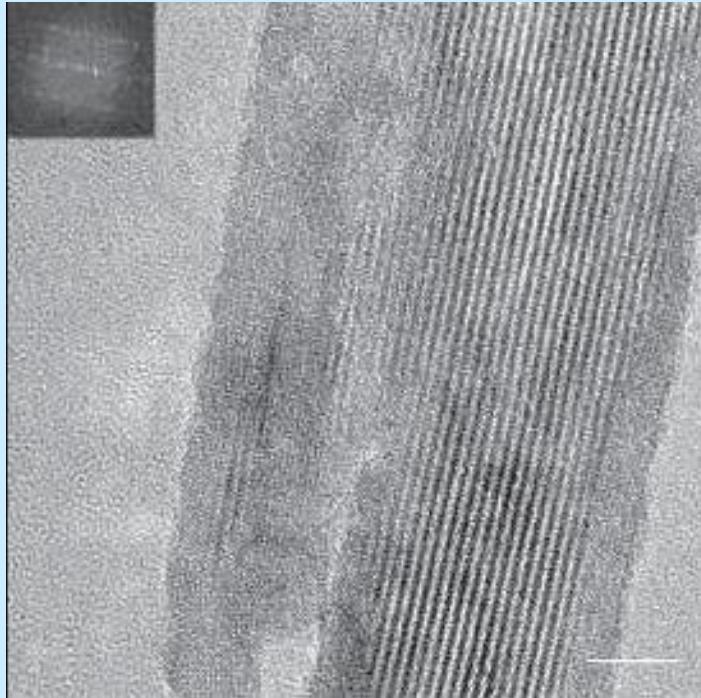
Indian Materials Heritage



- **Dancing Girl, Mohenjadaro** **2500 BC**
- **Wootz Steel** **300 BC**
- **Delhi Iron Pillar** **AD 400**
- **Zinc Extraction** **AD 1200**
- **Chola Bronze Icons** **AD 1200**
- **Kerala Bronze Mirrors** **AD 1600**



Indian Heritage: Nano Technology



Berne Historical Museum, Switzerland (produced by the famous blacksmith Assad Ullah in the 17th century)

**Rustless
Wonder**

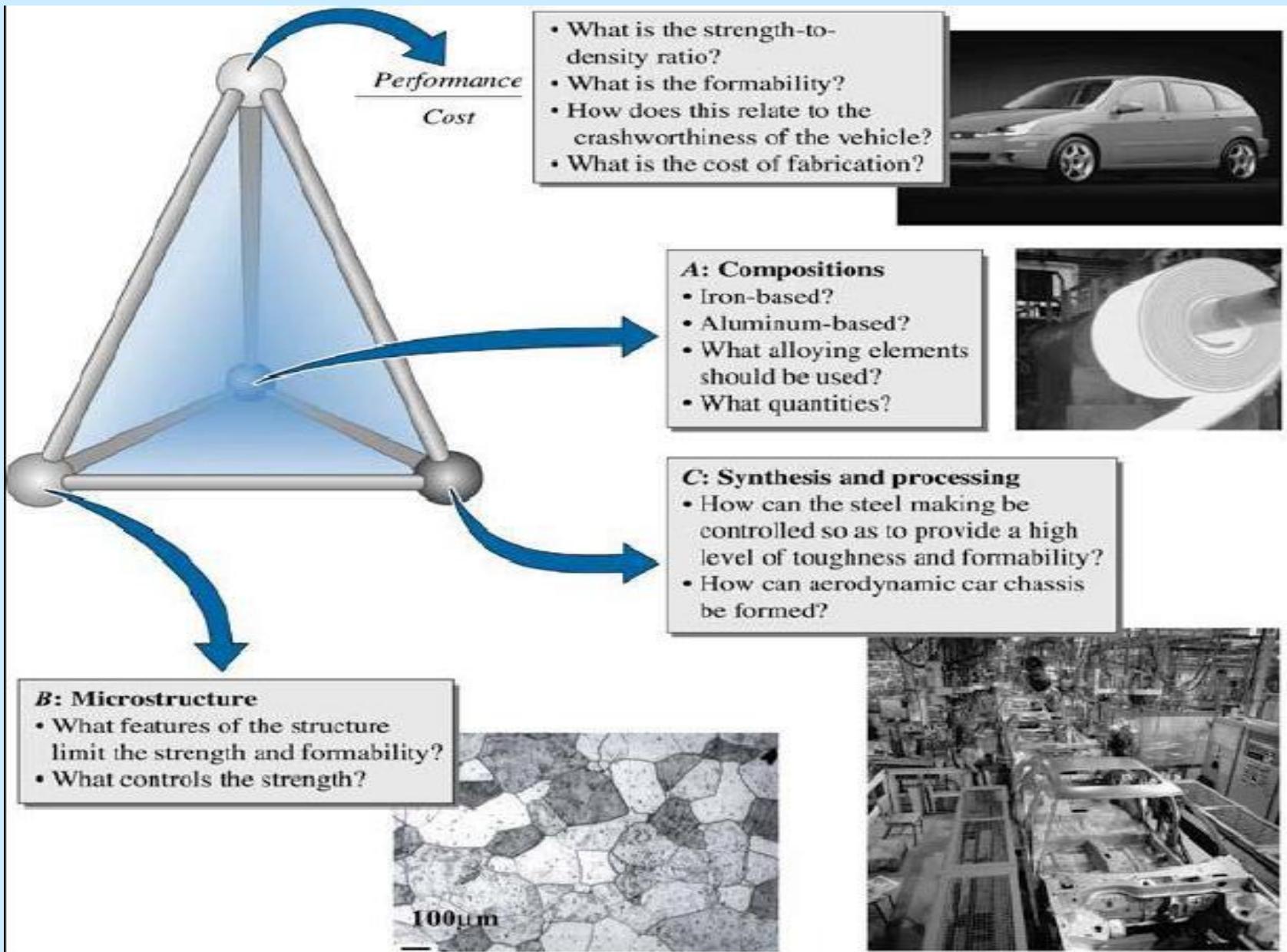
M. Reibold, P. Paufler, A.A. Levin, W. Kochmann,
N. Pätzke, D.C. Meyer, *Nature*, 444, 2006, 286.

"Many of the advances in the sciences that we consider today to have been made in Europe were in fact made in India centuries ago."

- Grant Duff, British Historian of India

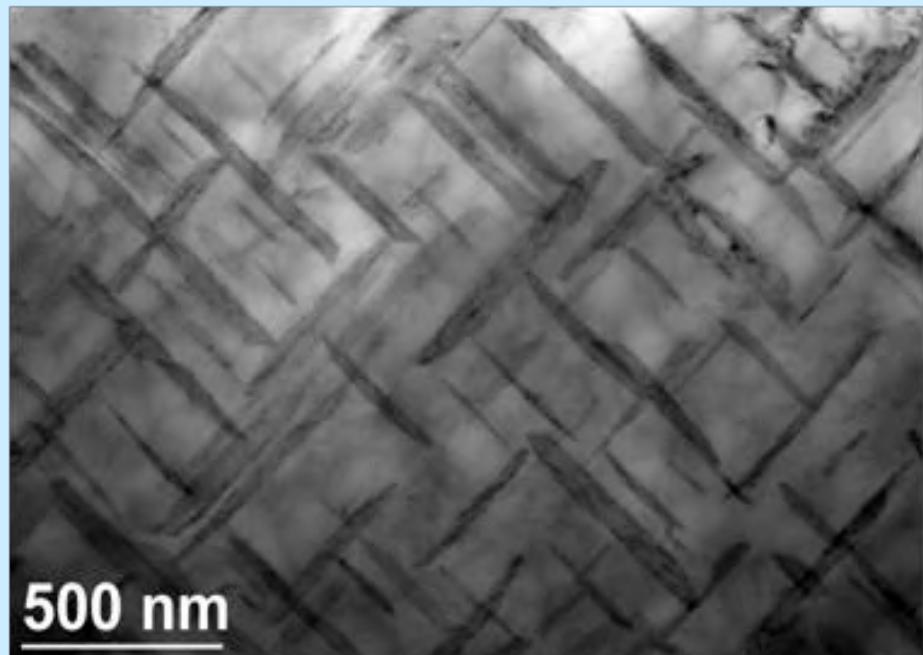
**Demascus
Sword
(Wootz Steel)**

Materials-Processing Pyramid

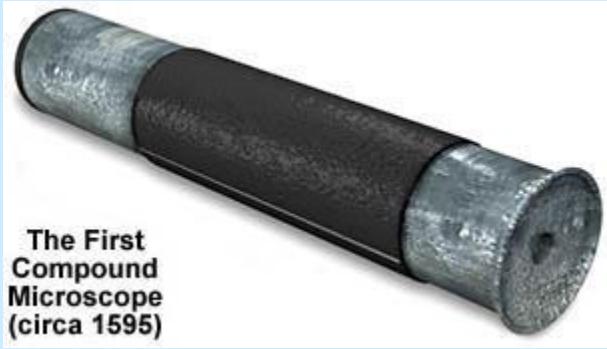
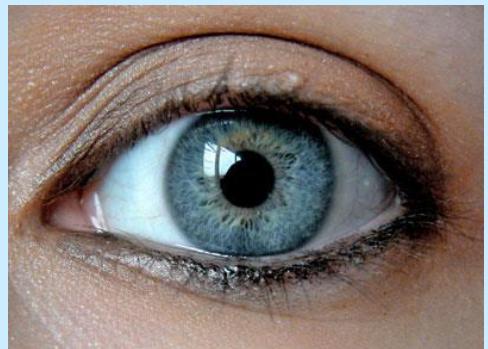


The Air Craft Alloy - The Accidental Discovery: The need for Higher Resolution

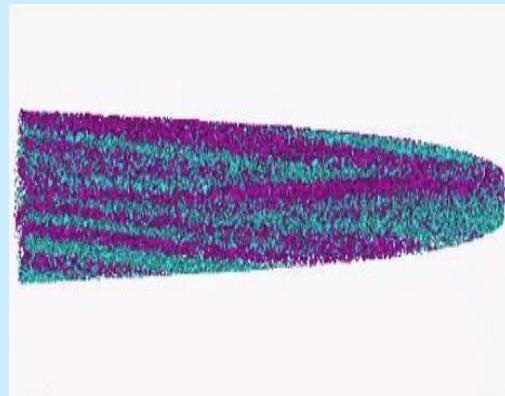
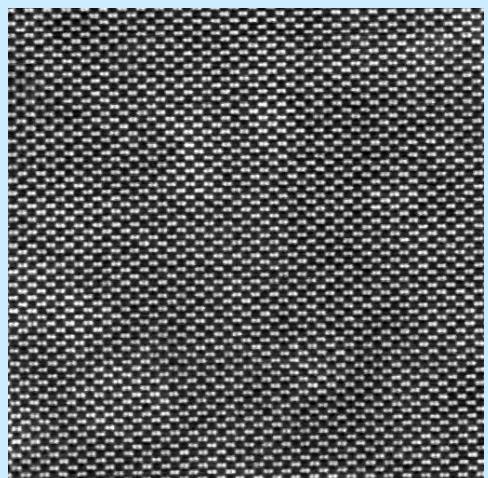
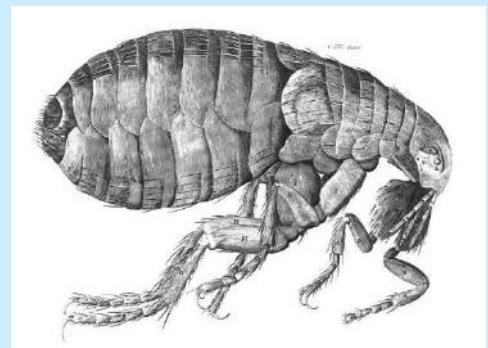
- Wilm in 1903
- First Aerospace Aluminum Alloy - Duraluminum
- The Wright Brothers Aircraft Crankcase



Microscopy: urge to see Inner World



The First
Compound
Microscope
(circa 1595)



Can We See Small Things ?

HAND



10 centimeters



1 centimeter

WHITE BLOOD CELL



10 microns



1 micron

DNA



1 millimeter



100 microns



100 nanometers



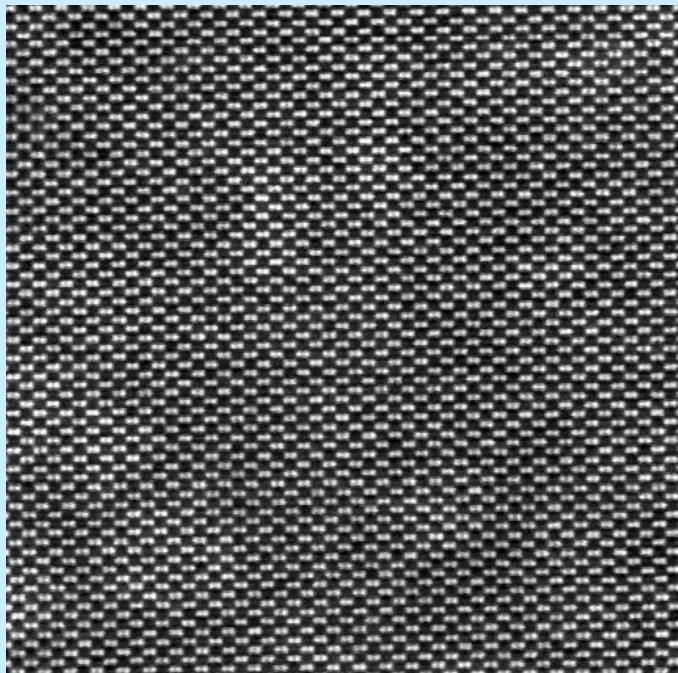
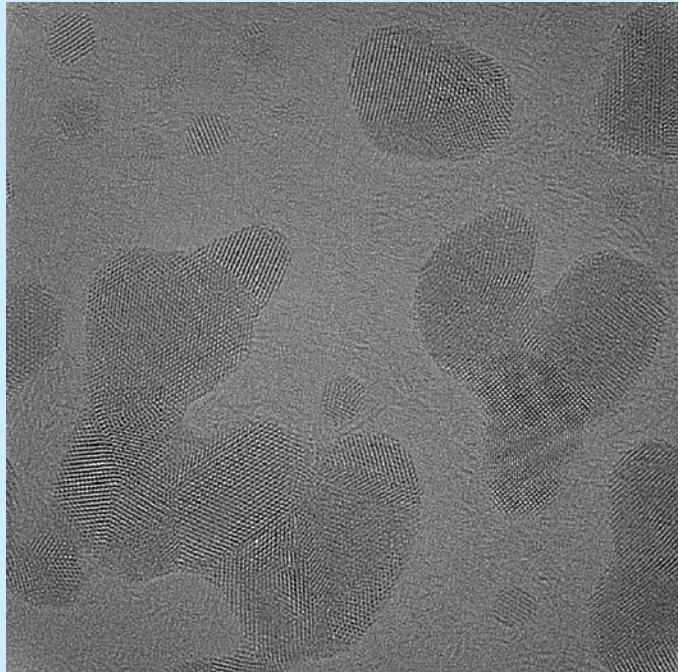
10 nanometers



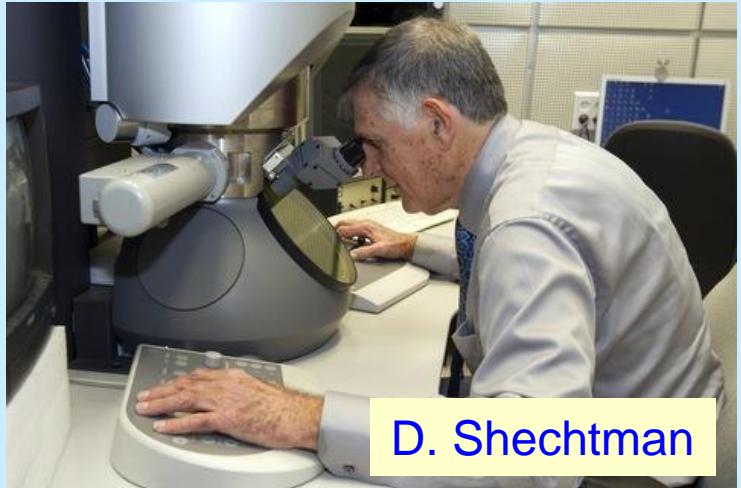
1 nanometer



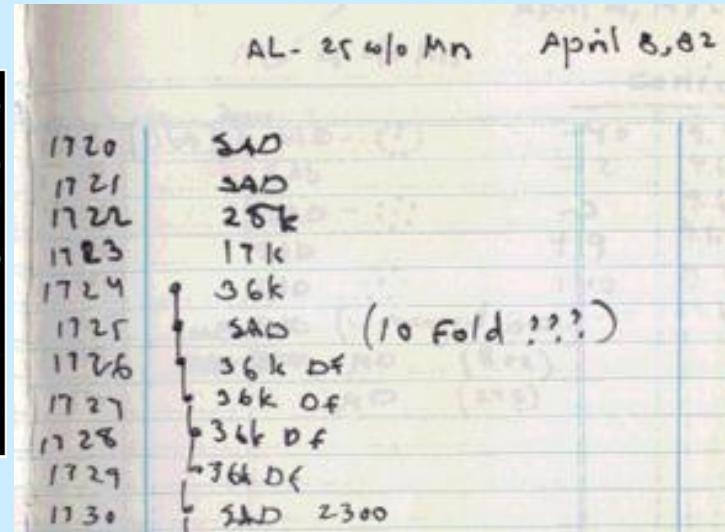
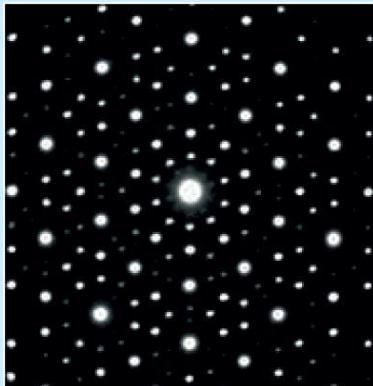
Titan at IITM



Quasicrystals: Nobel Prize (2011)



D. Shechtman

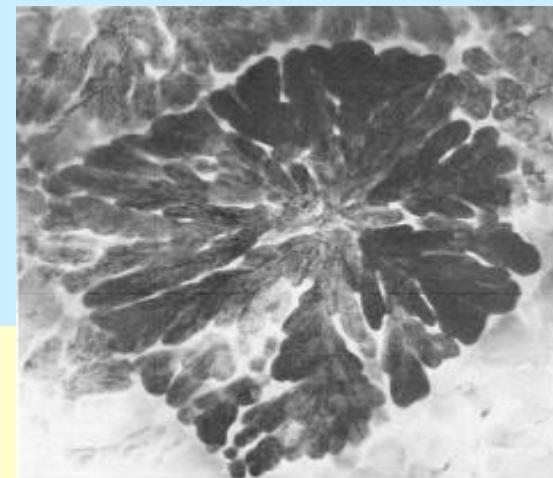


10 fold !!!

"Eyn chaya kazo"

"There can be no such creature."

Al-14%Mn



D. Shechtman, I. Blech, D. Gratias, and J.W. Cahn
Physical Review Letters, 1984, 53, 1951.

A NEW ORDERED PHASE IN THE Al-Pd SYSTEM

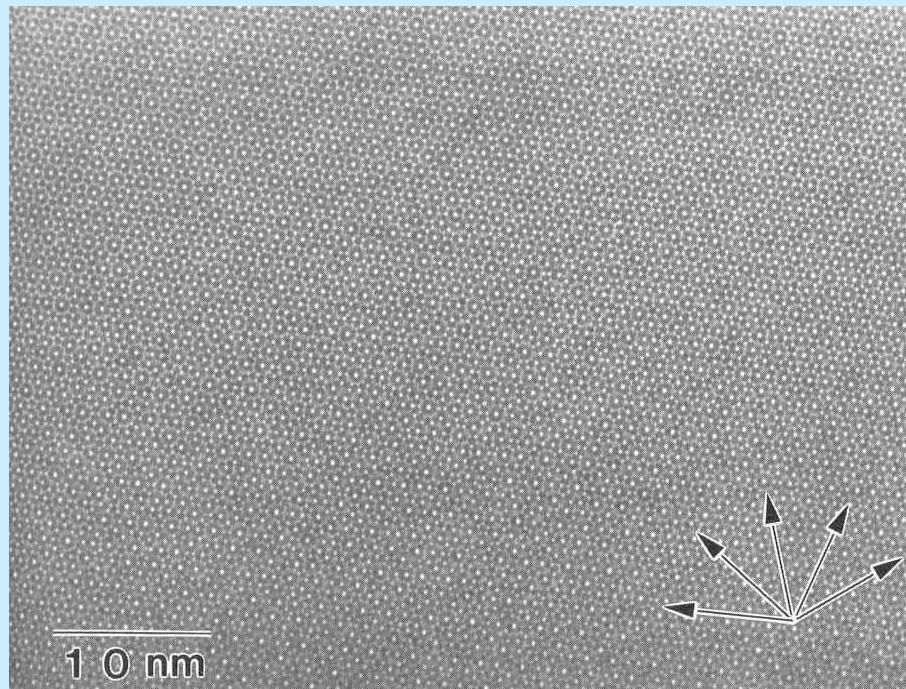
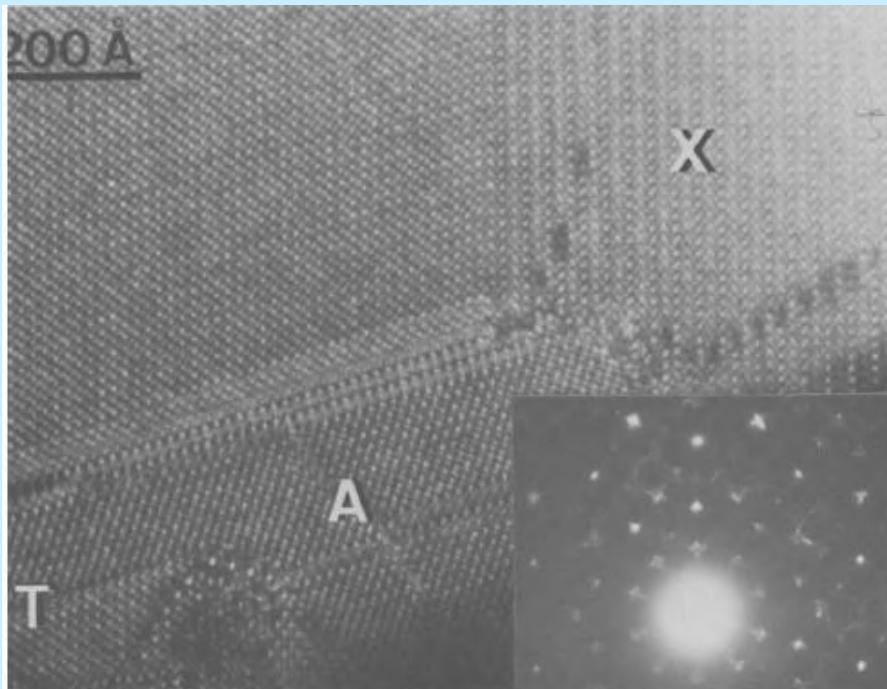
G.V.S. Sastry and C.Suryanarayana

Department of Metallurgical Engineering, Banaras Hindu University, Varanasi -
221005 India

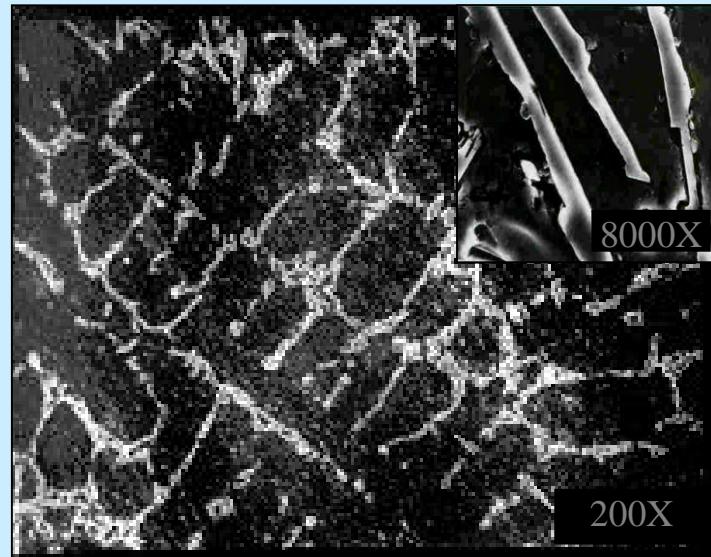
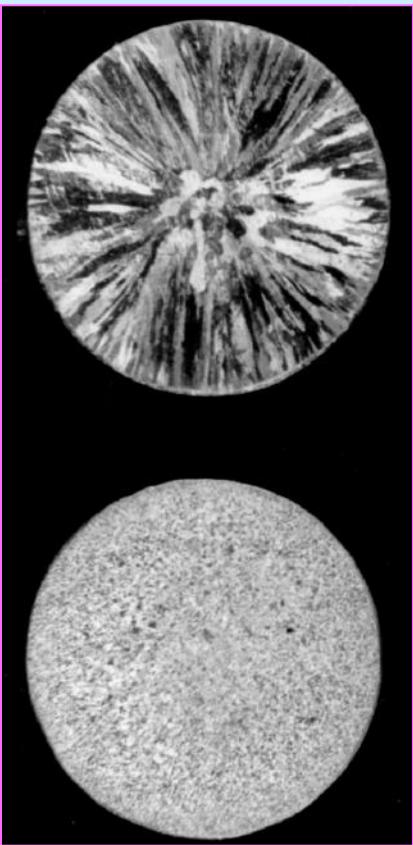
M.Van Sande and G.Van Tendeloo

Rijksuniversitair Centrum Antwerpen,Groenenborgerlaan 171B-2020Antwerp (Belgium)

(Received August 9, 1978; Communicated by S. Amelinckx)



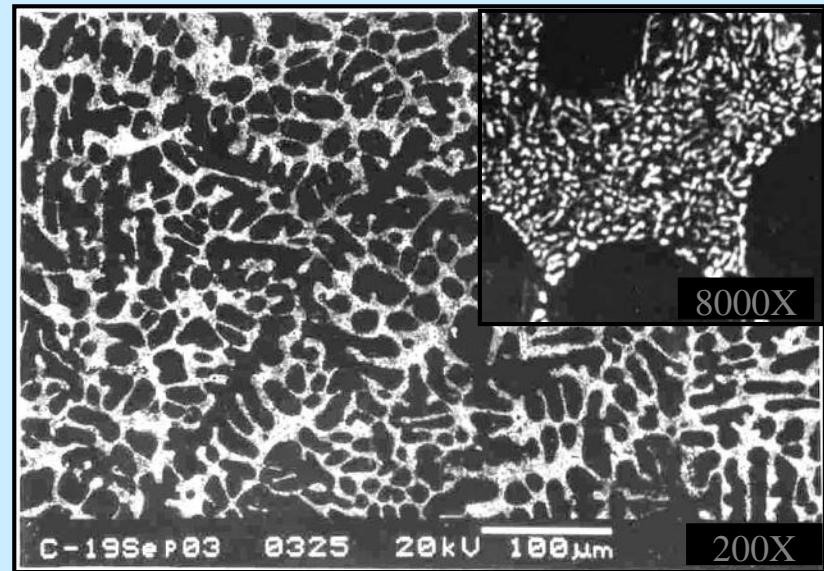
High Strength Light Alloys through Grain Refinement & Modification for Automotive Applications



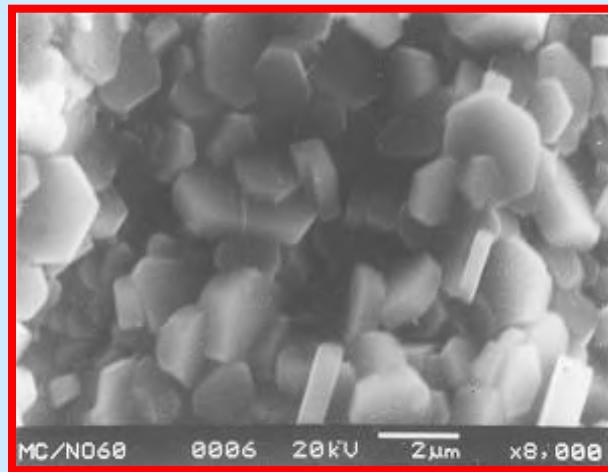
Without Grain
Refinement/Modification

Kori & Prasad

With Grain Refinement
and Modification
(Mg-13Al+ 0.02Sr) (5min)



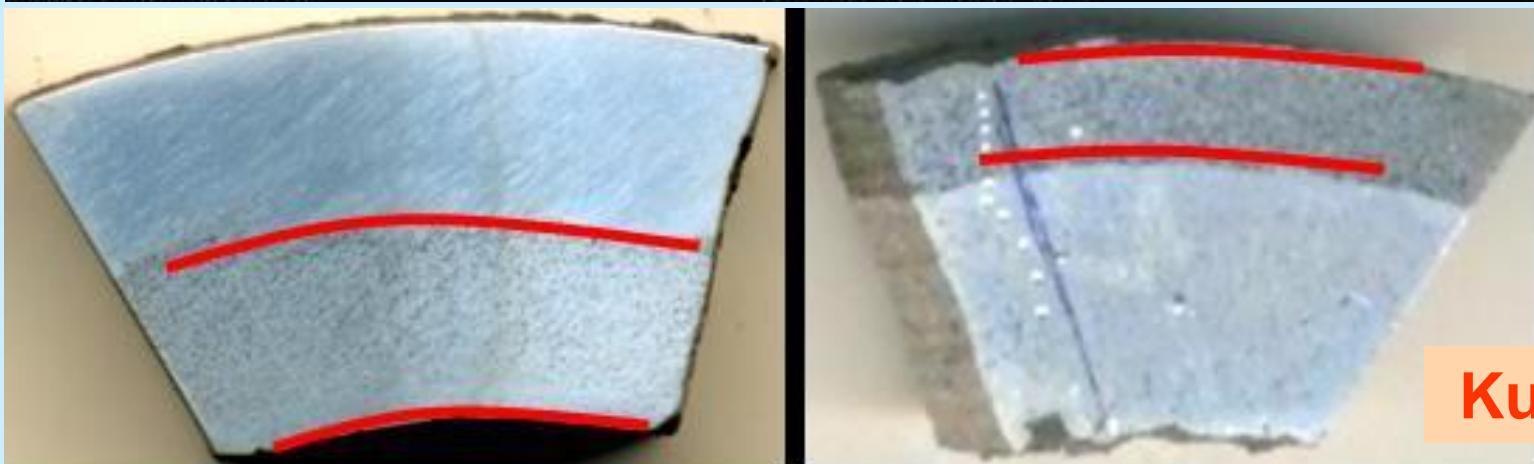
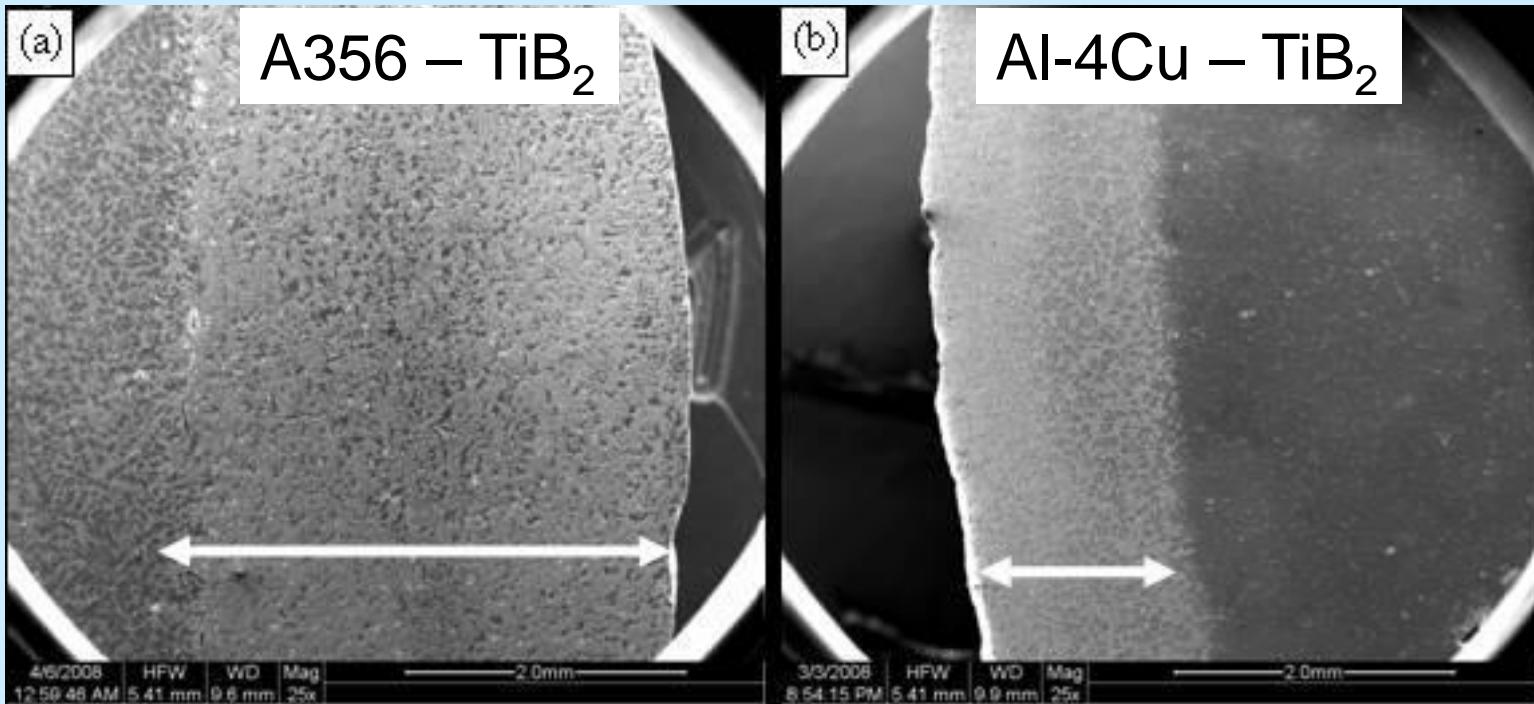
High Strength In-Situ Al-4Cu-TiB₂ Composites for High Load Bearing Automotive Applications



	As Cast			Peak Aged		
	UTS, MPa	0.2% YS, MPa	% El.	UTS, MPa	0.2% YS, MPa	% El.
Al-4Cu	117	108	11	276	216	21
Al-4Cu-2.5TiB ₂	196	171	23	284	230	23
Al-4Cu-5TiB ₂	232	208	20	297	252	22
Al-4Cu-7.5TiB ₂	260	220	18	334	270	18
Al-4Cu-10TiB ₂	290	230	15	383	280	19

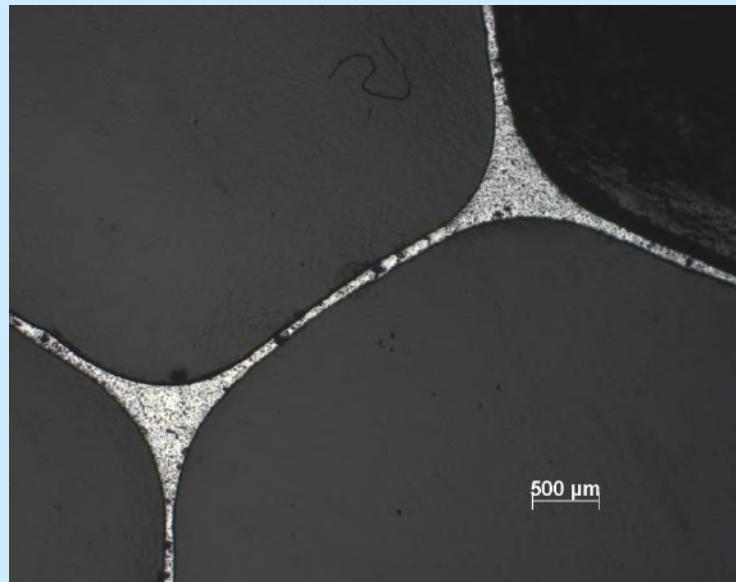
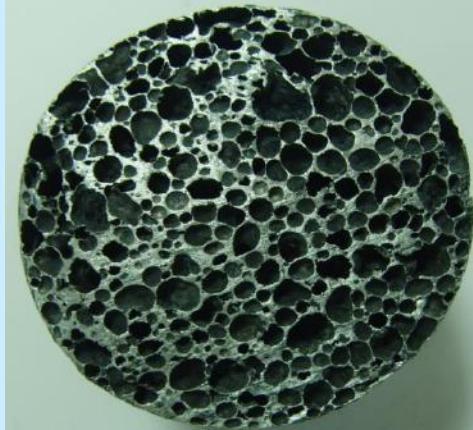
Animesh

Functionally Graded Al based in-situ Composites for High Wear Resistant Automotive Pistons

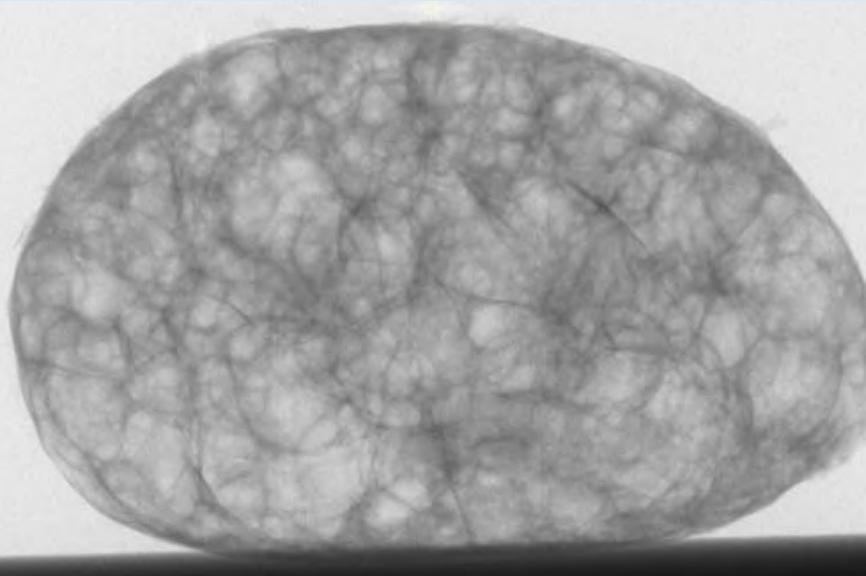


Al Foams for Light Weighting and Energy Absorption

Vinod & Harsha



TiB_2



TiC



Various Nano Products

Car Wash



Nano Ag
Tooth Paste

Textbook of Nanoscience and Nanotechnology
B.S. Murty, P. Shankar, Bakilev Raj,
B.B. Rath and James Murdy
978-81-731-798-3 Paperback
2011 296 pp ₹ 325.00
Universities Press-DIM
Series in Metallurgy and Materials Science
Author-in-Cover
Editor-in-Chief
Designer
Universities Press

A textbook for students taking a course in nanoscience and nanotechnology.

It provides an introduction to the terminology and historical perspectives of this domain of science, discusses the effects of size on the unique and widely differing properties of nanomaterials in comparison to bulk materials, and describes the synthesis methods and characterization techniques used for characterization techniques. The applications of nanoscience and technology, and emerging materials and technologies are also presented in the book.

Special Features:

- Current research findings and data, particularly from India
- Original images provided by scientists in the field
- Exercises and problems at the end of each chapter
- Glossary and Index

Cosmetics



Hair Dryer



Swim Suits



Nano Ag Ionic

Self Cleaning window Leather Protection



Nano Fluids

Mirror

Car Body

Wood Protection Textile Protection

Ancient Nanotechnologists



The First Nanotechnologists

Ancient stained-glass makers knew that by putting varying, tiny amounts of gold and silver in the glass, they could produce the red and yellow found in stained-glass windows. Similarly, today's scientists and engineers have found that it takes only small amounts of a nanoparticle, precisely placed, to change a material's physical properties.

Gold particles in glass

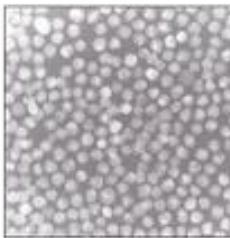
Size*: 25 nm

Shape: sphere

Color reflected:



100 nanometers = 0.0001 millimeter

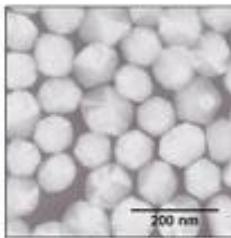


Silver particles in glass

Size*: 100 nm

Shape: sphere

Color reflected:



Size*: 50 nm

Shape: sphere

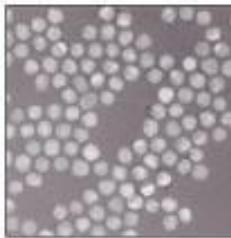
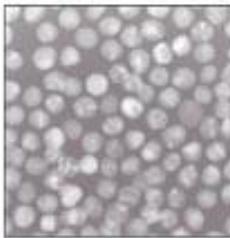
Color reflected:



Size*: 100 nm

Shape: sphere

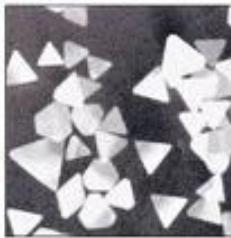
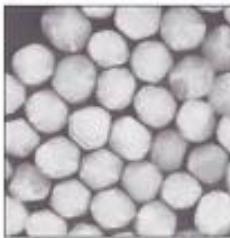
Color reflected:



Size*: 40 nm

Shape: sphere

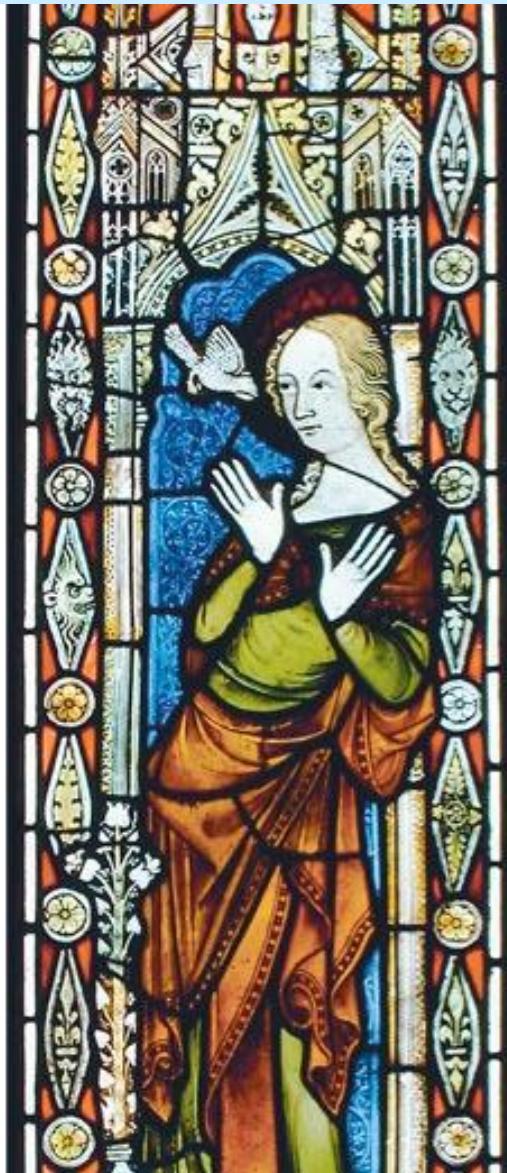
Color reflected:



Size*: 100 nm

Shape: prism

Color reflected:



Source: Dr. Chad A. Mirkin, Institute of Nanotechnology, Northwestern University

*Approximate

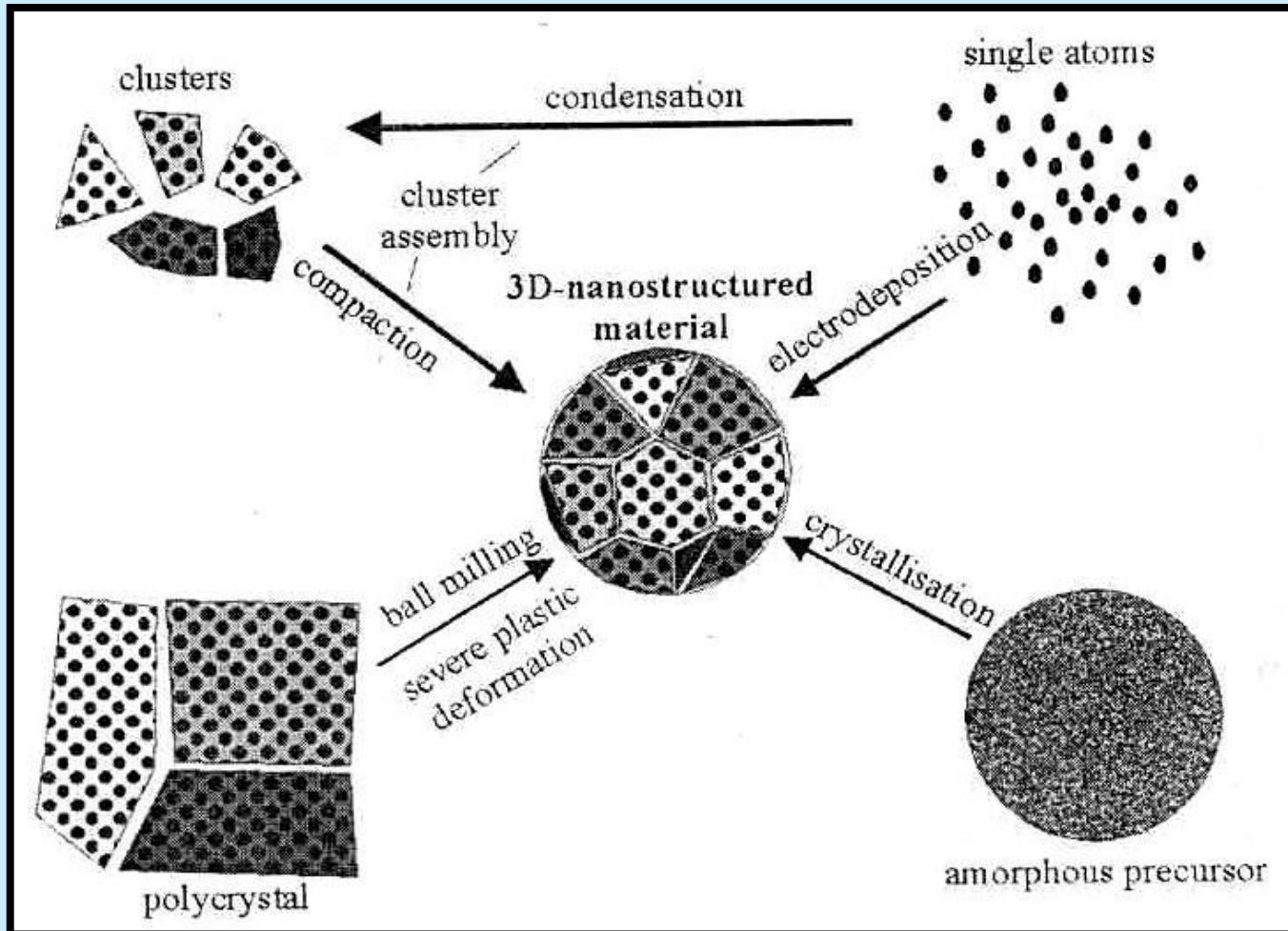
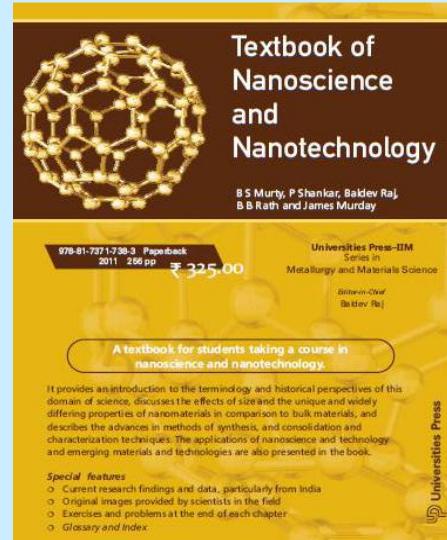
Nano Aerogels: The super materials



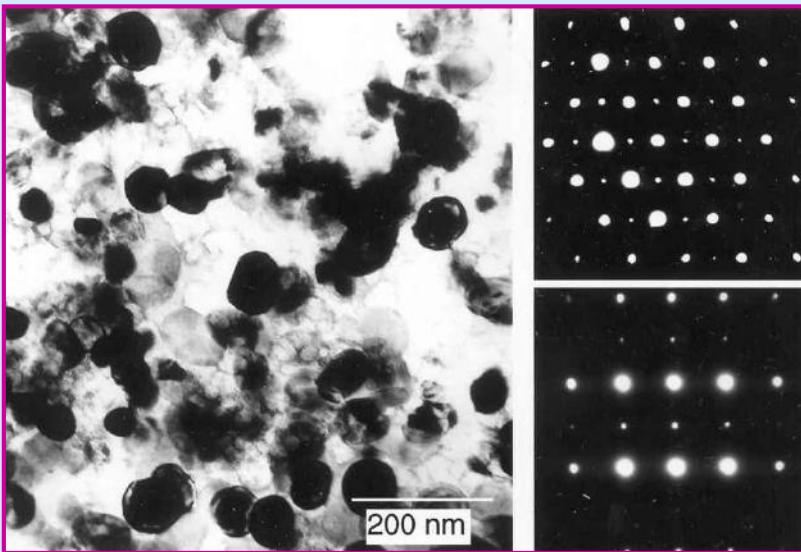
Prof. A.R. Kulkarni
IIT Bombay



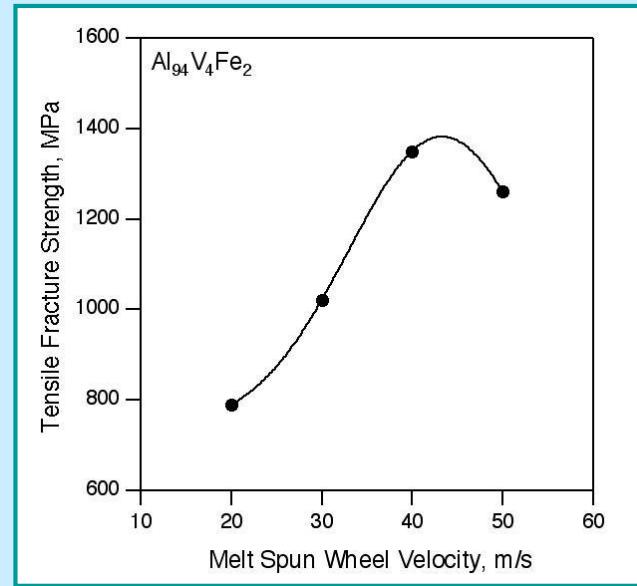
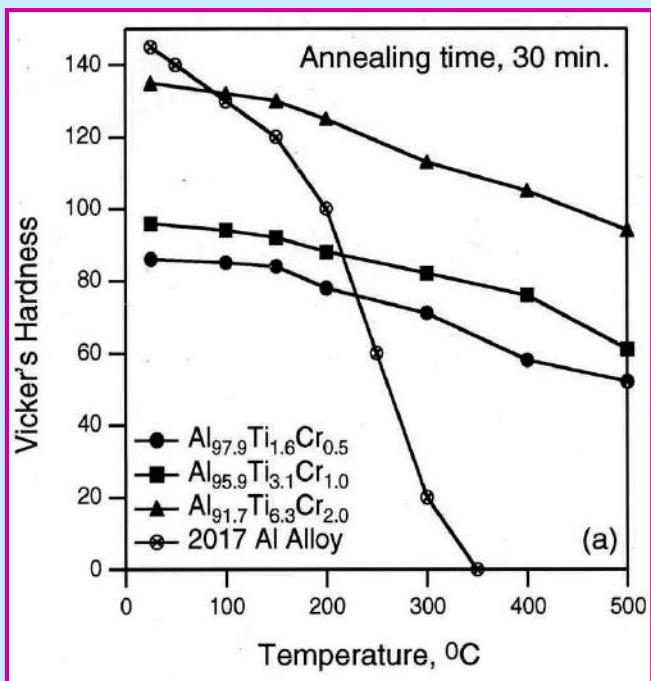
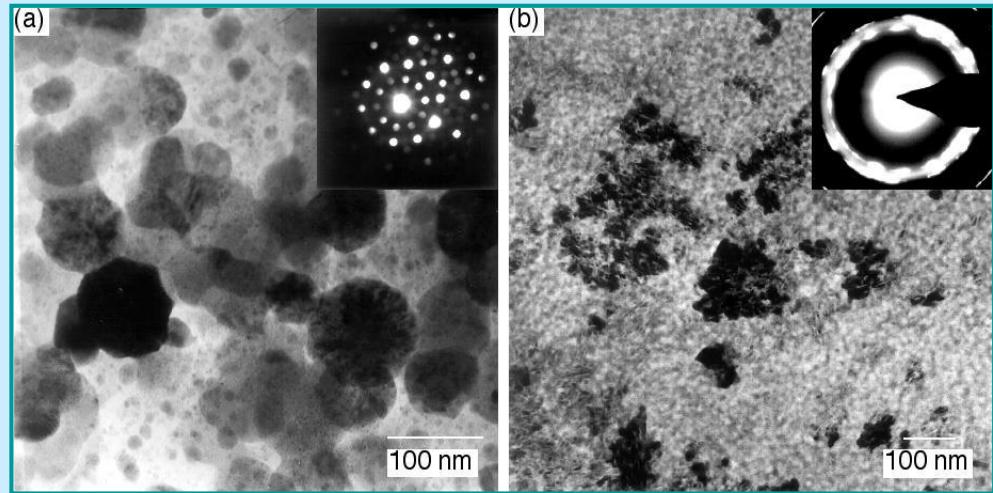
Routes for the Preparation of Nano Materials



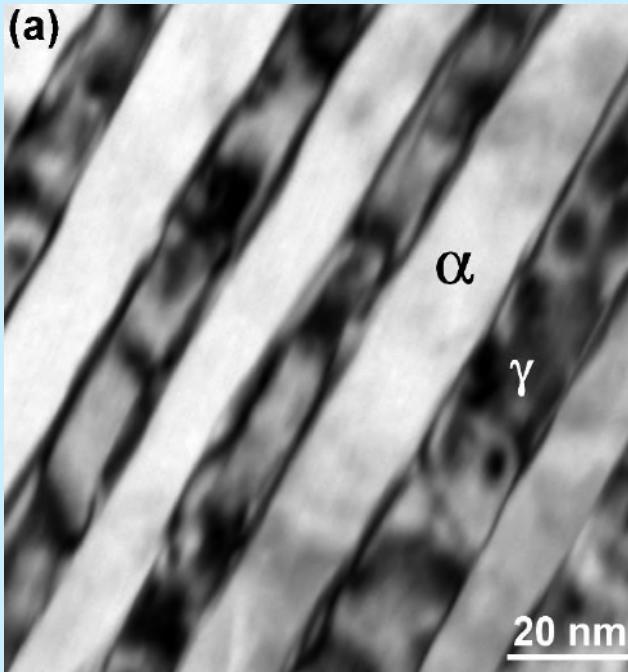
High Strength Al based Nanocomposites



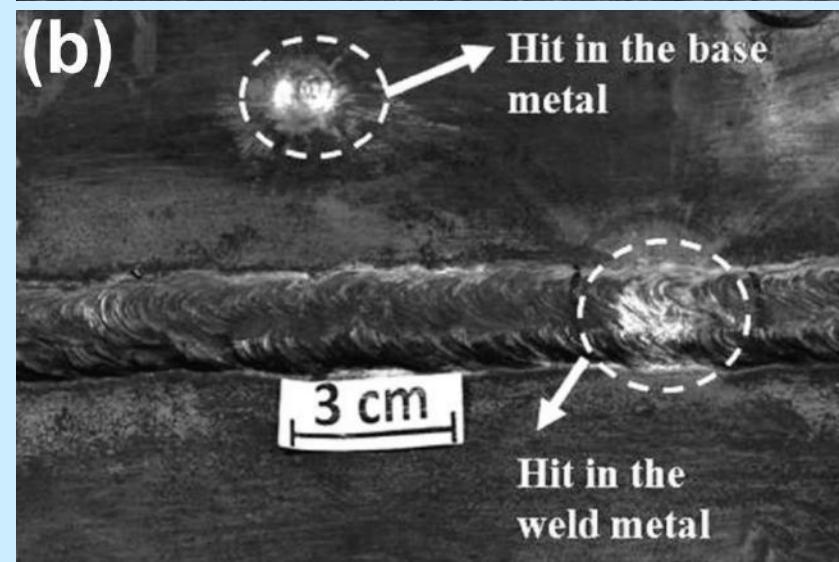
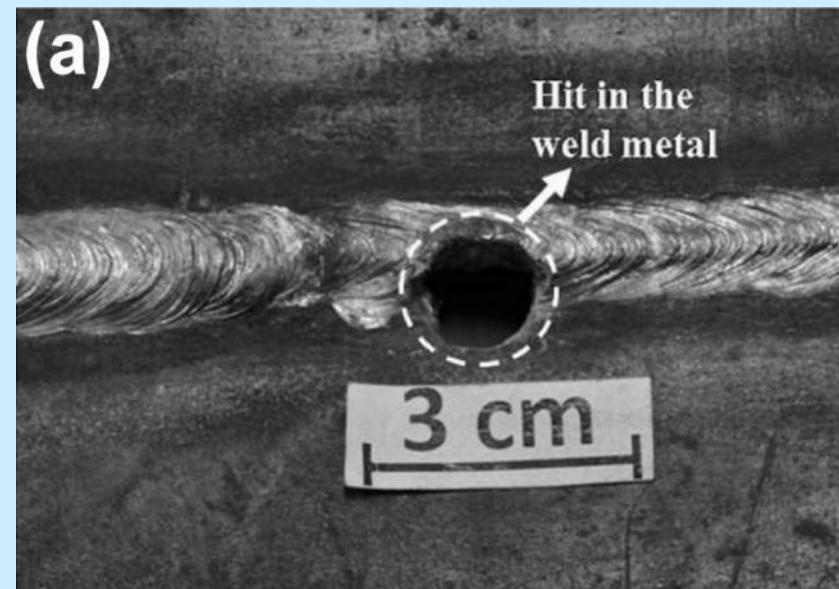
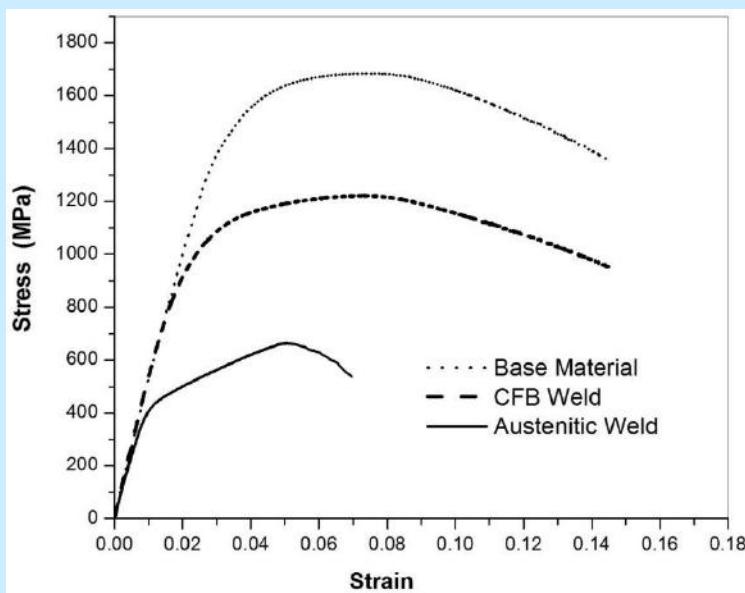
$\text{Al}_{94}\text{V}_4\text{Fe}_2$ Alloy



Nano Steel with Exceptional Toughness



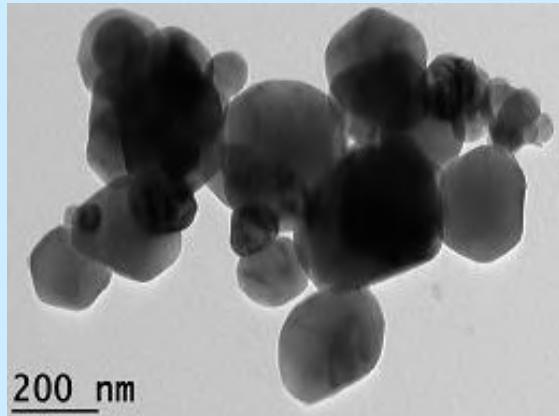
Krishna Murthy, CVRDE, Avadi



Nano Coatings

Prakash

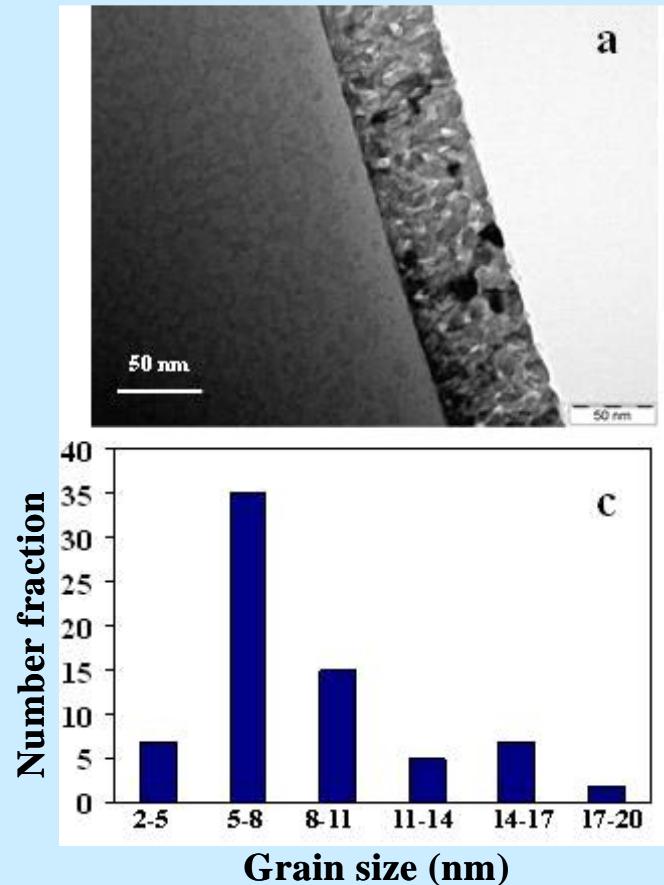
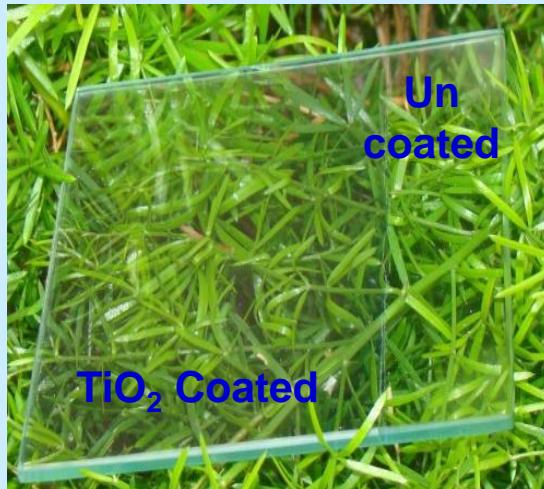
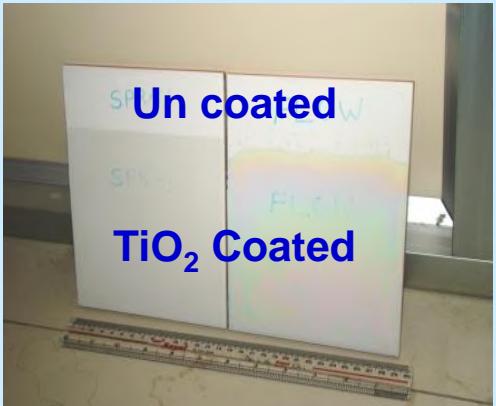
Nanocoating
on Ladle
refractories,
Vizag Steel
Plant



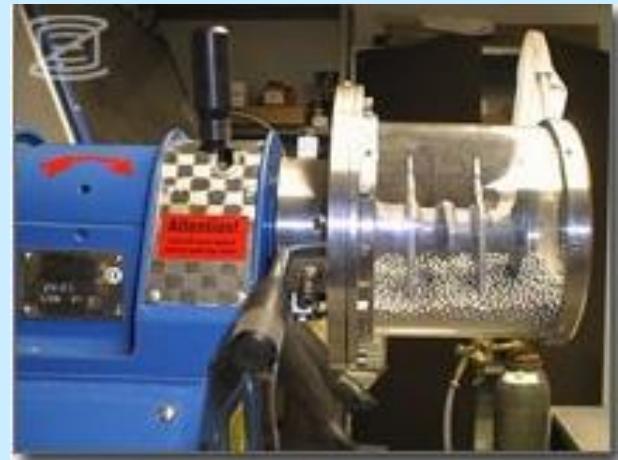
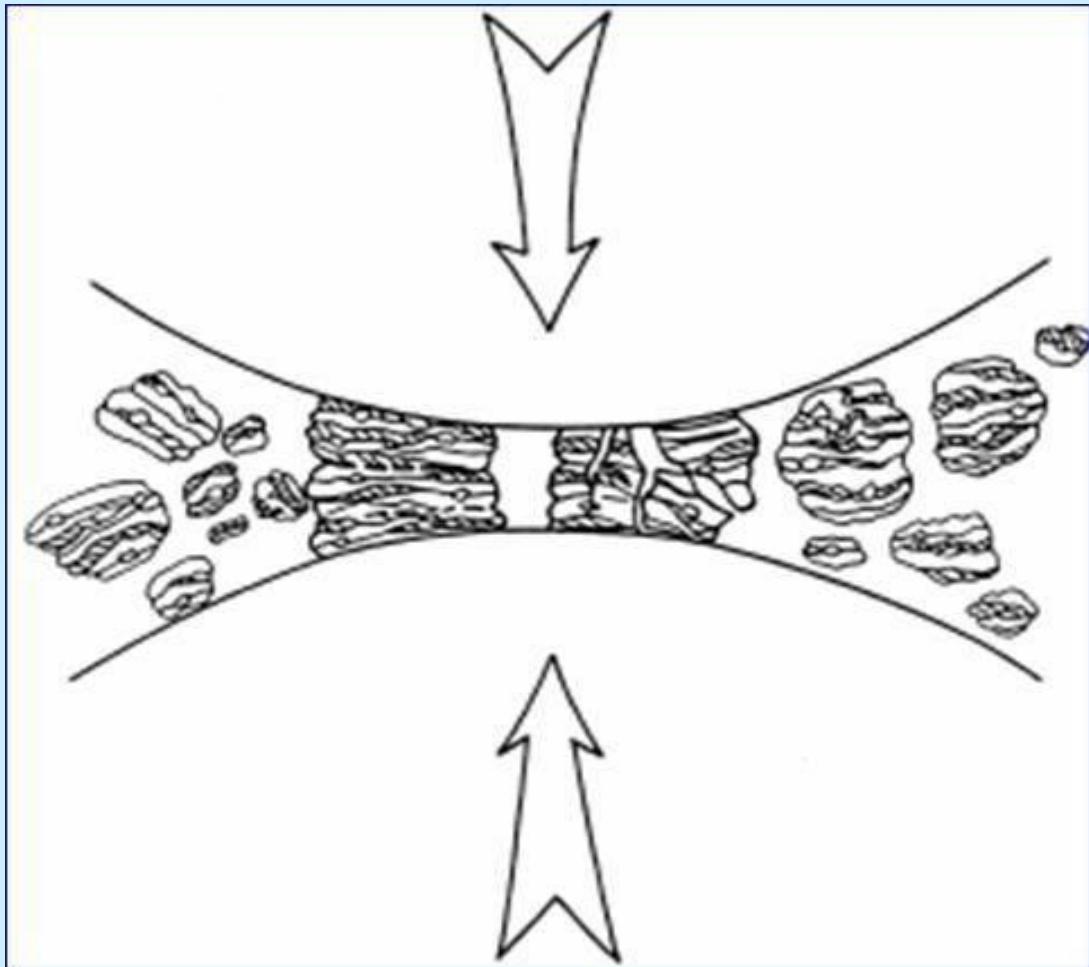
Sample condition	Hardness VHN
Uncoated	48
Nano Coated	781

Nanocoating for
self cleaning glasses, ARCI

Murugan, ARCI

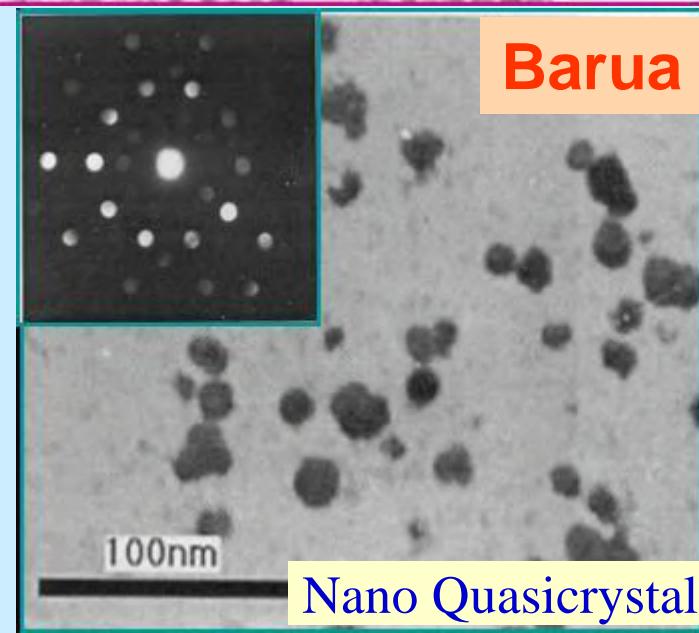
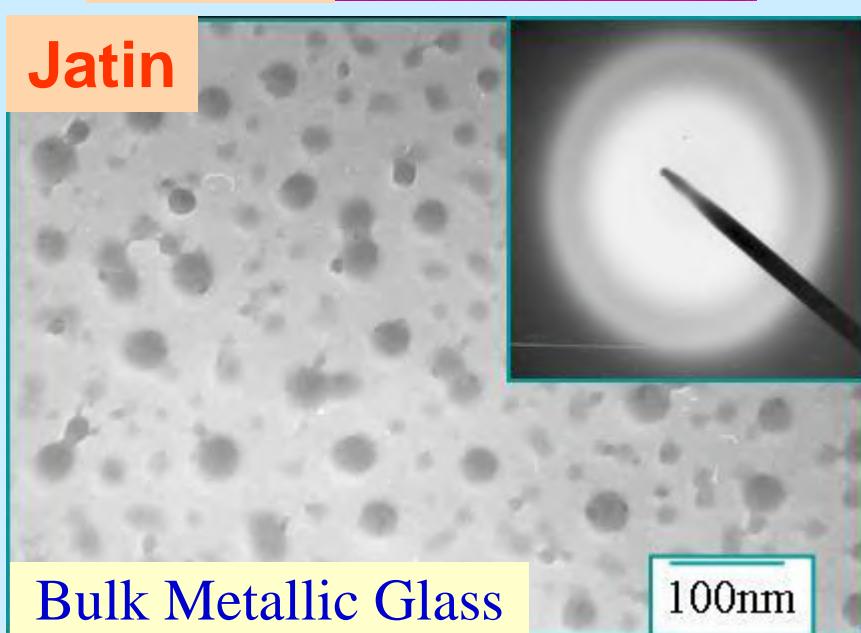
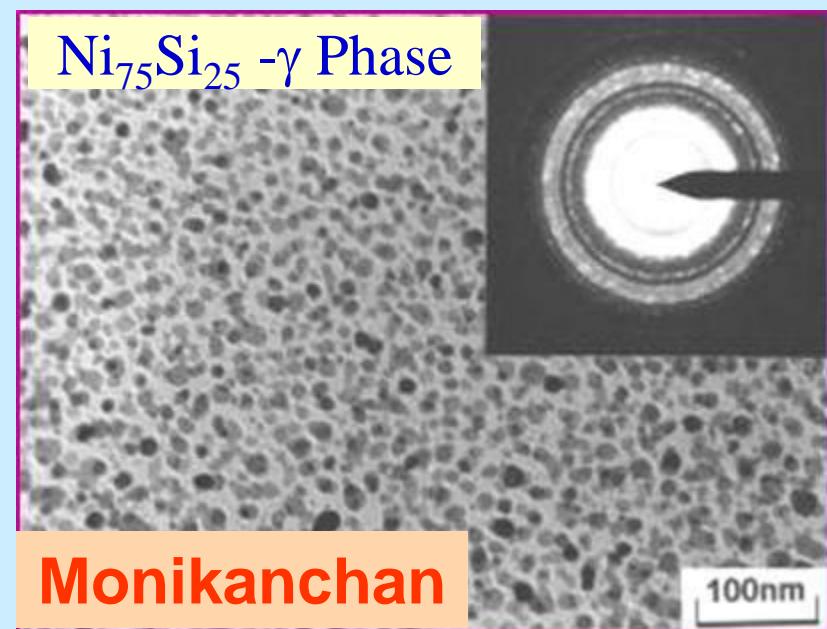
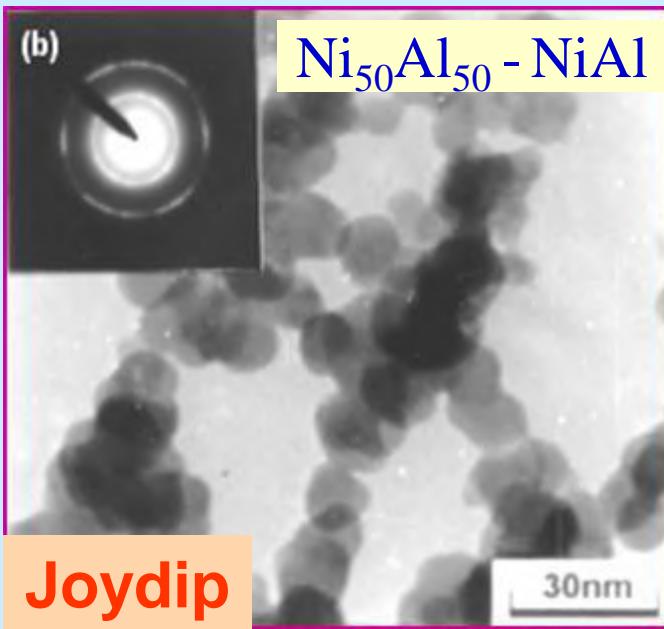


Mechanical Alloying



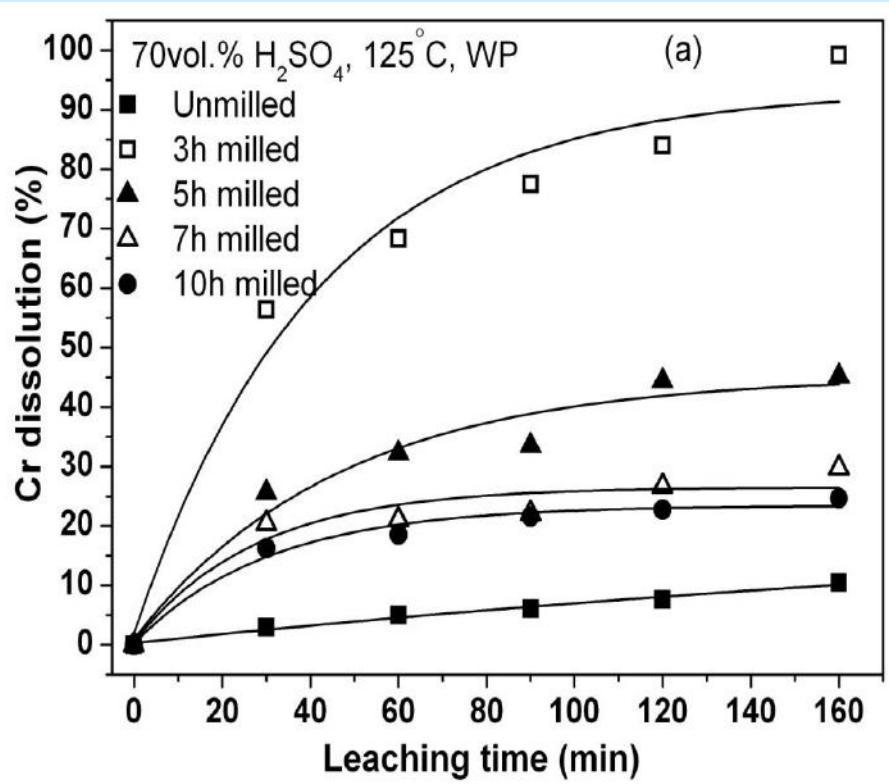
- Deformation
- Fracture
- Cold Welding

Nanocrystalline Phases by High Energy Ball Milling



Nano in Extractive Metallurgy

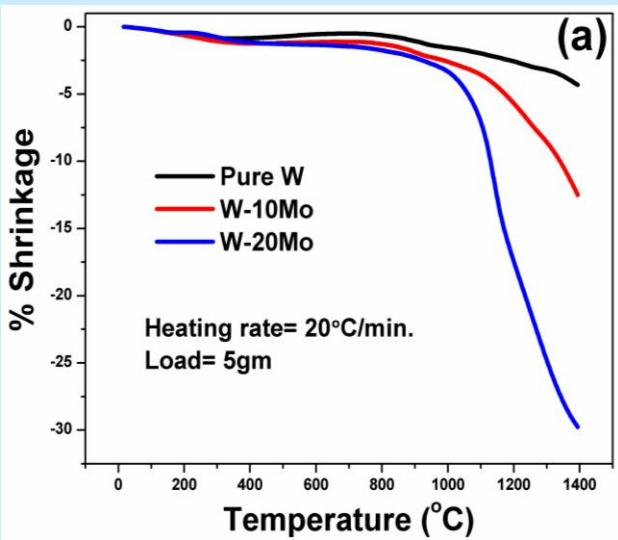
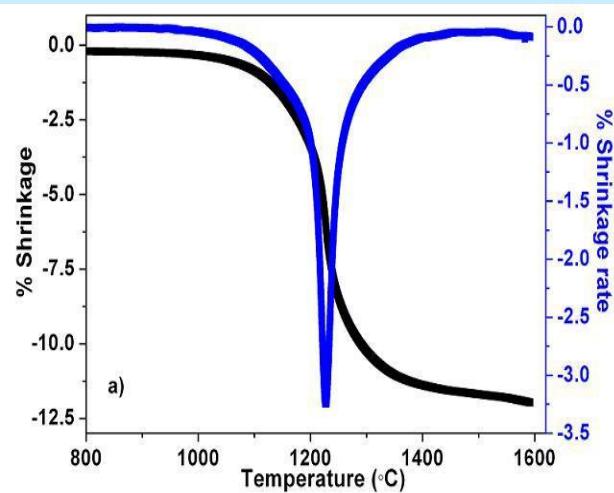
%Cr recovery



Recovery from conventional ore: 9%Cr
Recovery from 10h milled ore : 98%Cr

Alamelu

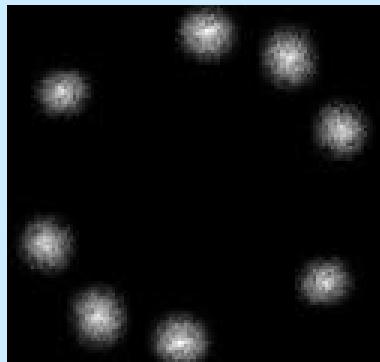
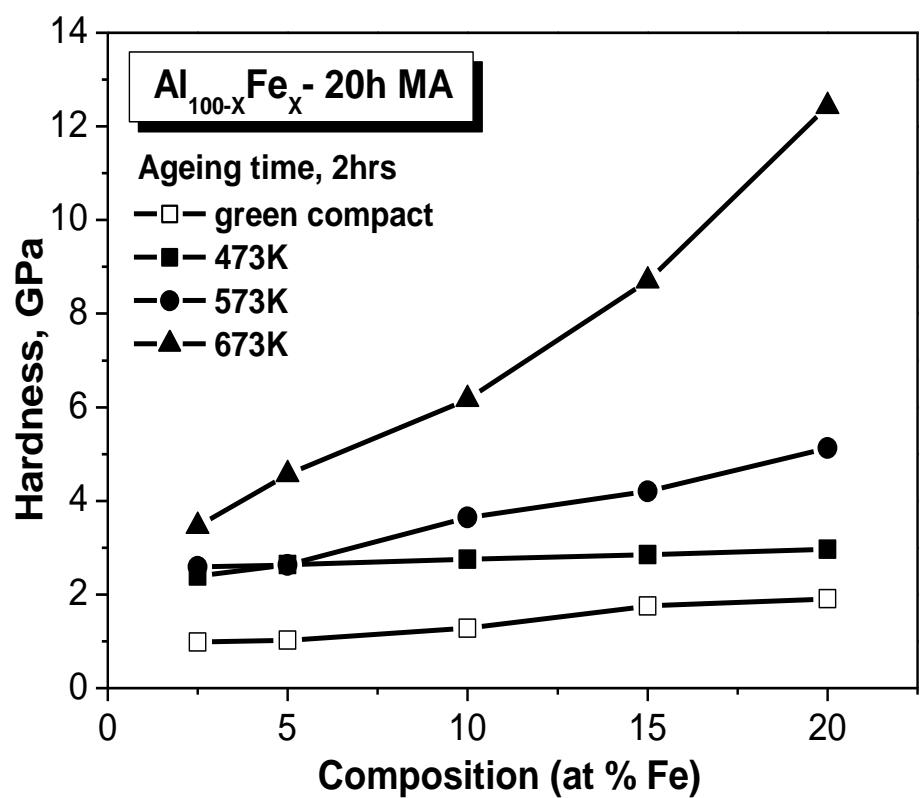
Sintering of Nano Tungsten



Breakthrough
99% densification at 1600°C

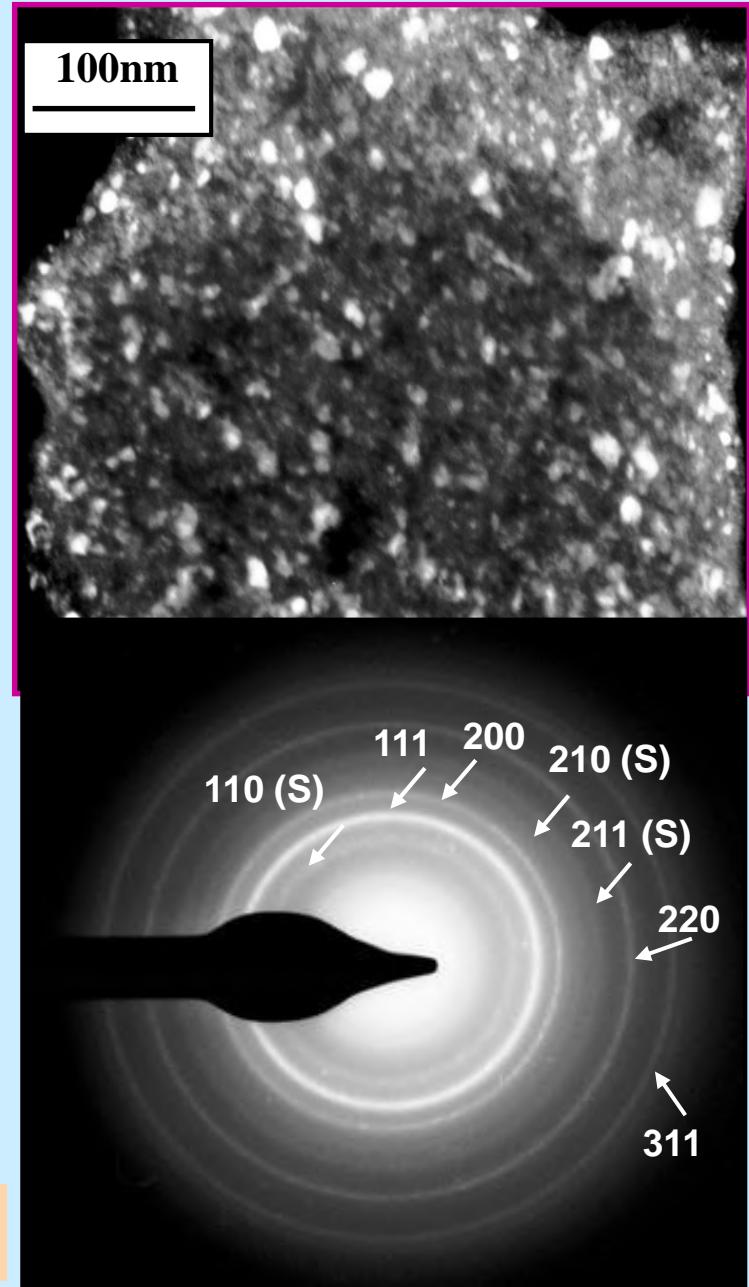
Ajeet

Exceptionally Strong In-situ Nanocomposites

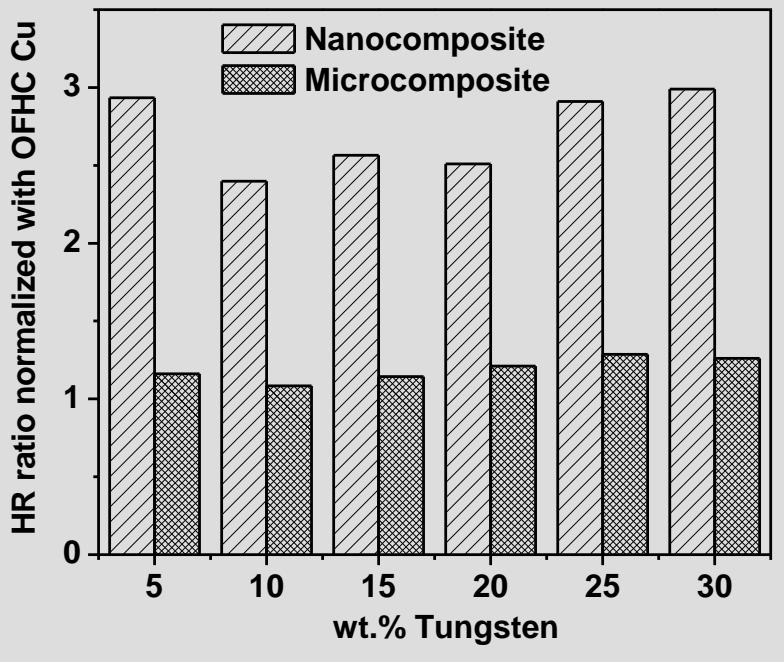


NanoQC phase

Sashank

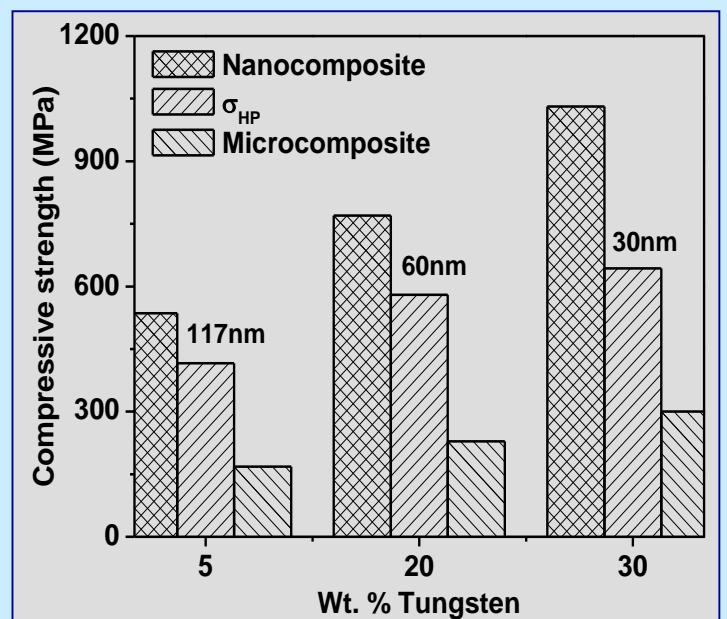
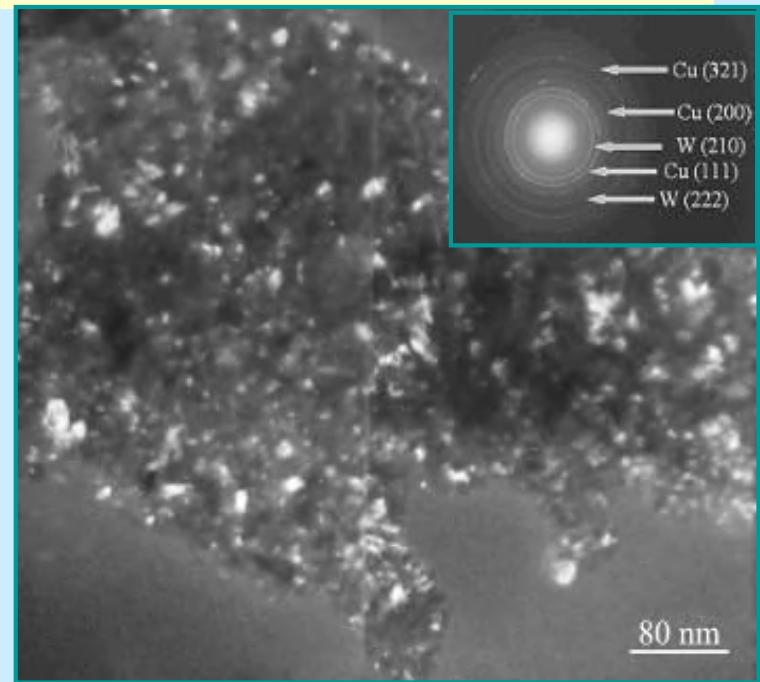


High Strength Conducting Cu Based Nanocomposites



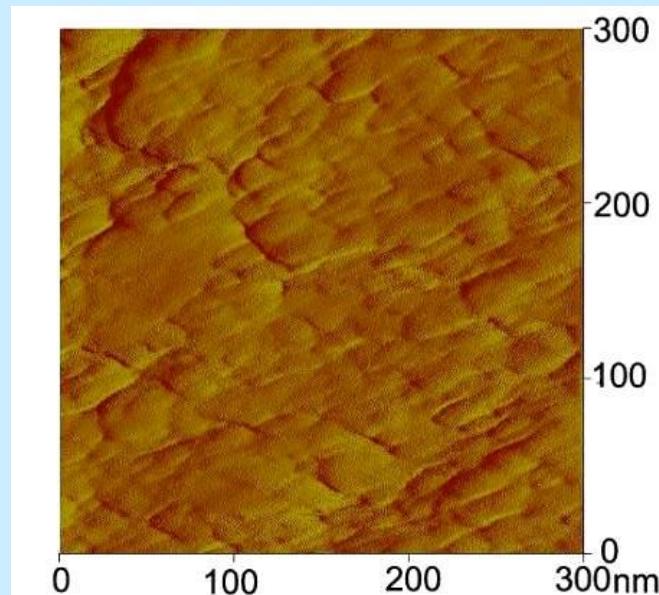
Venu

Cu-W



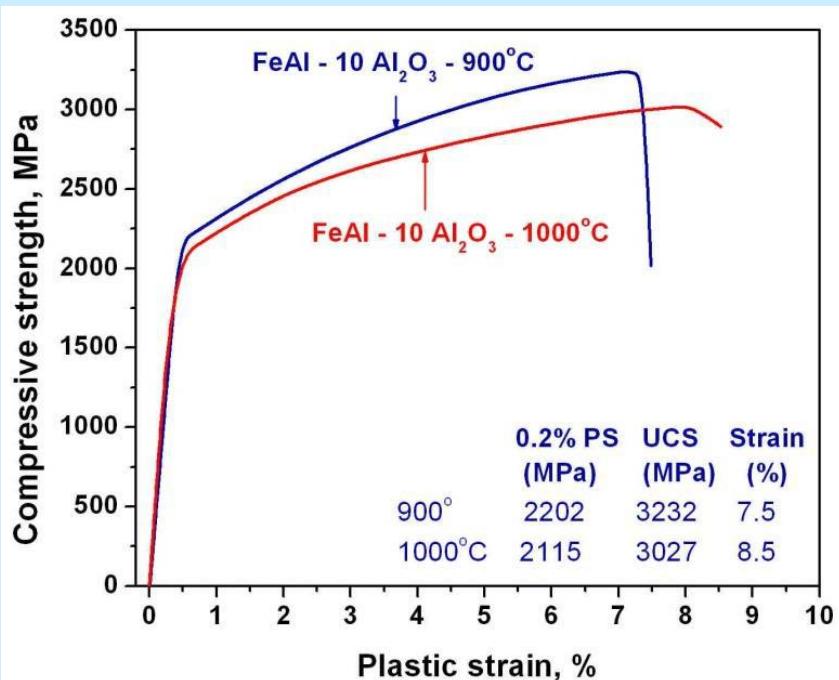
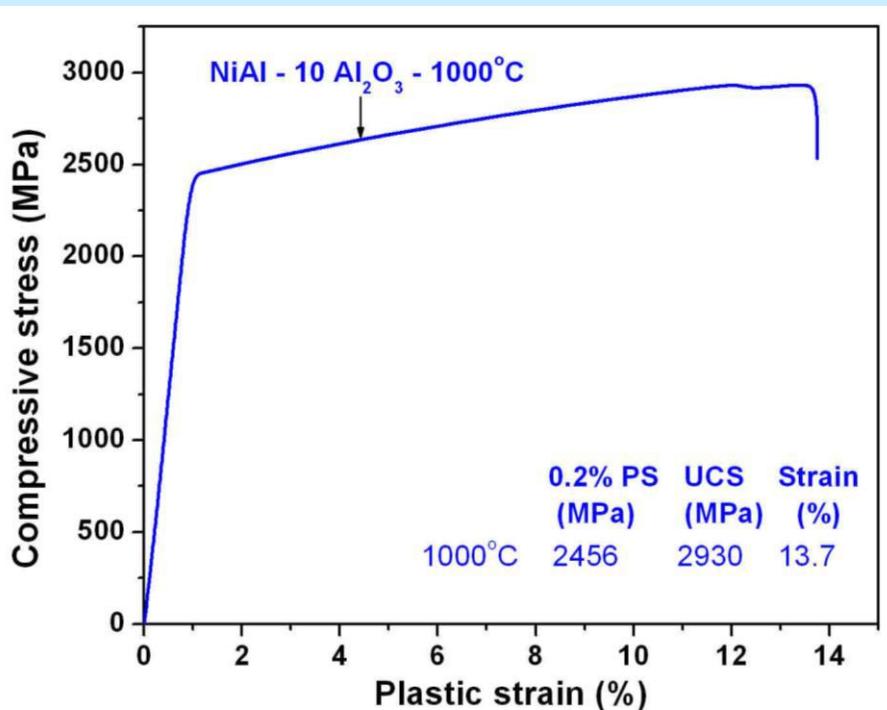
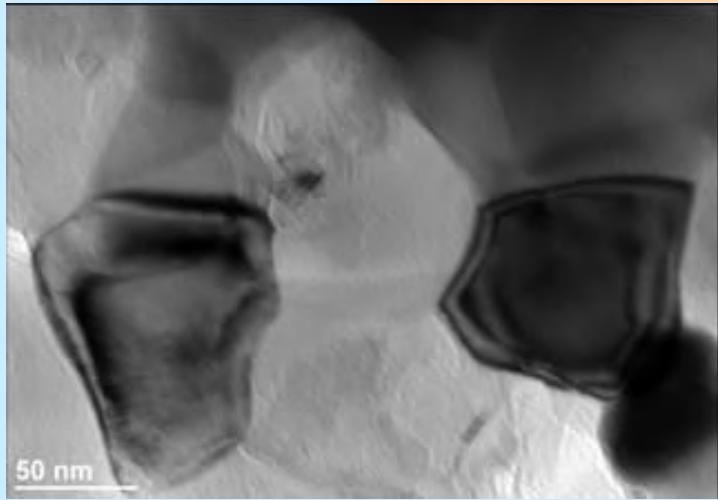
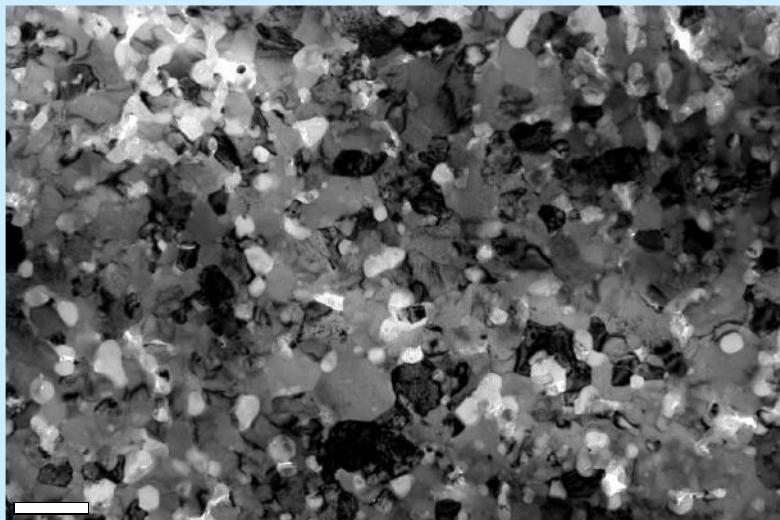
Cu-20%Ta at
500°C

Crompton
Greaves

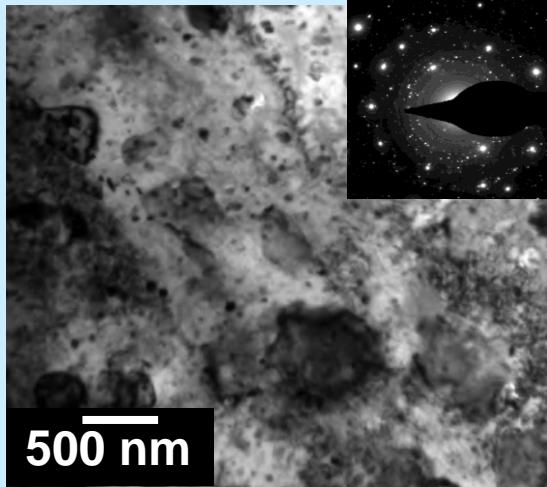
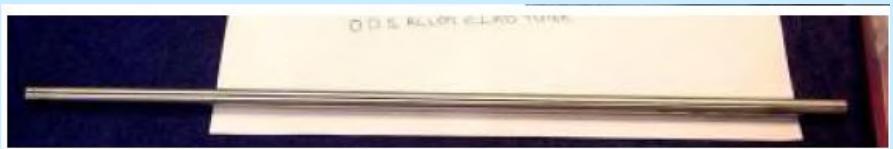
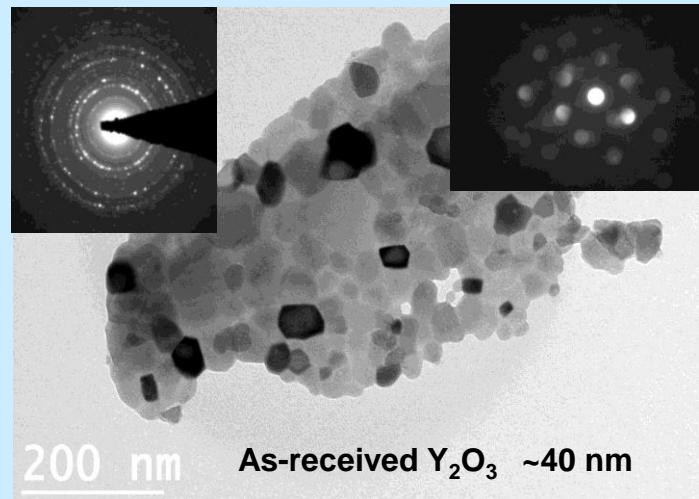
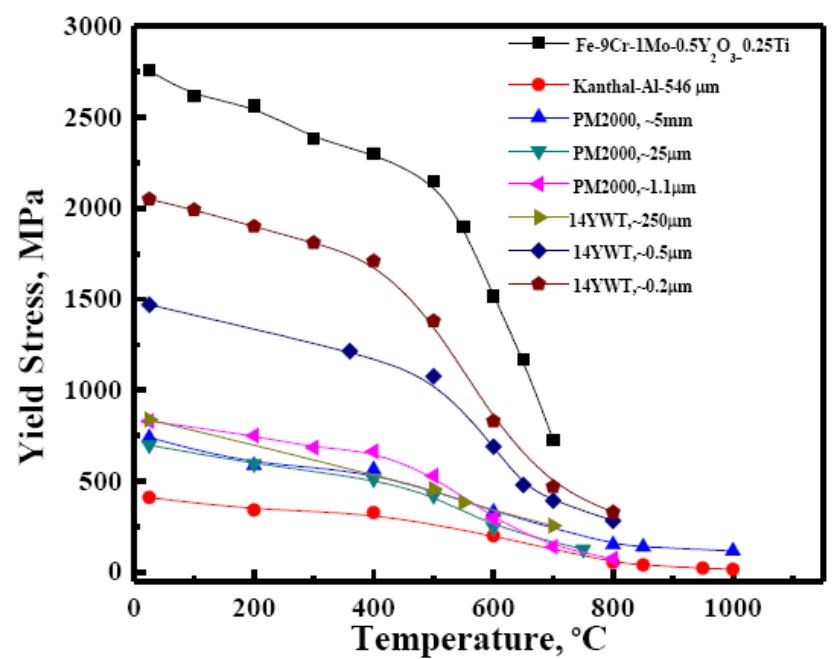


NiAl and FeAl – 10 Al₂O₃ Nanocomposites

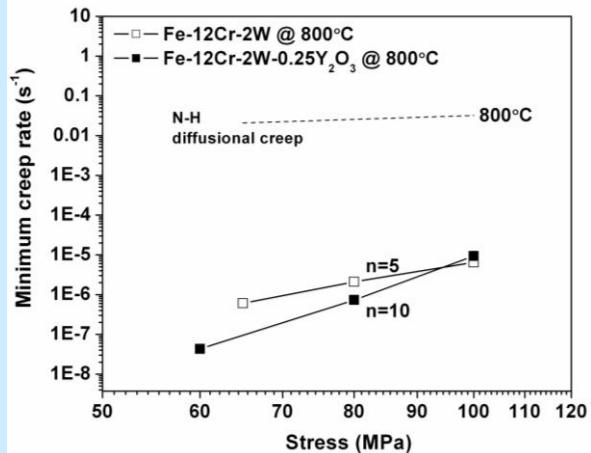
Udhayabhanu



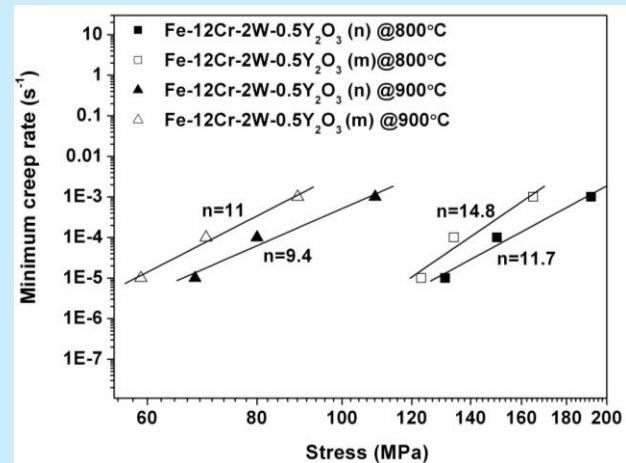
ODS Steels for Fast Breeder Nuclear Reactors



Fe-9Cr-1Mo-0.5Y₂O₃

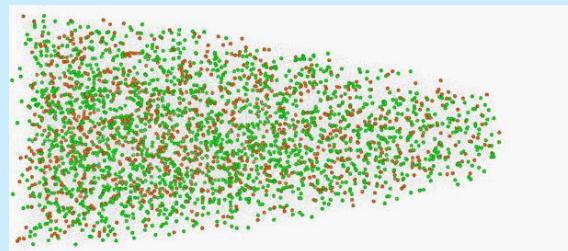
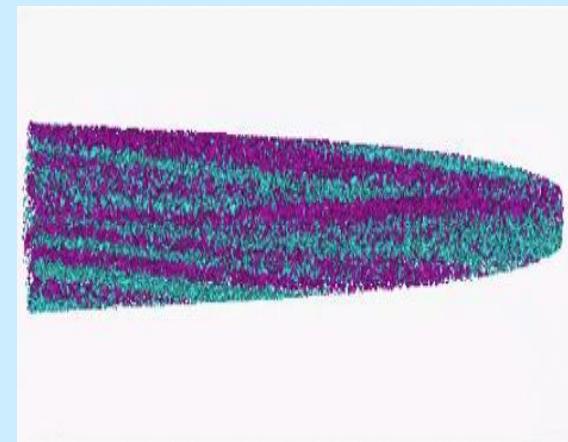


IGCAR, Kalpakkam



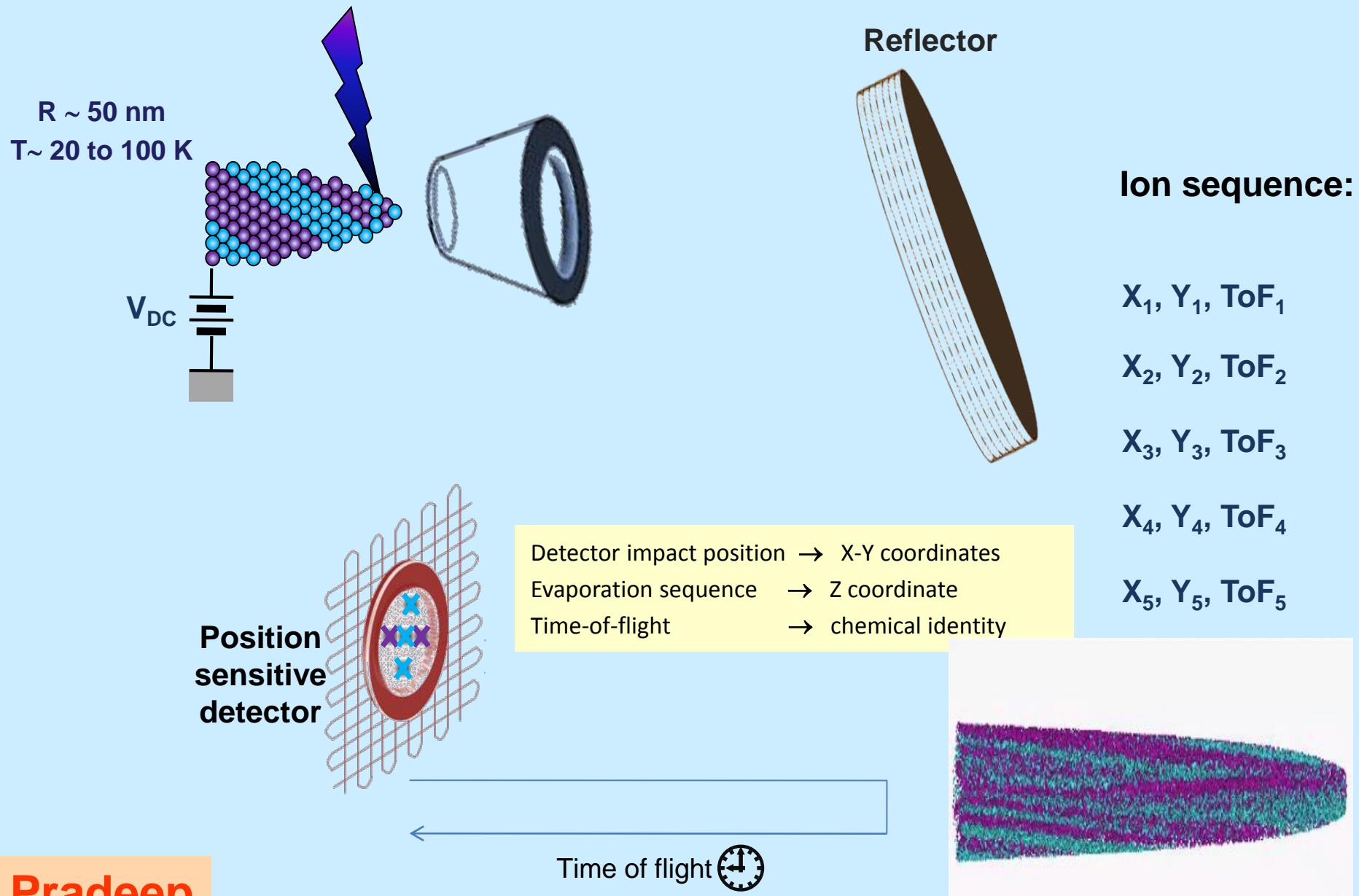
Karthikeyan

Local Electrode Atom Probe

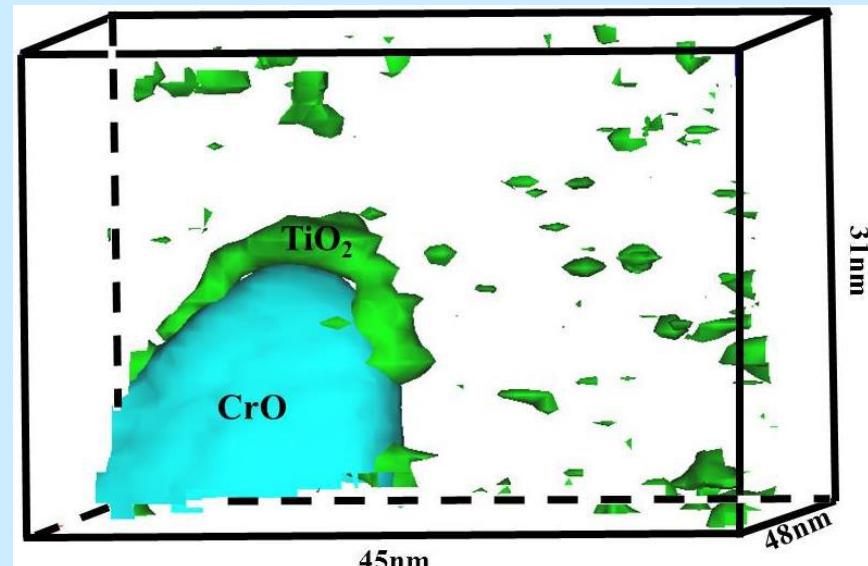
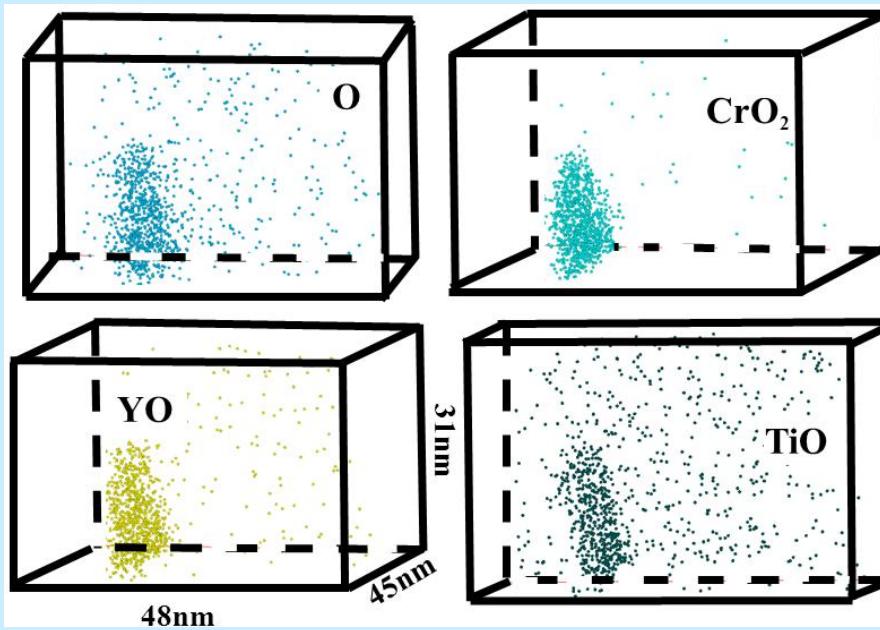
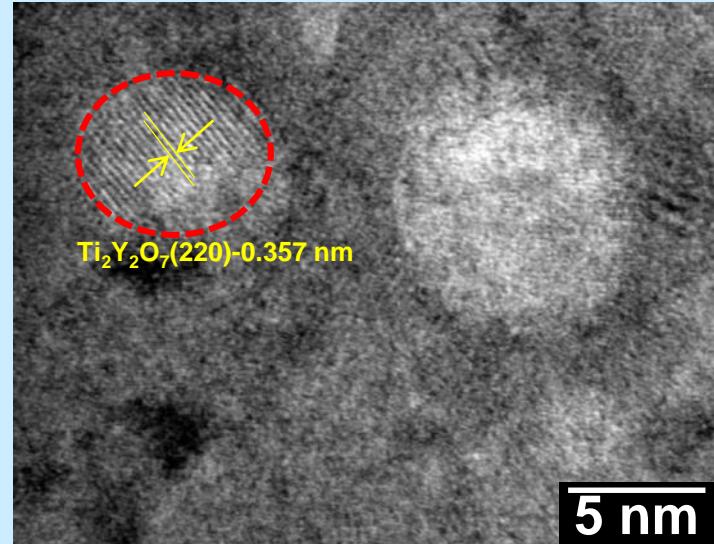
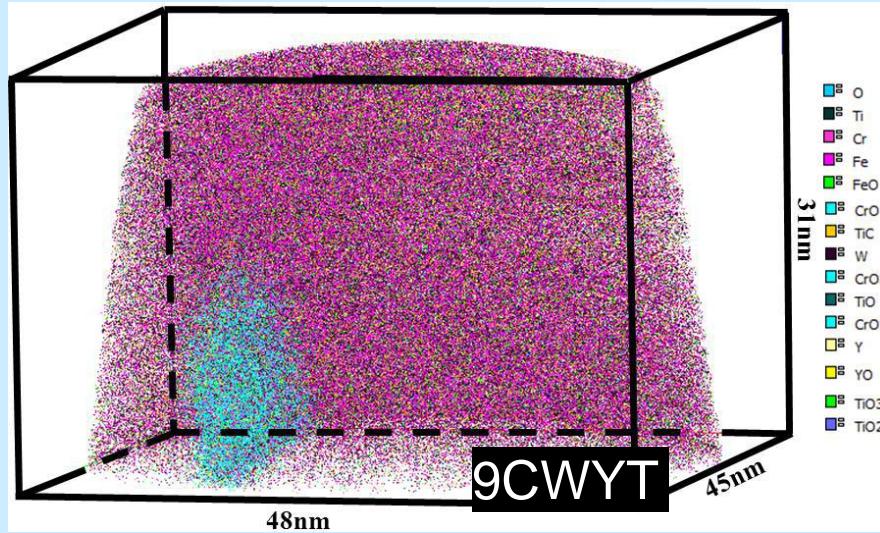


5000X XR (Reflectron system)

Atom Probe Tomography Principle



APT of Bulk Nanostructured Ferritic ODS Alloys

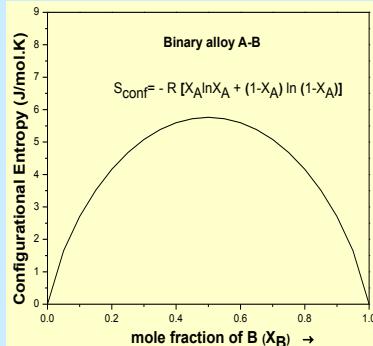


Krishna Rajan, Iowa State Univ.

Karthikeyan

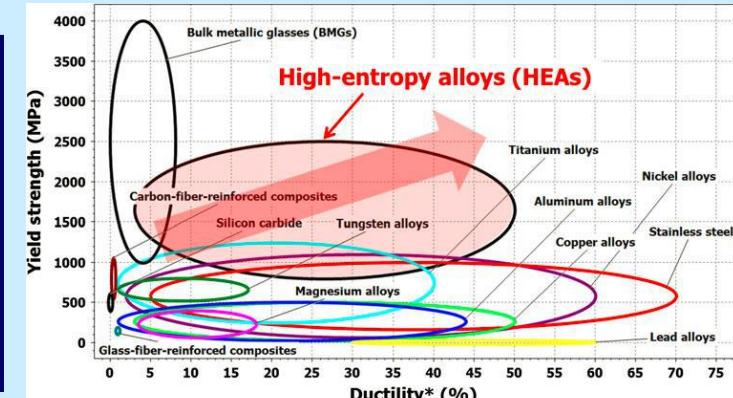
High Entropy Alloys

B.S. Murty
J.W. Yeh
S. Ranganathan

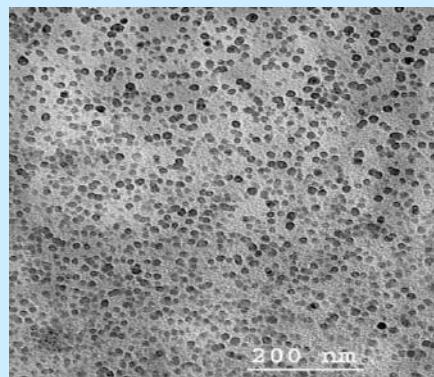
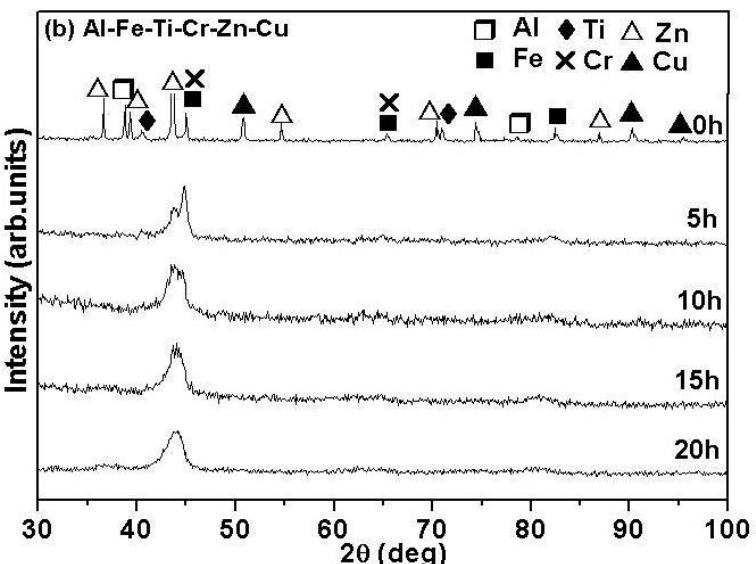


No. of Component	X_i	$S = -R \sum X_i \ln X_i \text{ J mol}^{-1} \text{ K}^{-1}$
2	0.500	5.822
3	0.330	9.220
4	0.250	11.645
5	0.200	13.519
6	0.167	15.064

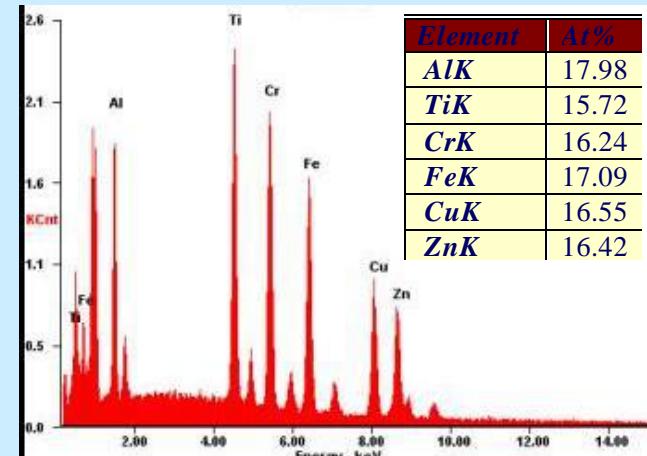
- ❖ J.W. Yeh *et al.* Adv. Eng. Mater., 6 (2004) 299.
- ❖ S. Varalakshmi *et al.* J. Alloys Compd., 460 (2008) 253.



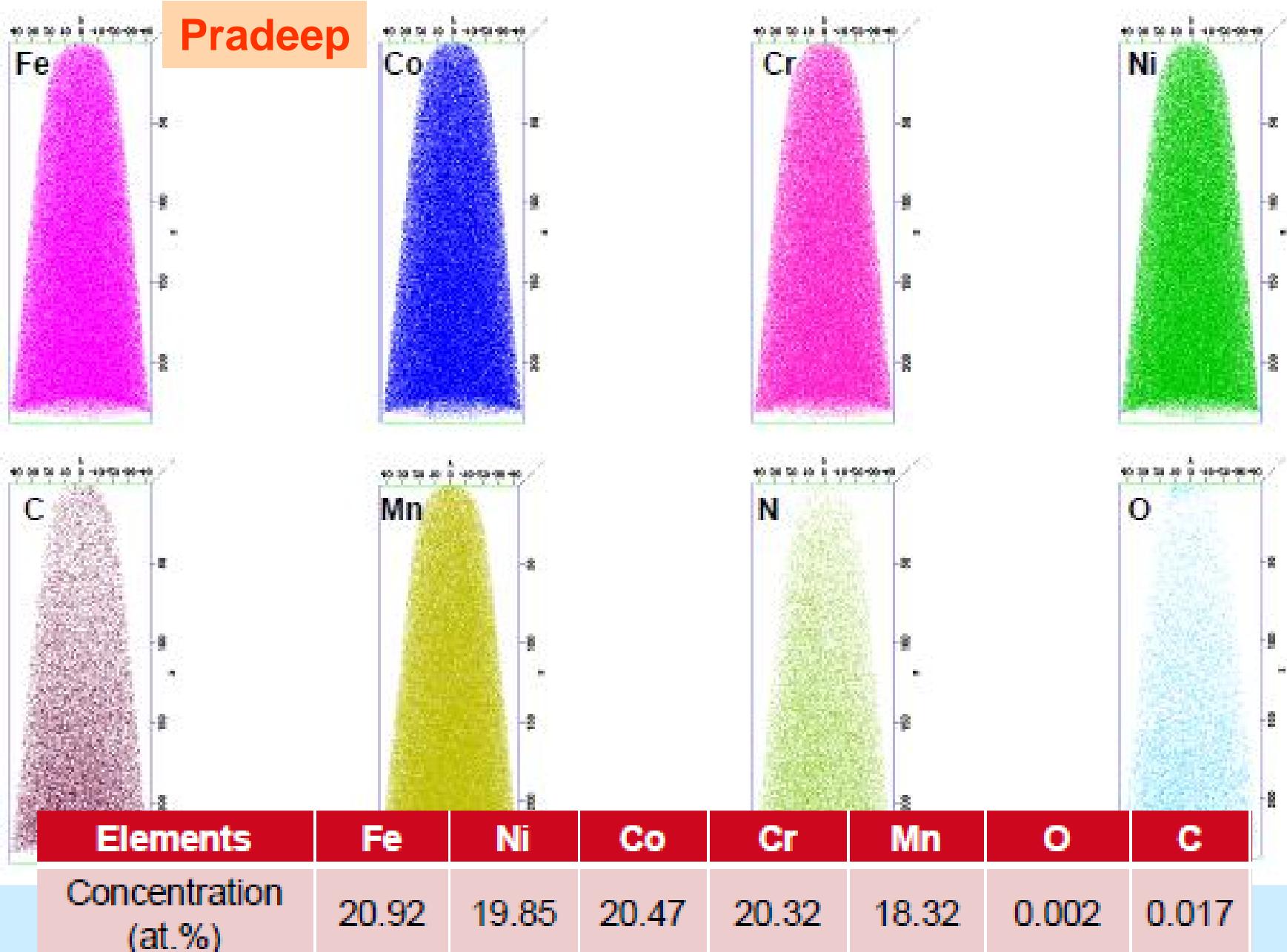
Tang et al. JOM, 2013



Vara



Uniform elemental distribution in CoCrFeMnNi HEA



AlCoCrCuFeNi Cast HEA



Sheela &
John Banhart
*Helmoltz
Zentrum, Berlin*

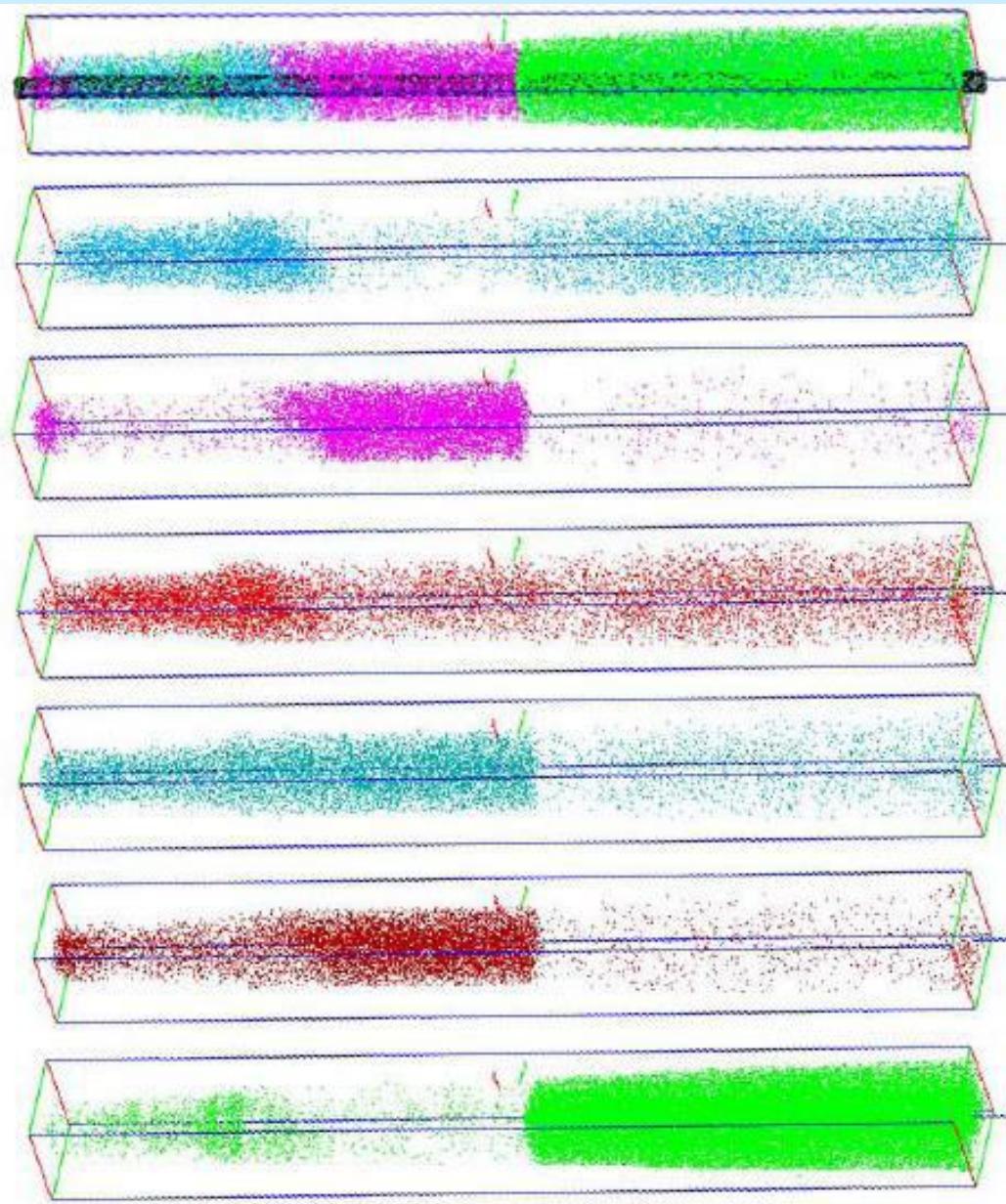
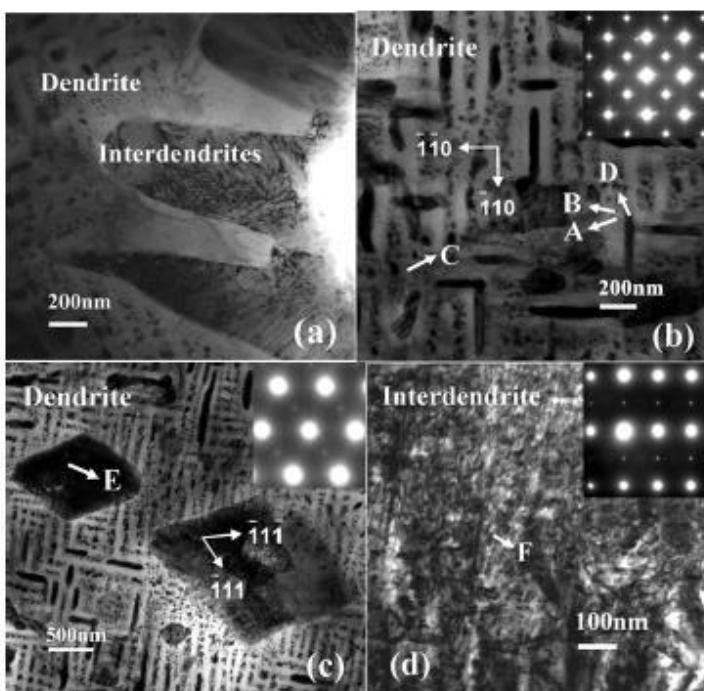
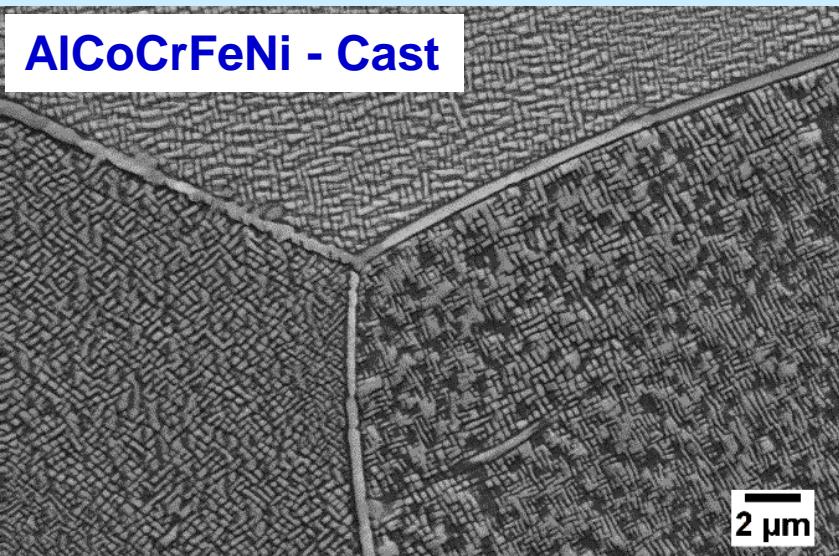
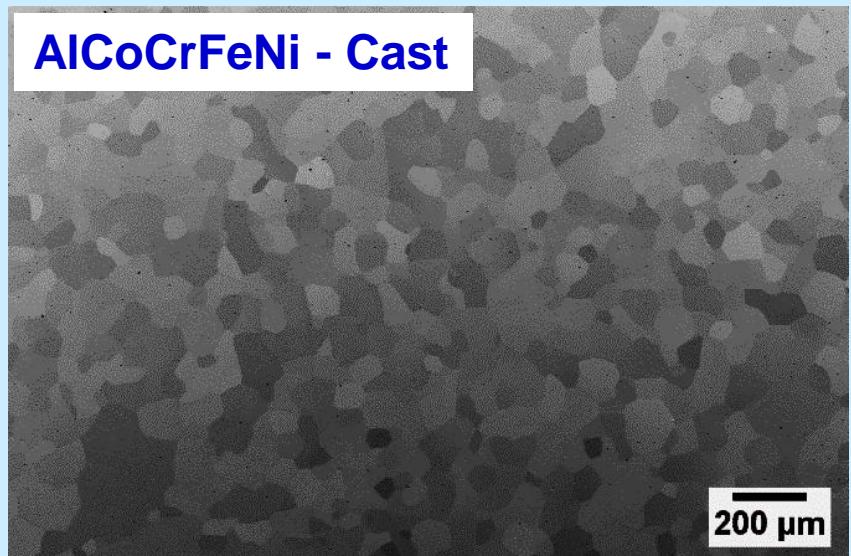
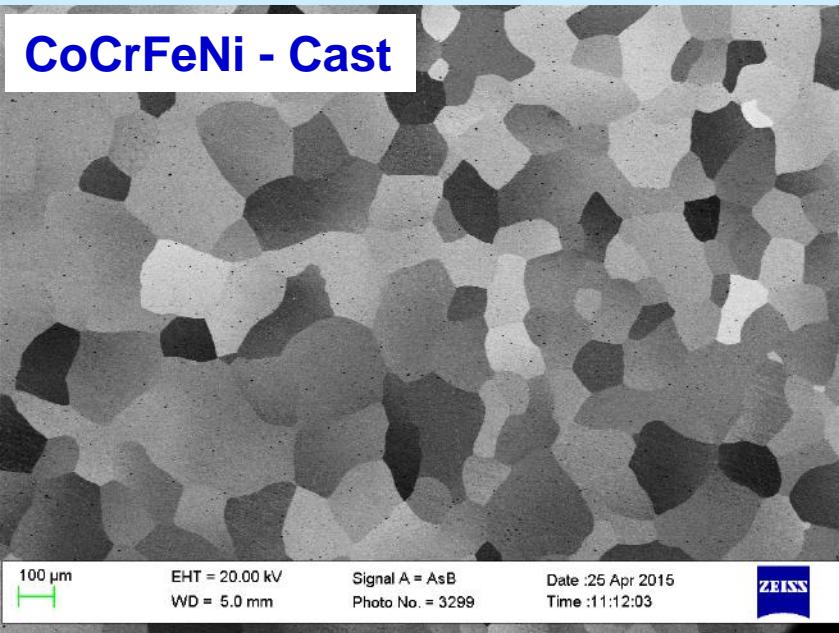
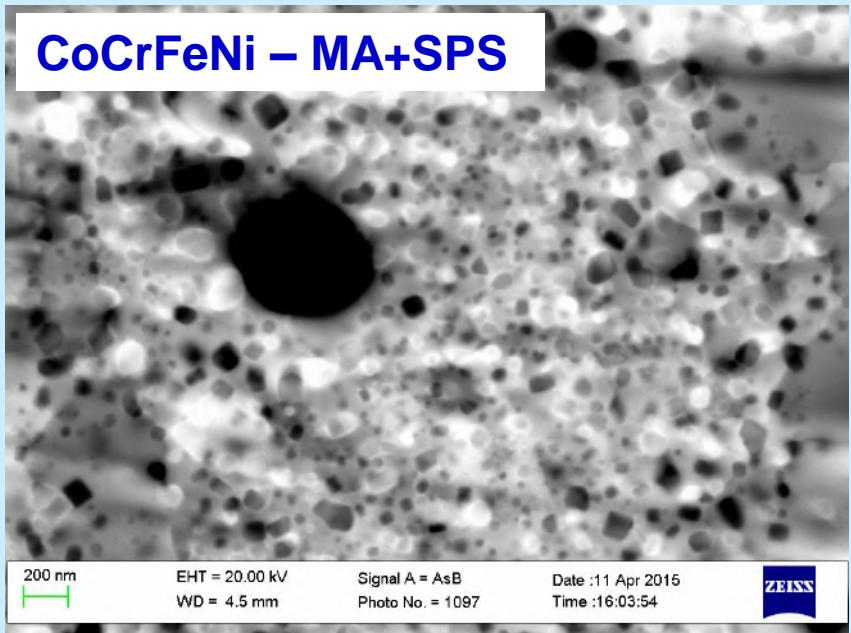


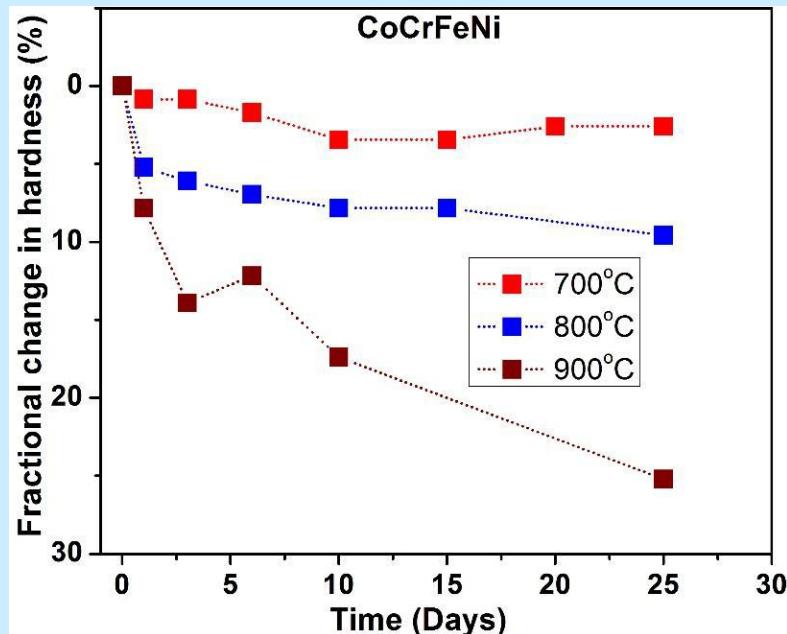
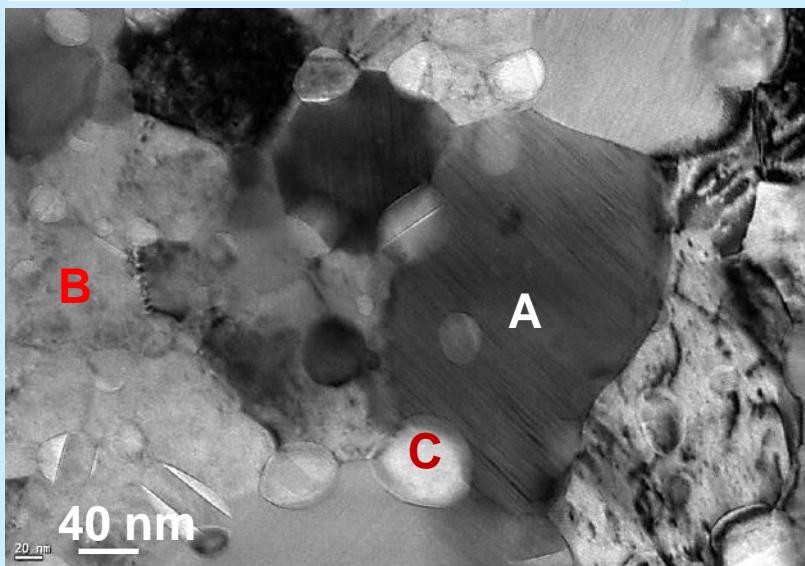
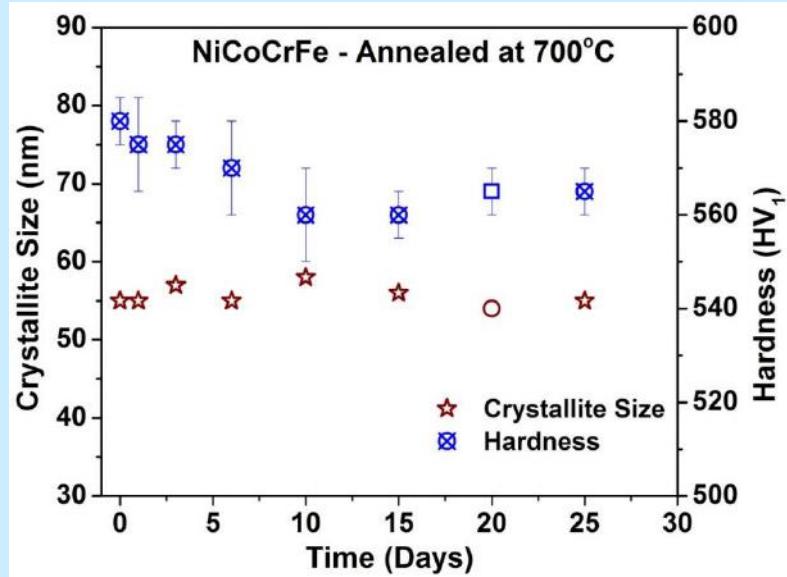
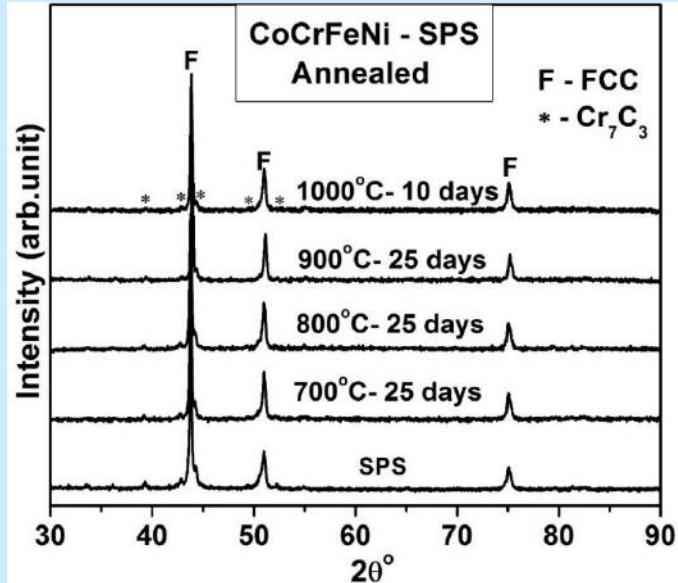
Fig. 4 Three dimensional reconstruction of Al, Cr, Ni, Co, Fe and Cu atom positions in an analyzed volume $9.5 \times 9.5 \times 93 \text{ nm}^3$ of as-cast AlCuCoCrNiFe high entropy alloy. The symbols for different atoms are Al: ●, Ni: ●, Cr: ●, Co: ●, Fe: ● and Cu: ●.

CoCrFeNi: MASPS vs. Casting

Rahul, Dan Fabijanic,
Deakin University

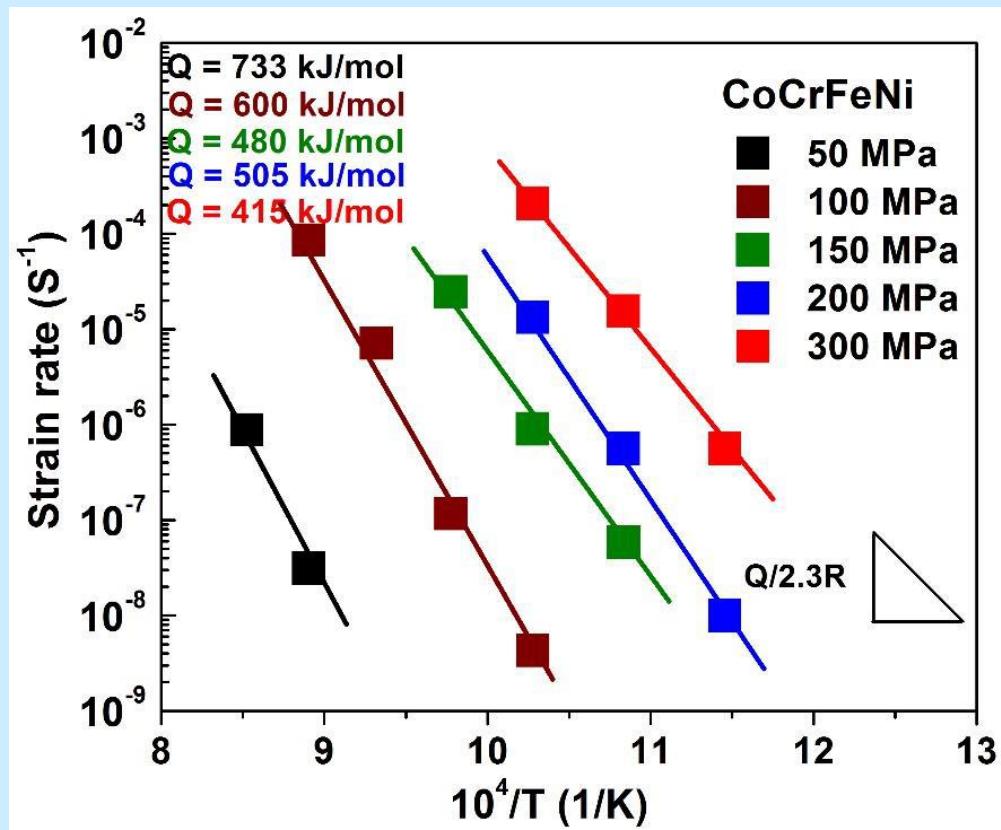
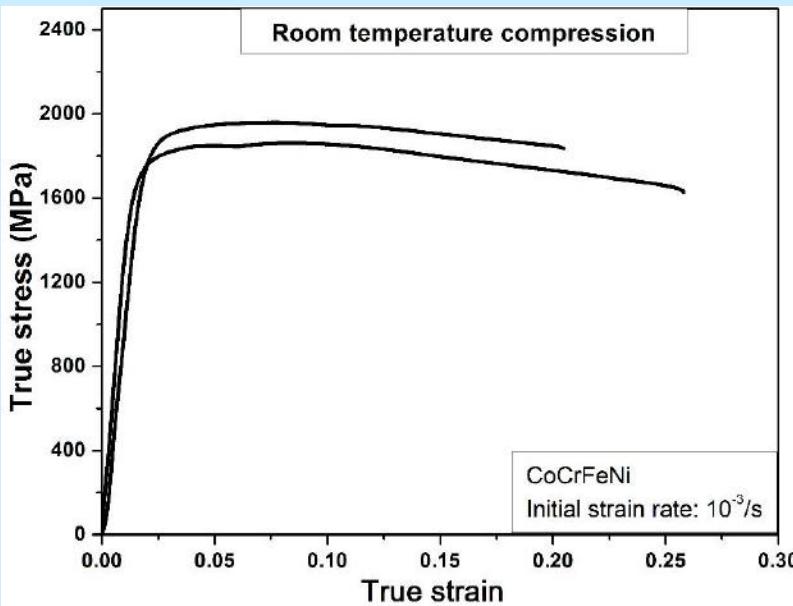
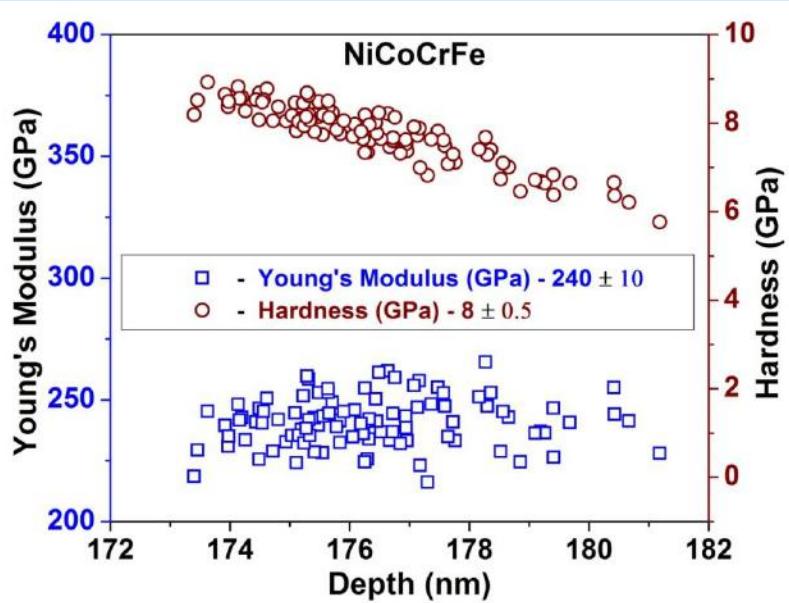


Thermal stability of CoCrFeNi: SPS & Annealing



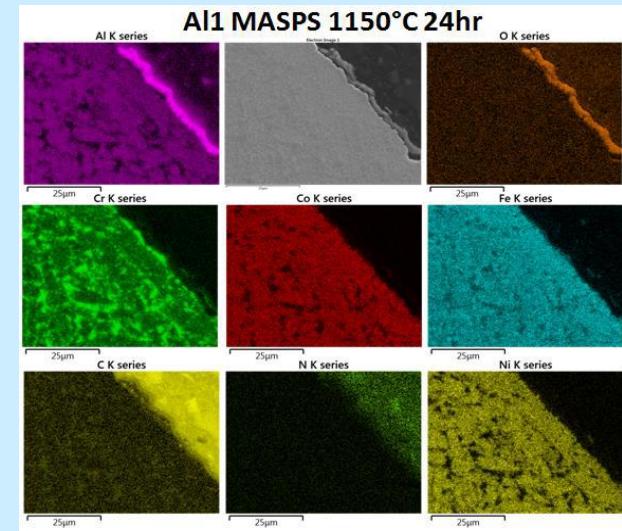
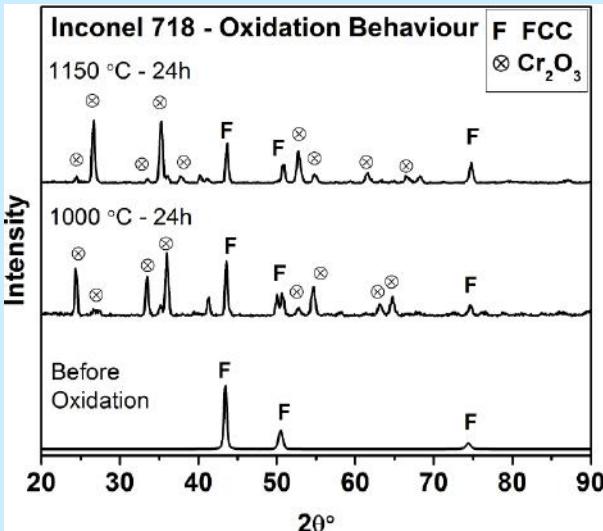
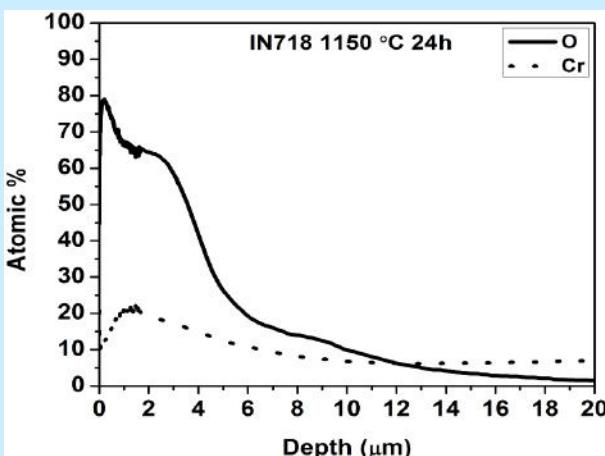
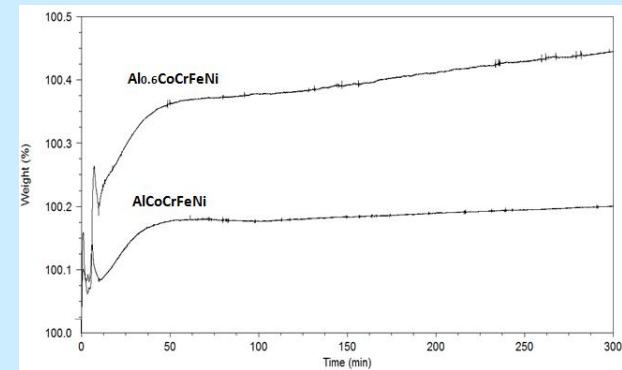
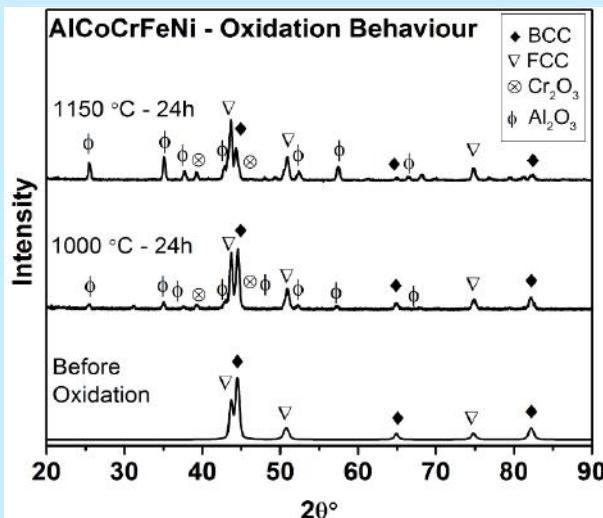
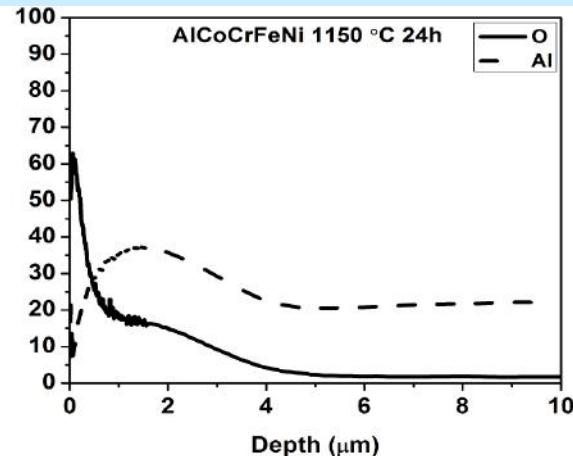
Mechanical Properties

Praveen &
Ravi Sankar



Oxidation behaviour of AlCoCrFeNi HEA vs. IN718

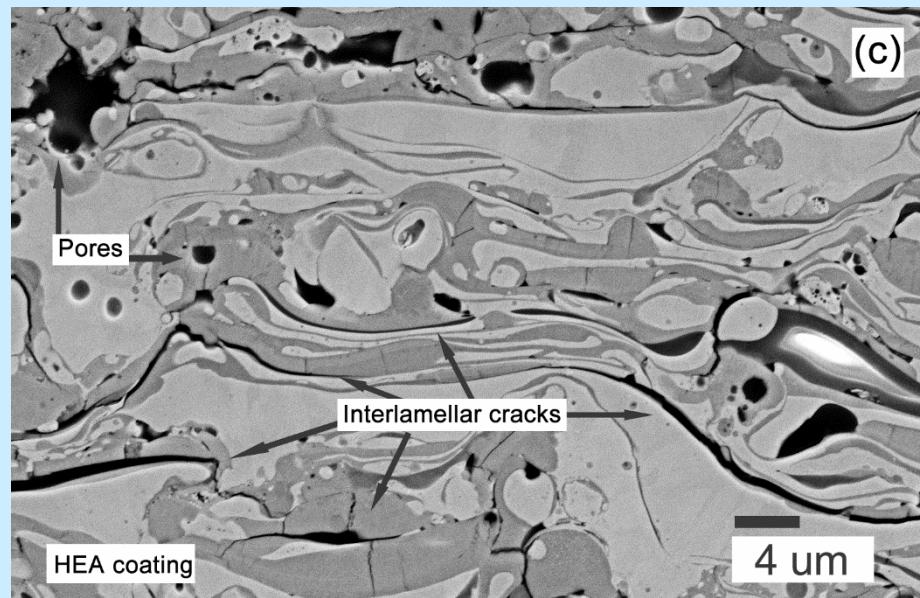
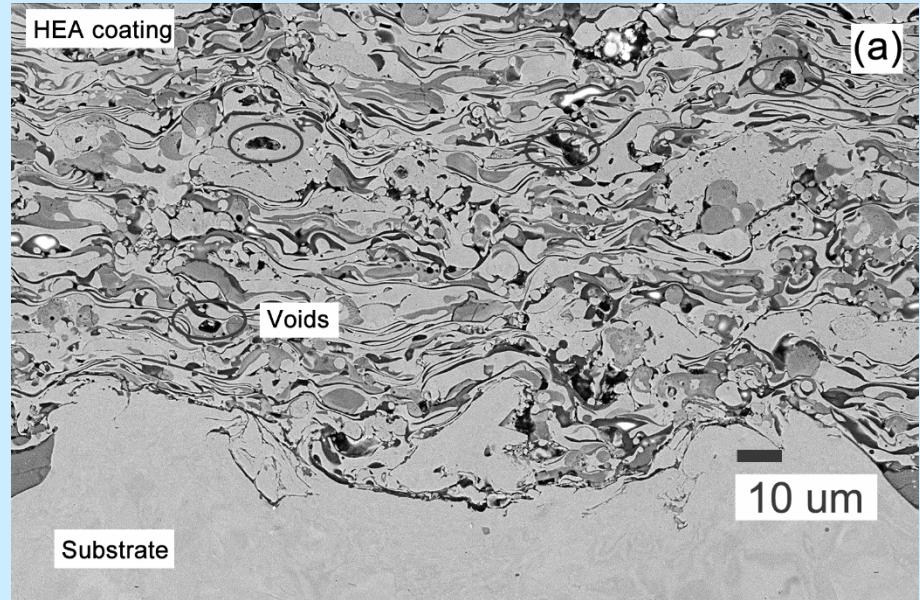
Rahul,
Dan Fabijanic
Peter Hodgeson,
Deakin University



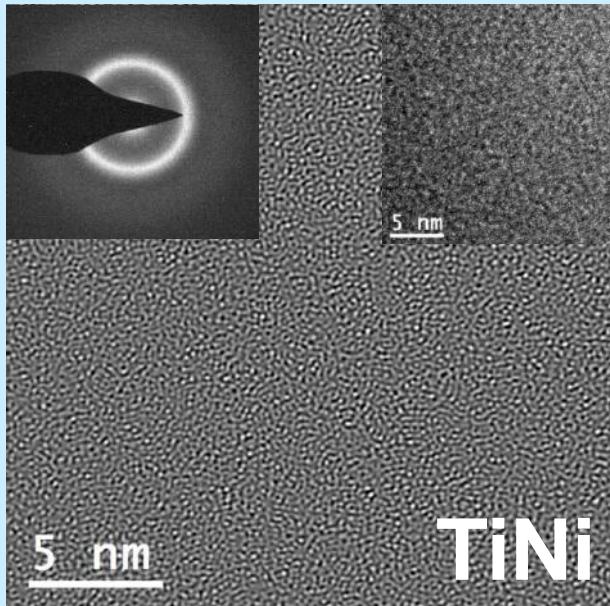
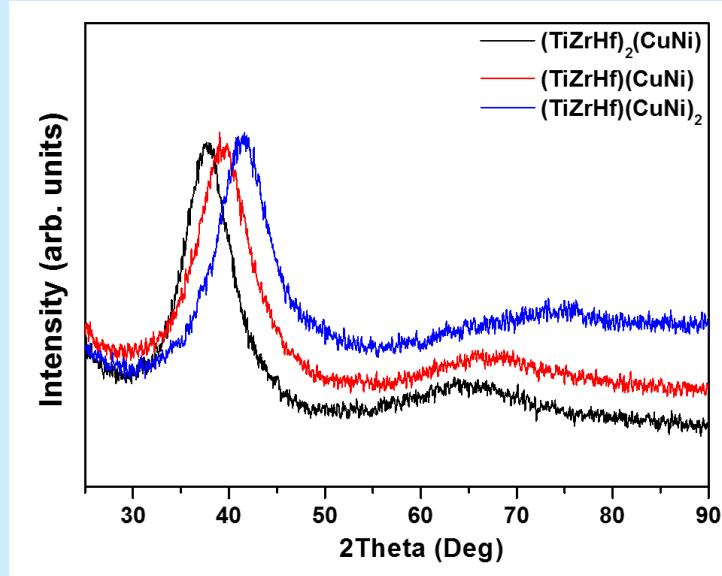
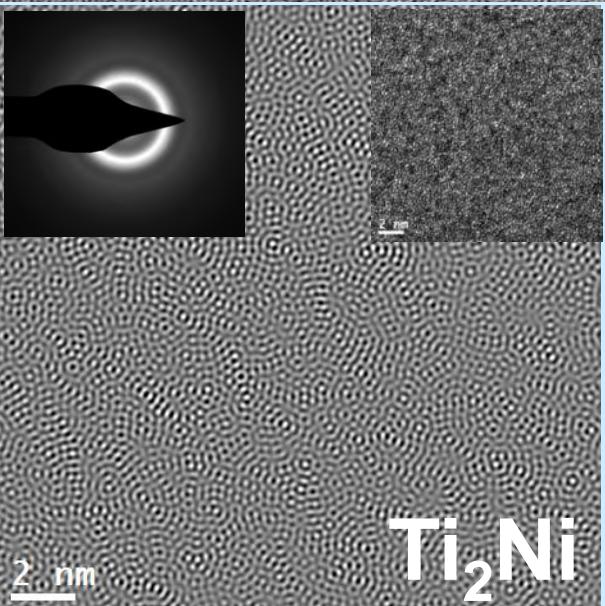
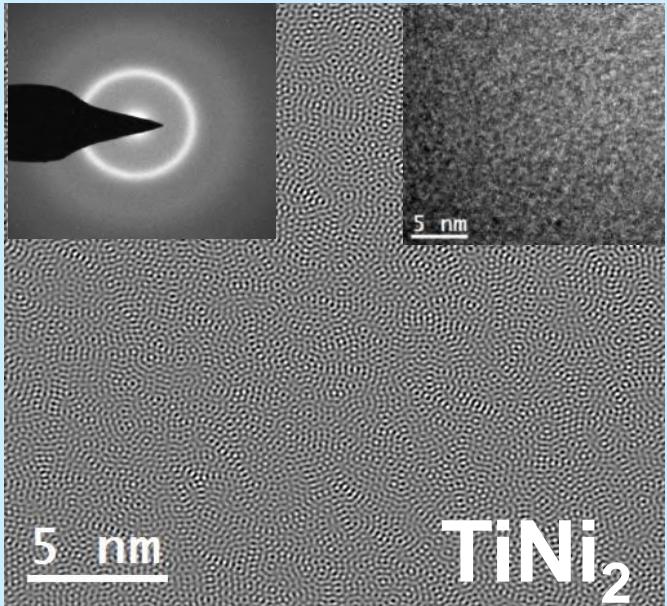
Plasma Spraying of HEAs on Steel

- HV_{0.3kgf} of AlCoCrFeNi
Coating: 4.13 ± 0.43 GPa
- HV_{0.3kgf} MnCoCrFeNi
Coating: 4.42 ± 0.60 GPa
- HV_{0.3kgf} of conventional plasma sprayed NiCrAlCoY₂O₃ bond coat is 2.45 GPa

Ameey Anupam,
Ravi Sankar, IITM &
Andrew Aang,
Chris Berndt
Swinburne Univ.,
Melbourne



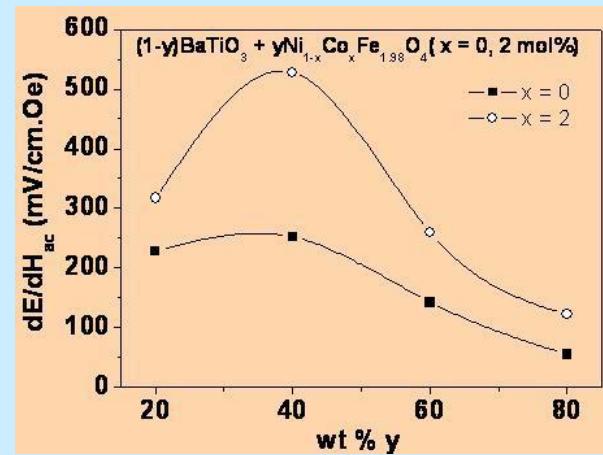
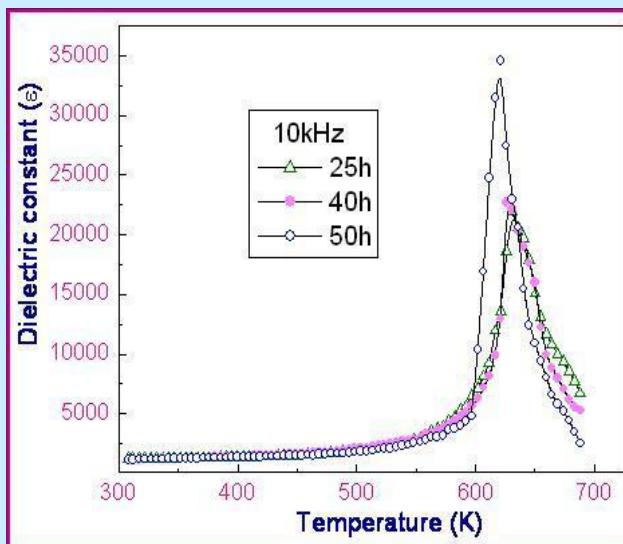
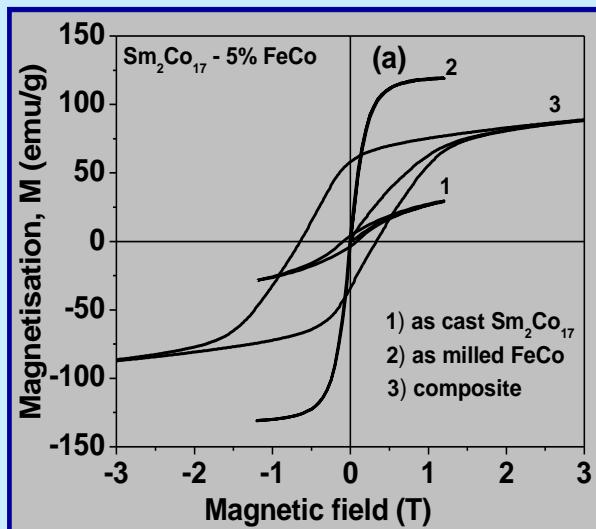
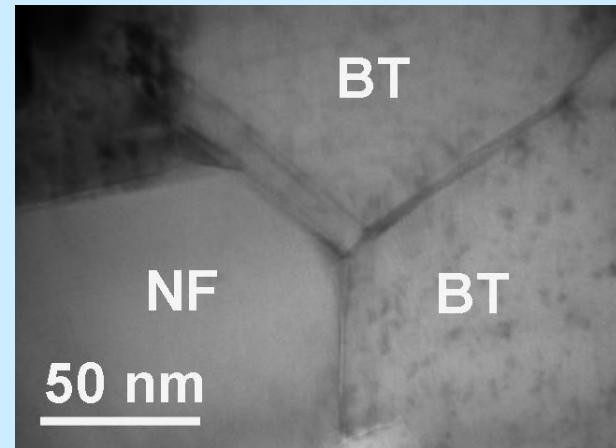
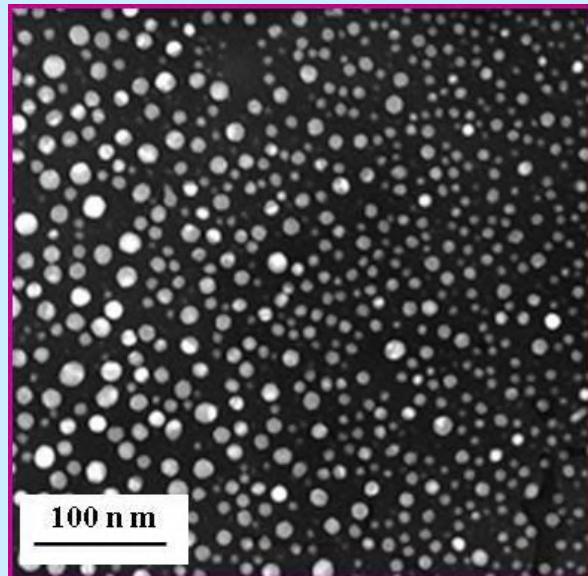
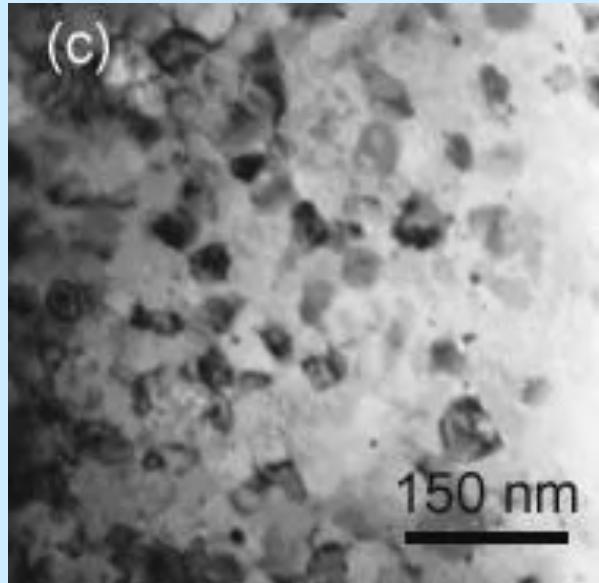
Can a binary intermetallic destabilise due to high entropy by multicomponent substitution



Ranganathan
IISc, Bangalore
Takeuchi &
Yokoyama
IMR, Sendai

Sanjay

Functional Nanocomposites with Exceptional properties



Sreenivasulu

Parashar

Sreenivasulu

A tropical beach scene featuring a palm tree on the left, its fronds reaching towards the top right. The sandy beach leads to a calm, light blue ocean under a clear, pale blue sky.

Thank You