Role of Advanced Materials in Transforming India into a Global Leader

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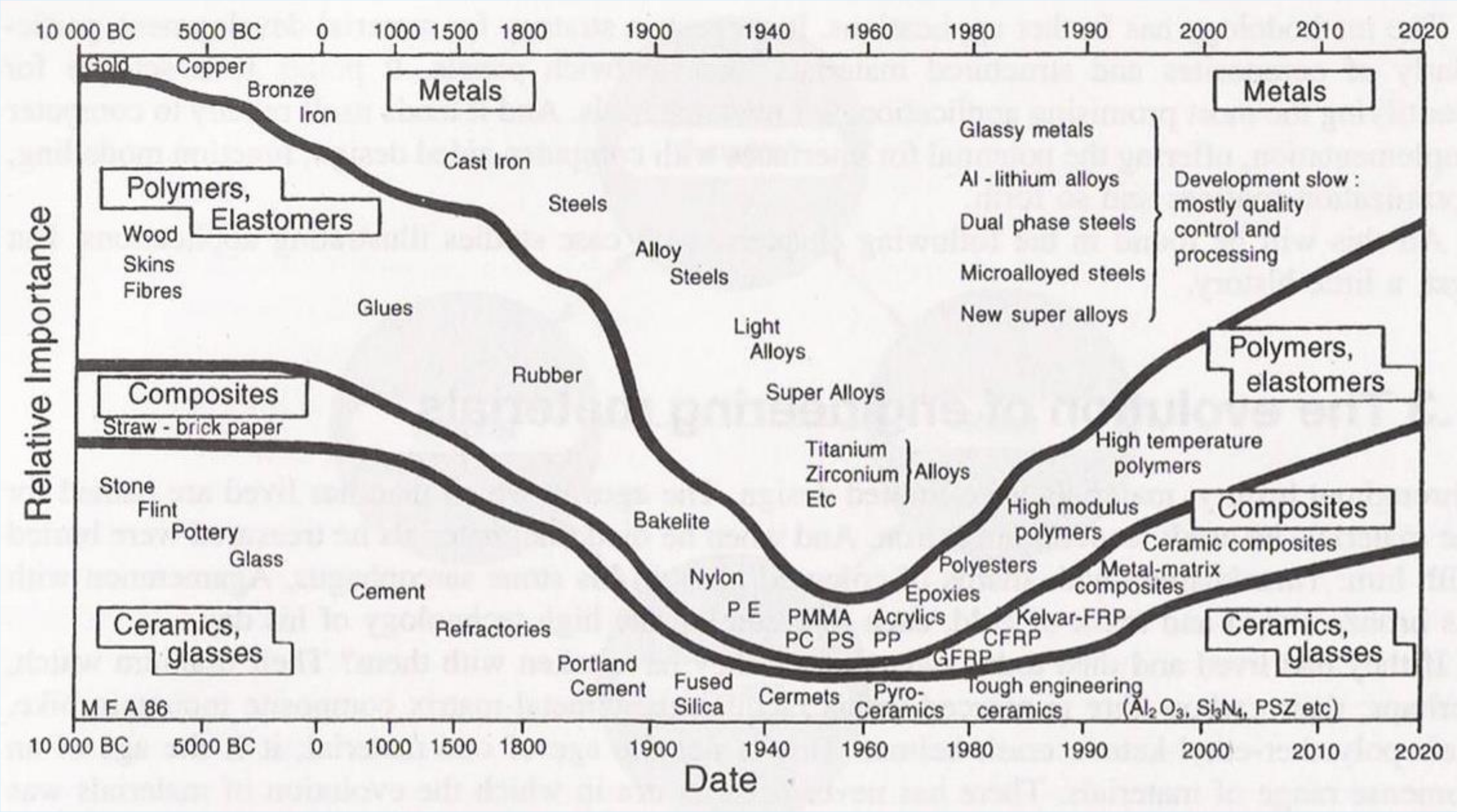
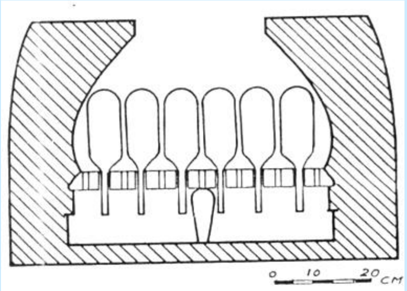
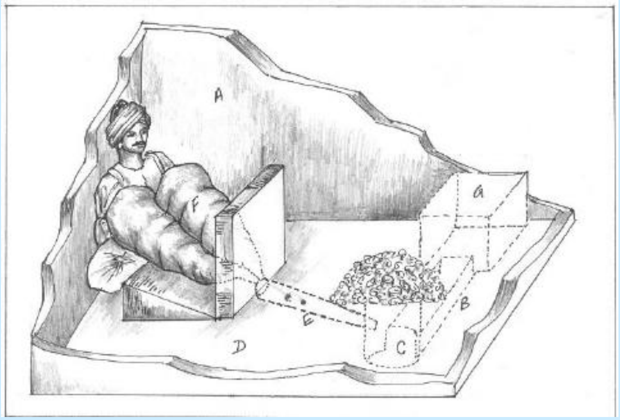
Use of Materials over ages



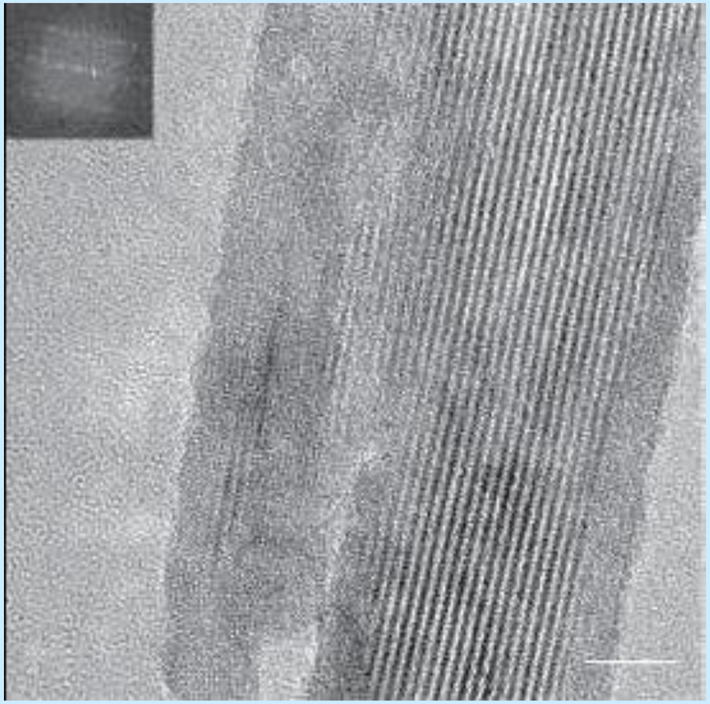
Indian Materials Heritage

- 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)

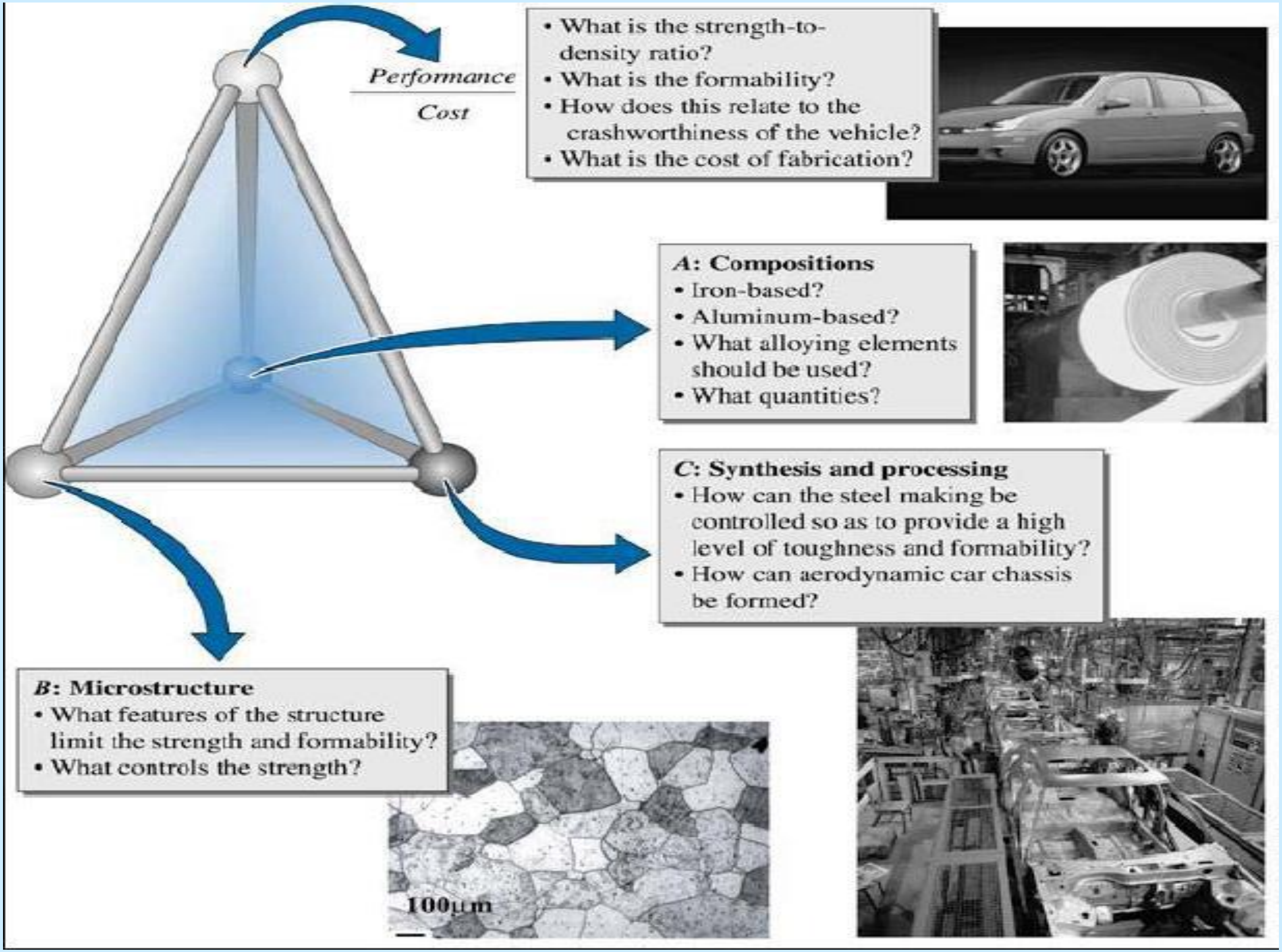
Rustless Wonder

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

Demascus Sword (Wootz Steel)

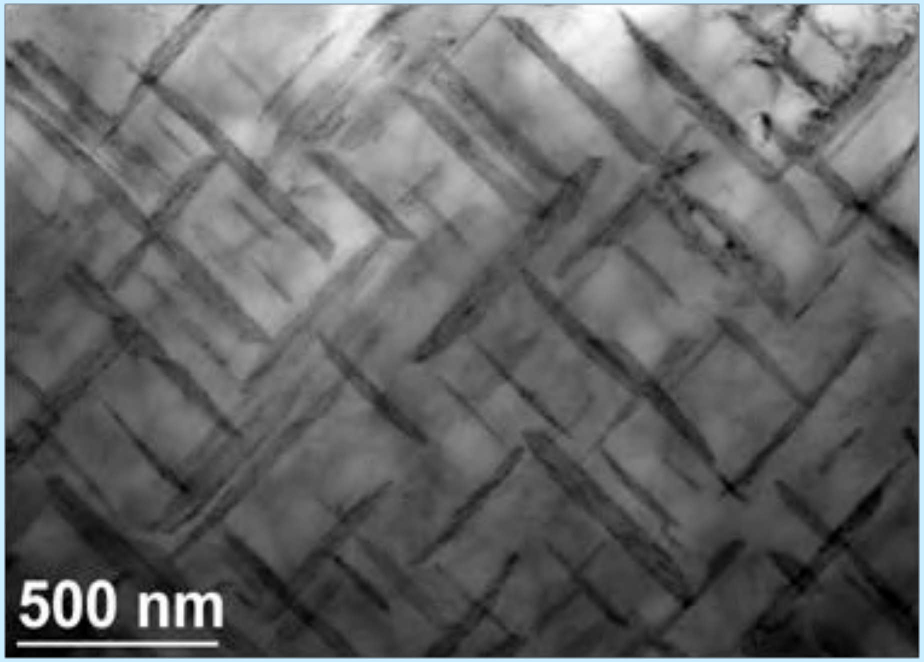
"Many of the advances in the sciences that we consider today to have been made in Europe were in fact made in India centuries ago."
- Grant Duff, British Historian of India

Materials-Processing Pyramid

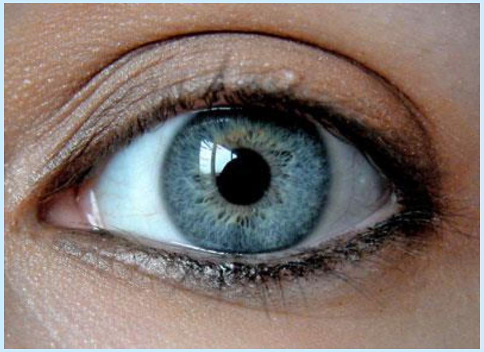


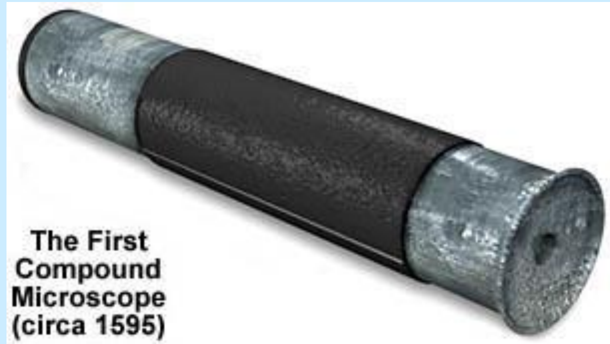
The Air Craft Alloy - The Accidental Discovery: The need for Higher Resolution

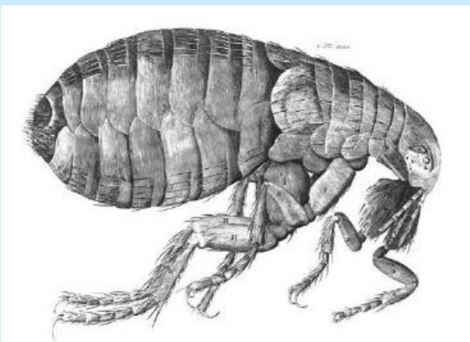
- Wilm in 1903
- First Aerospace Aluminum Alloy - Duraluminum
- The Wright Brothers Aircraft Crankcase

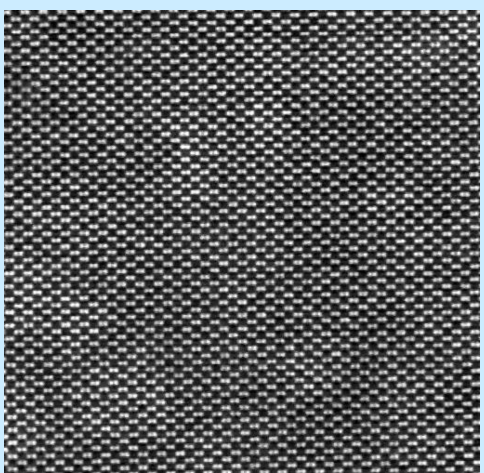


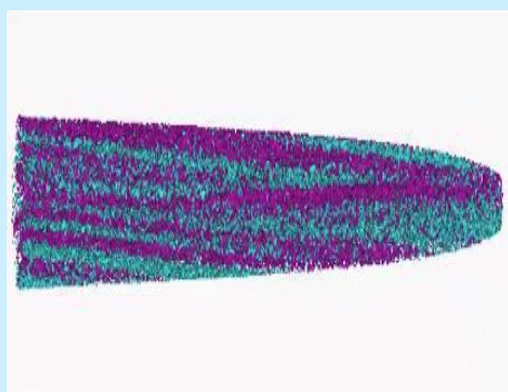
Microscopy: urge to see Inner World



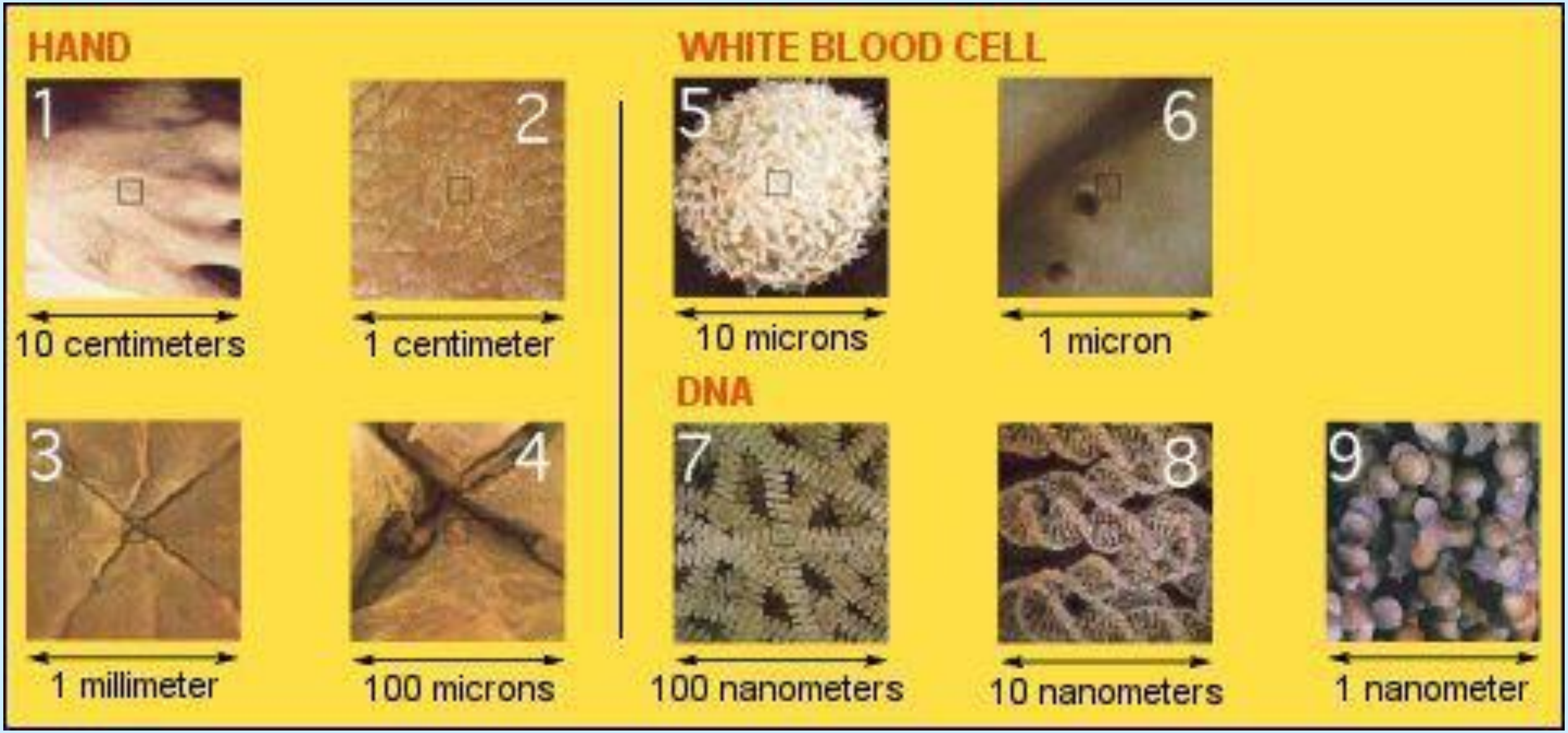




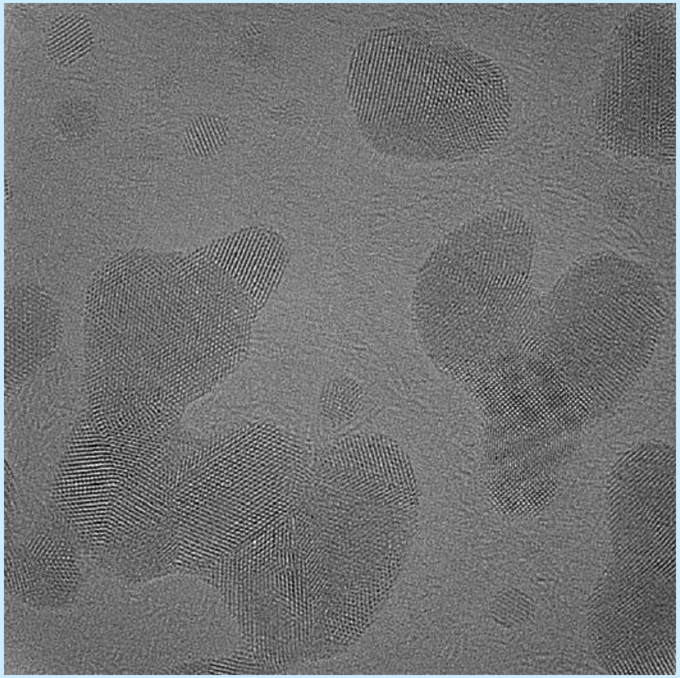


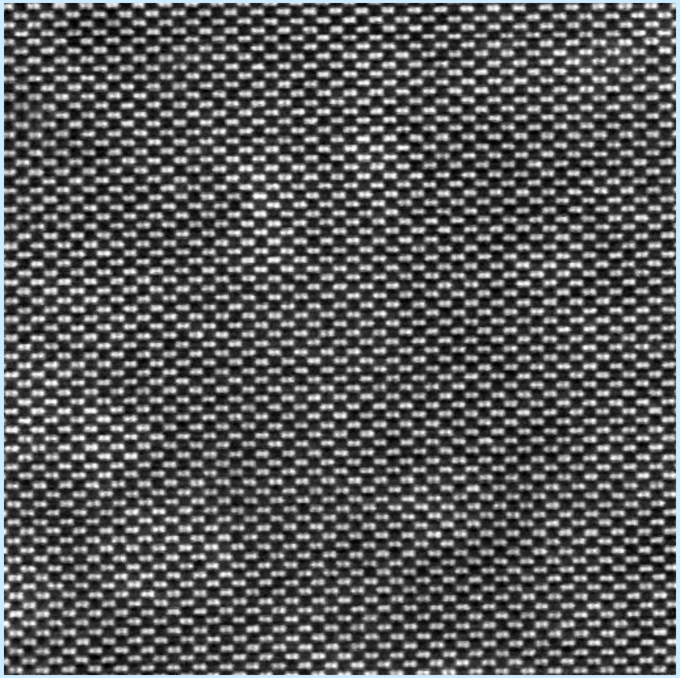


Can We See Small Things ?

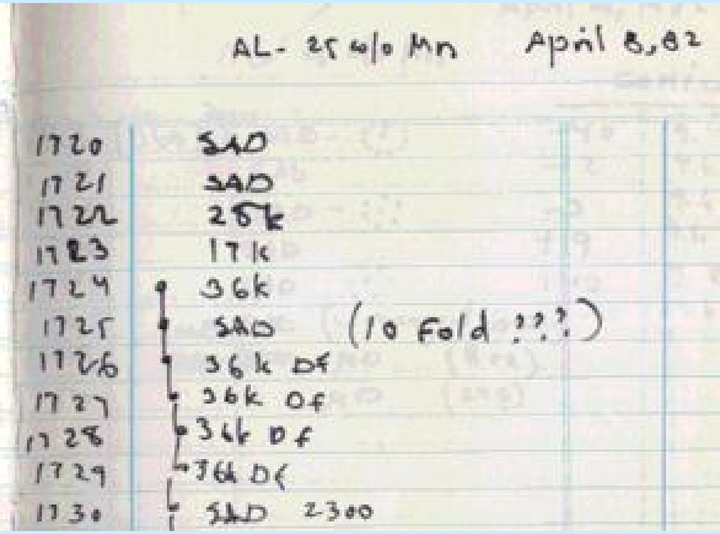


Titan at IITM





Quasicrystals: Nobel Prize (2011)

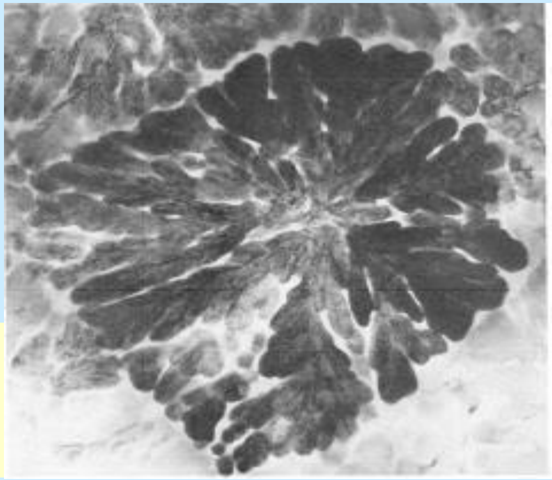


10 fold ! ! !

"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.

Mat. Res. Bull. Vol. 13, pp. 1065-1070, 1978.

A NEW ORDERED PHASE IN THE Al-Pd SYSTEM

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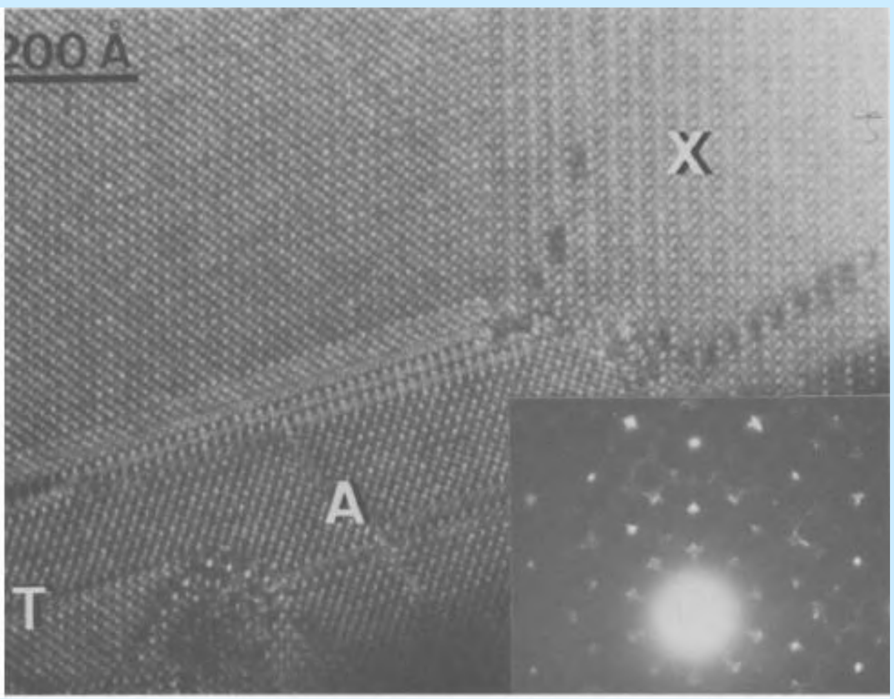
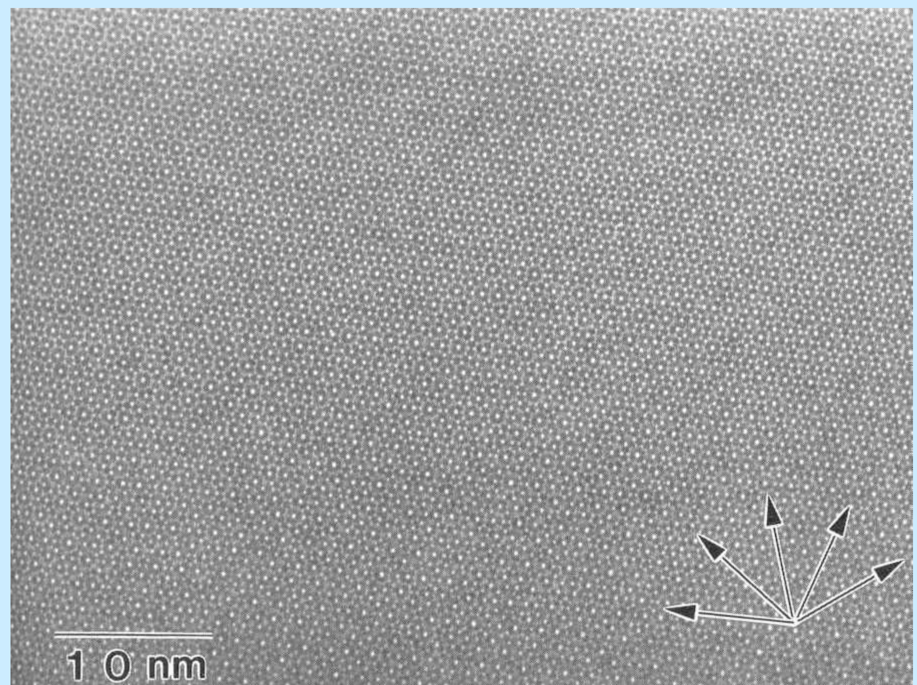
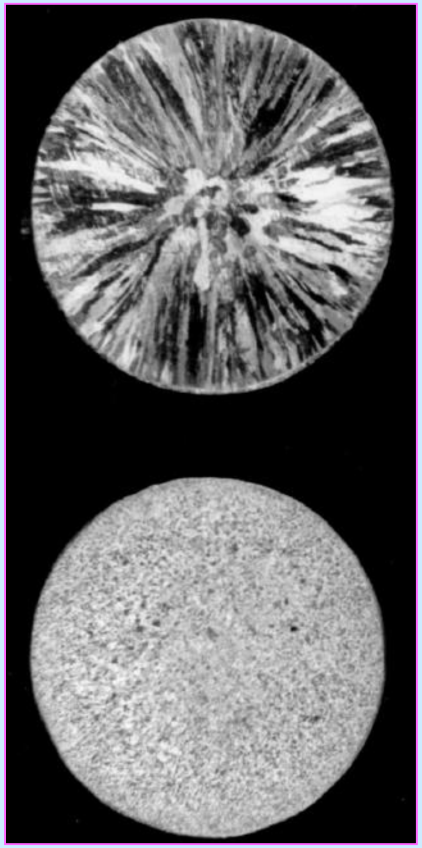
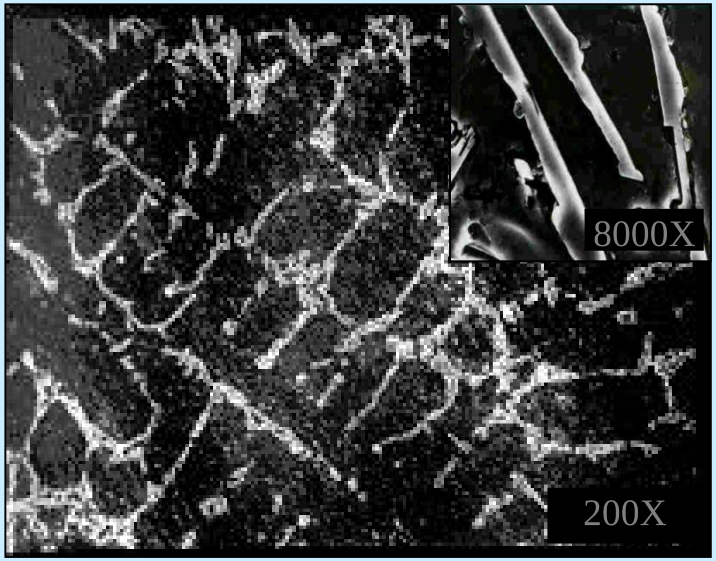
(Received August 9, 1978; Communicated by S. Amelinckx)





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



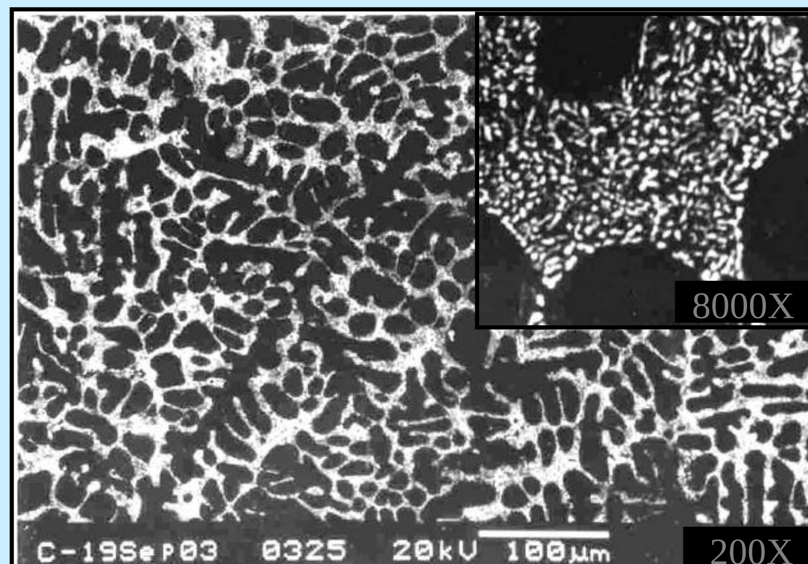


Without Grain Refinement/Modification

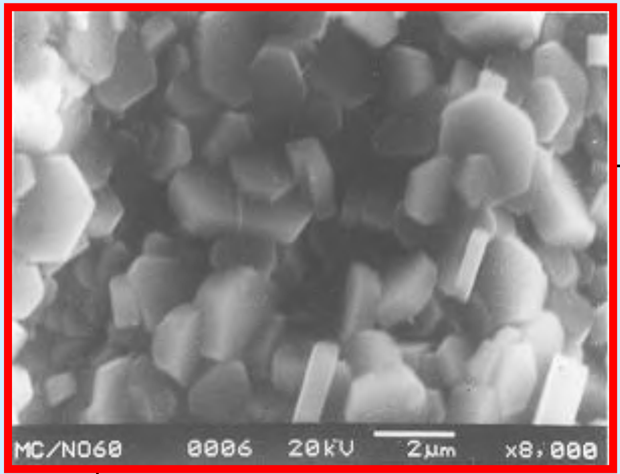
Kori & Prasad

With Grain Refinement and Modification

(1M13+ 0.02Sr) (5min)



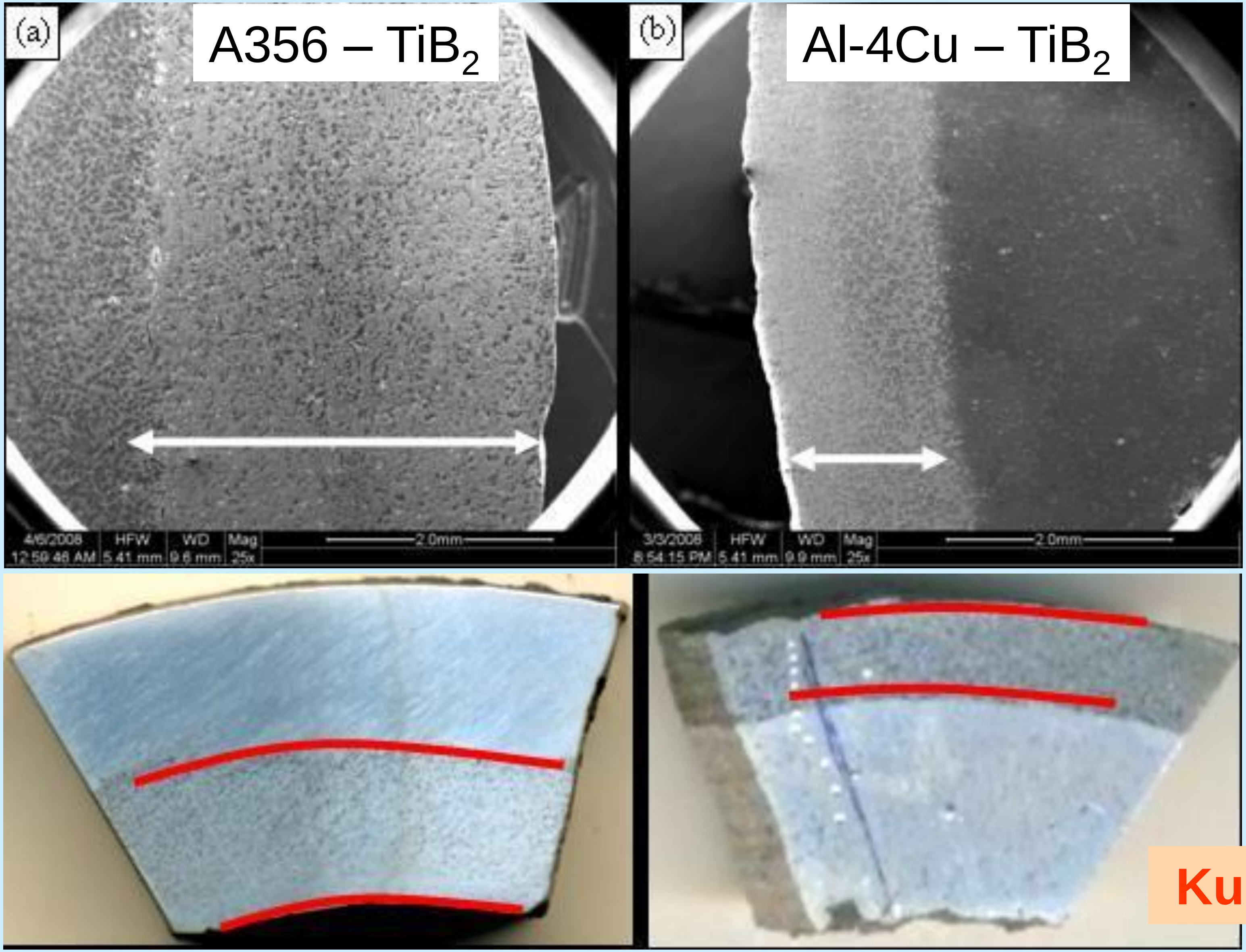
High Strength In-Situ Al-4Cu-TiB_2 Composites for High Load Bearing Automotive Applications



	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

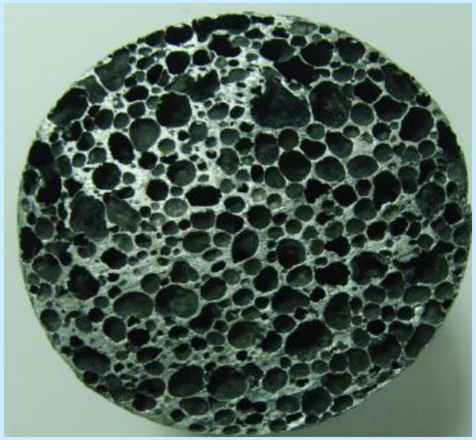
Functionally Graded Al based in-situ Composites for High Wear Resistant Automotive Pistons

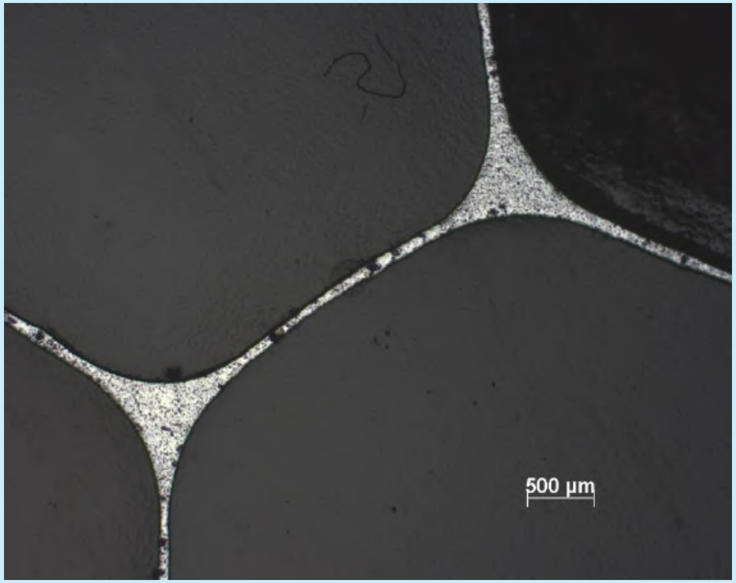


Kumar

Al Foams for Light Weighting and Energy Absorption

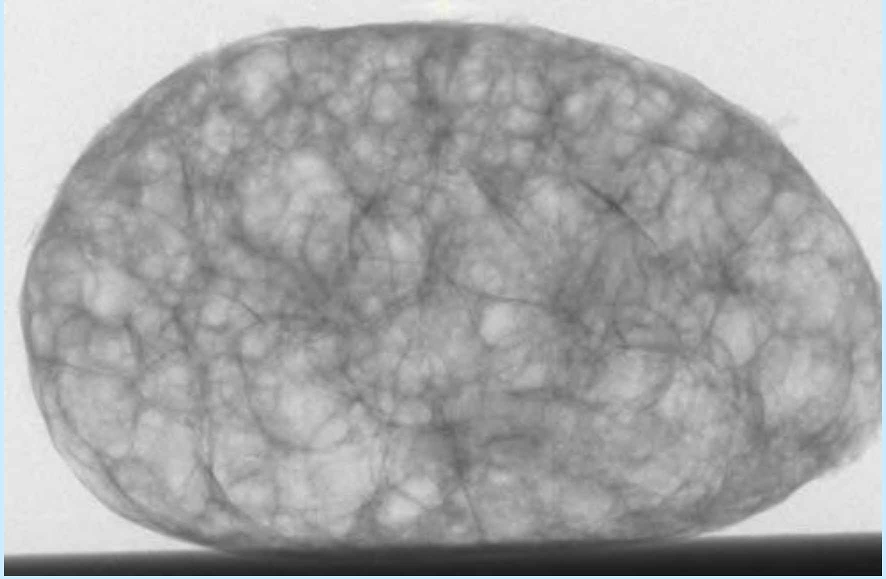
Vinod & Harsha





TiB_2

TiC

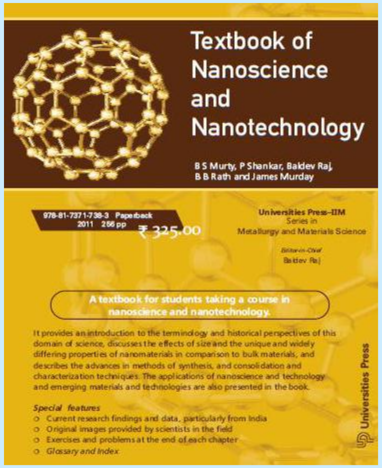


Various Nano Products

Car Wash

Cosmetics

Nano Ag Tooth Paste



Self Cleaning window

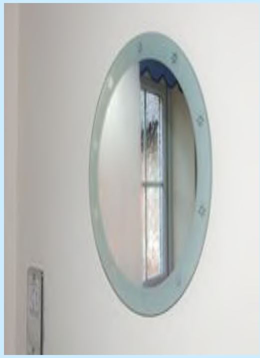
Leather Protection

Hair Dryer

Swim Suits

Nano Ag Ionic

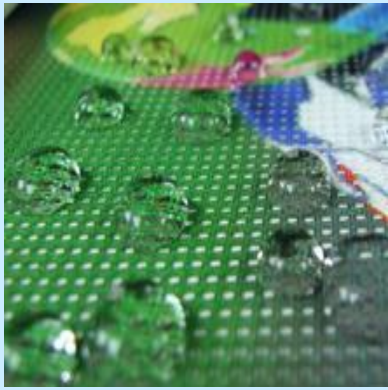
Nano Fluids



Mirror

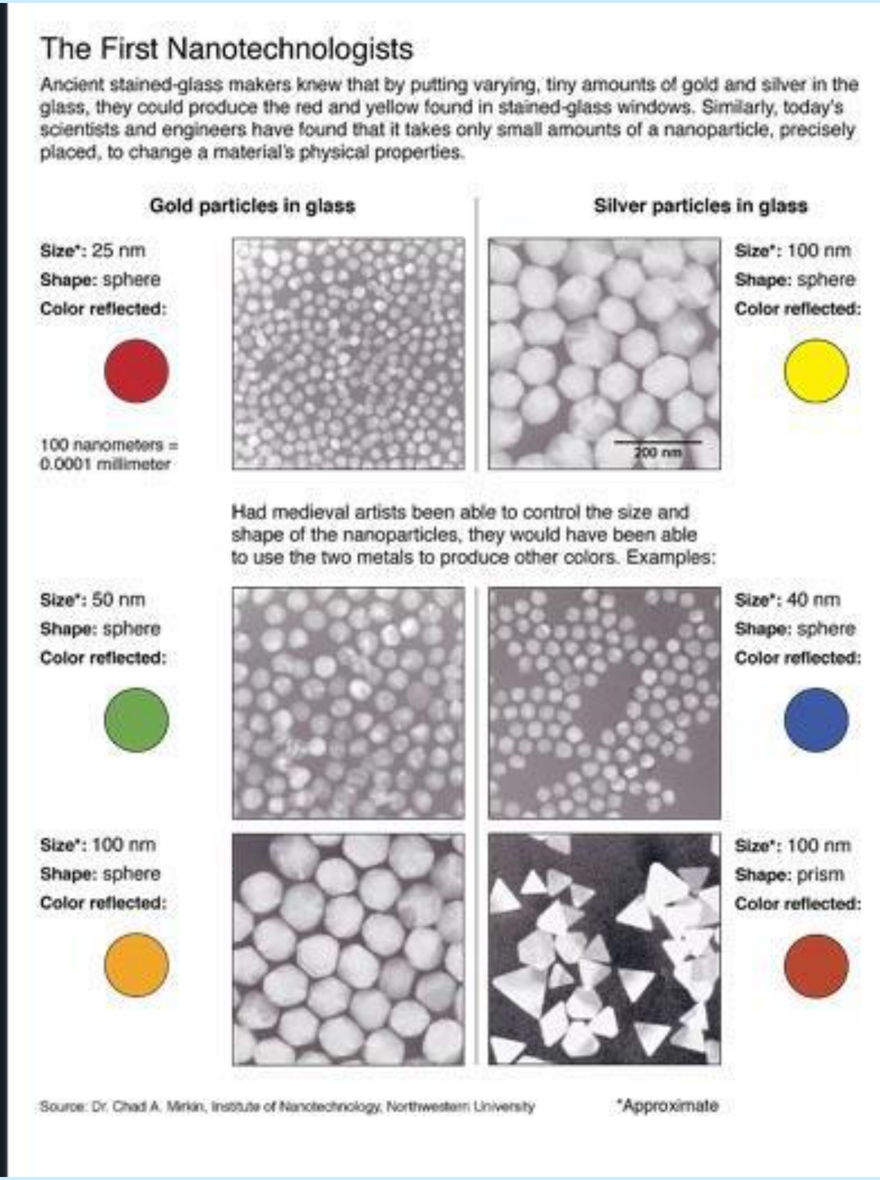
Car Body

Wood Protection

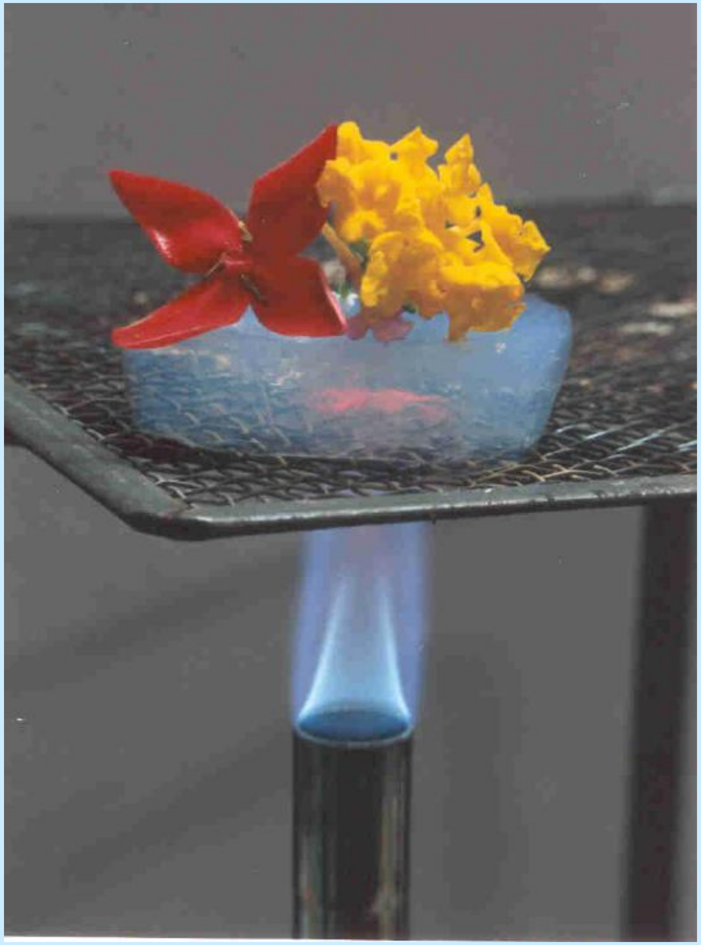


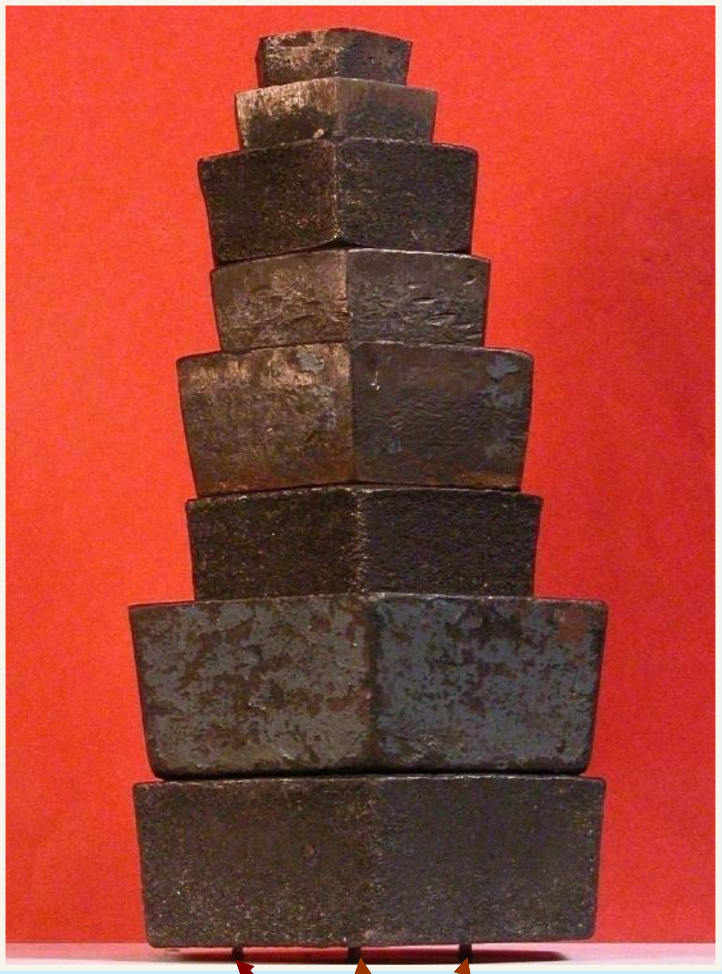
Textile Protection

Ancient Nanotechnologists



Nano Aerogels: The super materials

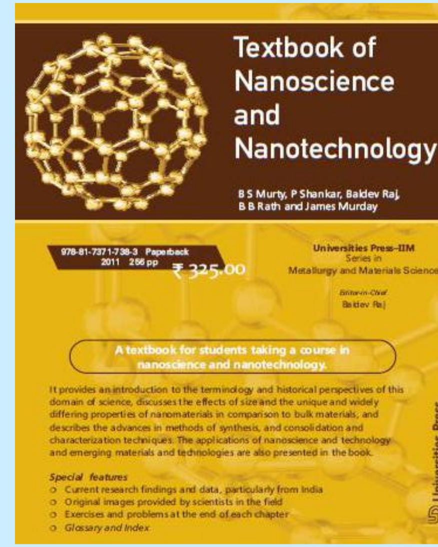


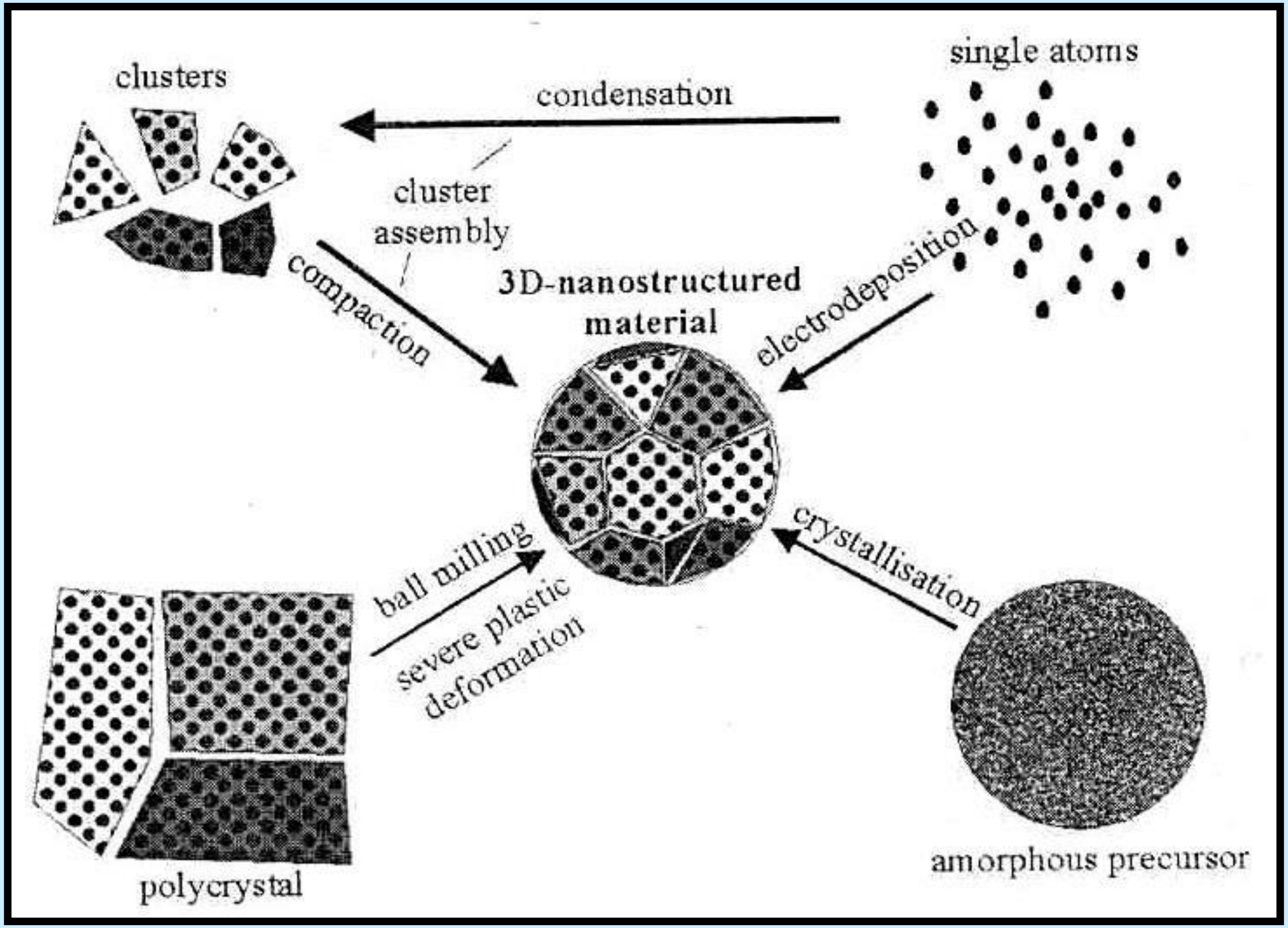


15 mgs of CNT-silica aerogel
Supporting 7.5 Kg load

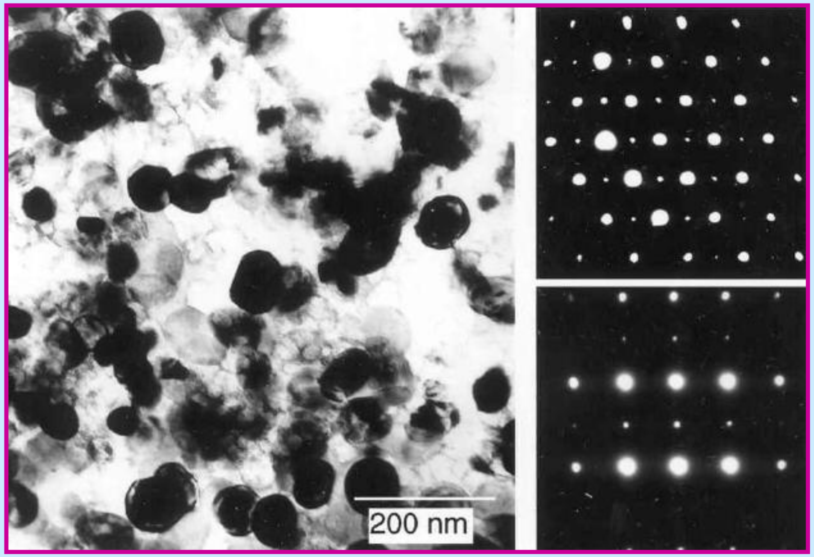
Prof. A.R. Kulkarni
IIT Bombay

Routes for the Preparation of Nano Materials

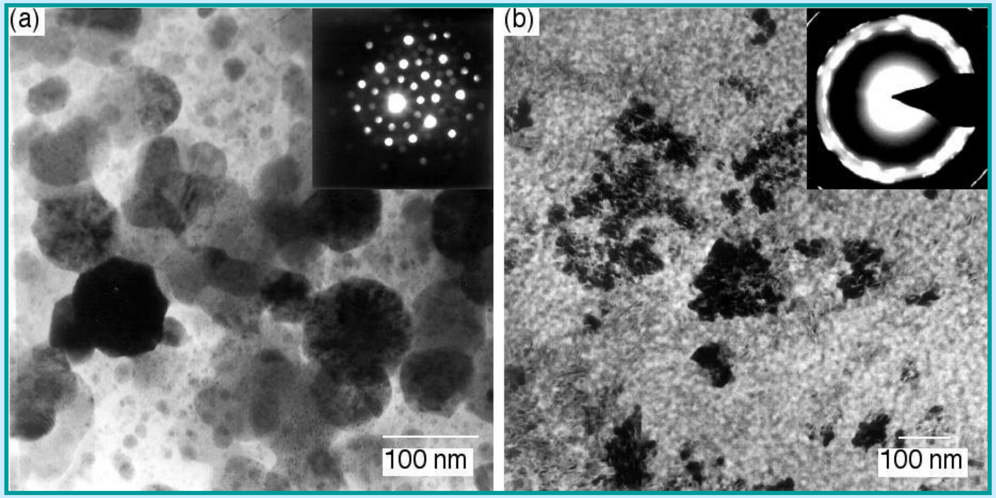


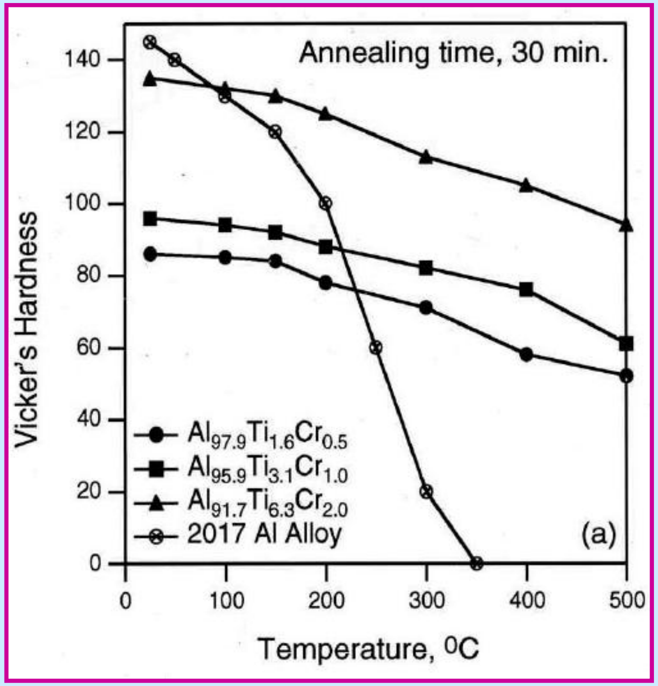


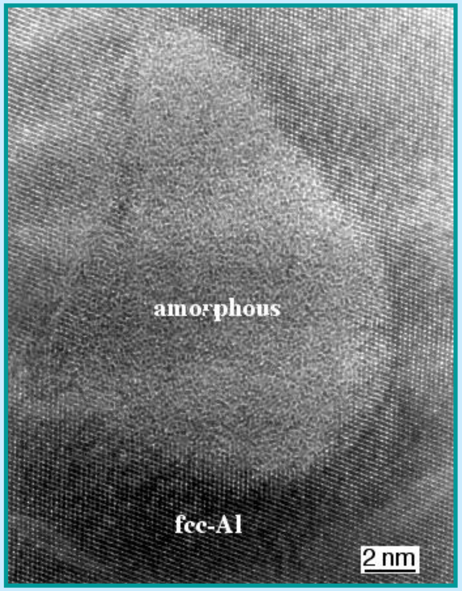
High Strength Al based Nanocomposites

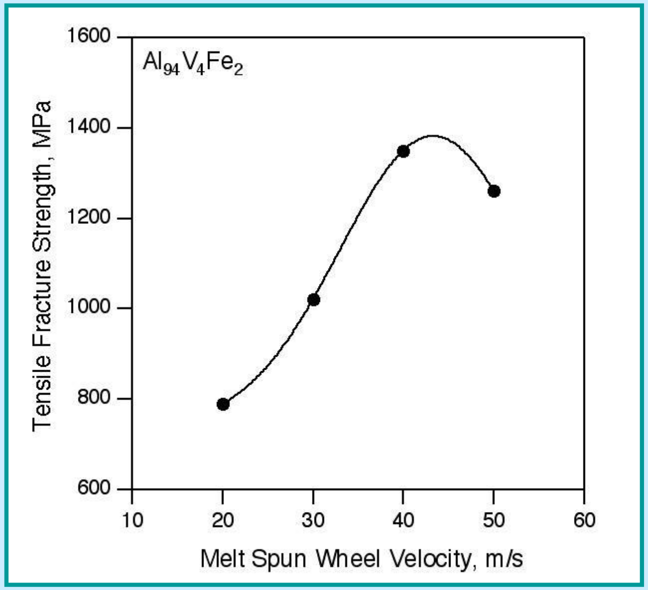


$Al_{94}V_4Fe_2$ Alloy



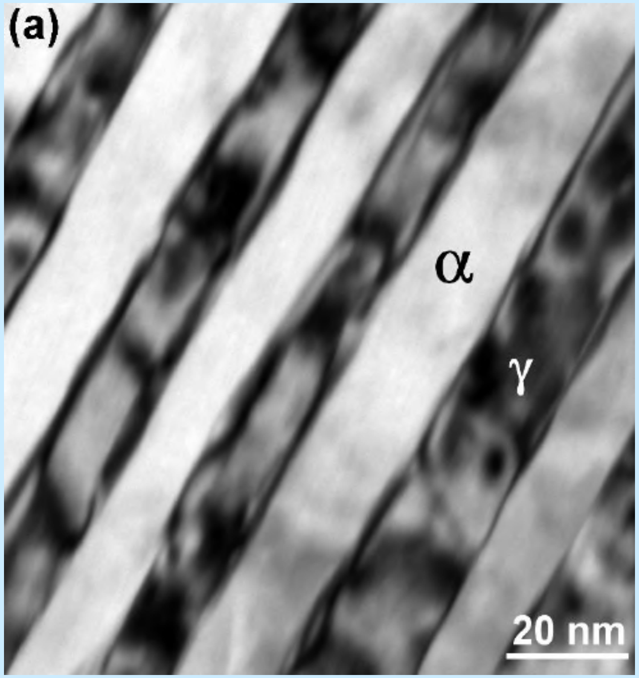


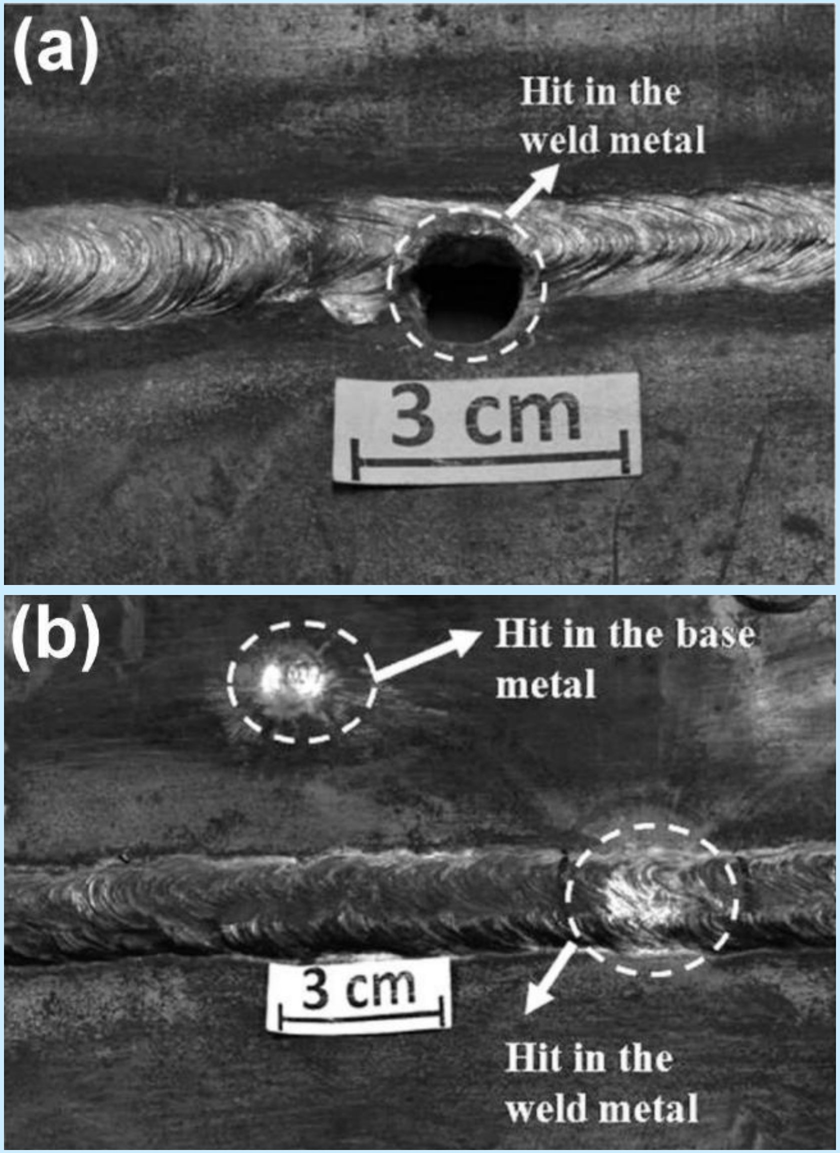


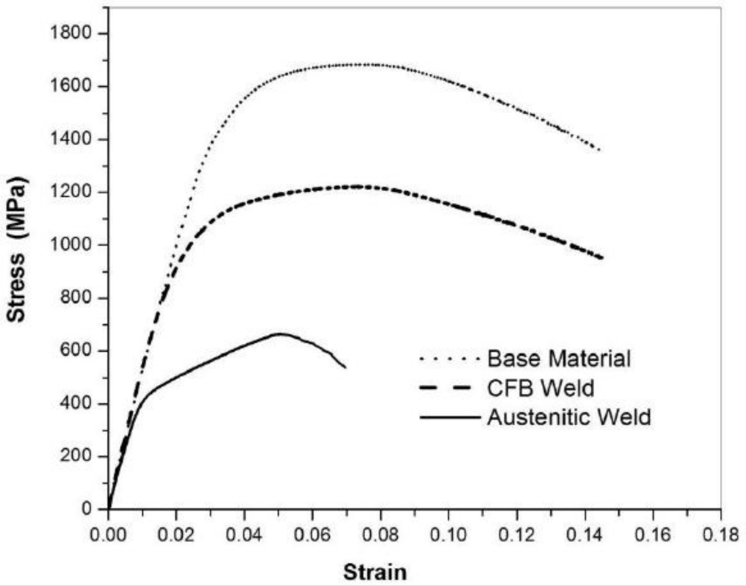


Nano Steel with Exceptional Toughness

Krishna Murthy, CVRDE, Avadi



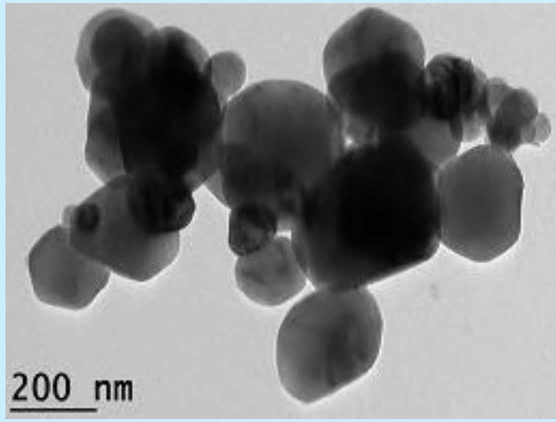




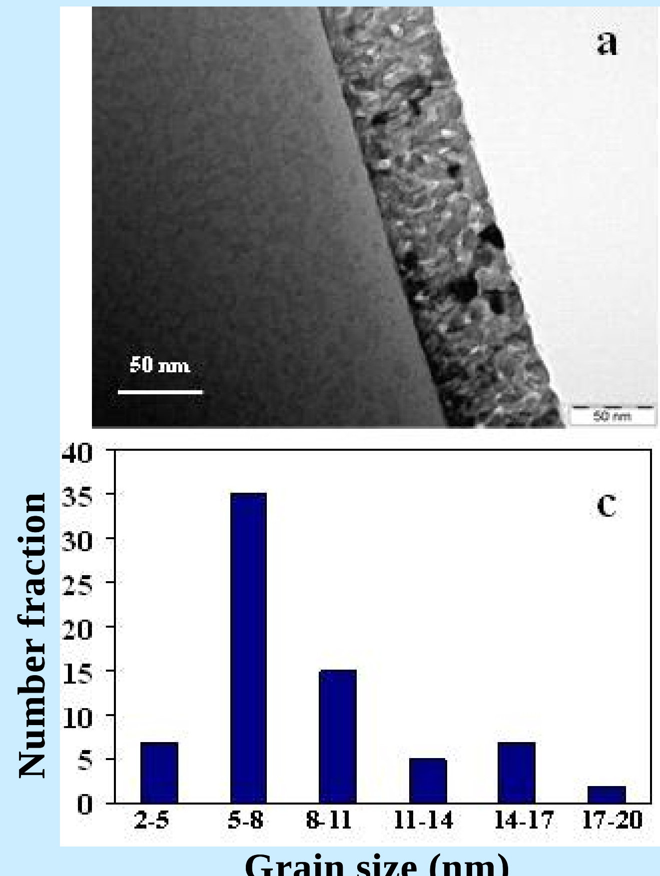
Nano Coatings

Prakash

Nanocoating on Ladle refractories, Vizag Steel Plant

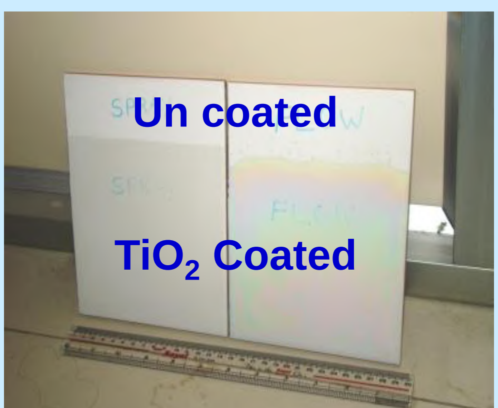


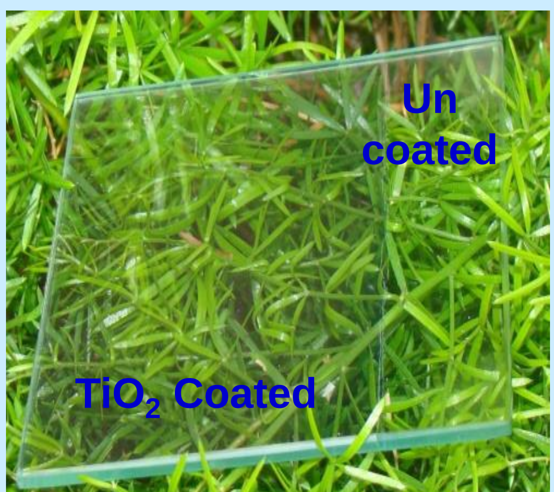
Sample condition	Hardness VHN
Uncoated	48
Nano Coated	781



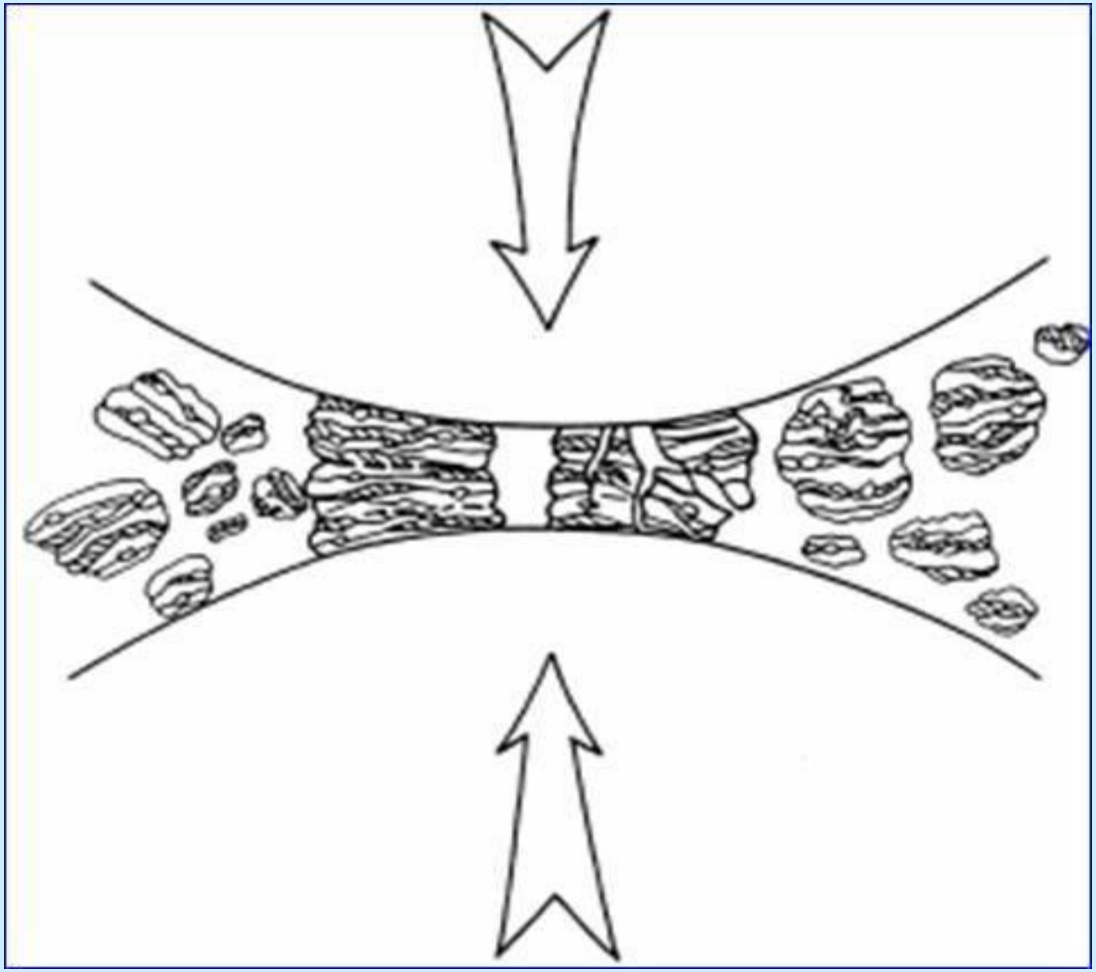
Nanocoating for self cleaning glasses, ARCI

Murugan, ARCI



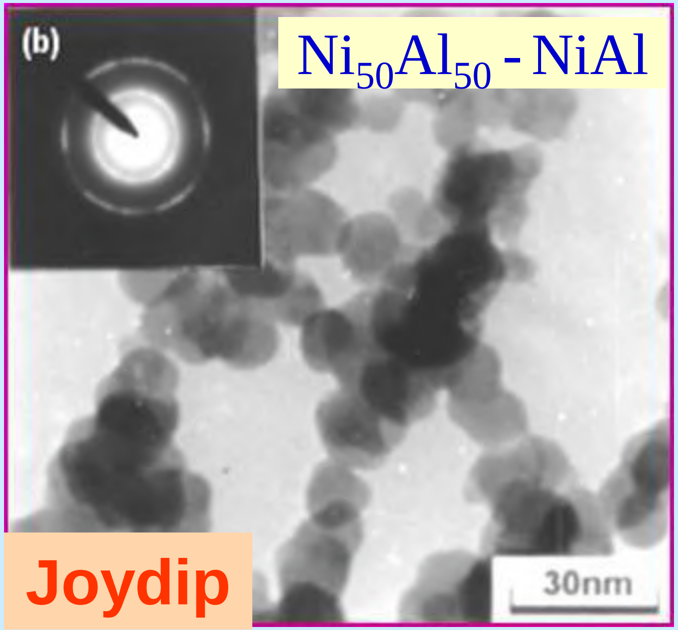


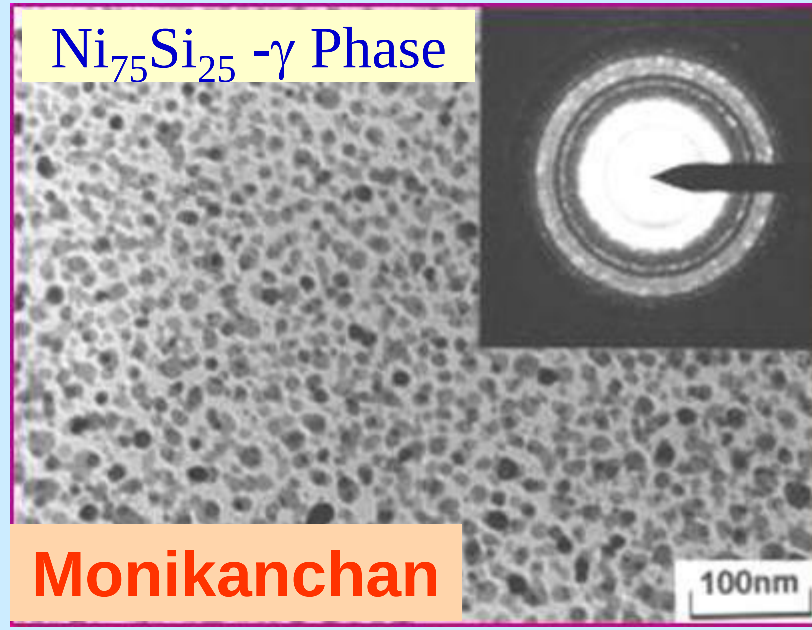
Mechanical Alloying

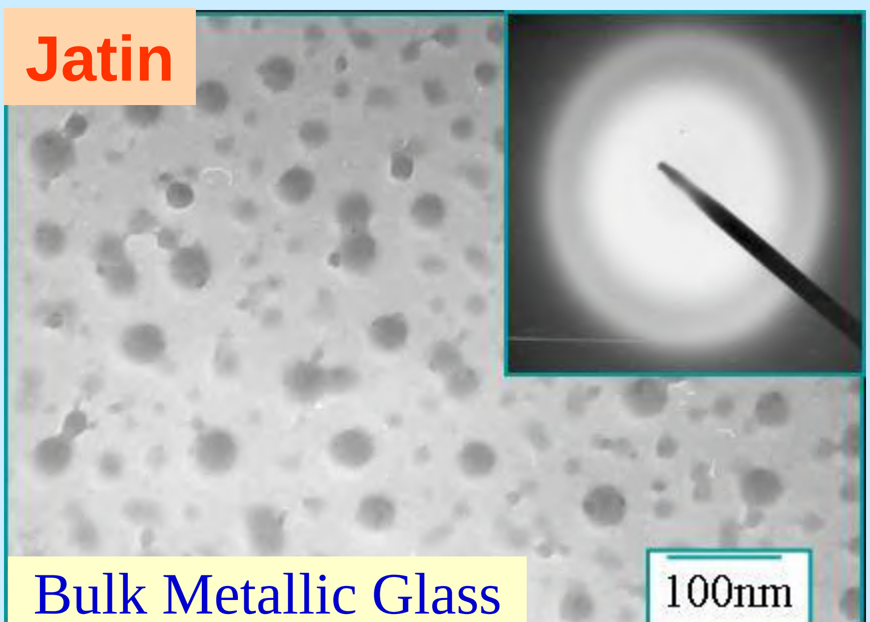


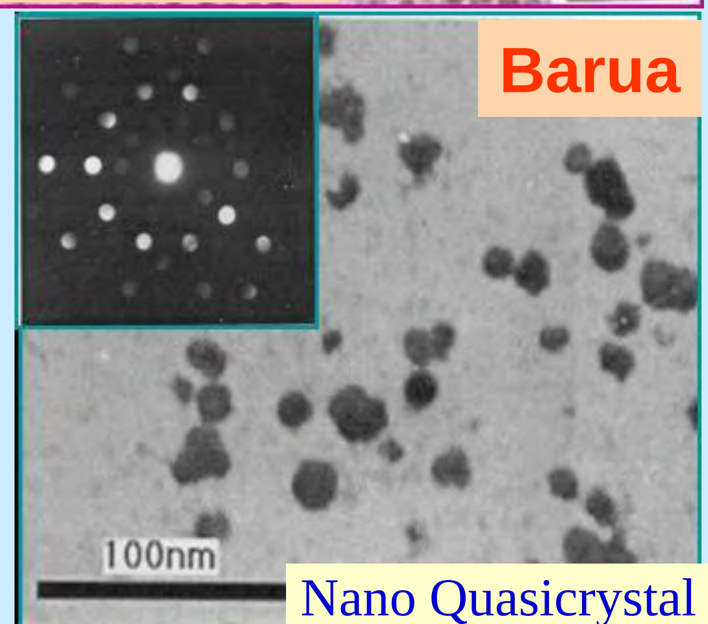
- Deformation
- Fracture
- Cold Welding

Nanocrystalline Phases by High Energy Ball Milling





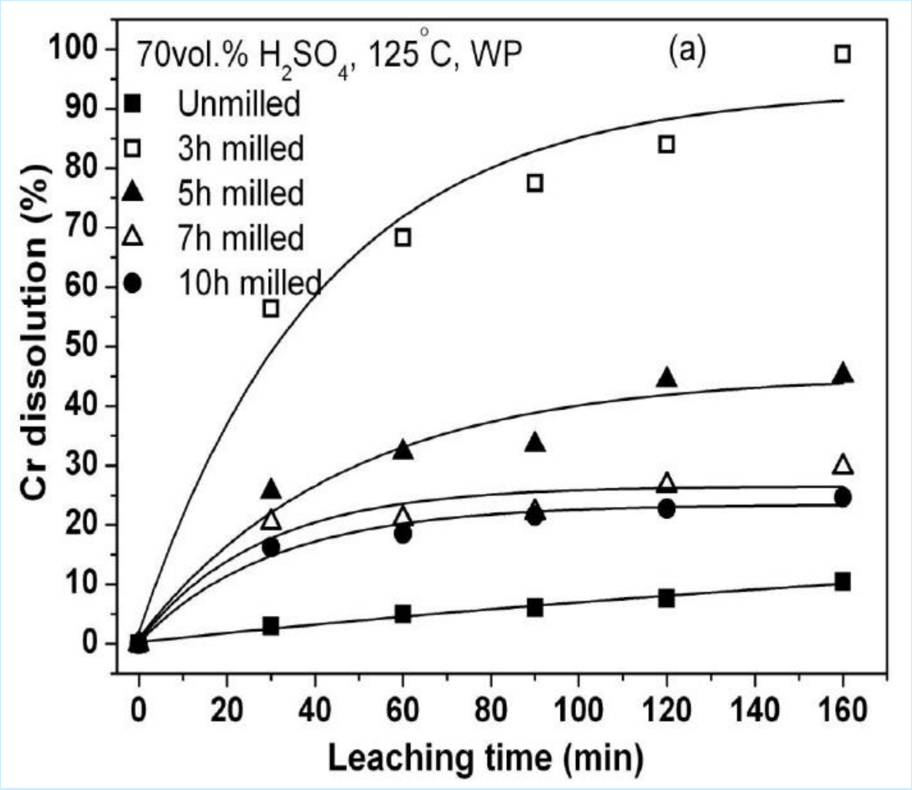


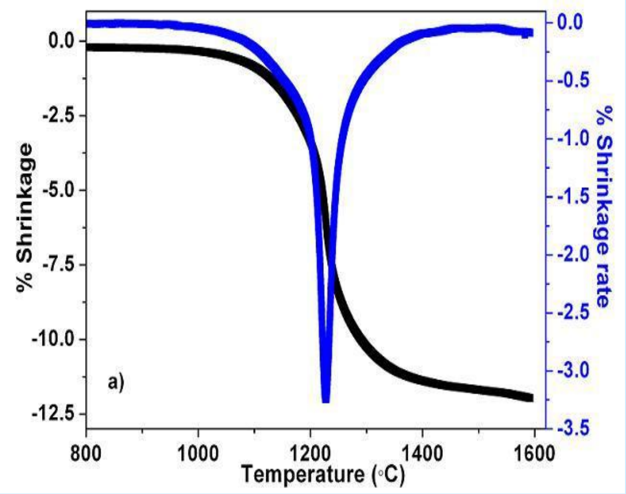


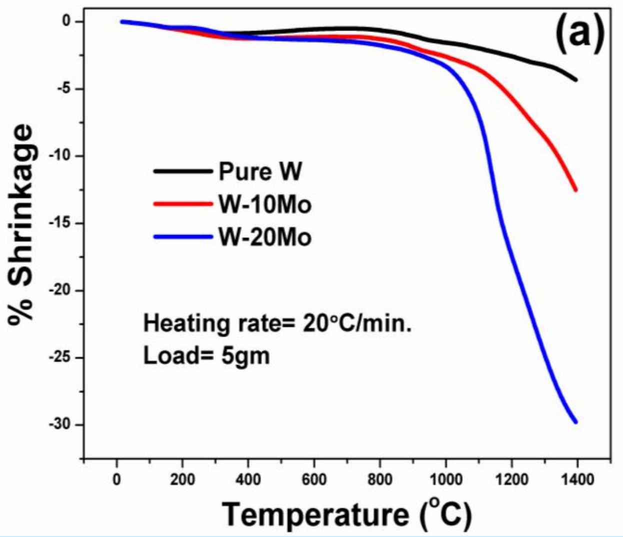
Nano in Extractive Metallurgy

Sintering of Nano Tungsten

%Cr recovery







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

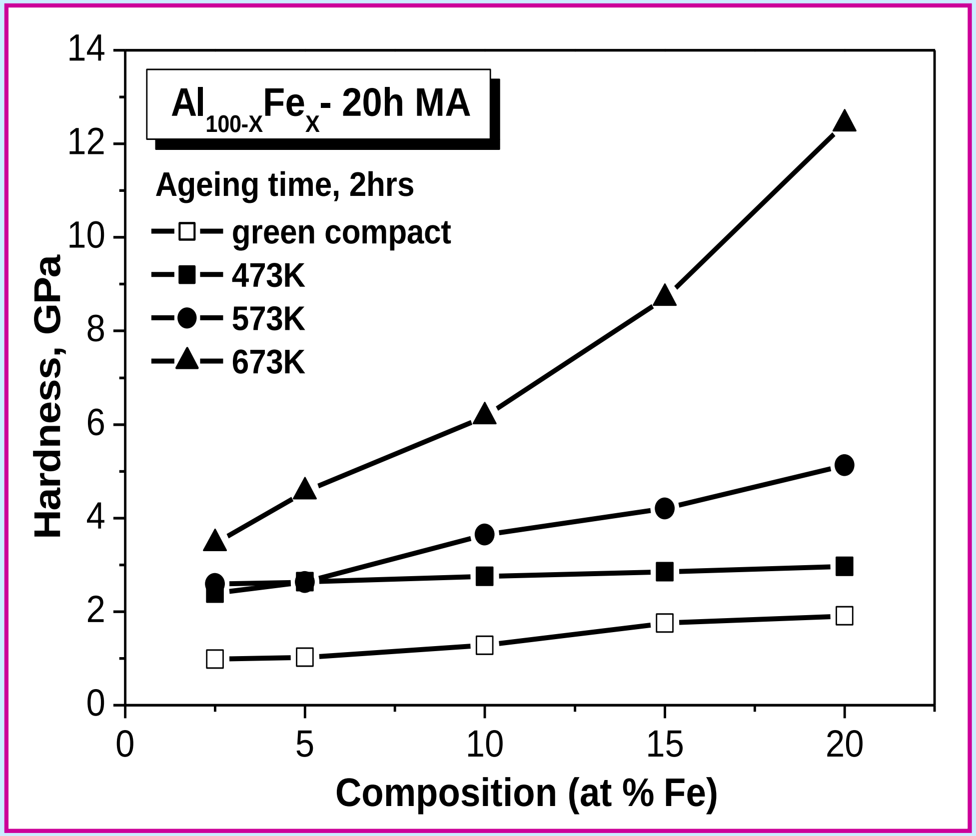
Alamelu

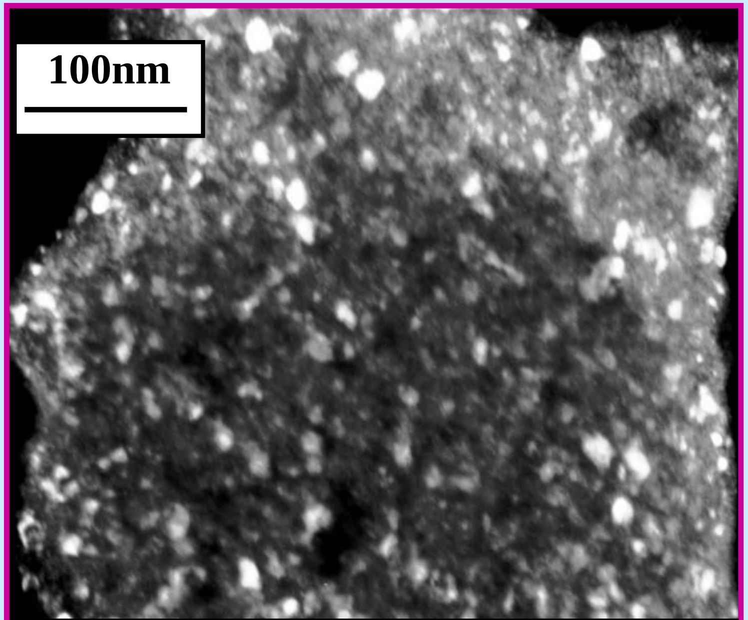
Ajeet

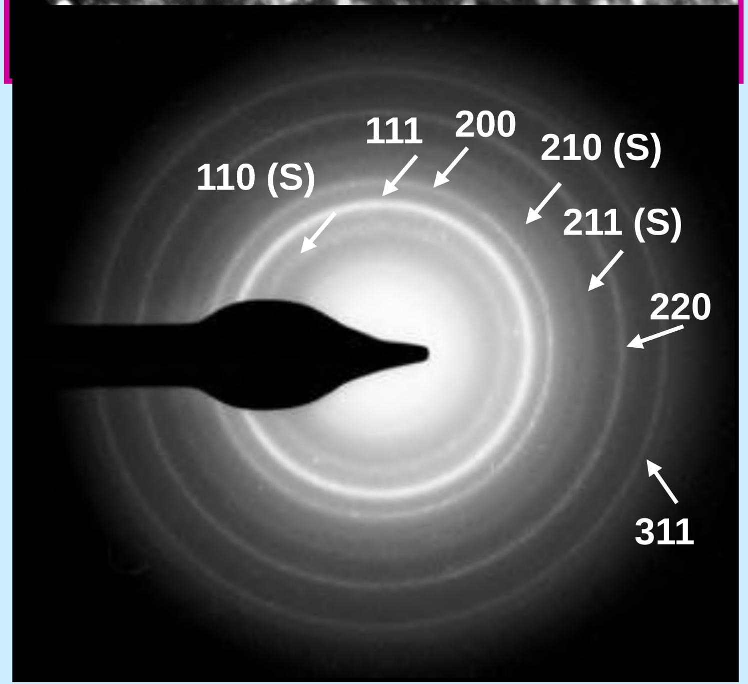
Breakthrough

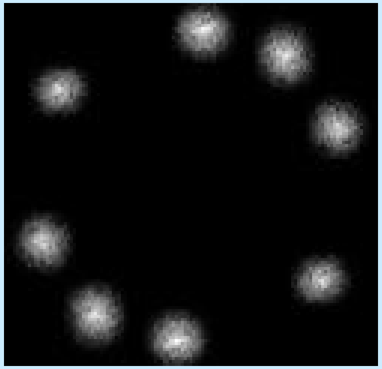
99% densification at 1600^0C

Exceptionally Strong In-situ Nanocomposites





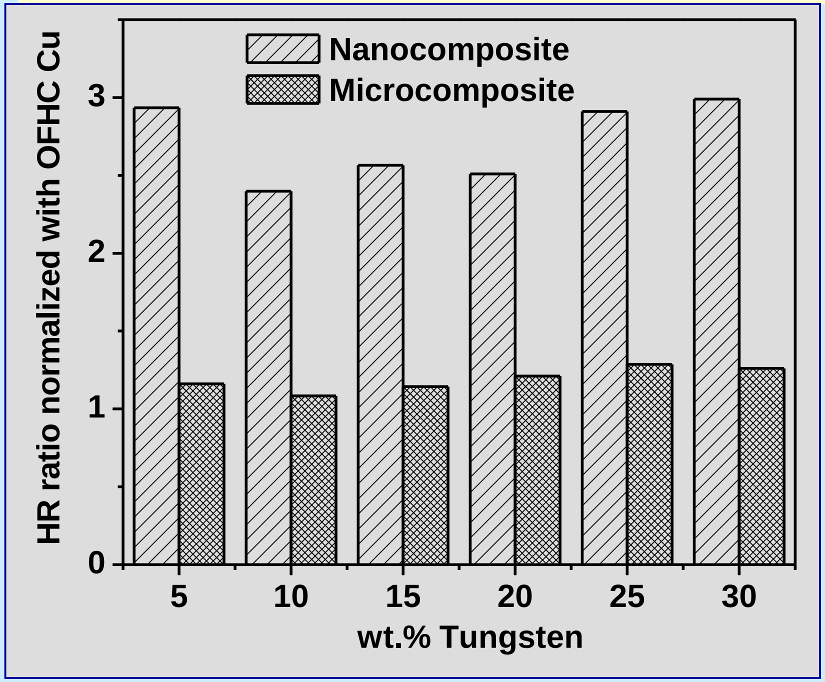




NanoQC phase

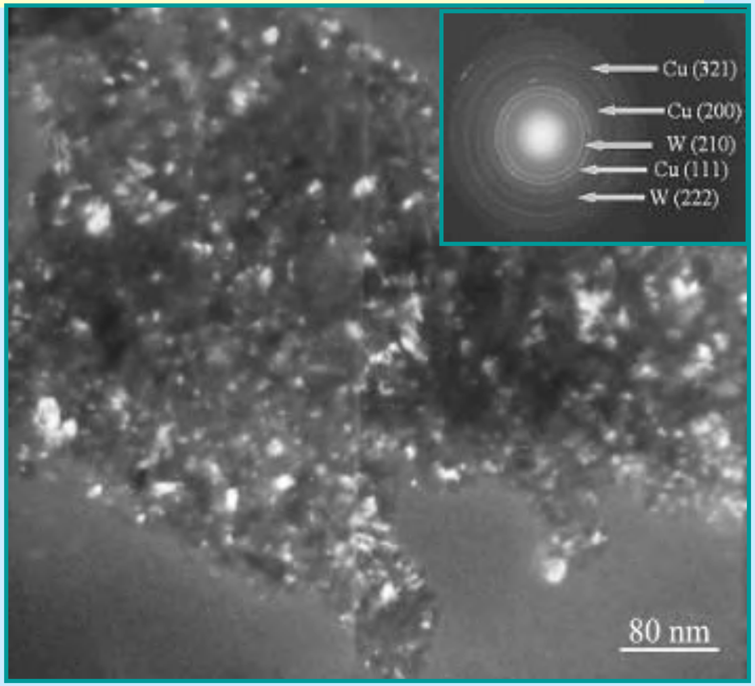
Sashank

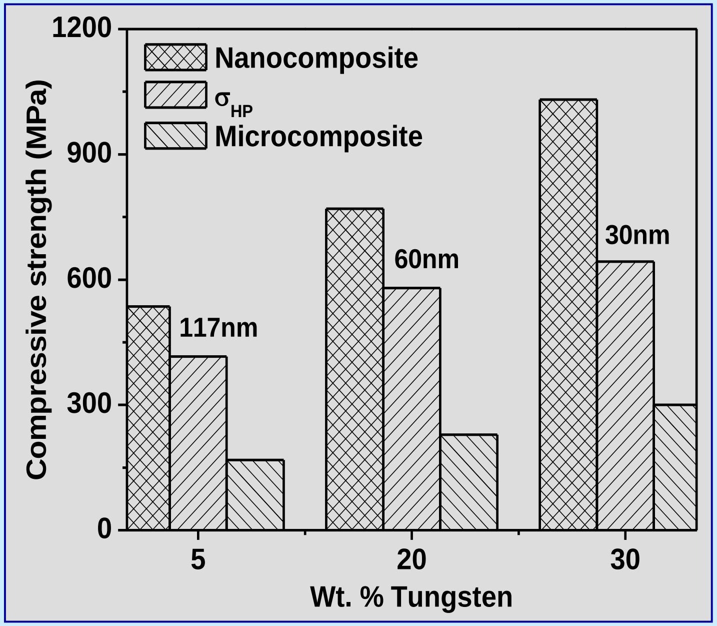
High Strength Conducting Cu Based Nanocomposites



Venu

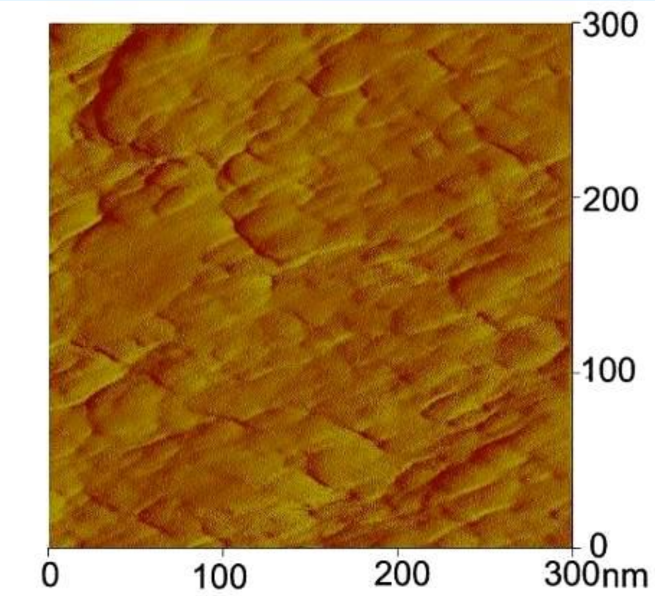
Cu-W





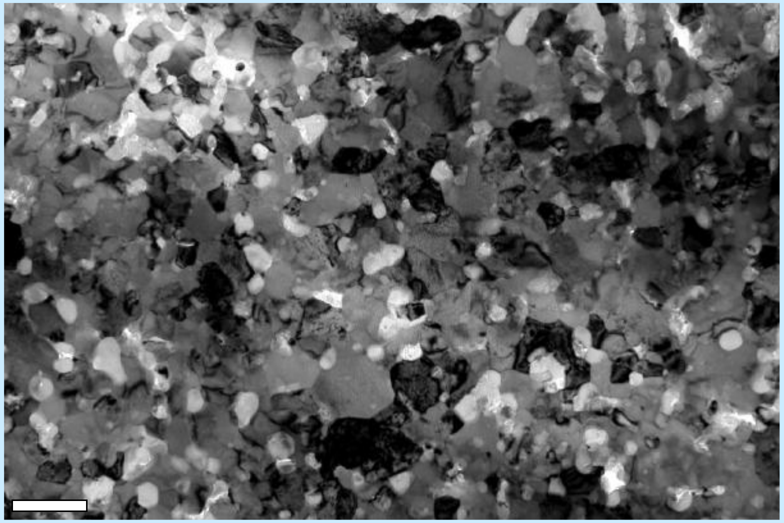
Cu-20%Ta at 500^oC

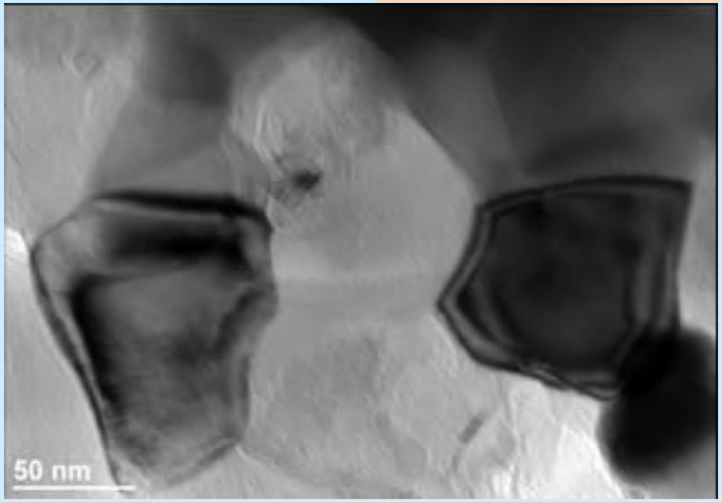
Crompton Greaves

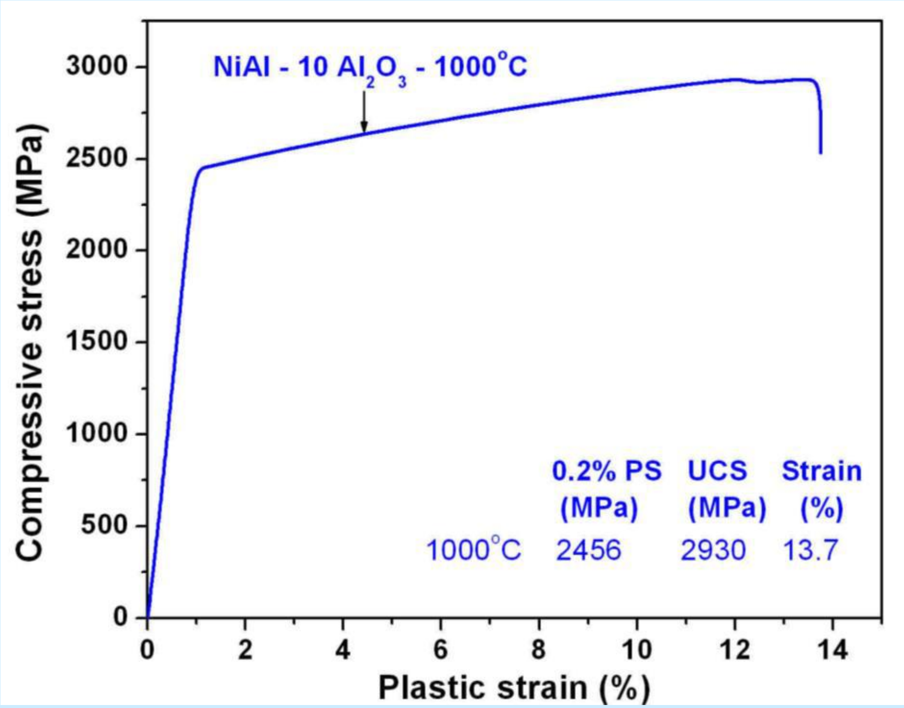


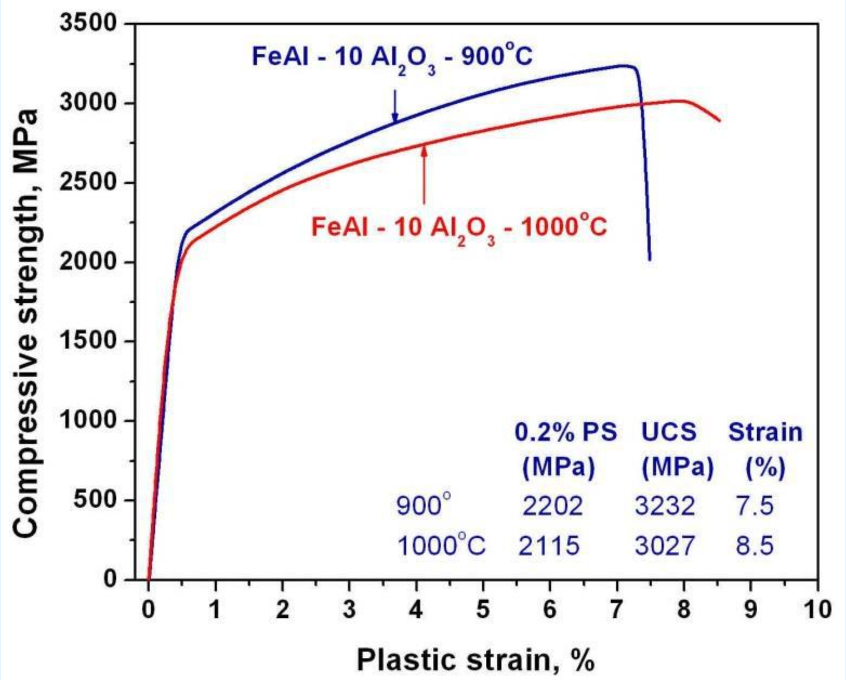
NiAl and FeAl – 10 Al_2O_3 Nanocomposites

Udhayabanu

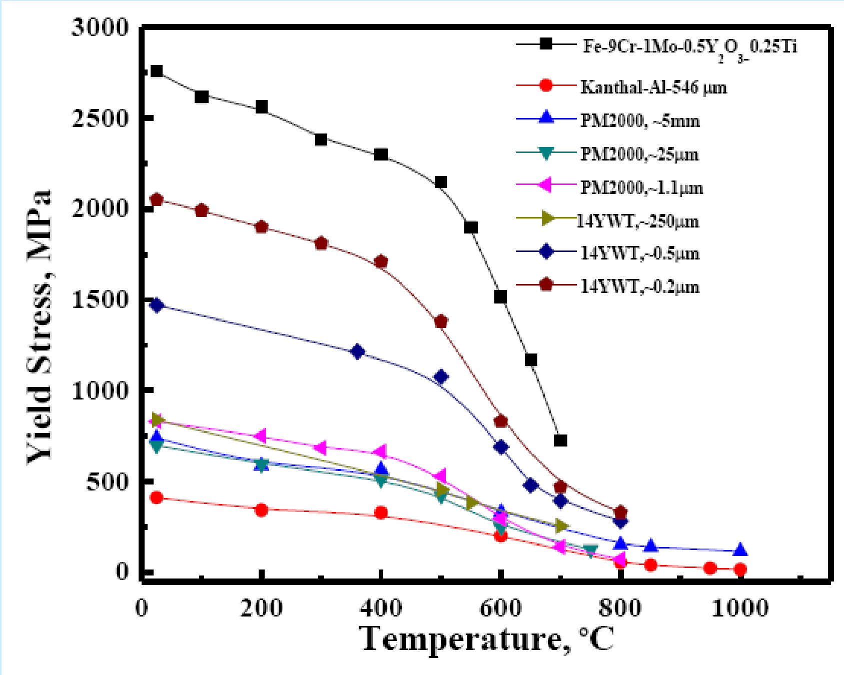


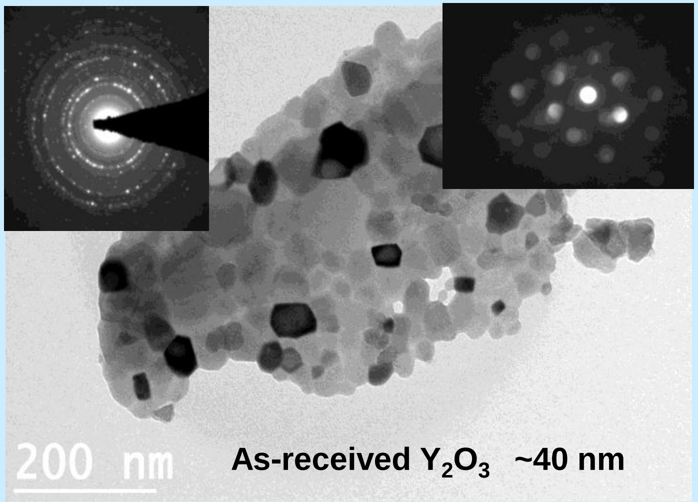


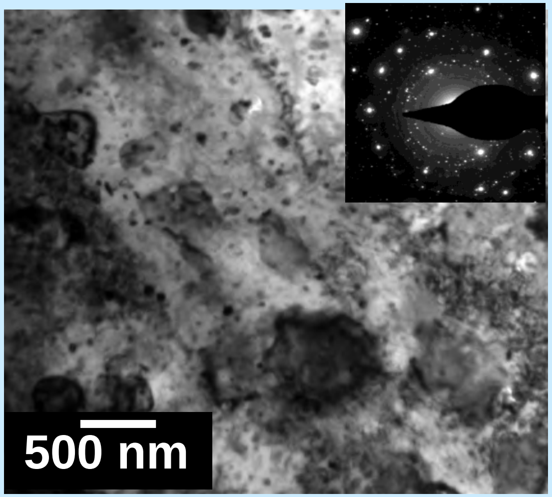


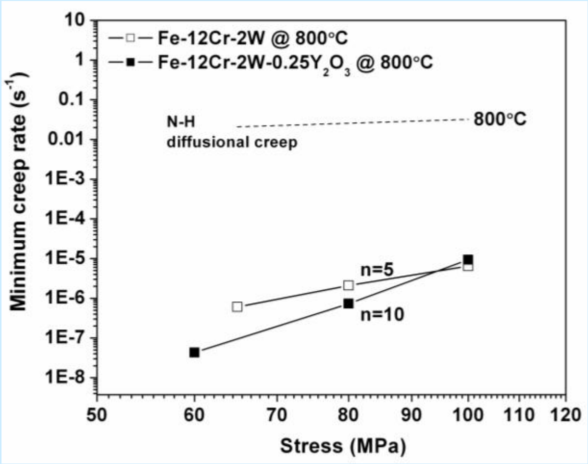


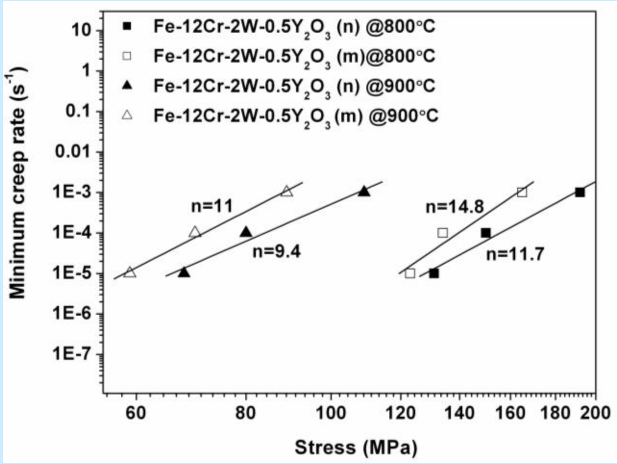
ODS Steels for Fast Breeder Nuclear Reactors









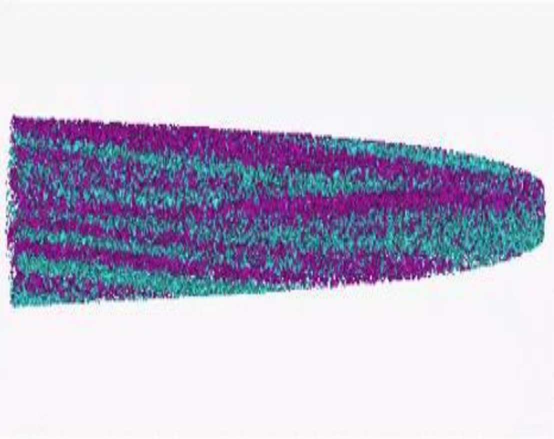


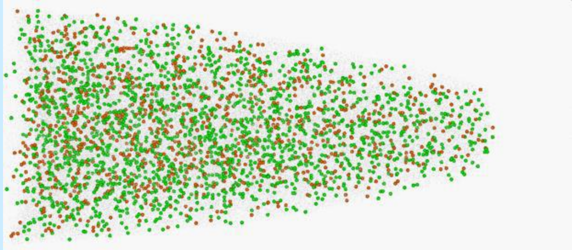
Fe-9Cr-1Mo-0.5Y_2O_3

IGCAR, Kalpakkam

Karthikeyan

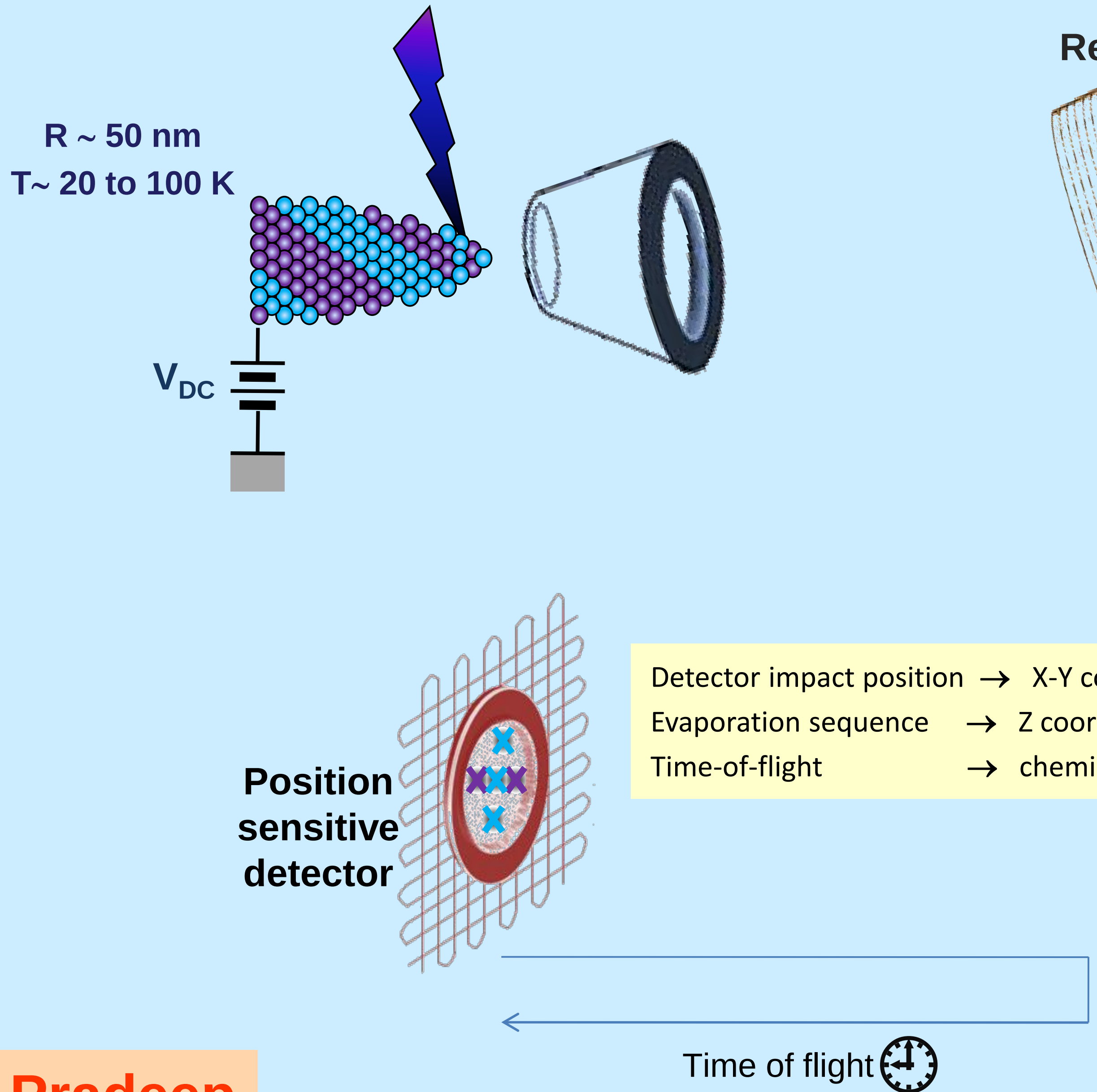
Local Electrode Atom Probe





5000X XR (Reflectron system)

Atom Probe Tomography Principle



Ion sequence:

X_1, Y_1, ToF_1

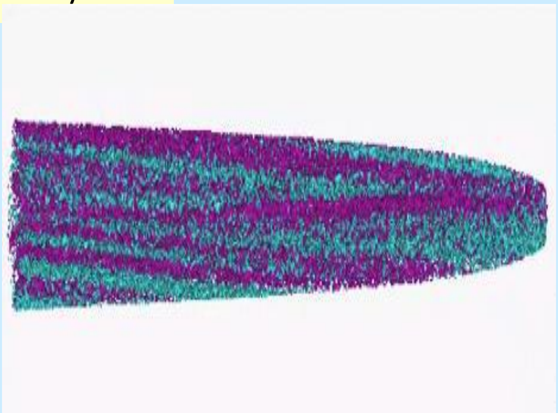
X_2, Y_2, ToF_2

X_3, Y_3, ToF_3

X_4, Y_4, ToF_4

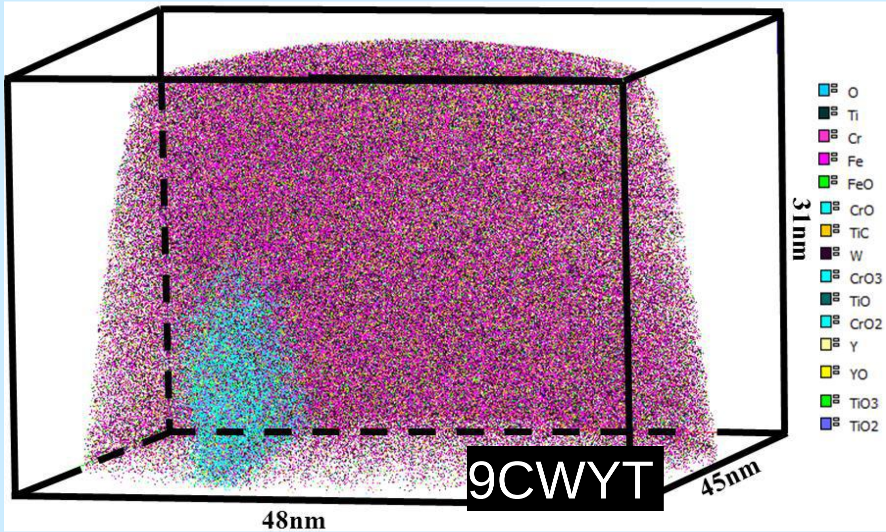
X_5, Y_5, ToF_5

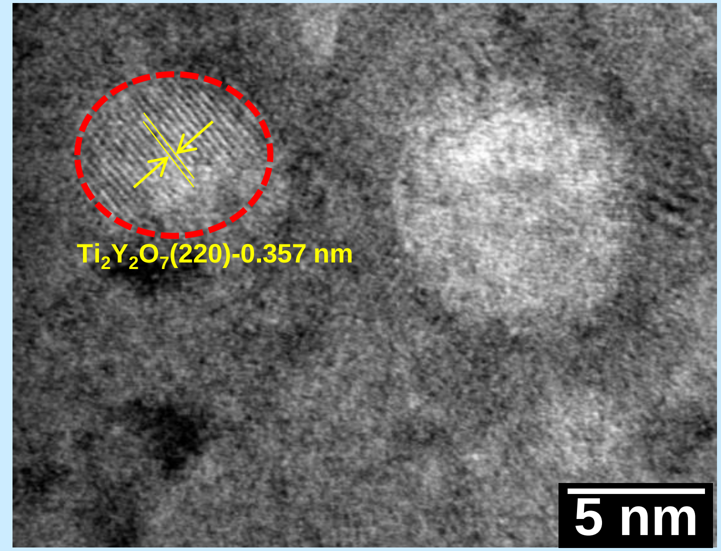
Detector impact position	→	X-Y coordinates
Evaporation sequence	→	Z coordinate
Time-of-flight	→	chemical identity

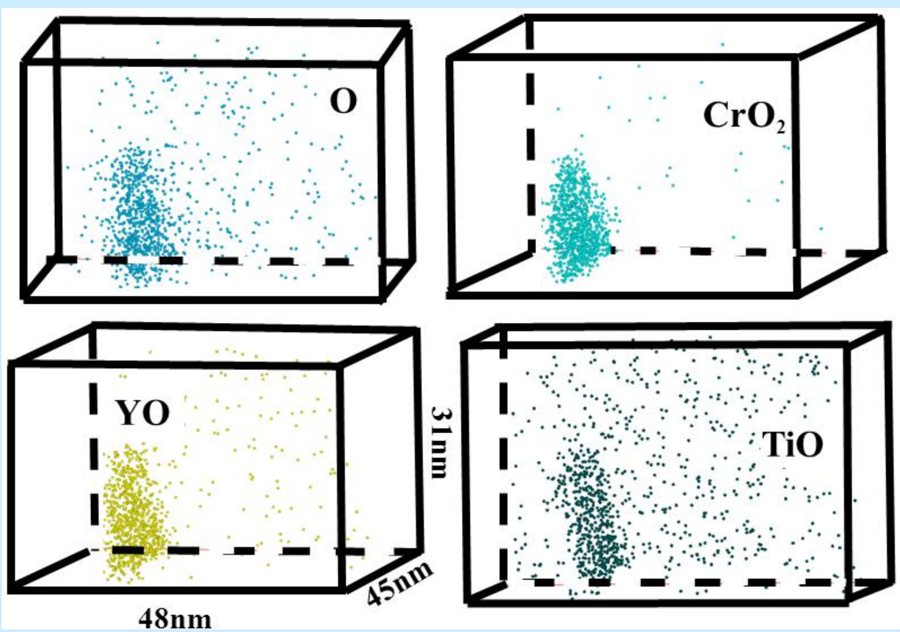


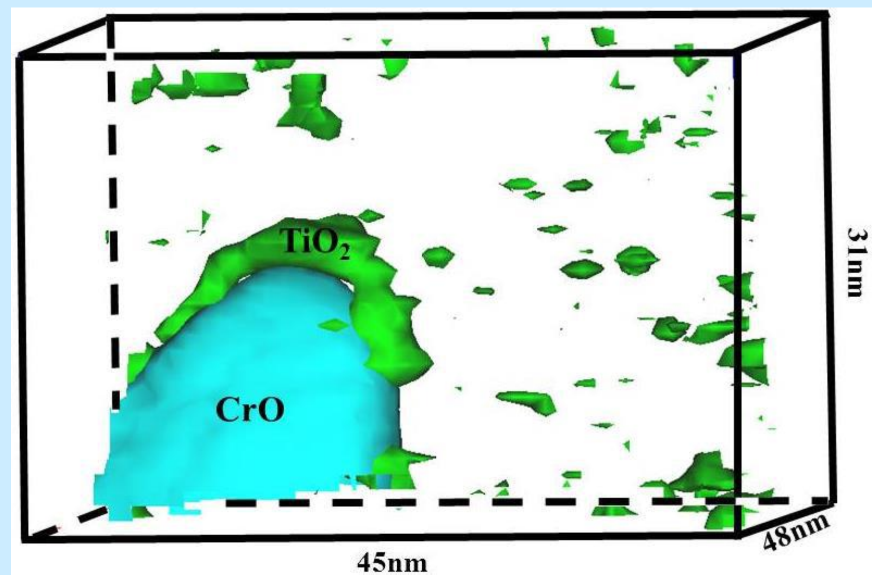
Pradeep

APT of Bulk Nanostructured Ferritic ODS Alloys



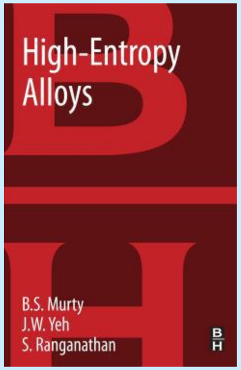






Krishna Rajan, Iowa State Univ.

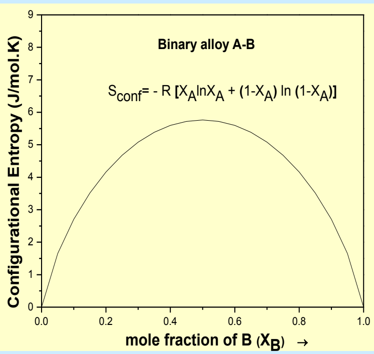
Karthikeyan



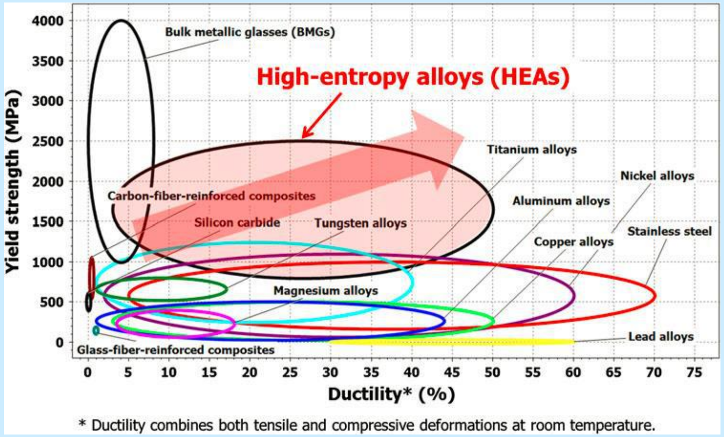
High Entropy Alloys

$$\Delta S_{conf} = k_B \ln w = -R \sum X_i \ln X_i$$

$$\Delta S_{conf\,max} = R \ln N$$



No. of Component	X_i	$S = -R \sum X_i \ln X_i$ J mol^{-1} 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



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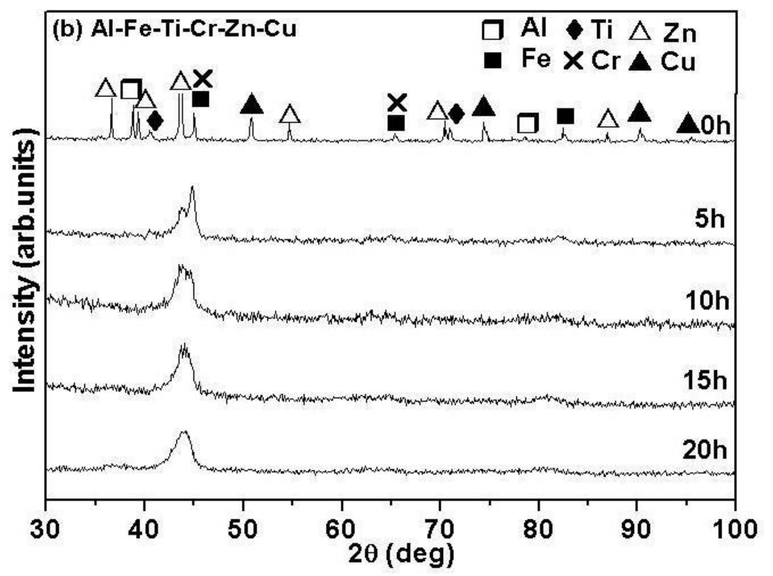
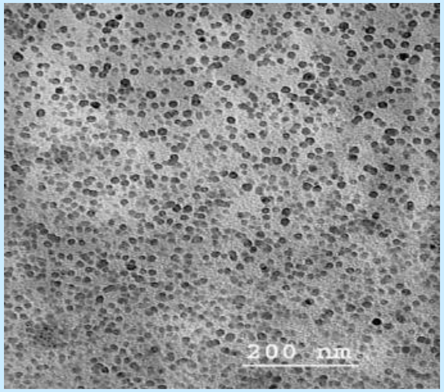
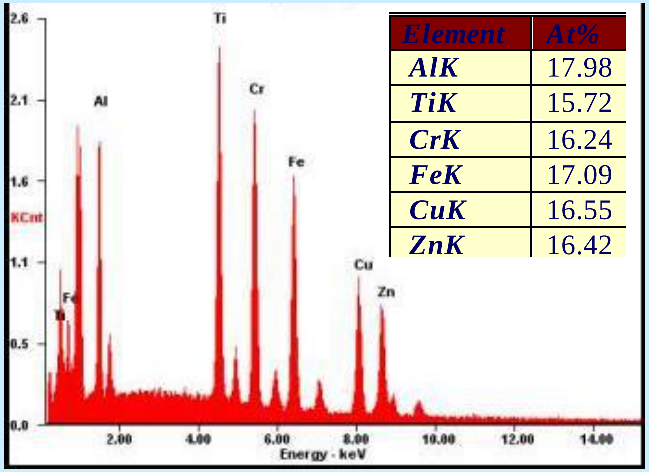
- S. Varalakshmi *et al.* J. Alloys Compd., 460 (2008) 253.

Tang et al. JOM, 2013





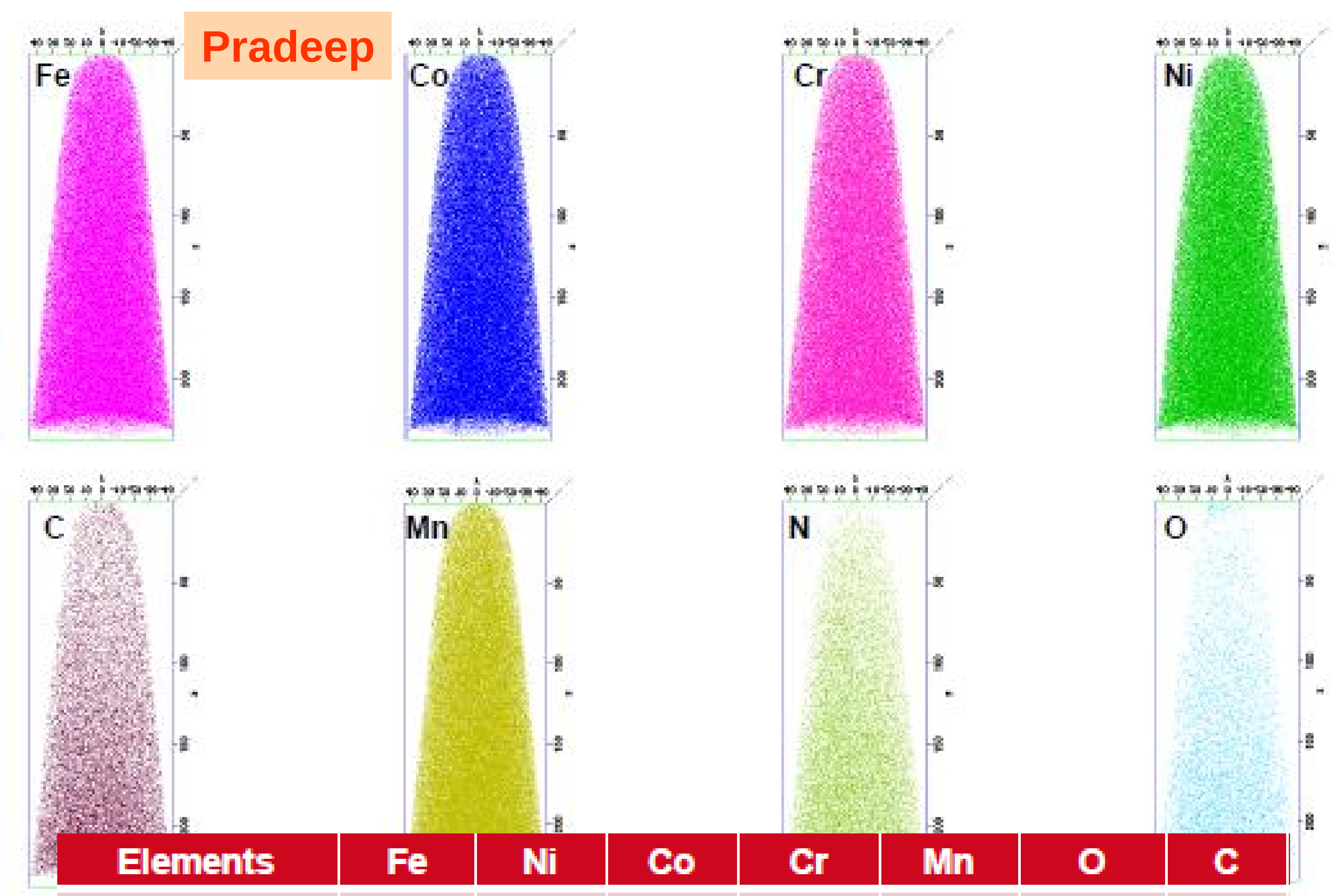
Vara



Element	At%
AlK	17.98
TiK	15.72
CrK	16.24
FeK	17.09
CuK	16.55
ZnK	16.42

Uniform elemental distribution in CoCrFeMnNi HEA

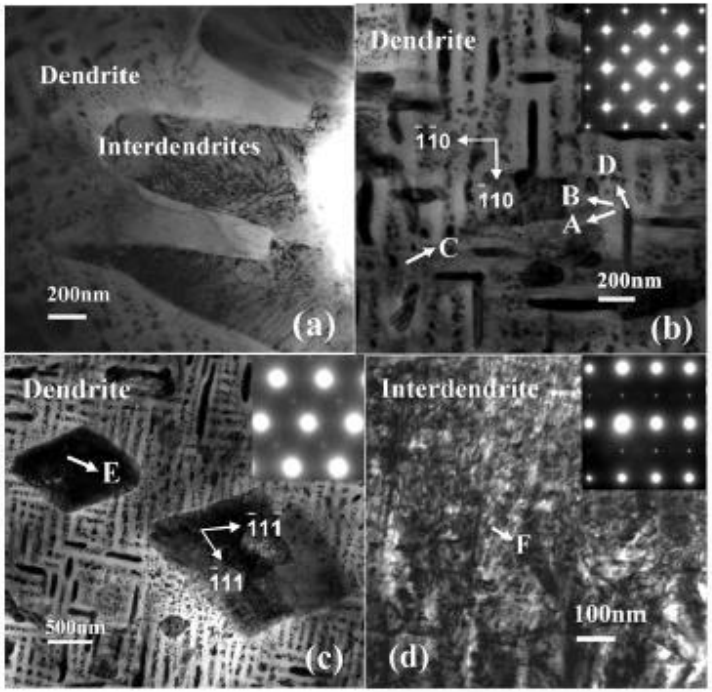
Pradeep



Elements	Fe	Ni	Co	Cr	Mn	O	C
Concentration (at.%)	20.92	19.85	20.47	20.32	18.32	0.002	0.017

AlCoCrCuFeNi Cast HEA

Sheela &
John Banhart
Helmoltz
Zentrum, Berlin



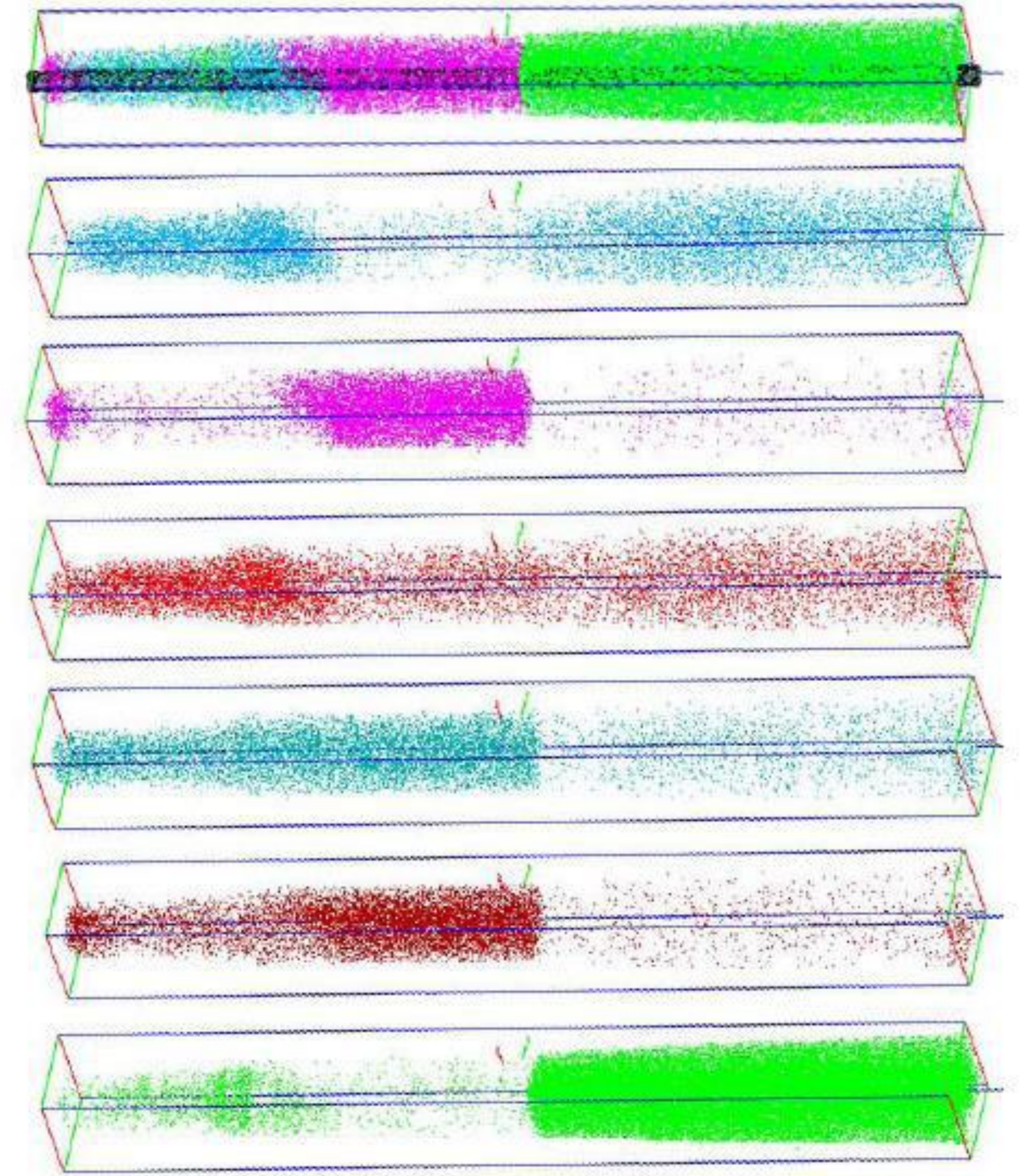
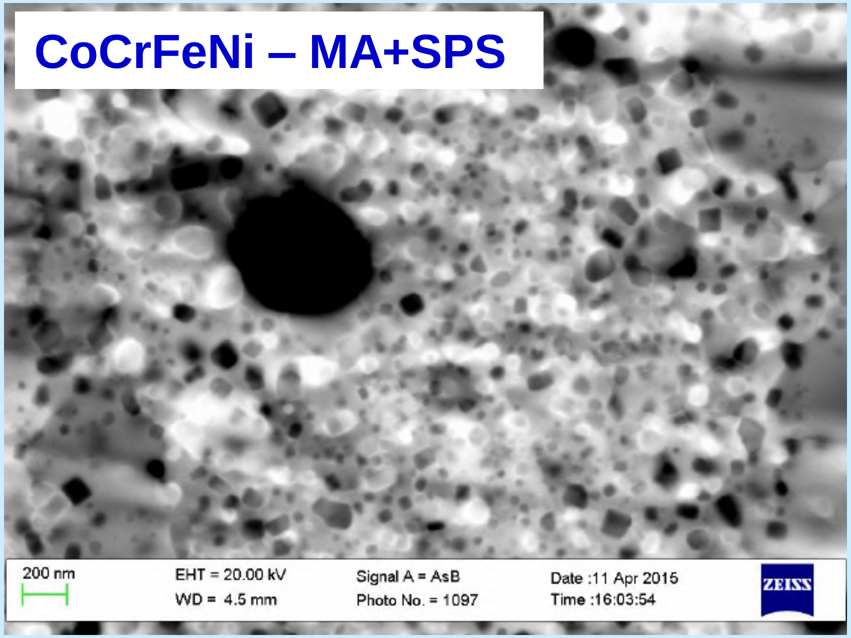
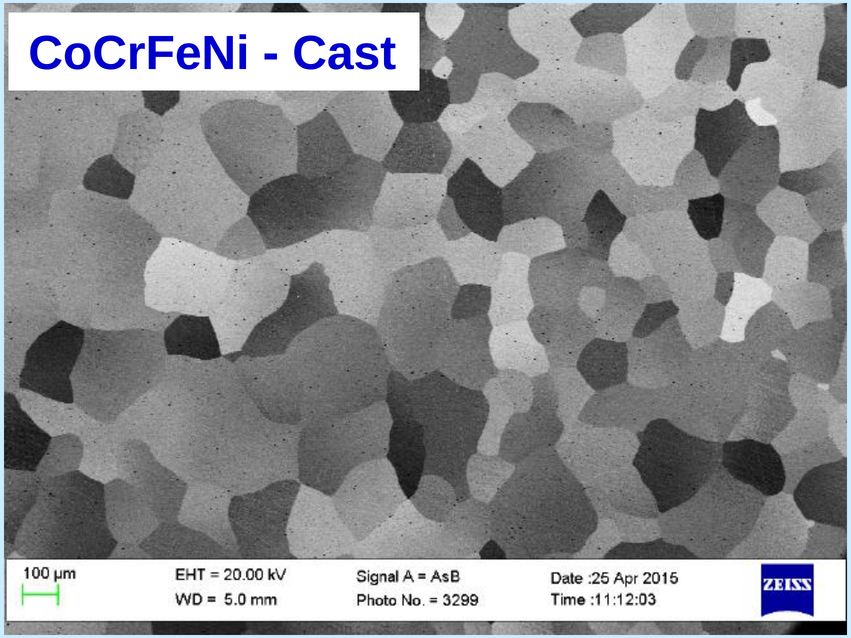


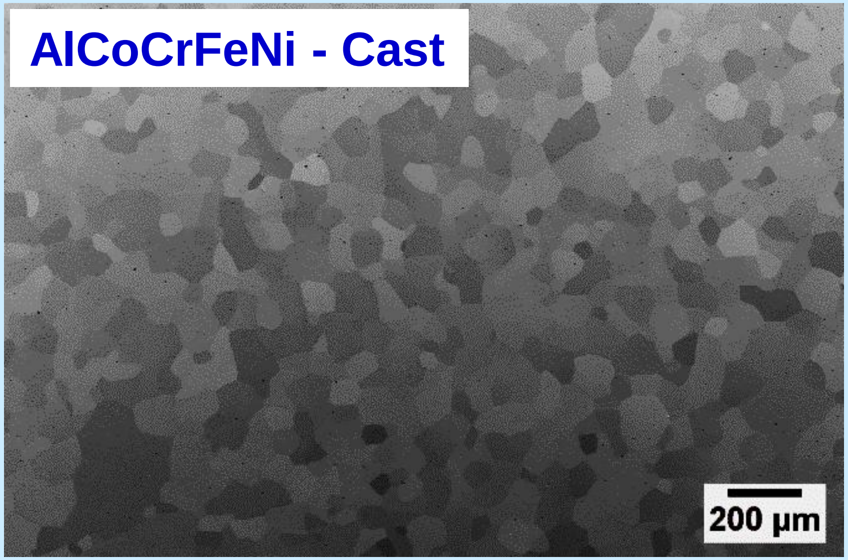
Fig. 4 Three dimensional reconstruction of Al, Cr, Ni, Co, Fe and Cu atom positions in an analyzed volume $9.5x9.5x93nm^3$ of as-cast AlCuCoCrNiFe high entropy alloy. The symbols for different atoms are Al: ● , Ni: ●, Cr: ●, Co: ● , Fe: ● and Cu: ●

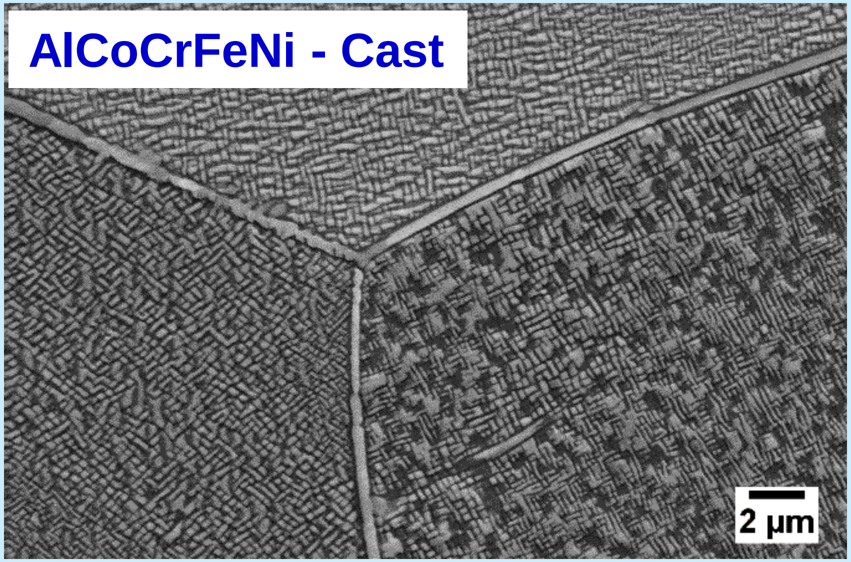
CoCrFeNi: MASPS vs. Casting

Rahul, Dan Fabijanic,
Deakin University

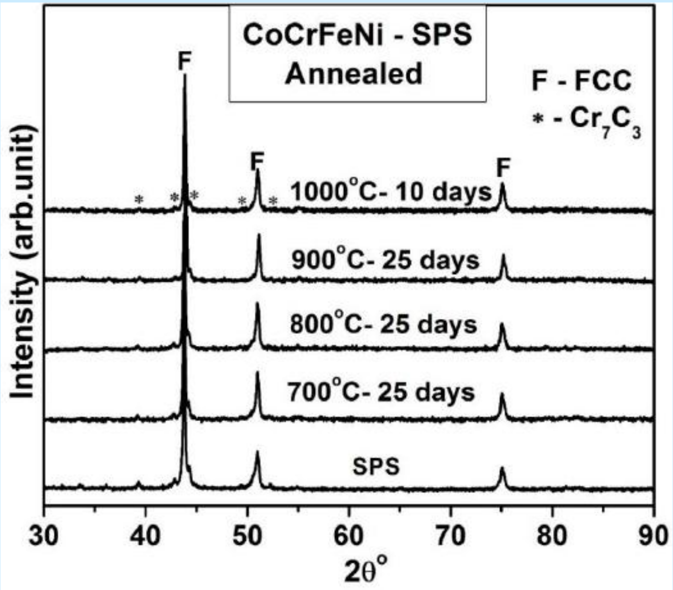


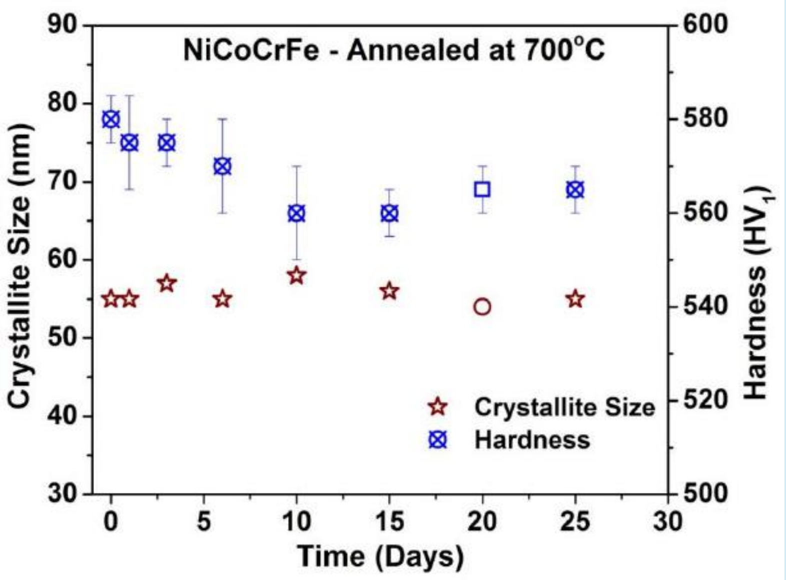


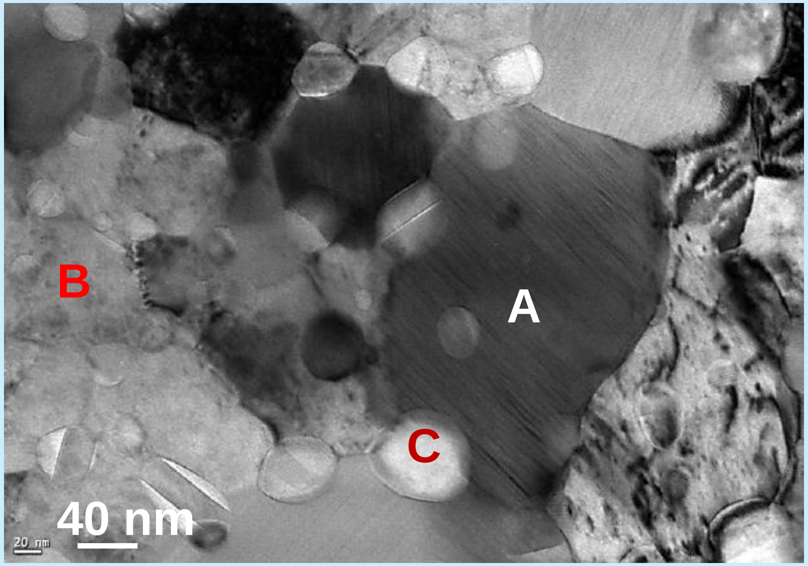


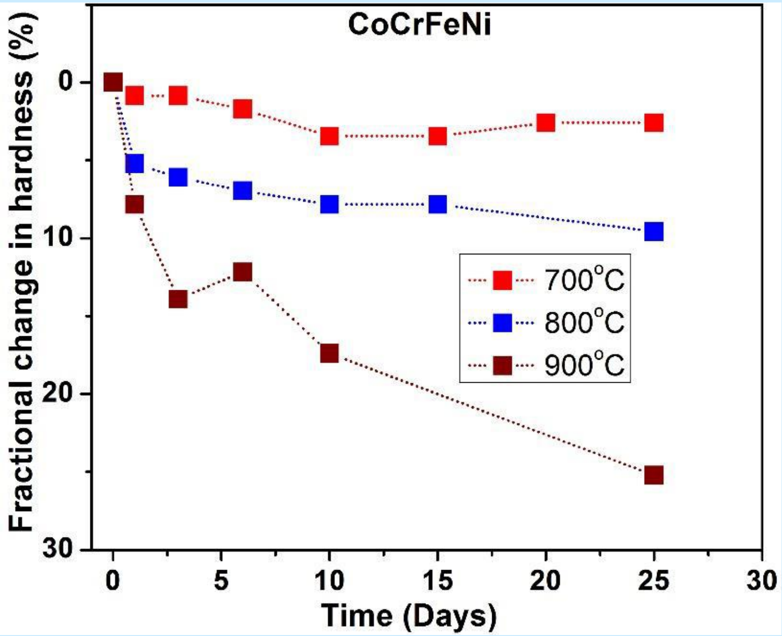


Thermal stability of CoCrFeNi: SPS & Annealing





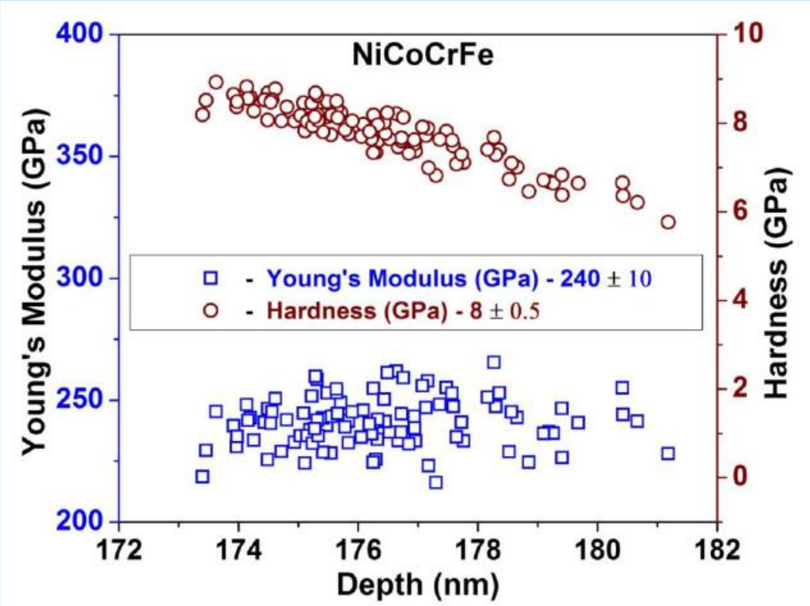


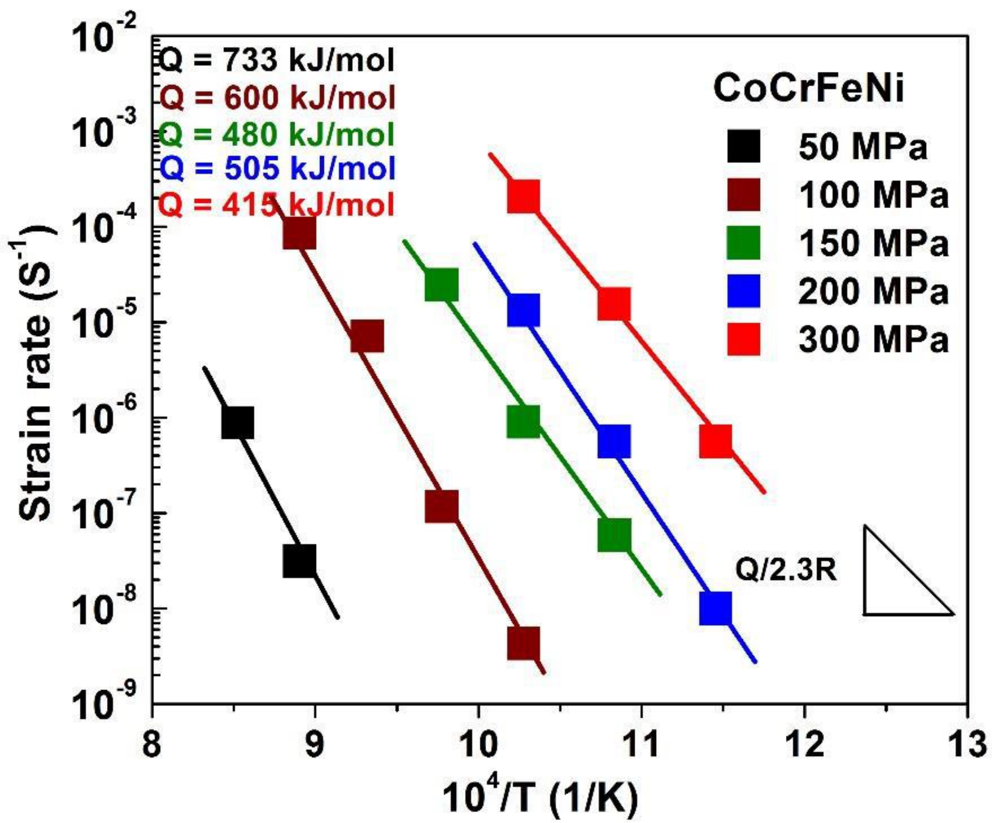


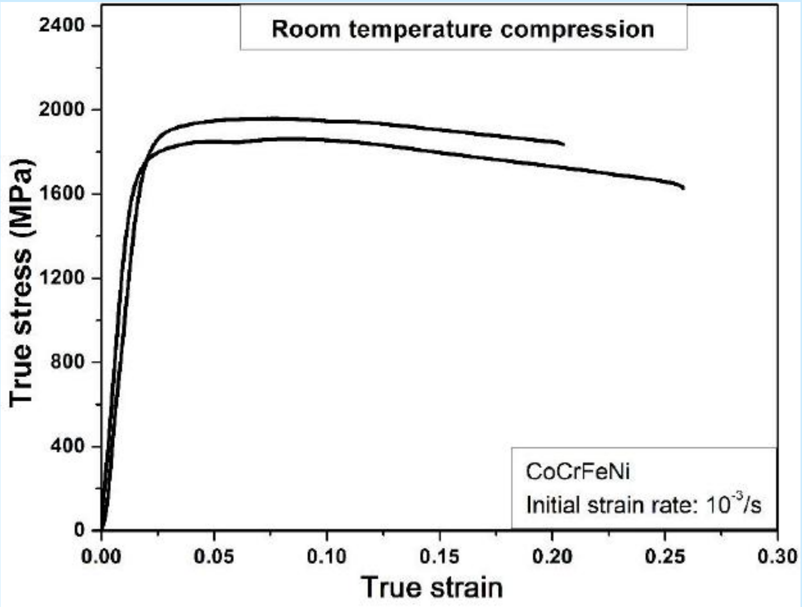
Praveen & Ravi Sankar

Mechanical Properties

Praveen &
Ravi Sankar

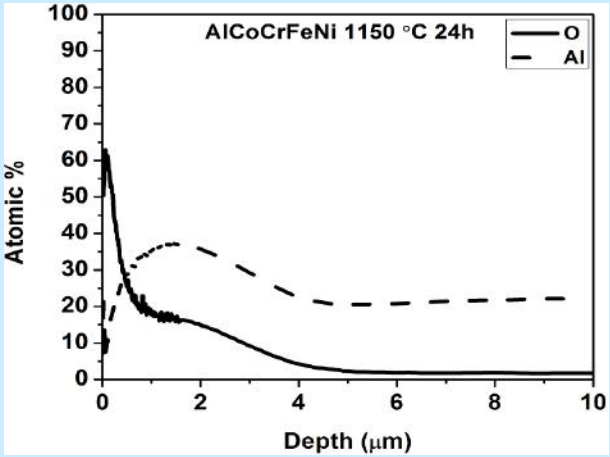


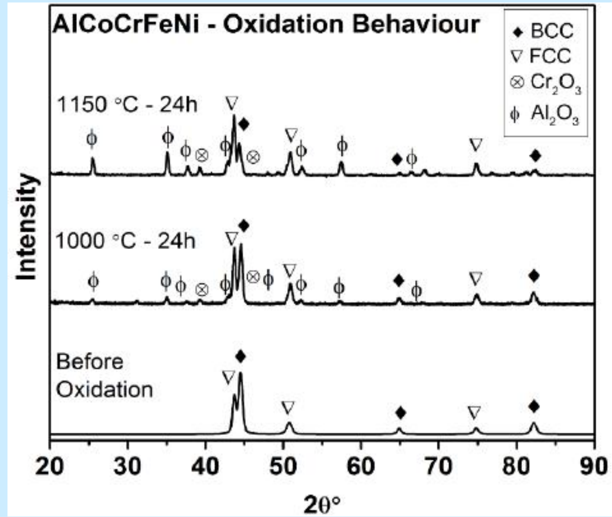


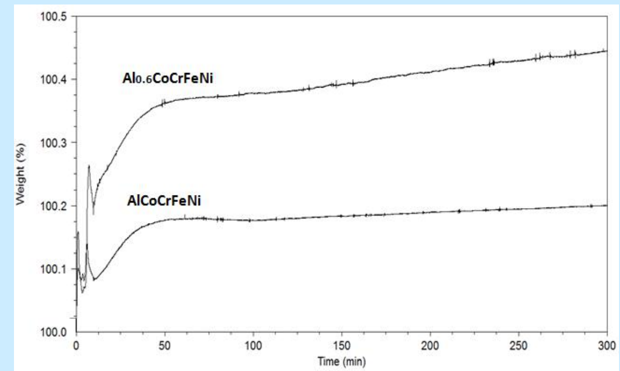


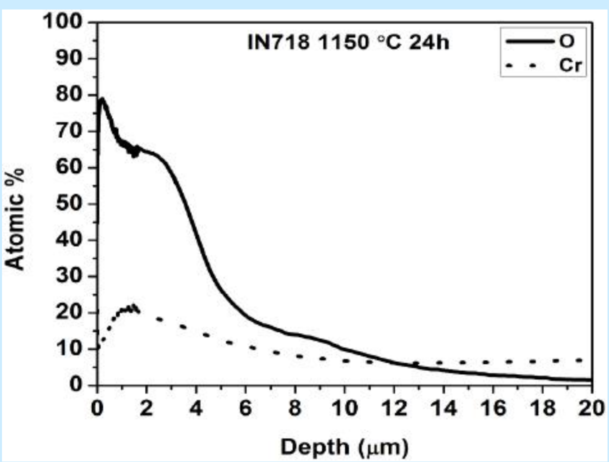
Oxidation behvaiour of AlCoCrFeNi HEA vs. IN718

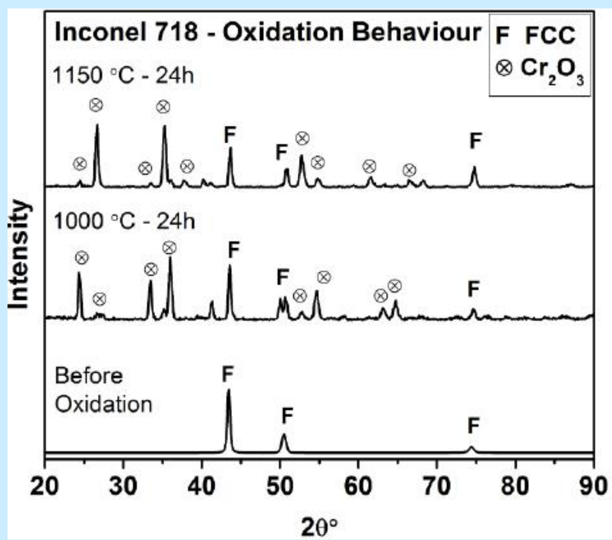
Rahul,
Dan Fabijanic
Peter Hodgeson,
Deakin University

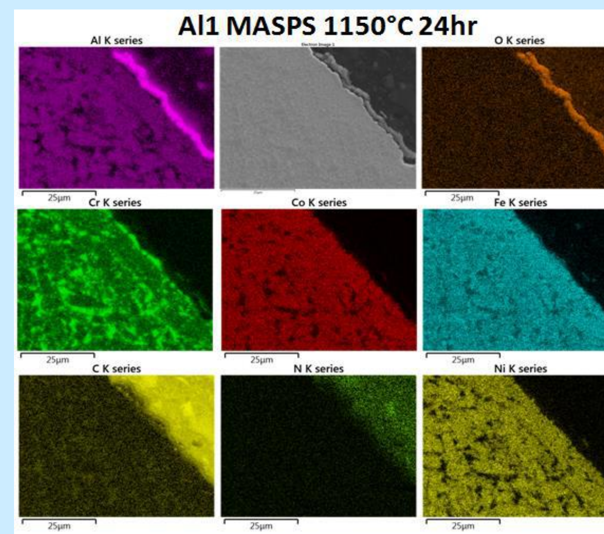










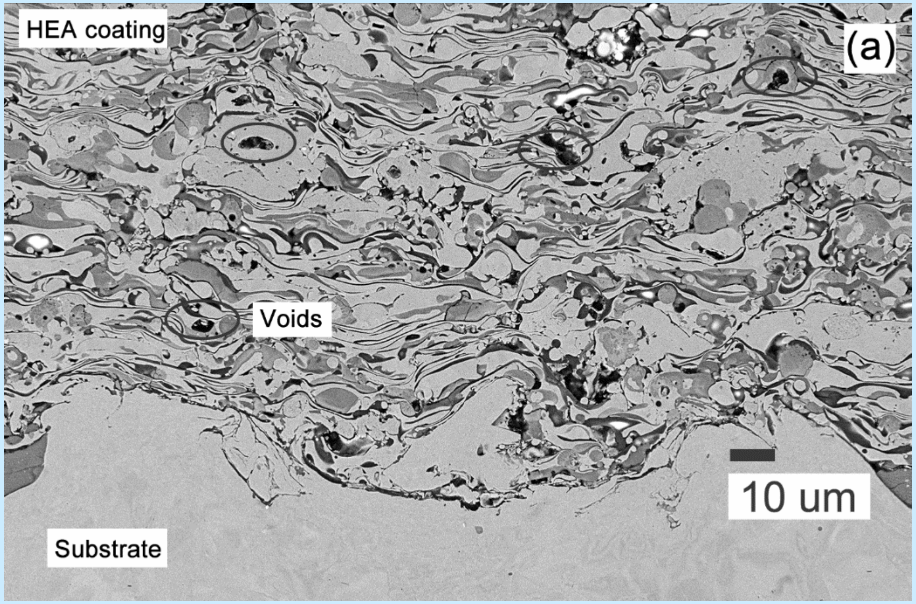


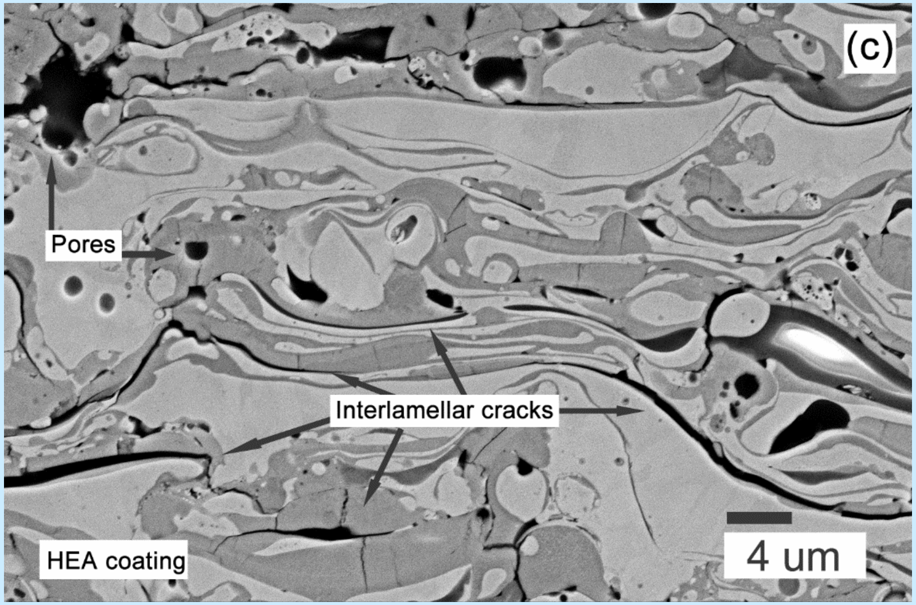
Plasma Spraying of HEAs on Steel

- $HV_{0.3kgf}$ of AlCoCrFeNi Coating: 4.13 ± 0.43 GPa
- $HV_{0.3kgf}$ MnCoCrFeNi Coating: 4.42 ± 0.60 GPa

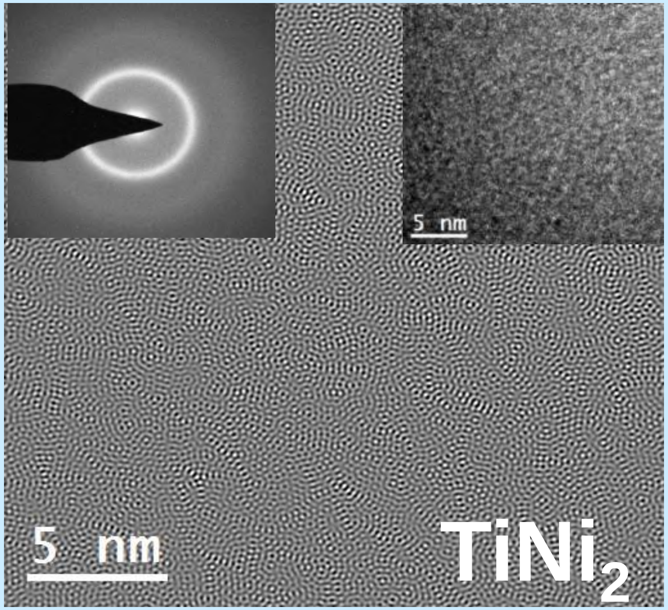
- $HV_{0.3kgf}$ of conventional plasma sprayed $NiCrAlCoY_2O_3$ bond coat is 2.45 GPa

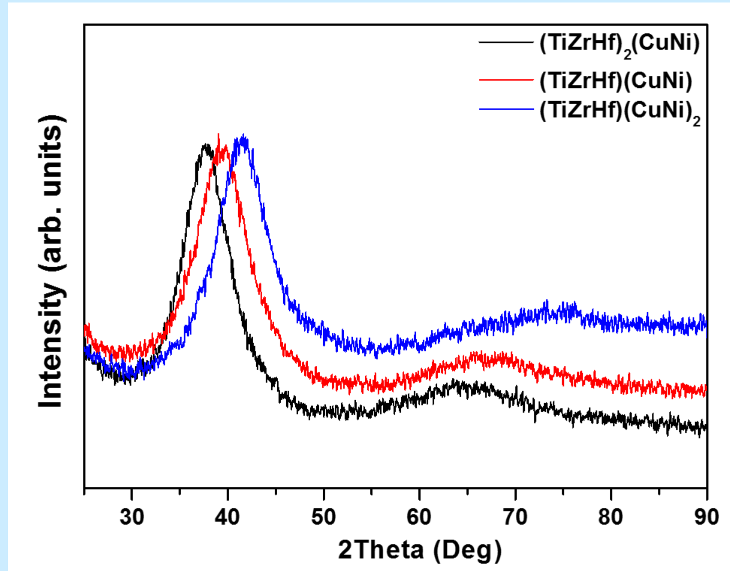
Ameey Anupam,
Ravi Sankar, *IITM* **&**
Andrew Aang,
Chris Berndt
Swinburne Univ., Melbourne



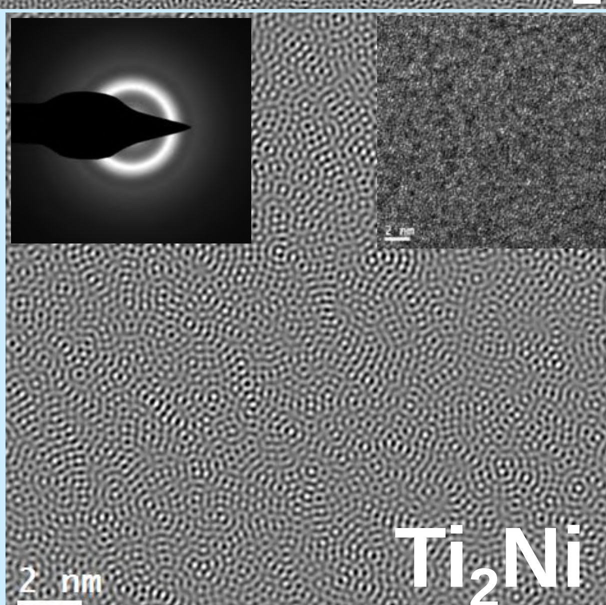


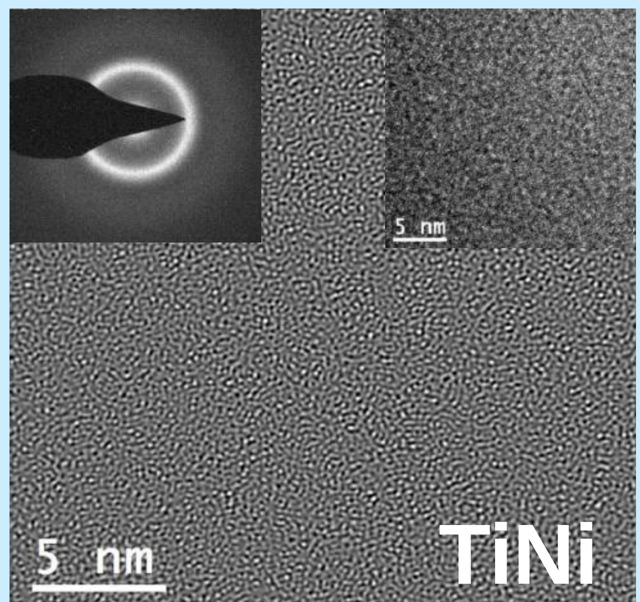
Can a binary intermetallic destabilise due to high entropy by multicomponent substitution





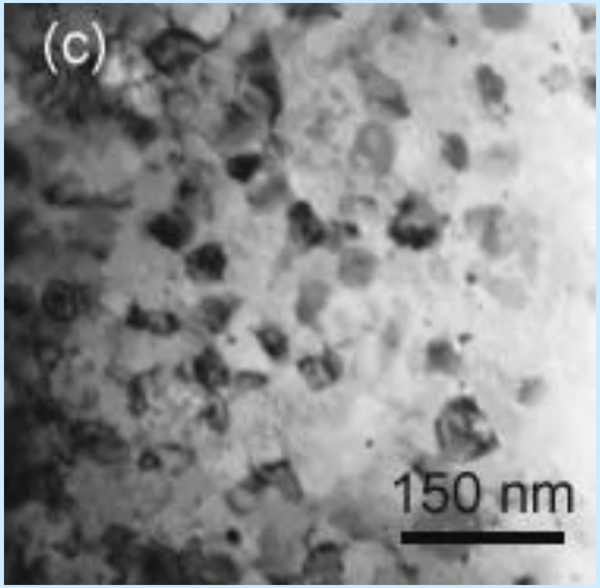
Ranganathan
IISc, Bangalore
Takeuchi & Yokoyama
IMR, Sendai

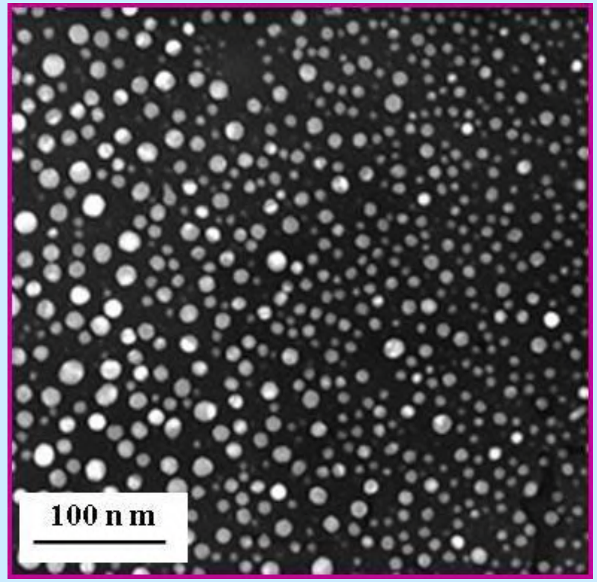


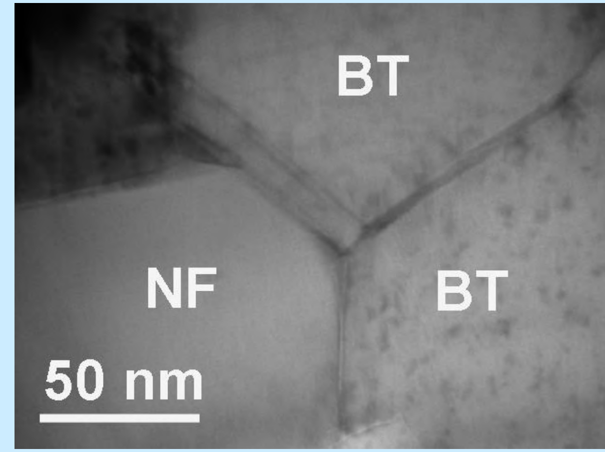


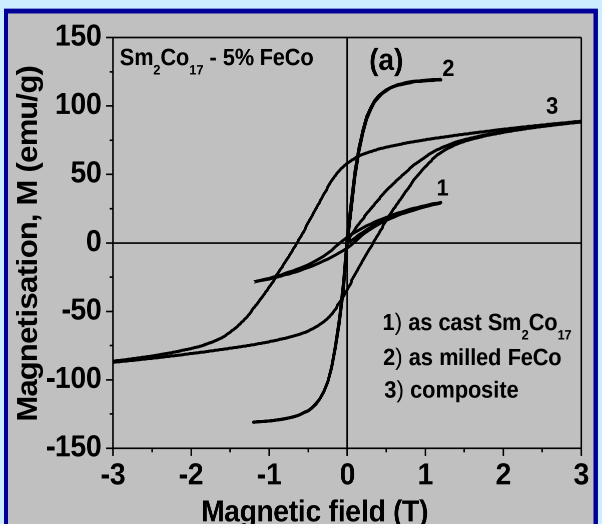
Sanjay

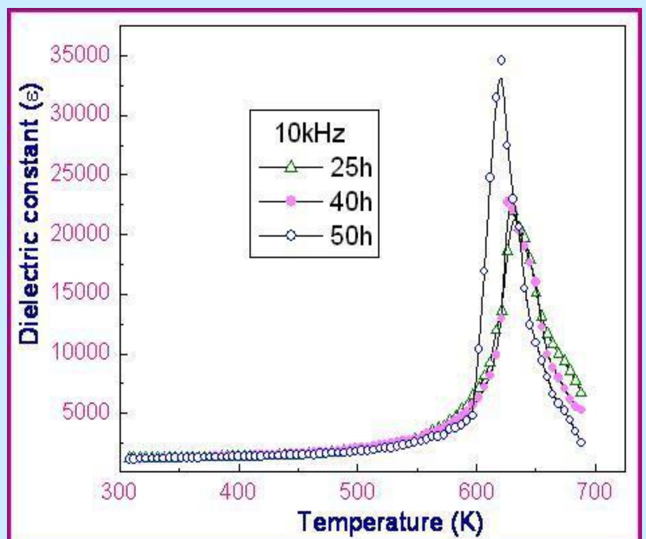
Functional Nanocomposites with Exceptional properties

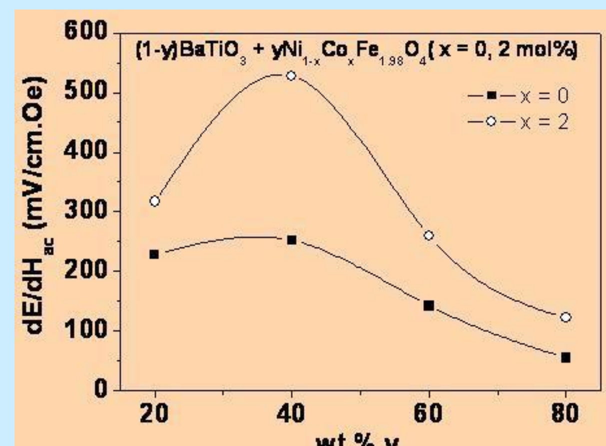












Sreenivasulu

Parashar

Sreenivasulu


Thank
You