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PR 1789/1-1

Tailored precipitation strengthened compositionally complex FeMnCoCrAl alloy

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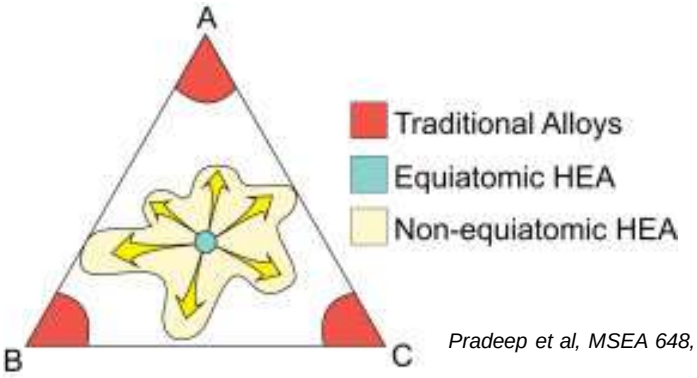
MOTIVATION

Efficient and sustainable energy generation

Ultra super critical turbines (> 750° C)

- **High temperature creep resistance**

Alstom power Ltd.



Pradeep et al, MSEA 648, 2015

- **Ni, Co based superalloys**
- **Ferritic based superalloys (Fe, Al)**
- **High entropy alloys = ?**

- ❑ **Single and dual phase microstructure (stable > 750° C)**
- ❑ **Controlled B2, $L2_1$ precipitation**
- ❑ **Low density (Al)**

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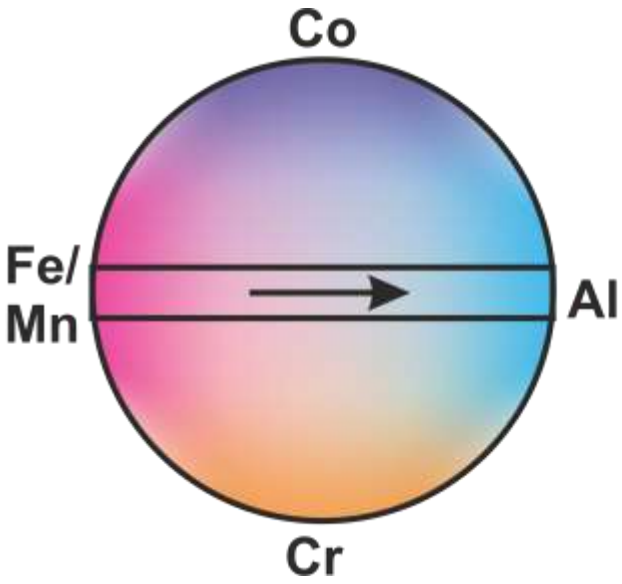
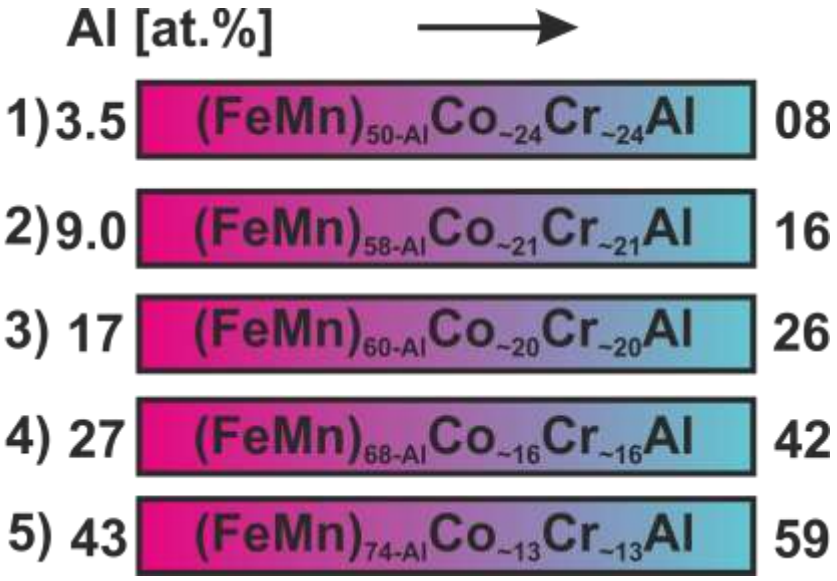
FeMnCoCrAl THIN FILM HEA

- FeNiCoCrAl (B2 matrix + BCC precipitate)[1]
- FeMnCoCrAl (BCC)[2]
- BCC matrix + B2 precipitate = ?

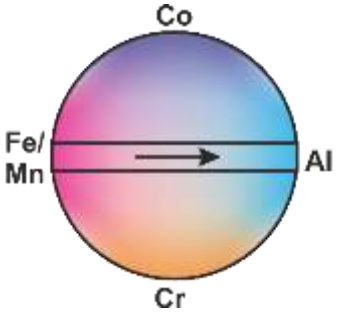
Combinatorial synthesis

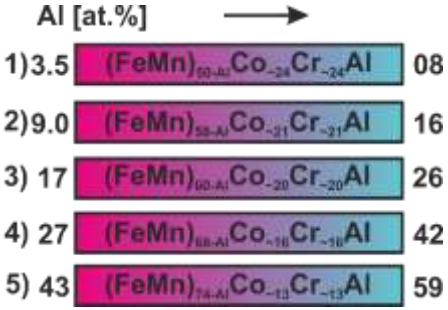


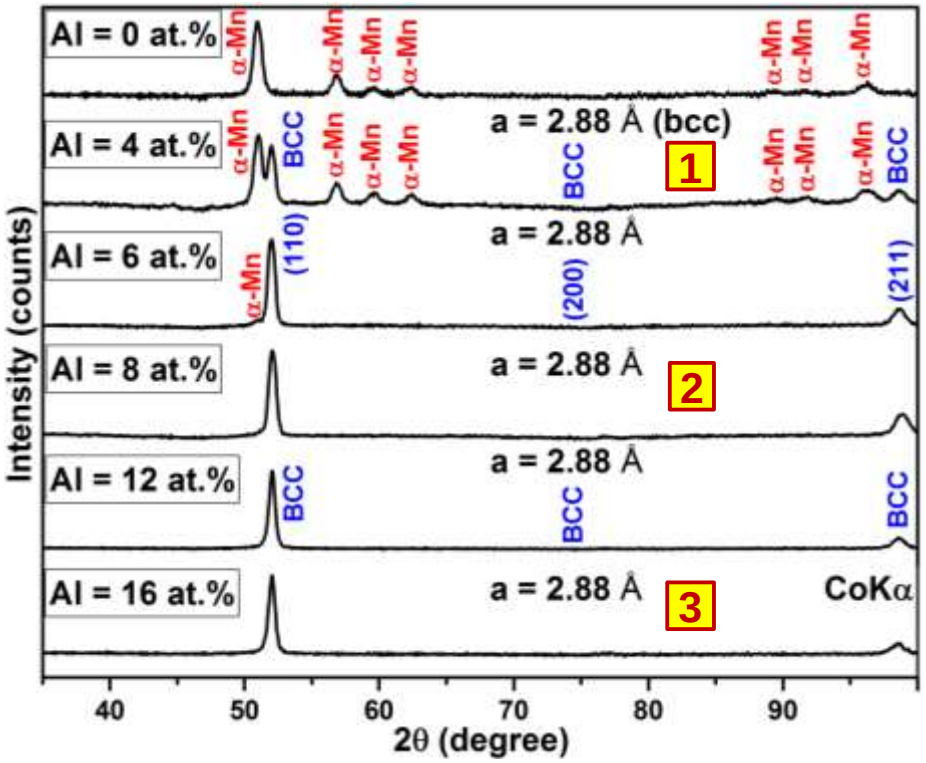


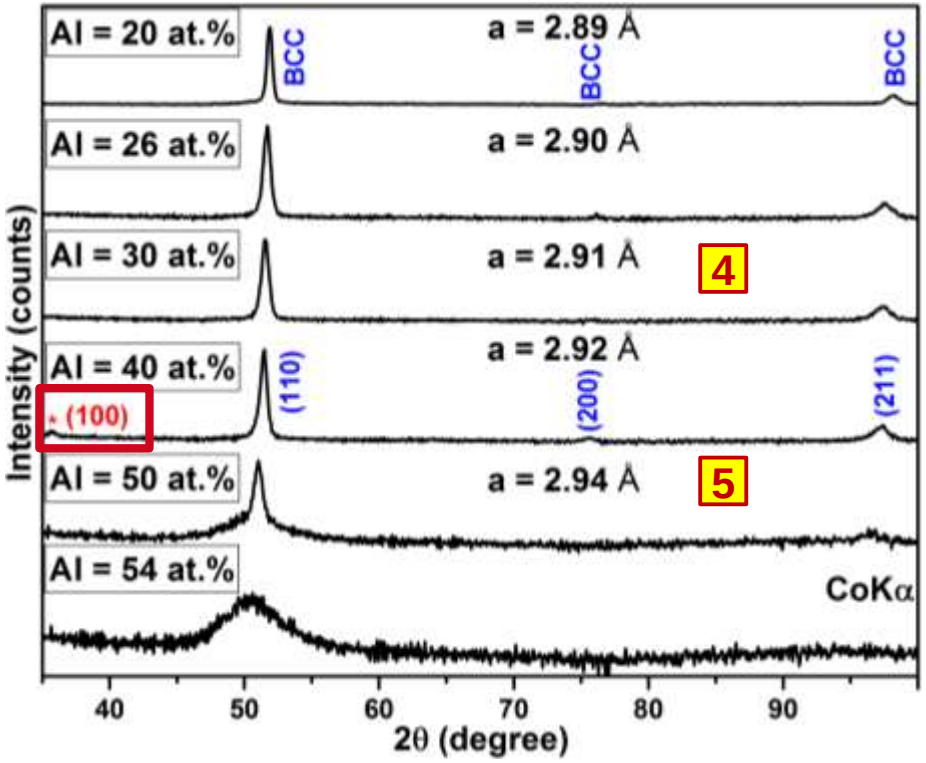
[1] Manzoni et al, Ultramicroscopy 132, 2013
[2] Marshal et al, JALCOM, 2017

High-throughput XRD





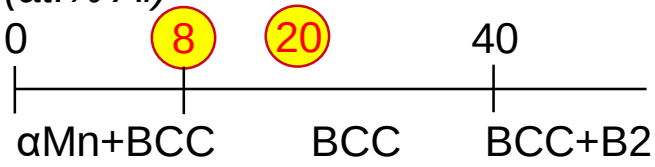




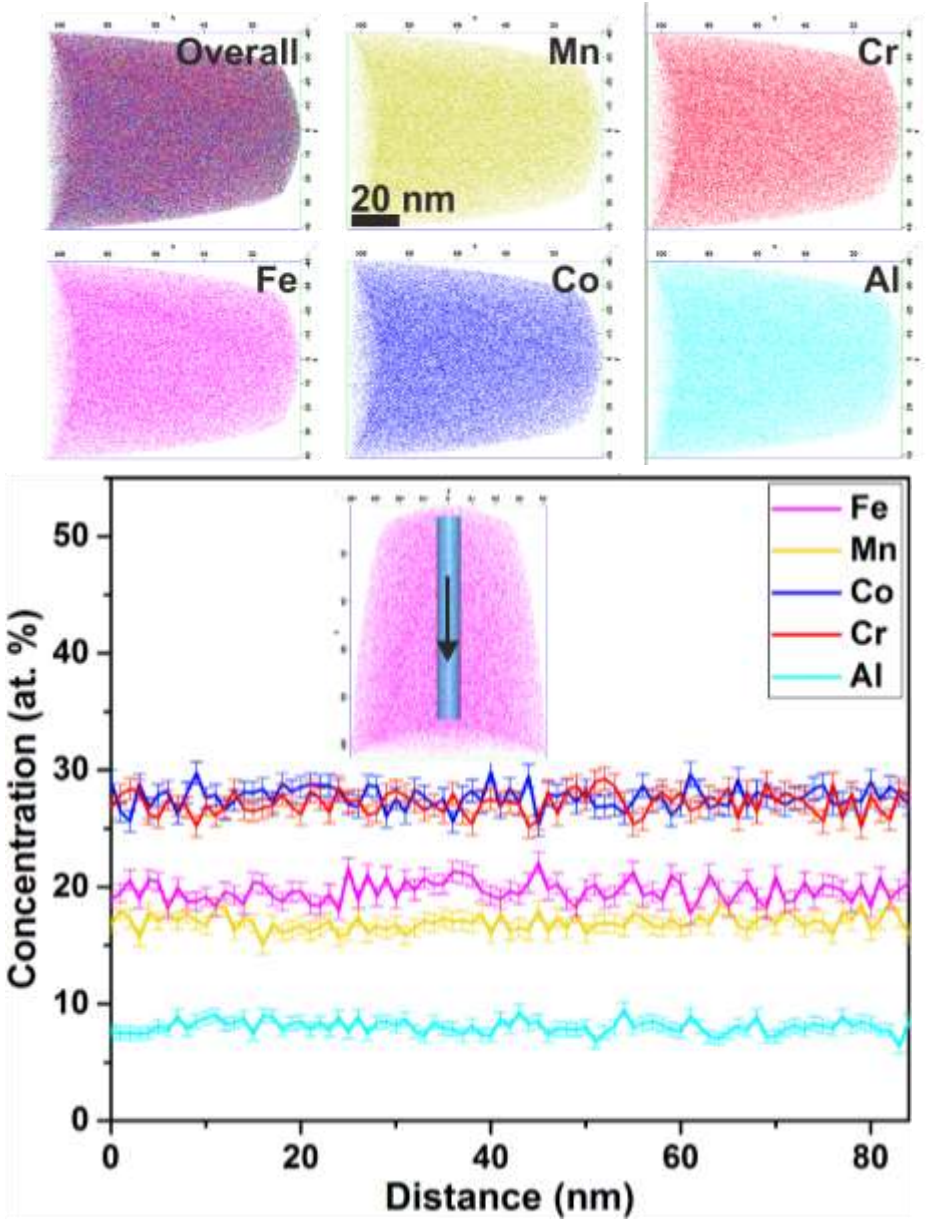
FeMnCoCr-8Al APT

XRD:

(at.% Al)



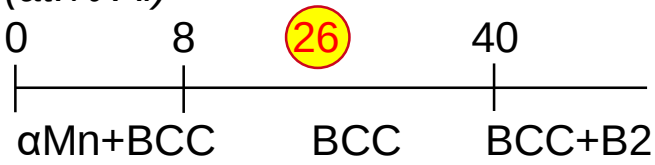
- **20 at.% Al → homogenous distribution**



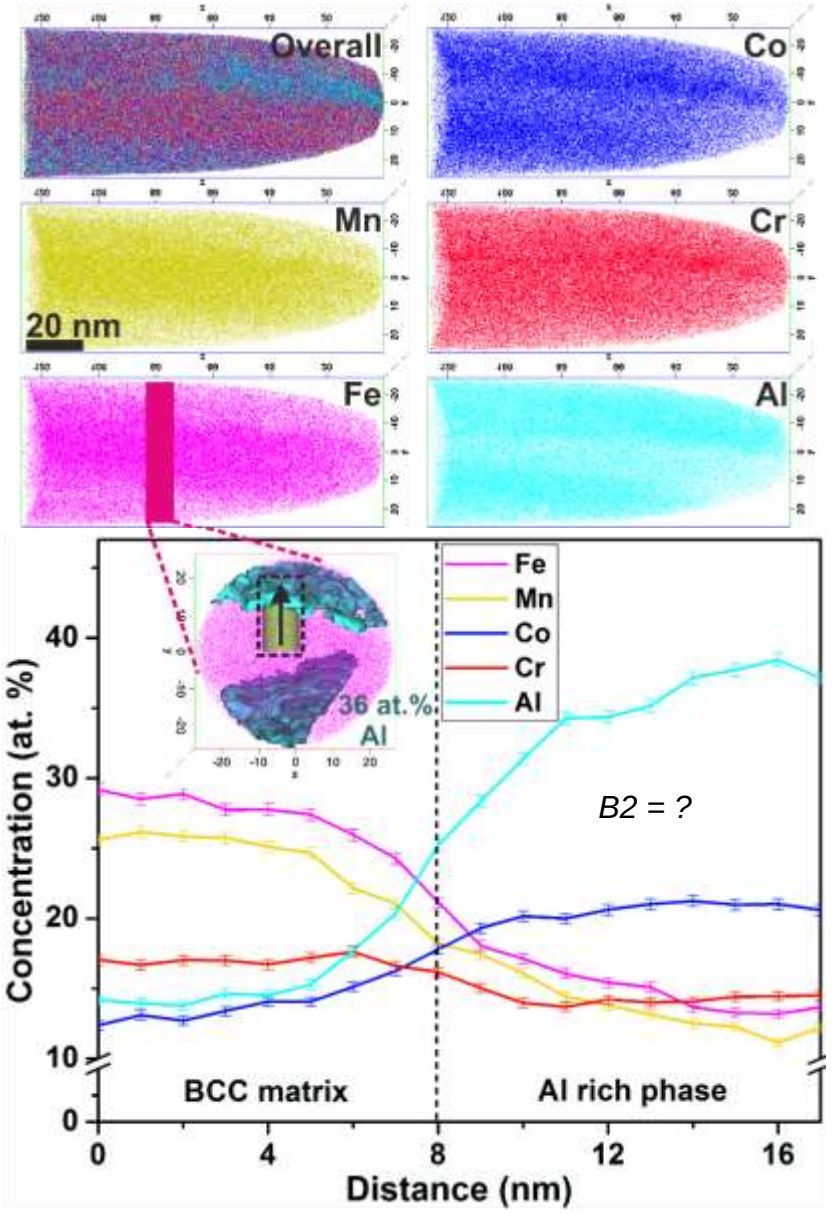
FeMnCoCr-26Al APT

XRD:

(at.% Al)



- **Al-Co → large negative ΔH_{mix}**
- **B2 = ? (TEM)**



FeMnCoCrAl EQUIATOMIC HEA

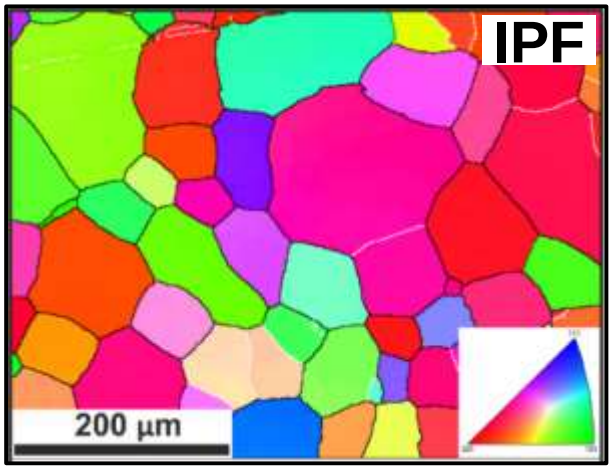
10^2 K/sec

Cooling rate

10^9 K/sec

❑ FeMnCoCrAl bulk HEA

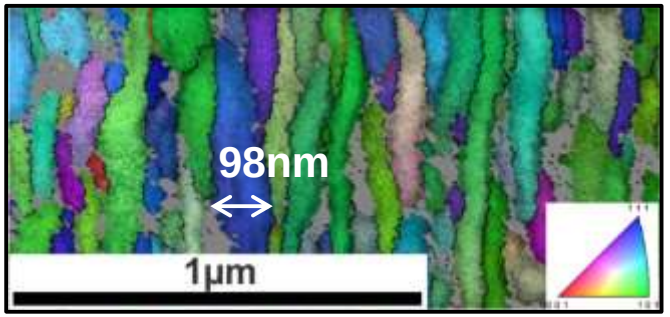
- Arc melted, casted.
- Equiaxed grain (81.3 ± 5 μm)
- Low cooling rate



EBSD

❑ FeMnCoCrAl thin film HEA

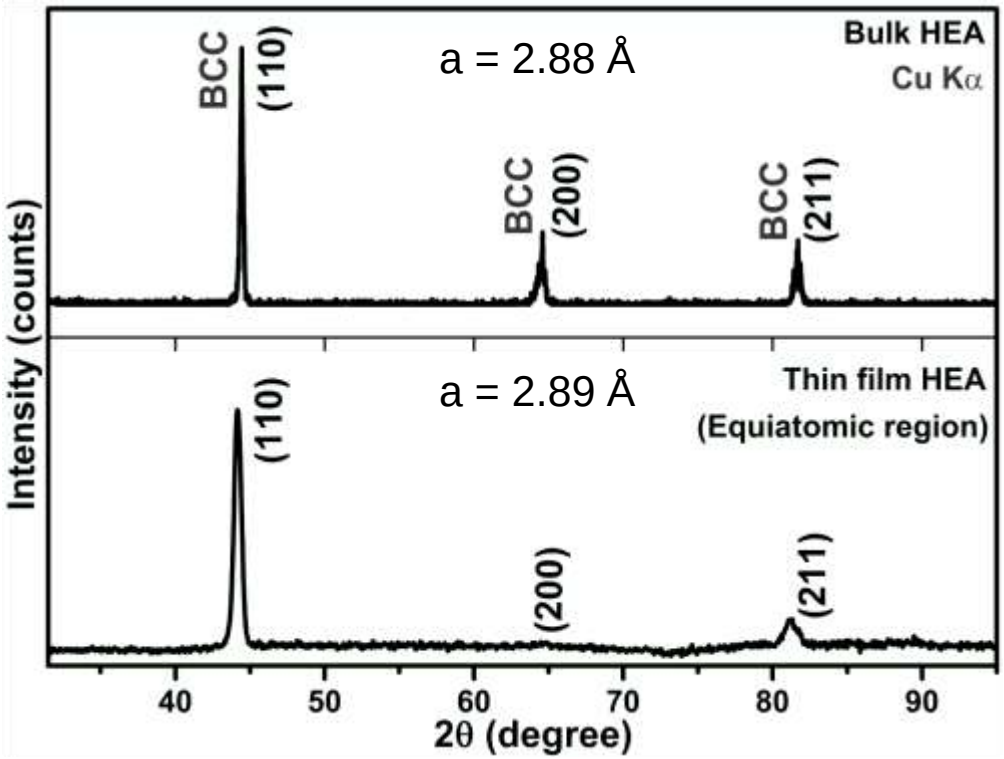
- Sputtered thin film HEA
- High cooling rate



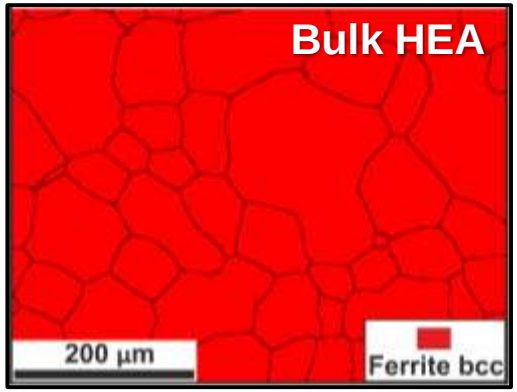
T-EBSD

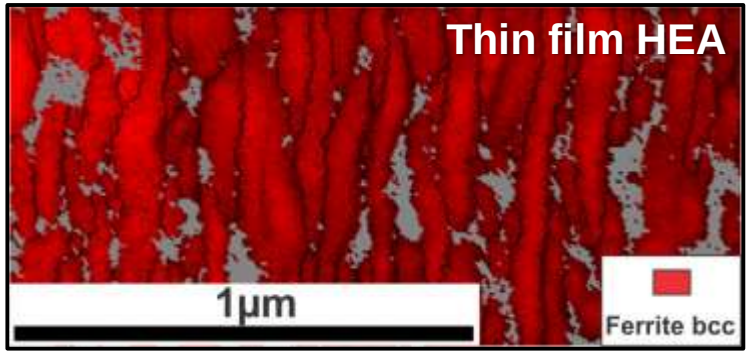
FeMnCoCrAl EQUIATOMIC HEA

XRD

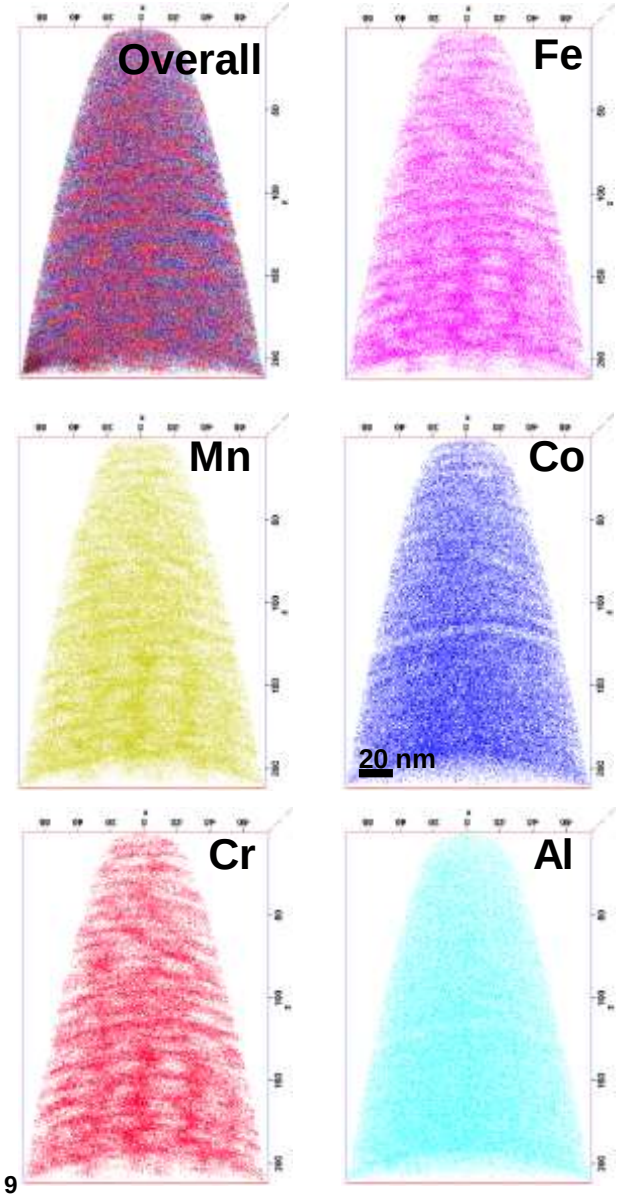


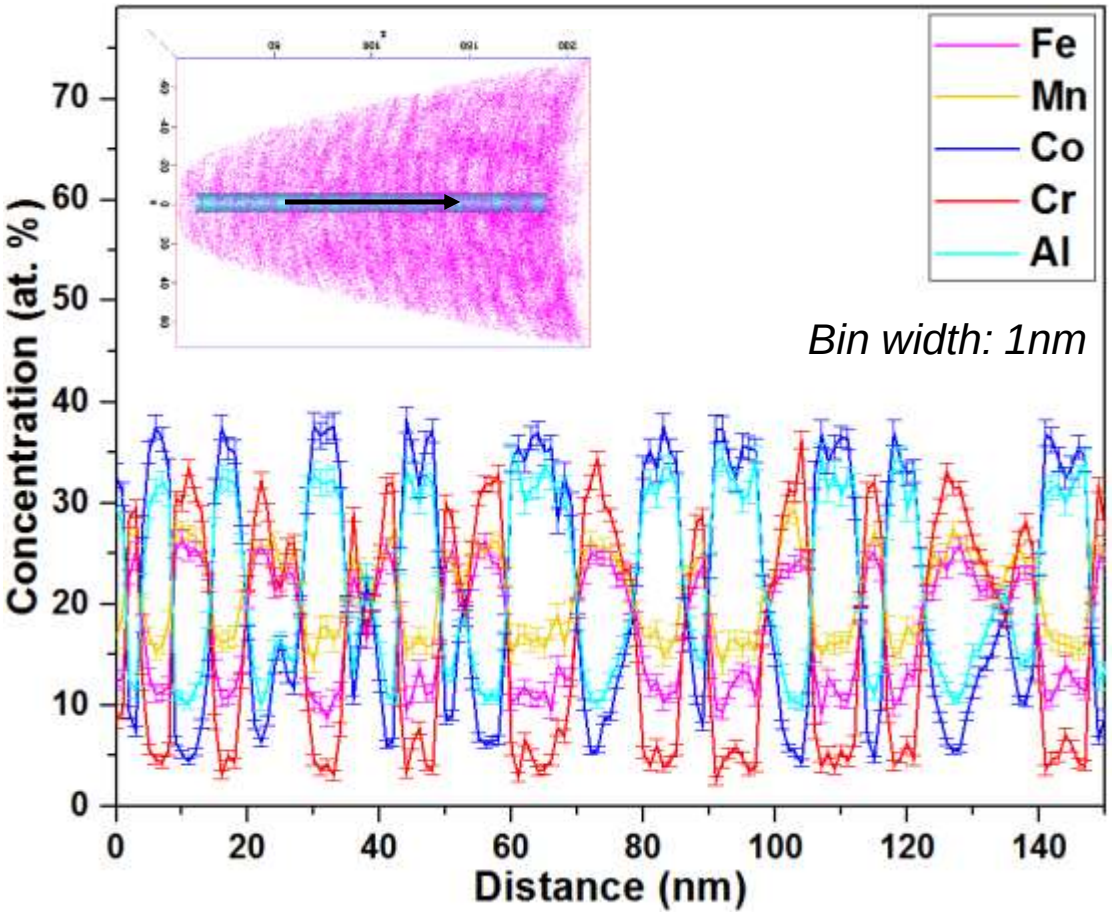
EBSD phase mapping





Bulk HEA - APT





- **Co-Al ↔ Cr-Fe-Mn anti-correlated fluctuations**
- **Separation similar to 26 at.% thin film HEA**

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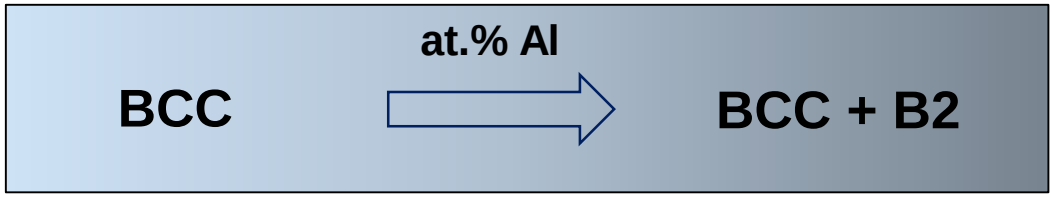
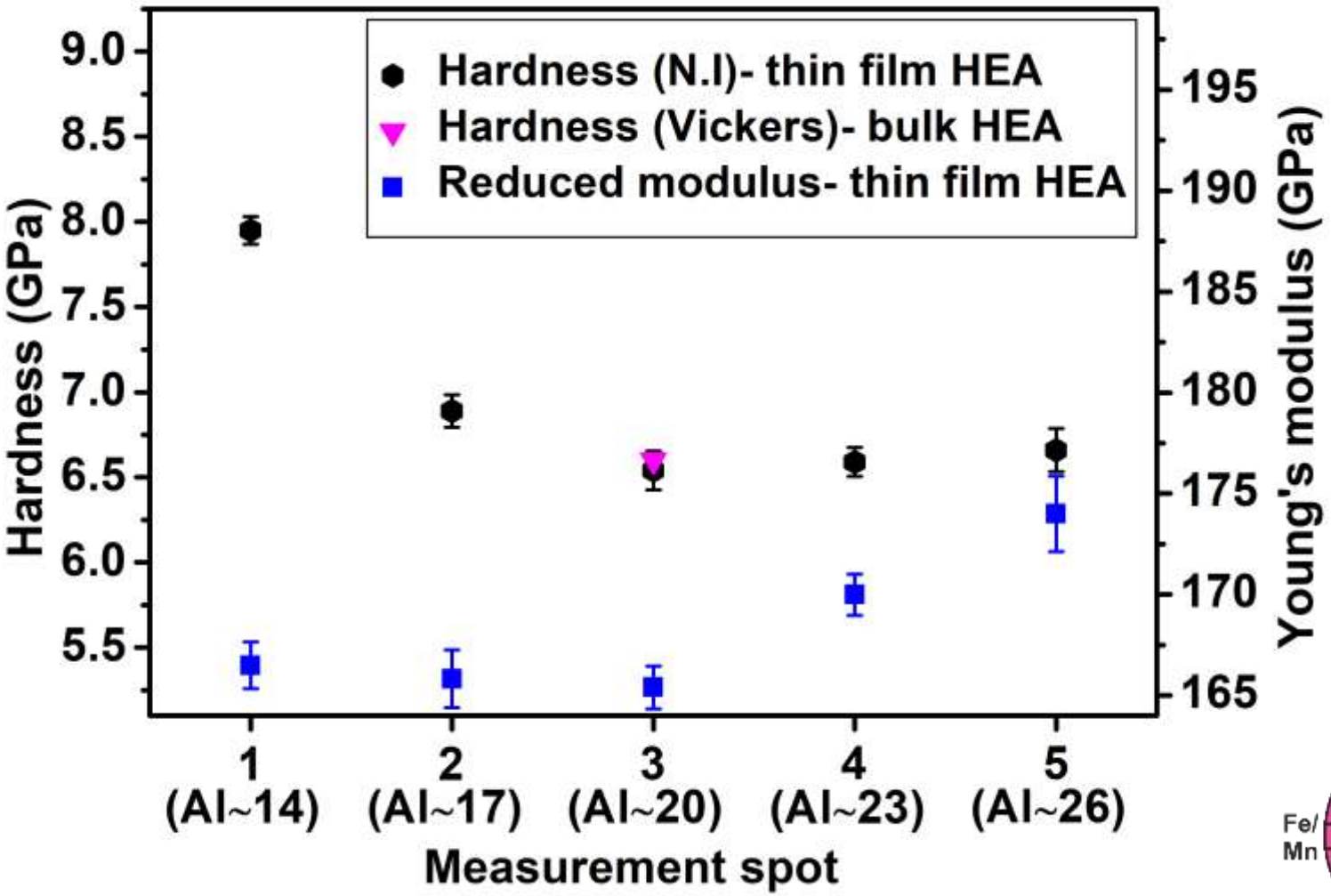
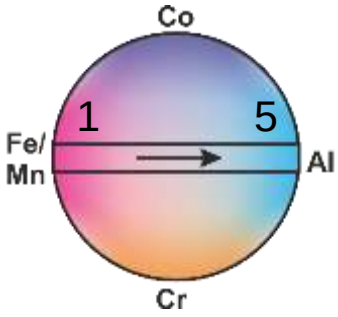
FeMnCoCrAl
PHASE FORMATION

Al (at.%)	< 8	20 (thin film)	20 (bulk)	26	40
XRD	BCC + αMn	Single BCC	BCC + (B2)	BCC + (B2)	BCC + B2
APT	-	Random	Co-Al	Co-Al	Co-Al



PROPERTIES


Hardness (N.I)- thin film HEA
Hardness (Vickers)- bulk HEA
Reduced modulus- thin film HEA
Hardness (GPa)
Young's modulus (GPa)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
195
190
185
180
175
170
165
1 (Al~14)
2 (Al~17)
3 (Al~20)
4 (Al~23)
5 (Al~26)
Measurement spot


Co
1
5
Fe/
Mn
Al
Cr

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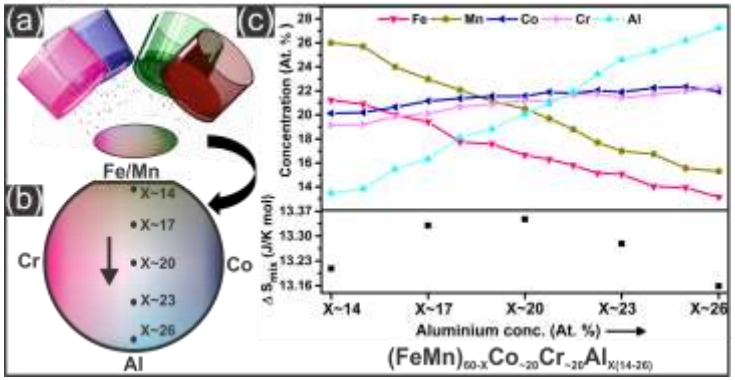
WORK PLAN

RWTH



MPIE

Isaac Butterworth Ltd.

Silas Wolff-Goodrich

Christian Liebscher

- **Combinatorial synthesis**
  FeCrAl (Mn, Co, Ni, Ti)
- **STEM, APT**
  (before, after deformation)

⇒ **Bulk HEA**

⇔ **Bulk mechanical testing, Creep**

- **BCC + B2 (AlCo)**
  FeMnCoCrAl

BCC + $L2_1$ = ?
FeCrAlNiTi

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Thank you