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Project no. :S17024o

Laser additive manufacturing of high entropy alloys

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Supervisor: Prof. dr. Yutao Pei

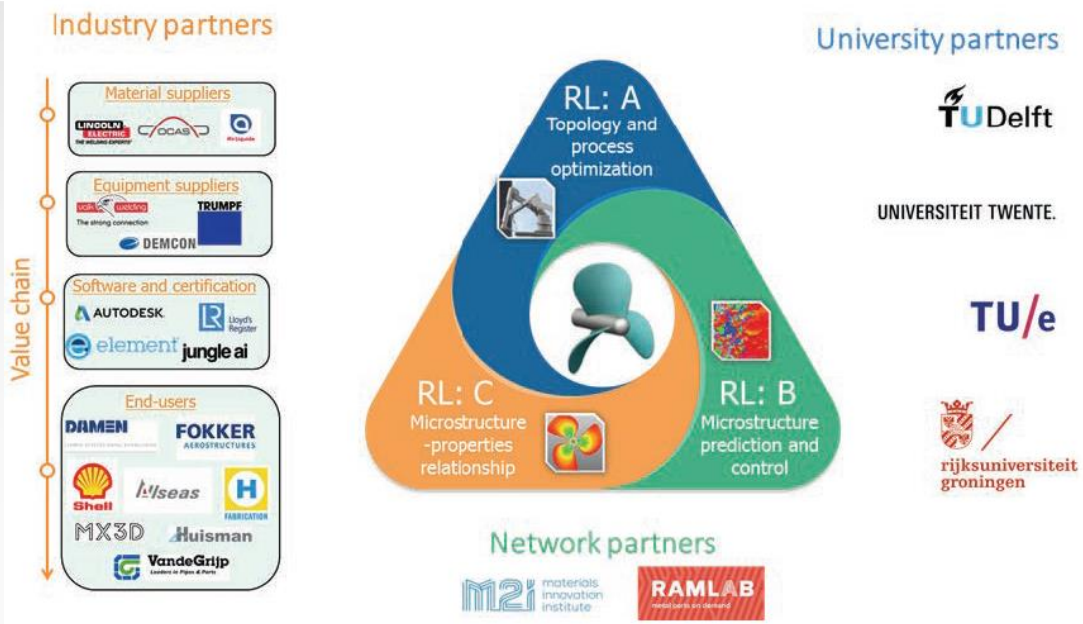
materials innovation institute

university of groningen

NWO

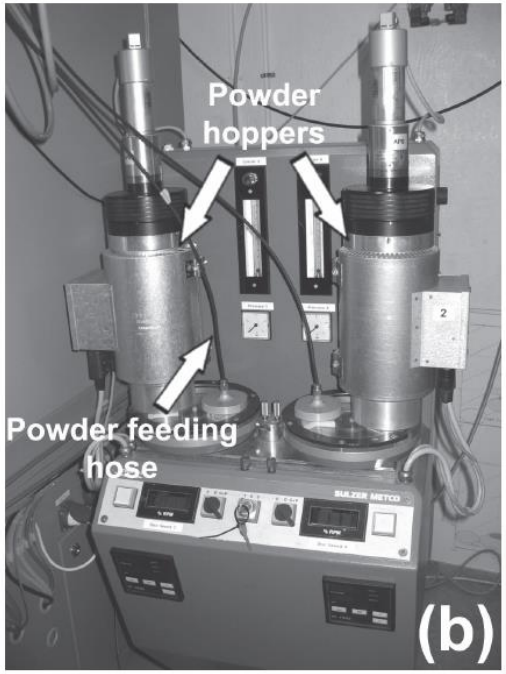
RAMLAB

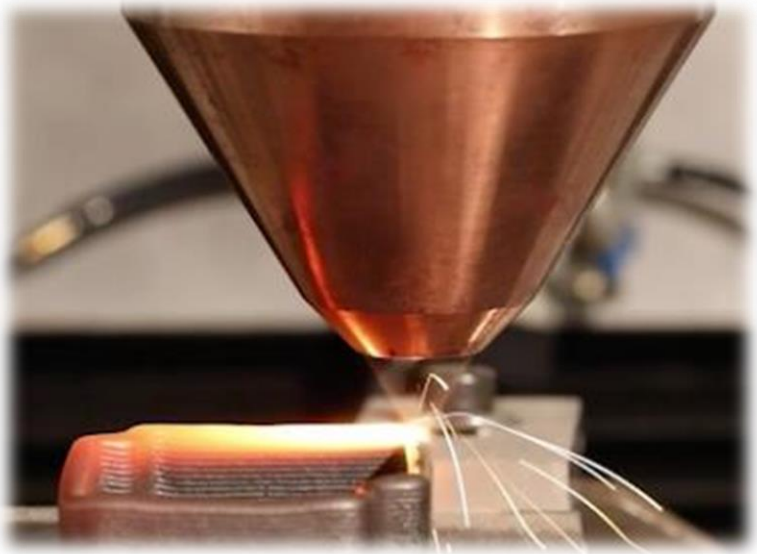
Additive Manufacturing for Extra Large Metal Components (AiM2XL)



- **Generation of locally controlled microstructures for target properties**
- **Production of tailored, graded microstructures**
- **Characterisation of microstructural and mechanical properties**
- **Investigation of material and component properties**

Laser metal deposition



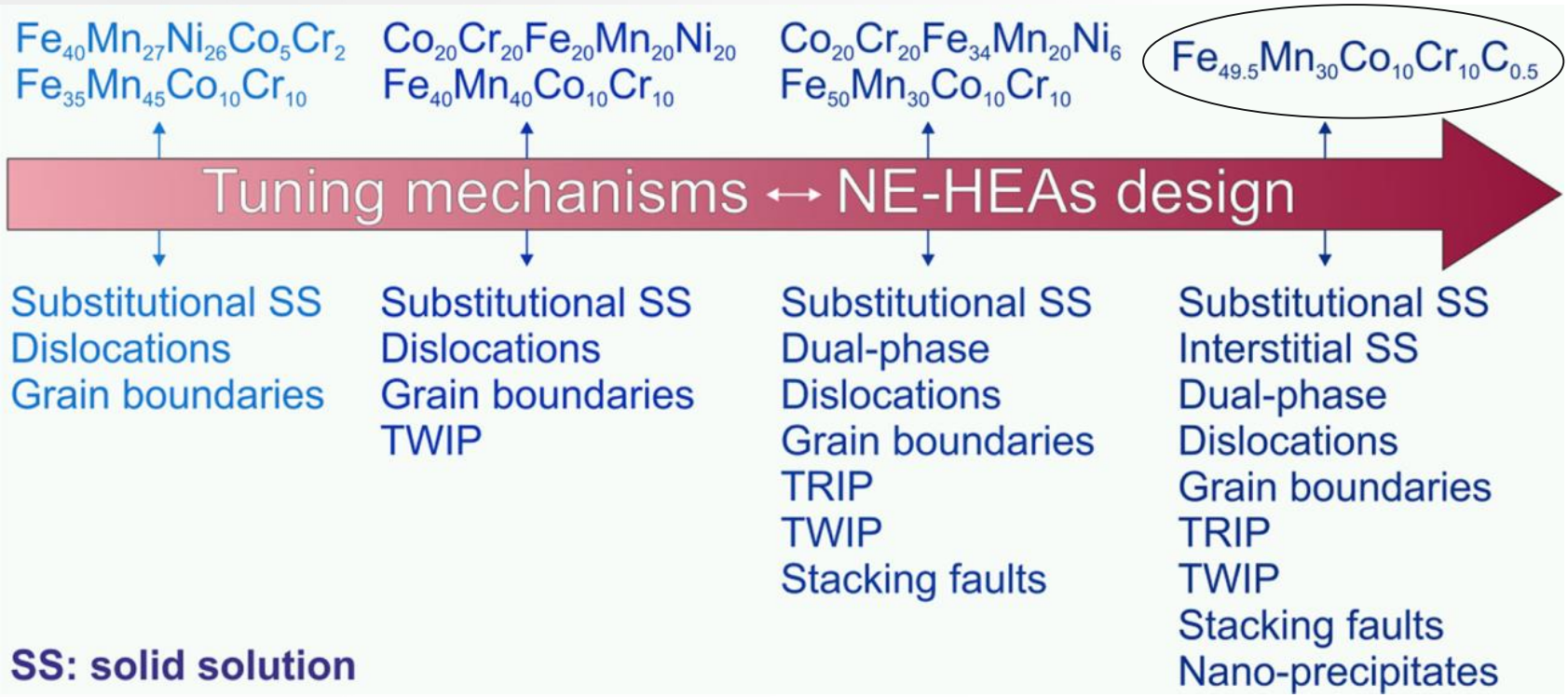


YLS-3000 fiber laser:

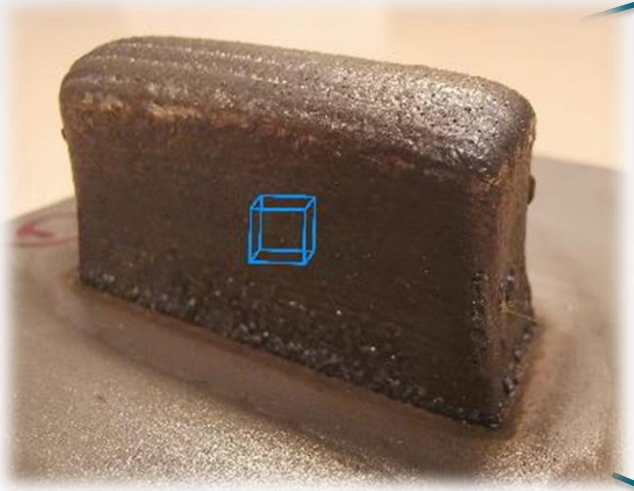
ytterbium doped fiber source,
500-3000 watts of laser power,
wavelength 1070-1080 nm,
wall-plug efficiency of > 30%

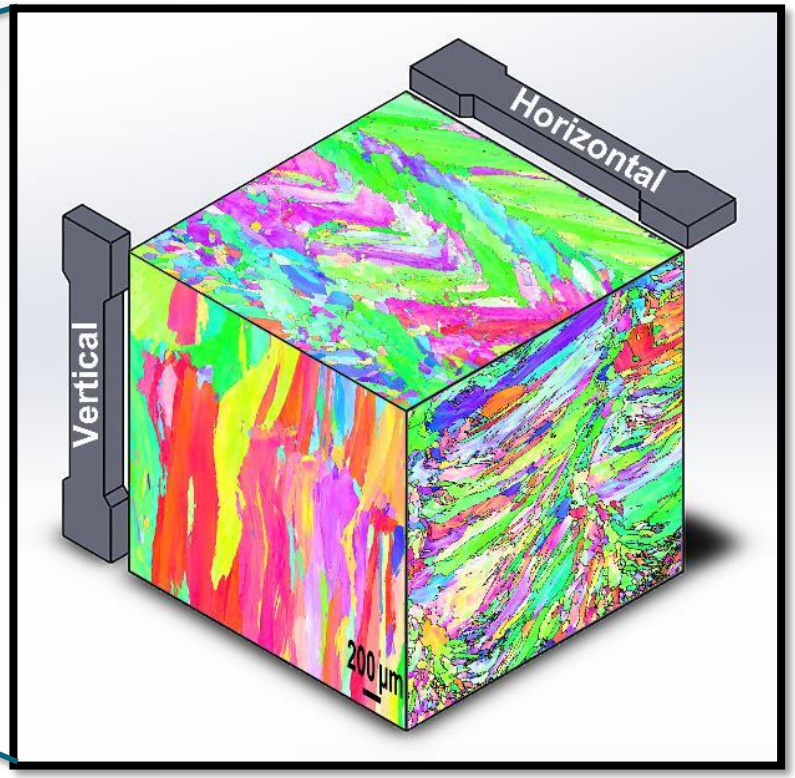
Hemmati, I. (2013). Laser-deposited metallic coatings: processing, characterization, alloy development. s.n.

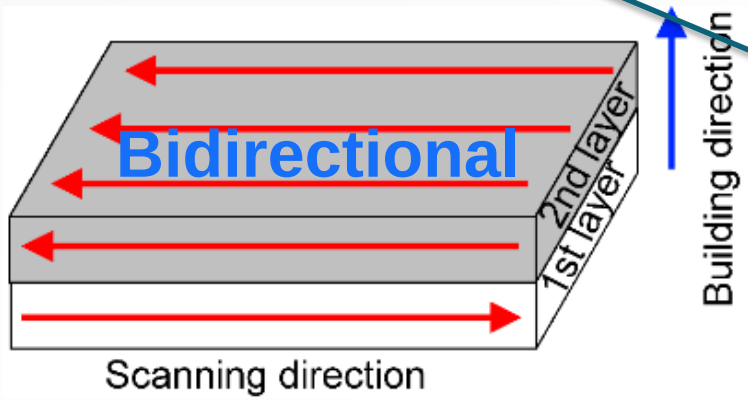
Non-equiatomic (NE) high entropy alloy



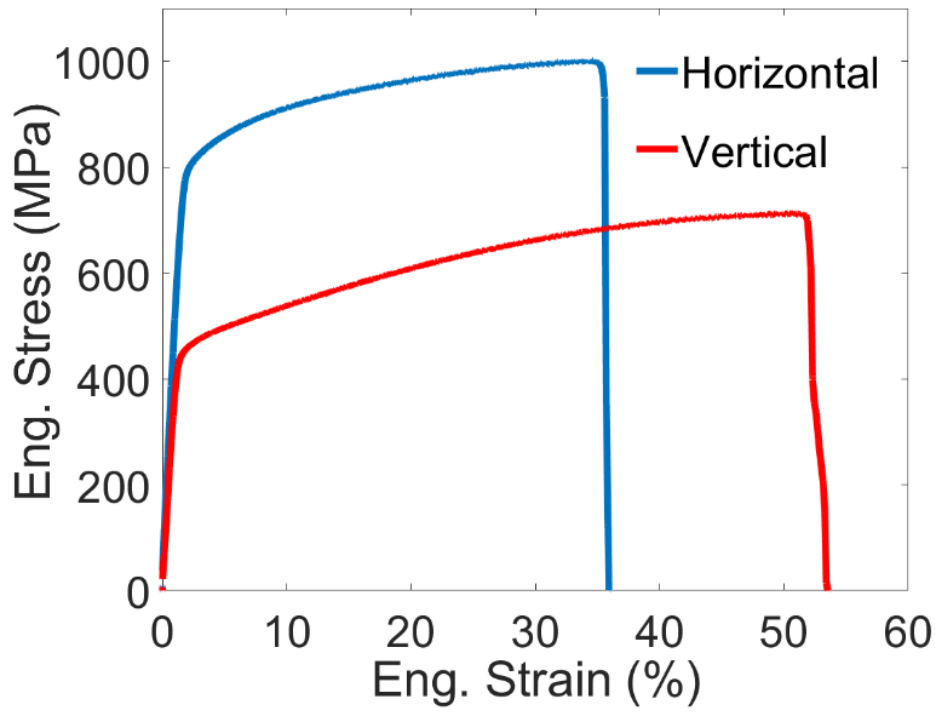
- Deposited crack-free HEA with a thickness of 15 mm, length of 40 mm and height of 25 mm.

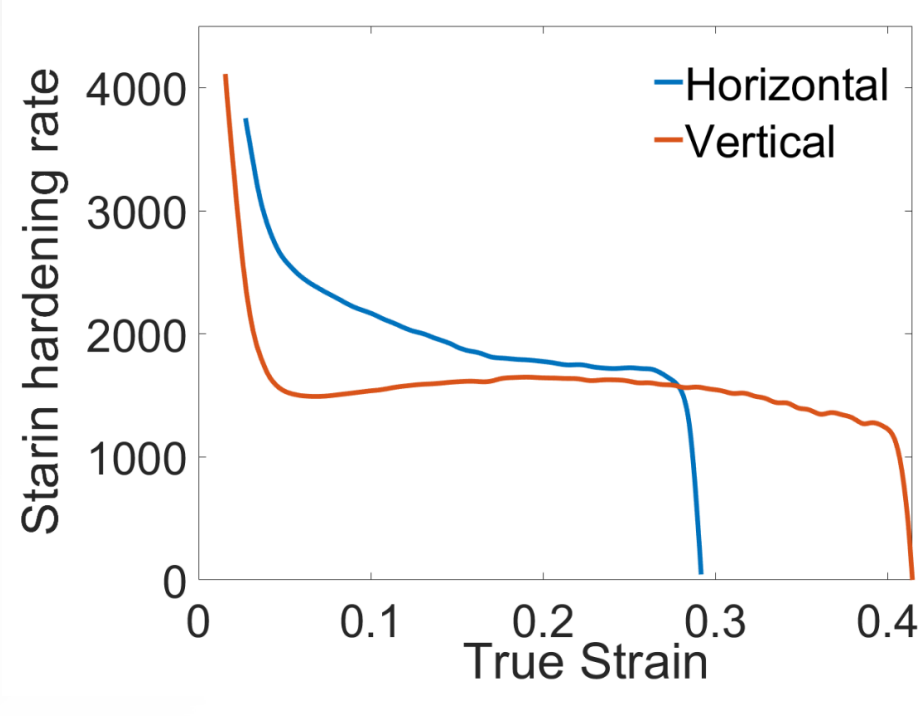






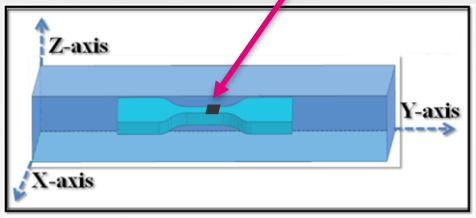
Tensile properties





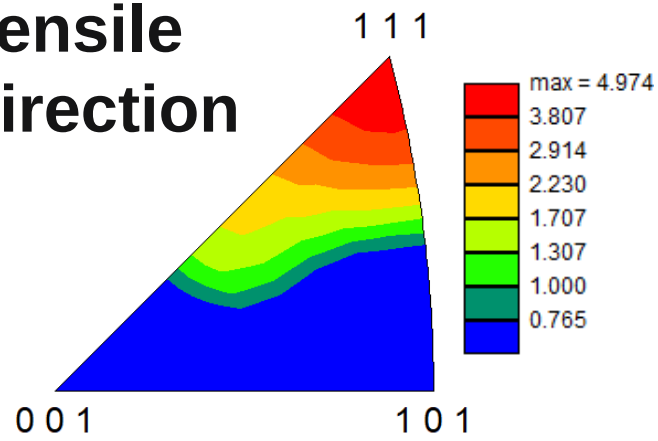
Horizontal
Before deformation

EBSD scan

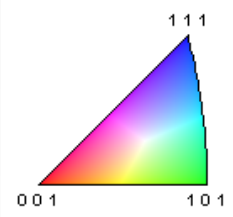


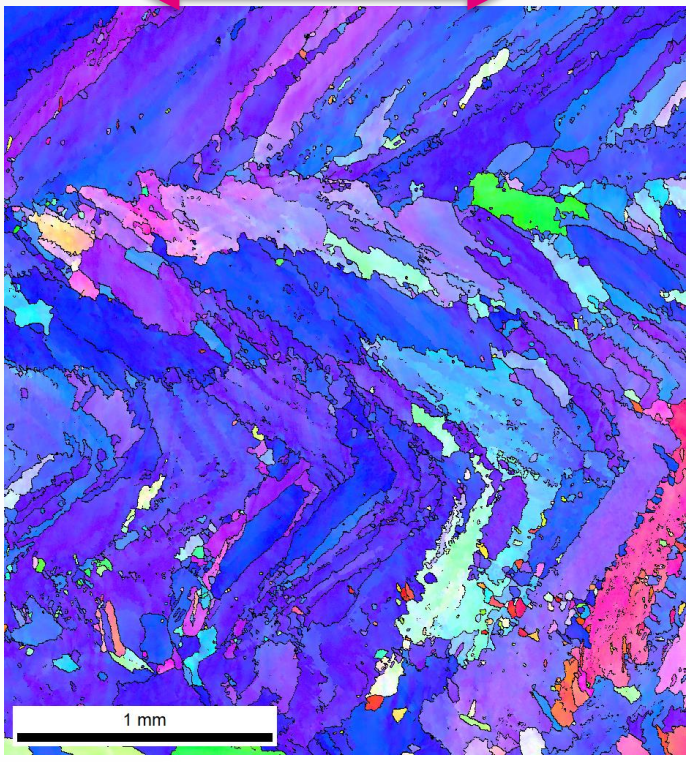
Single FCC phase

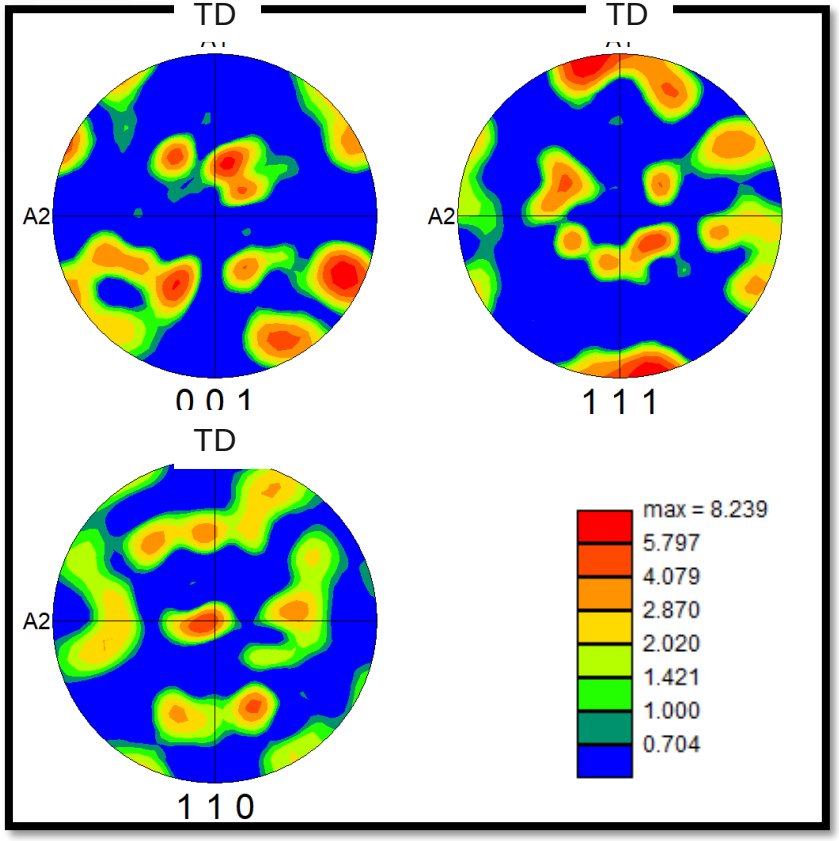
Tensile direction



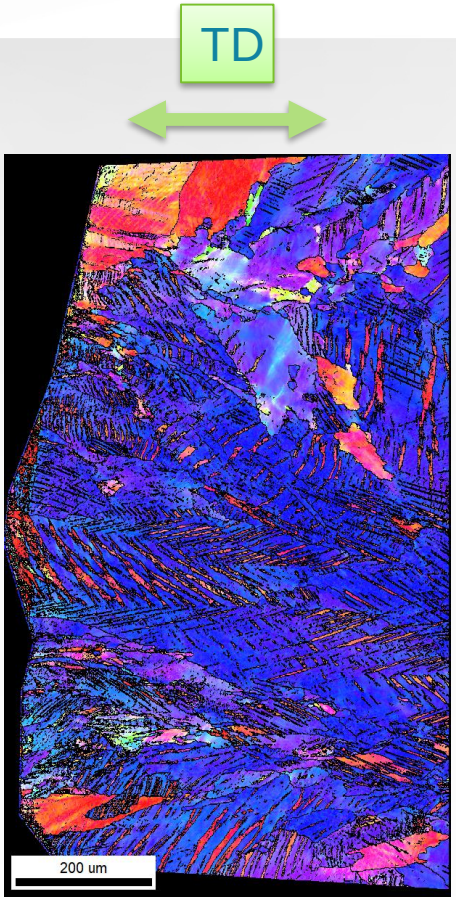
Tensile direction(TD)

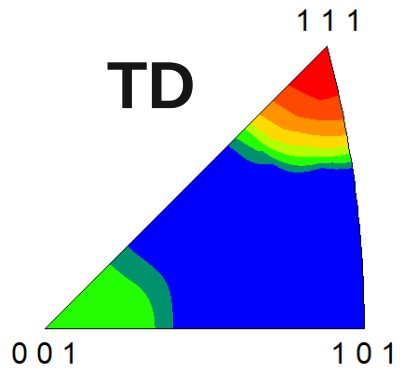


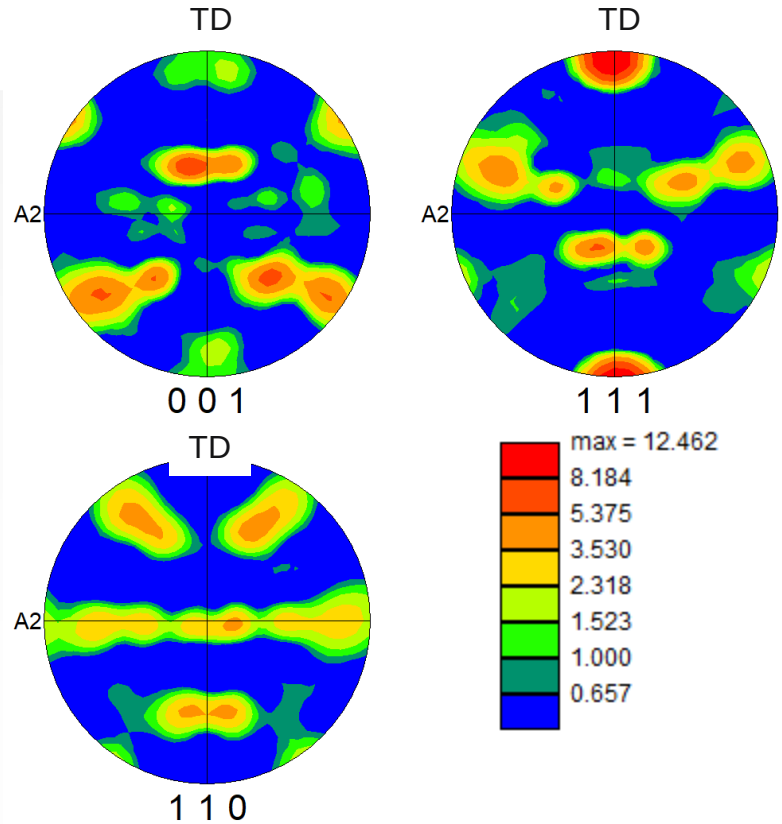


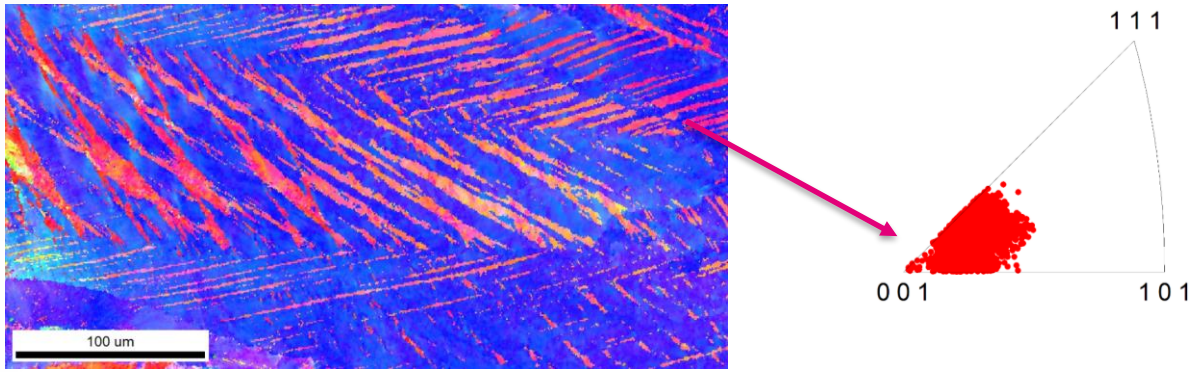


Horizontal Fractured



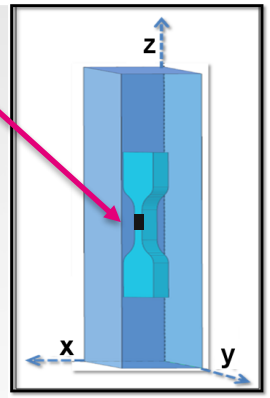


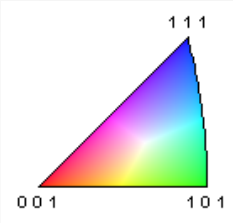


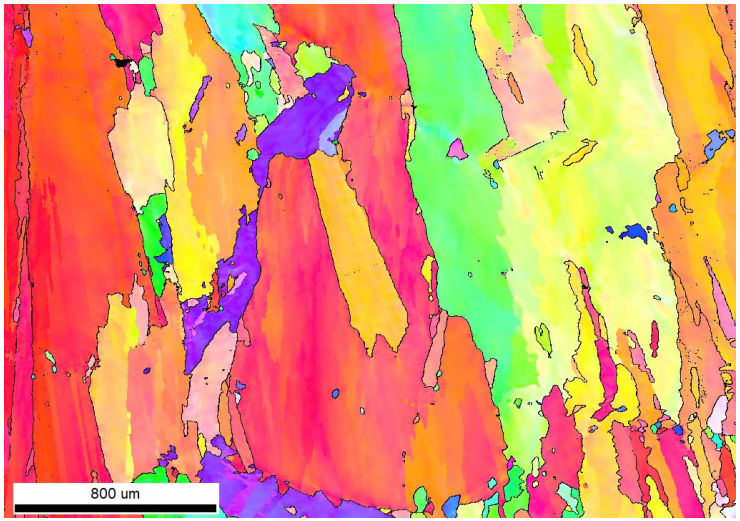


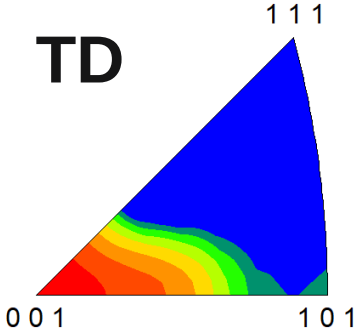
Vertical
Before deformation

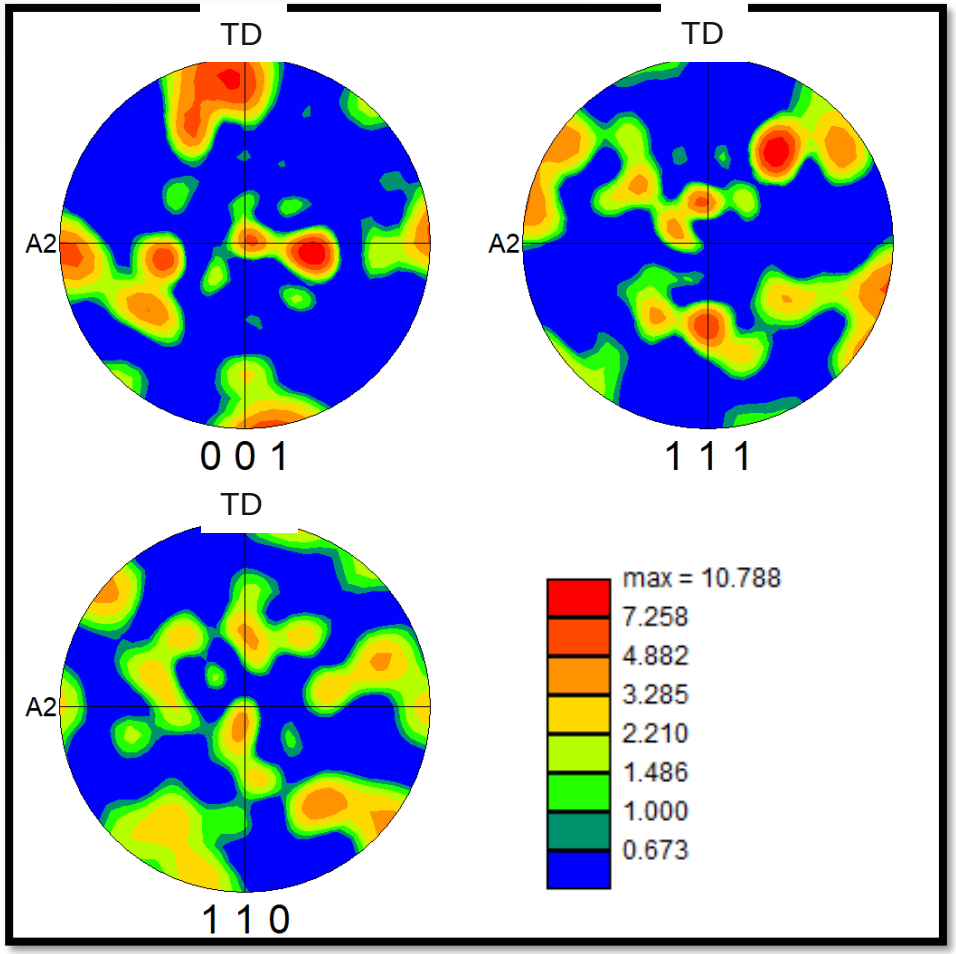
EBSD



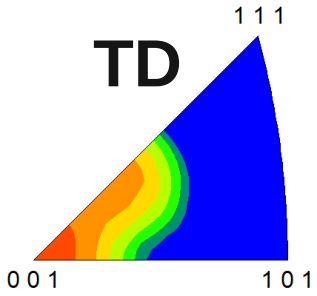


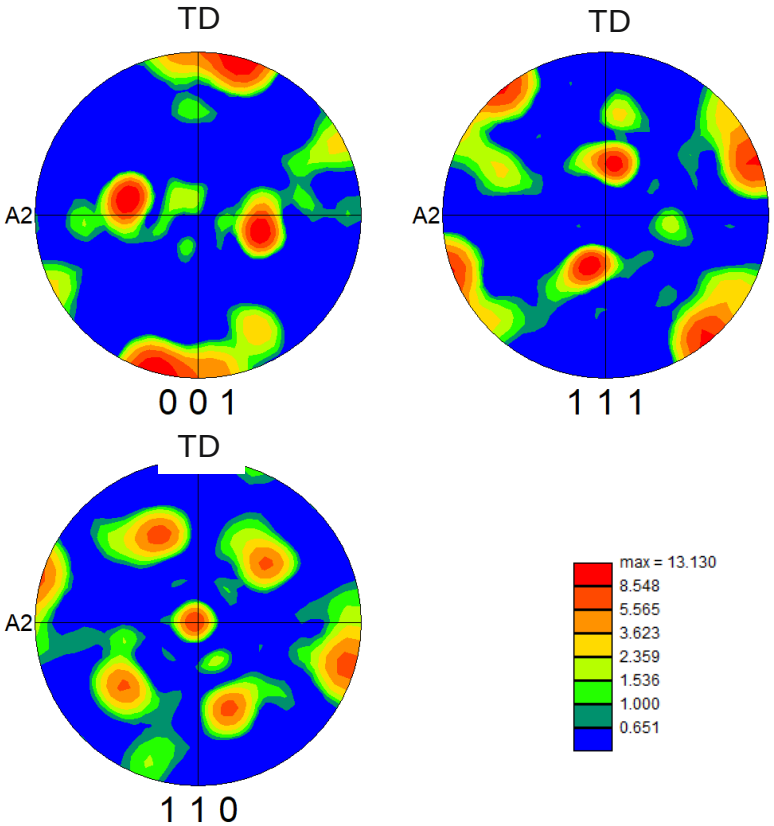


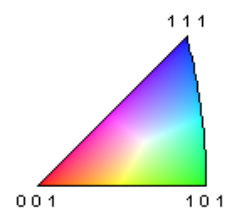




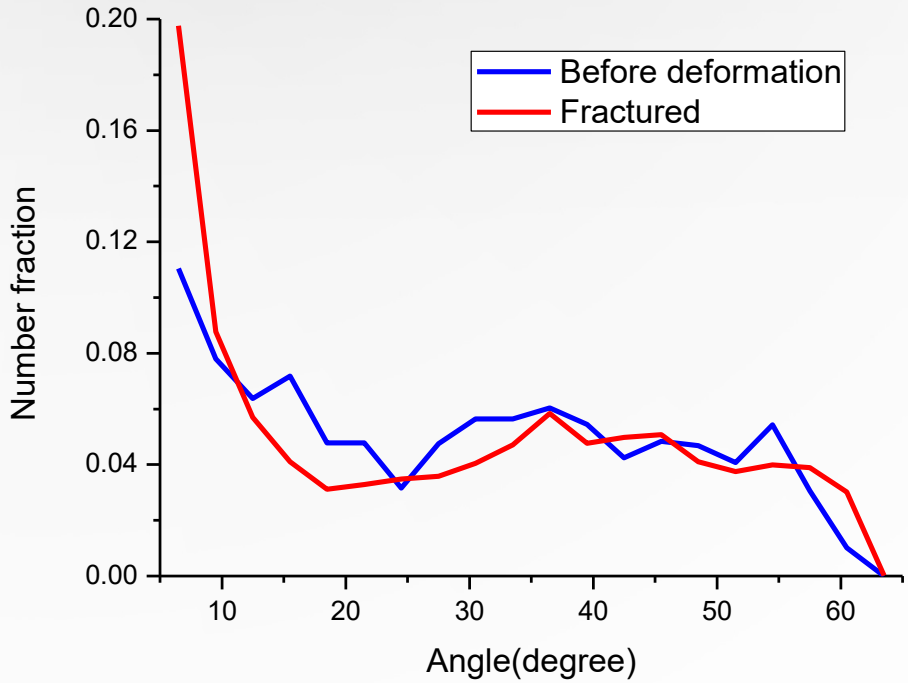
Vertical fractured





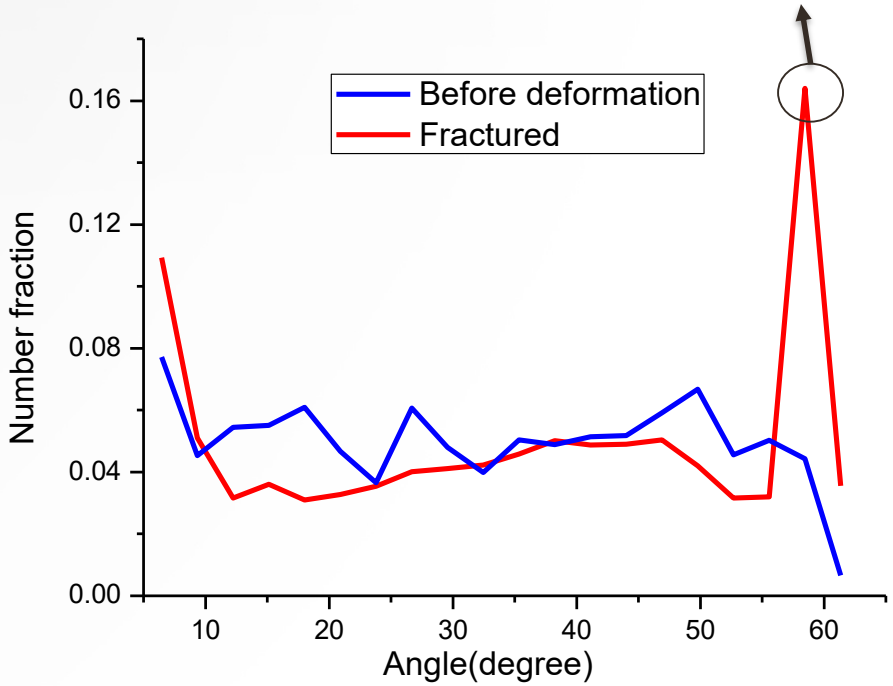


Vertical



Horizontal

$\sum 3$



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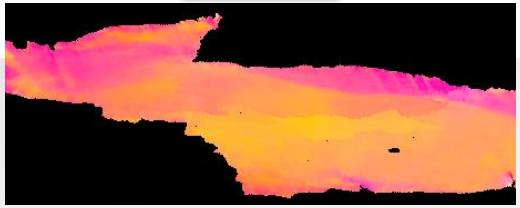

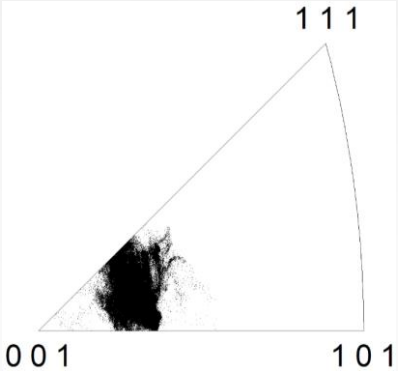

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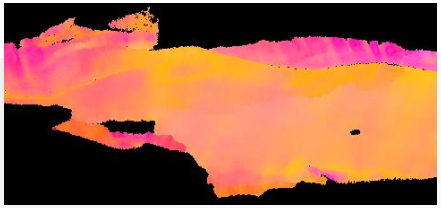

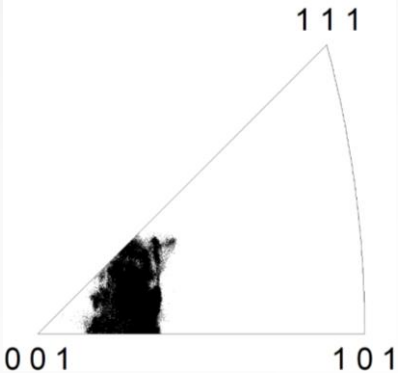

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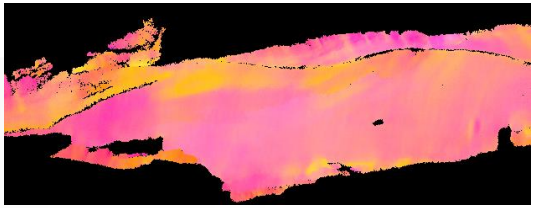

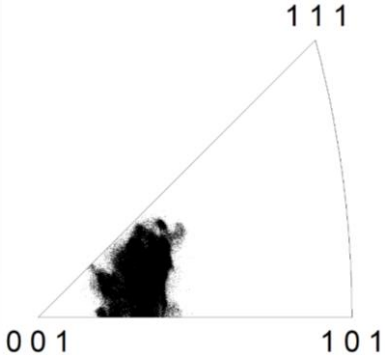

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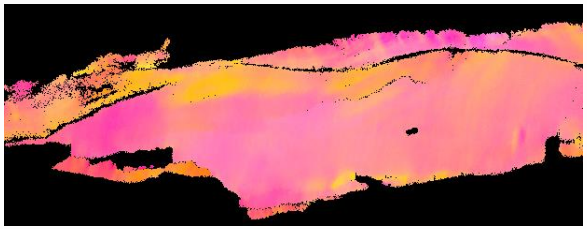

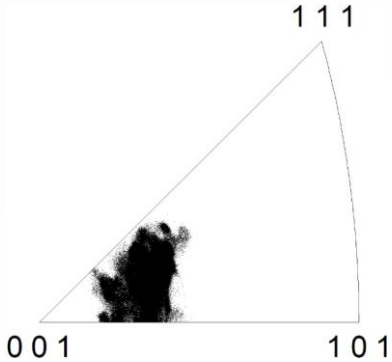

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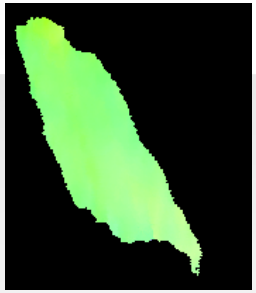

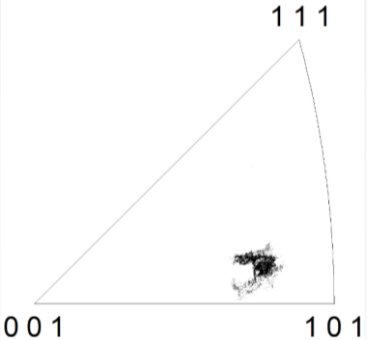

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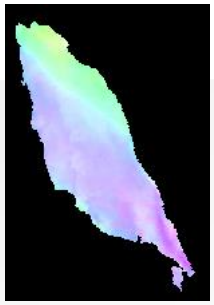

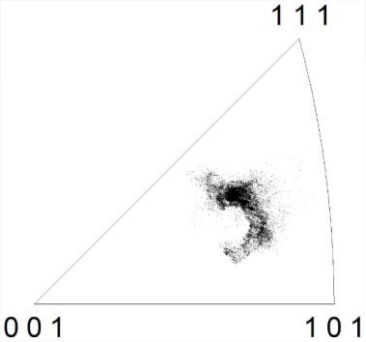

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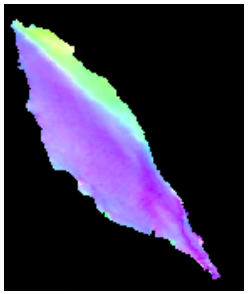

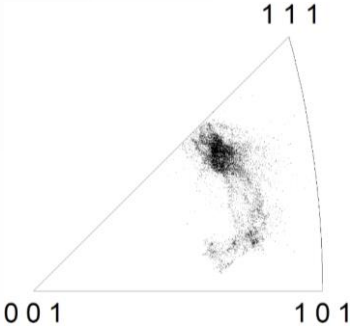

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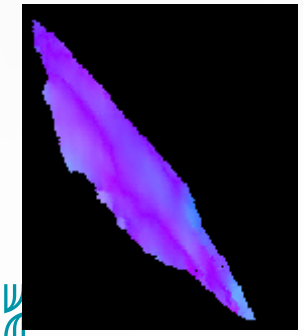

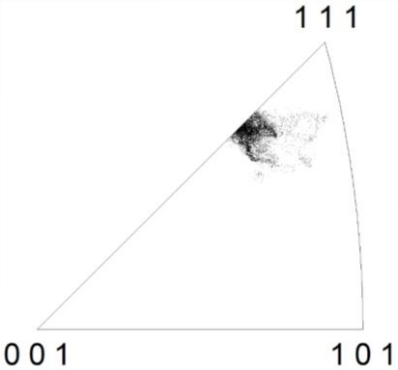

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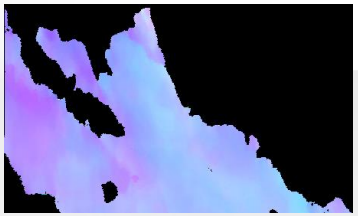

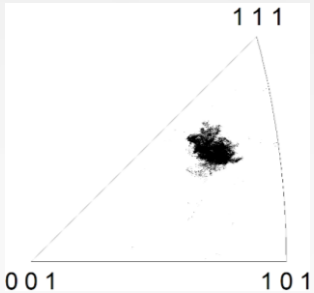
1 1 1
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1 0 1

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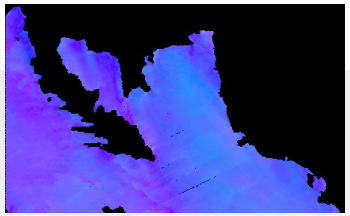

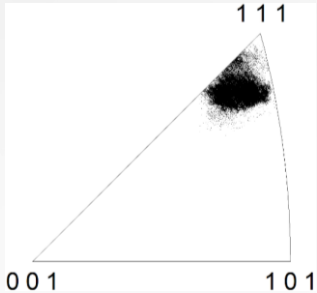
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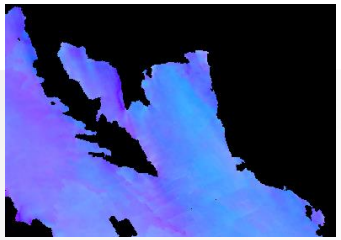

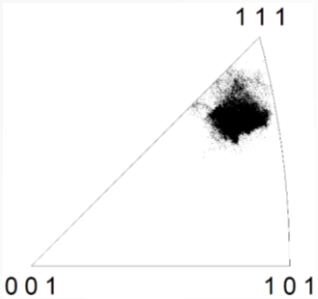
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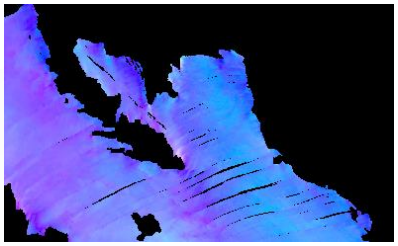

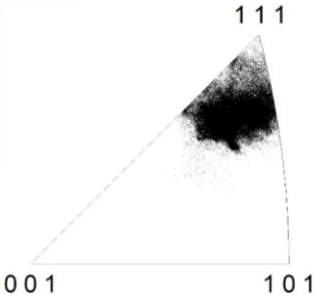
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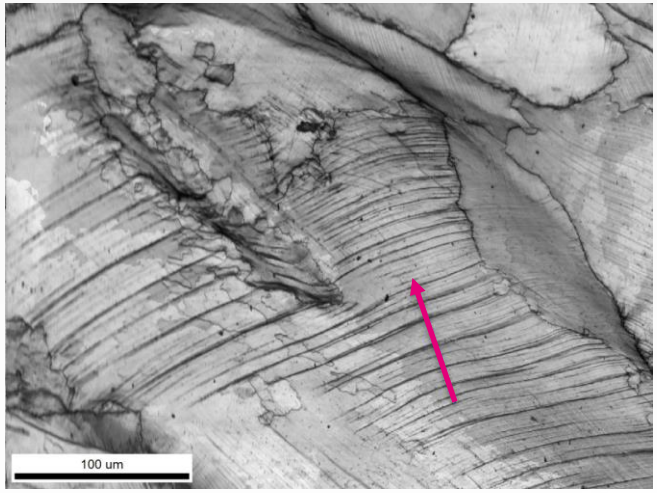
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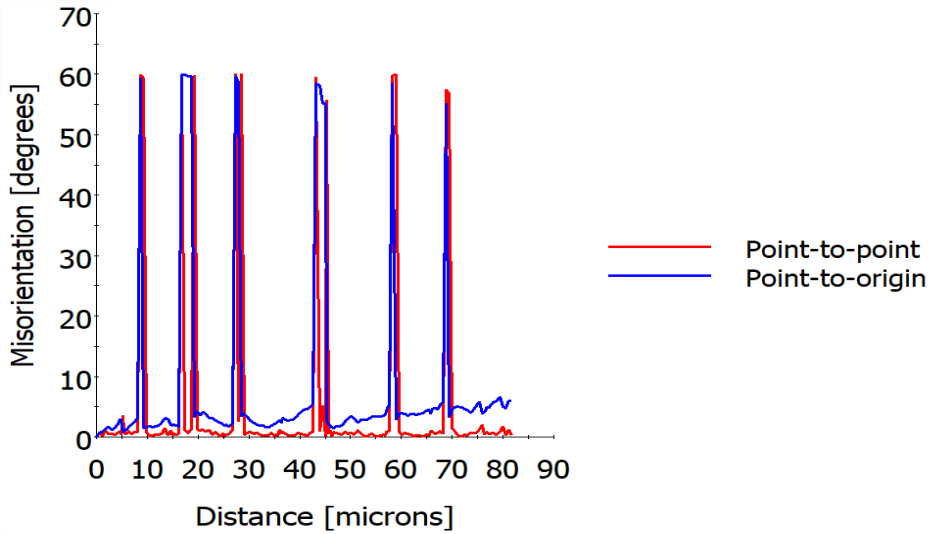
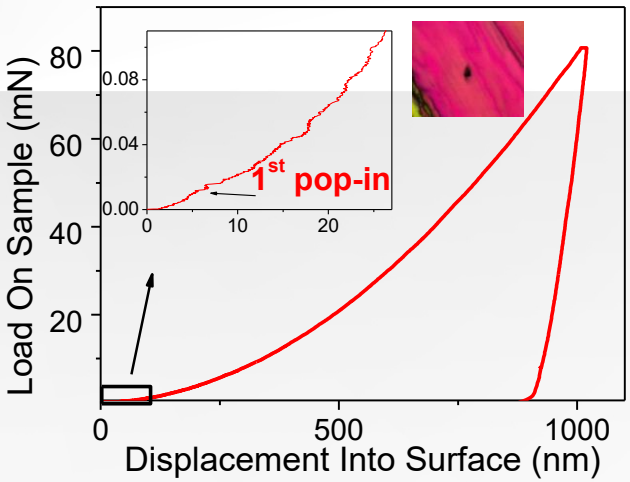
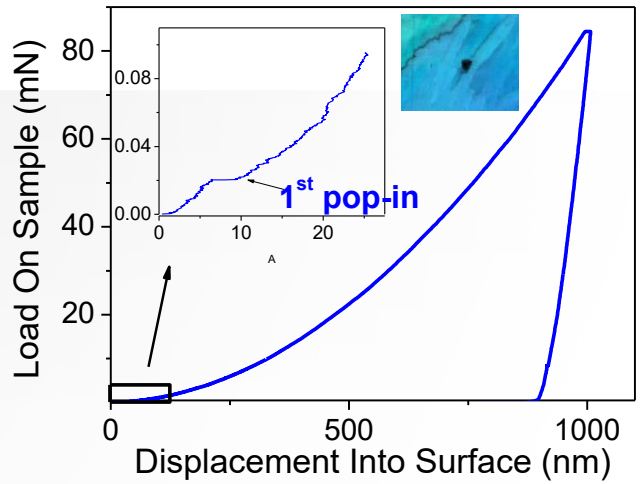

Misorientation [degrees]
0
10
20
30
40
50
60
70
0 10 20 30 40 50 60 70 80 90
Distance [microns]
Point-to-point
Point-to-origin

Nanoindentation



On grain with <001> II indentation direction (*ID*)

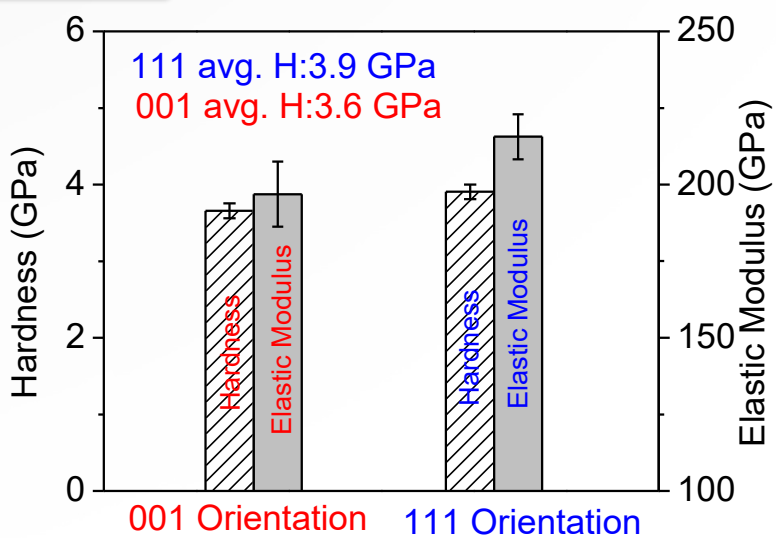


Indentation on grain with <111> II ID

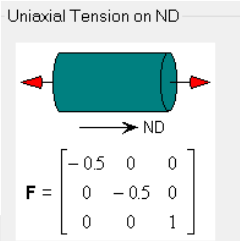
maximum elastic shear stress underneath the indenter(τ_{max})

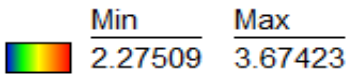
2.4 GPa (001 II ID)

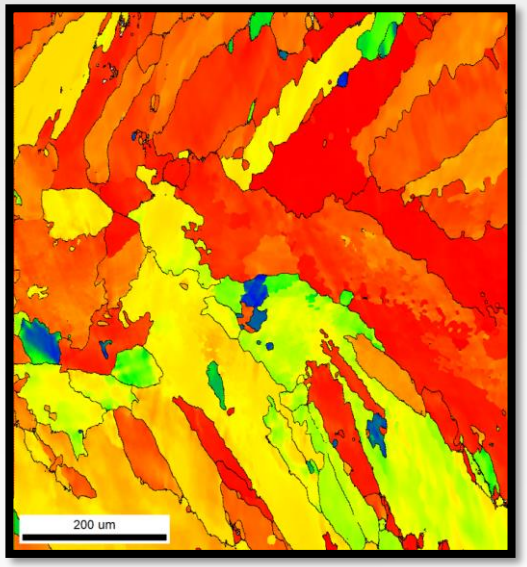
3.2 GPa (111 II ID)

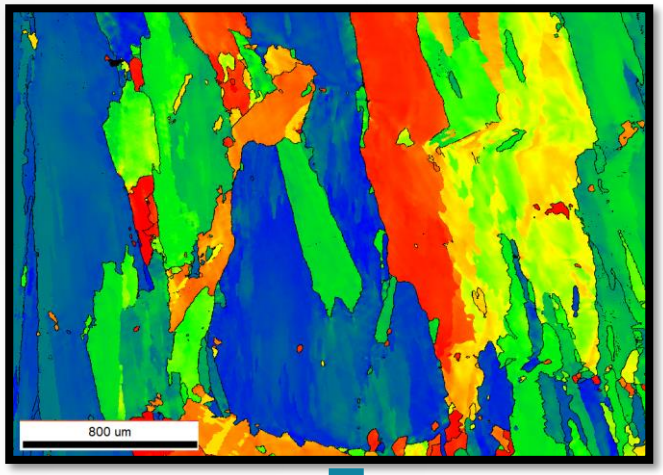


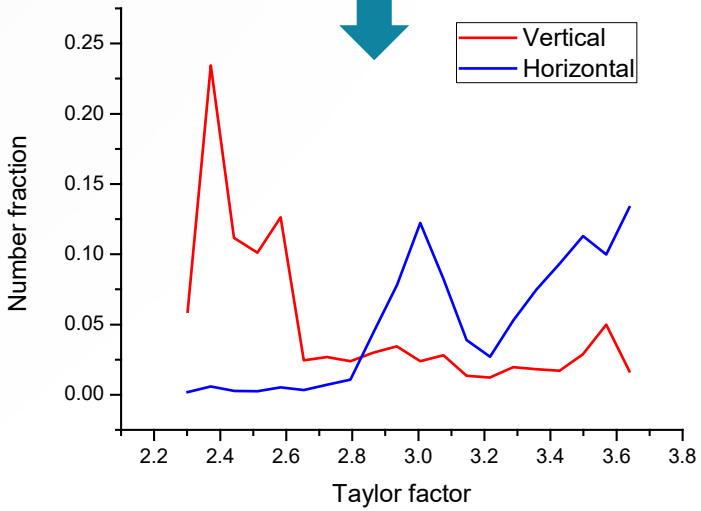
Taylor map







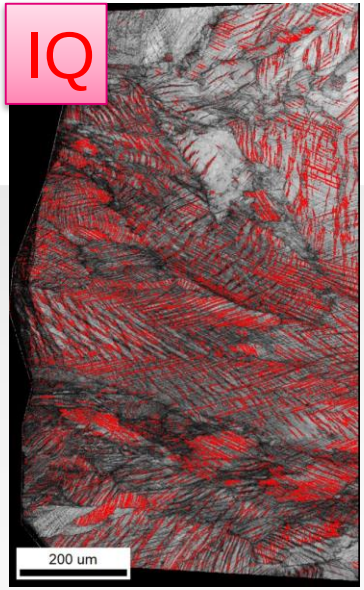




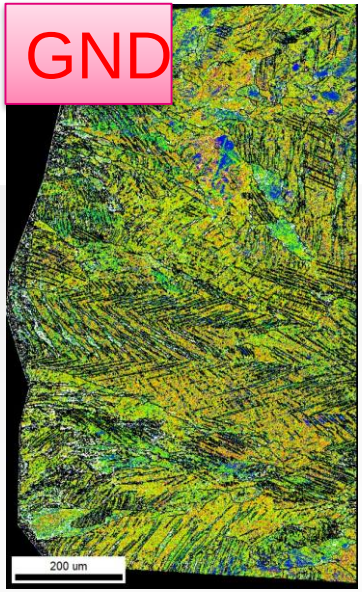
A structure having a higher Taylor factor experiences a greater strain hardening and develops a higher dislocation density to maintain strain compatibility with the neighboring grains.

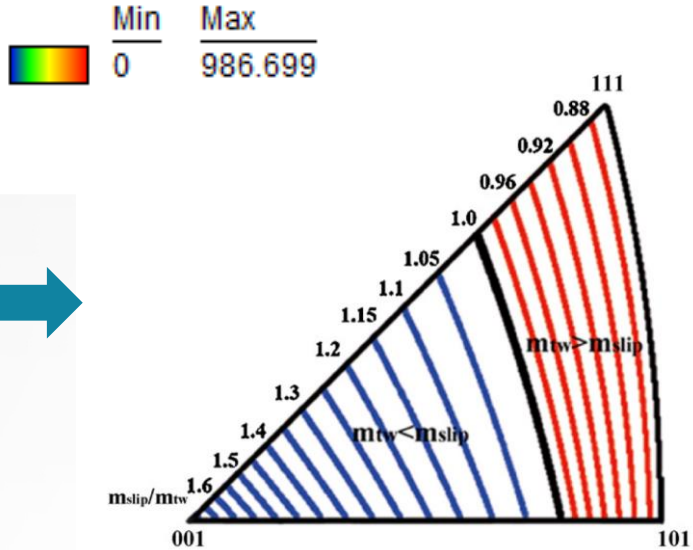
Horizontal

IQ



GND

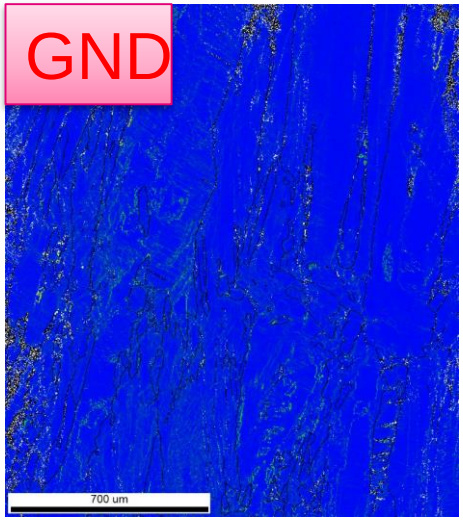


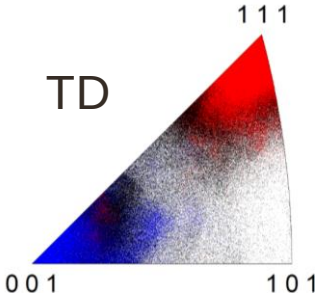


Vertical

IQ

GND

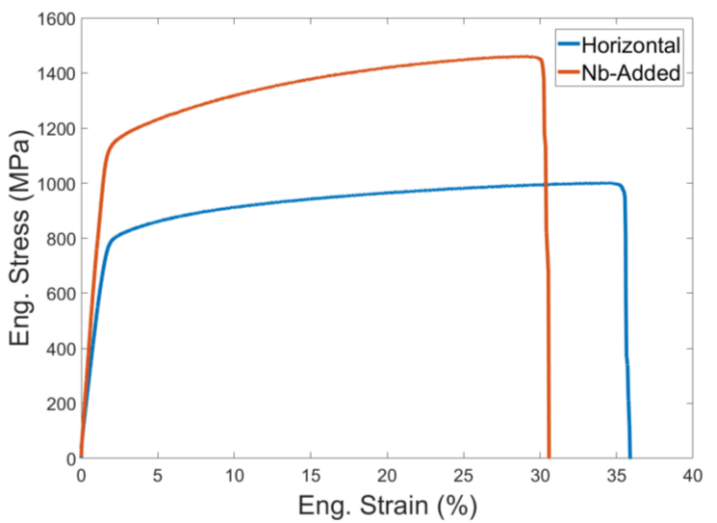


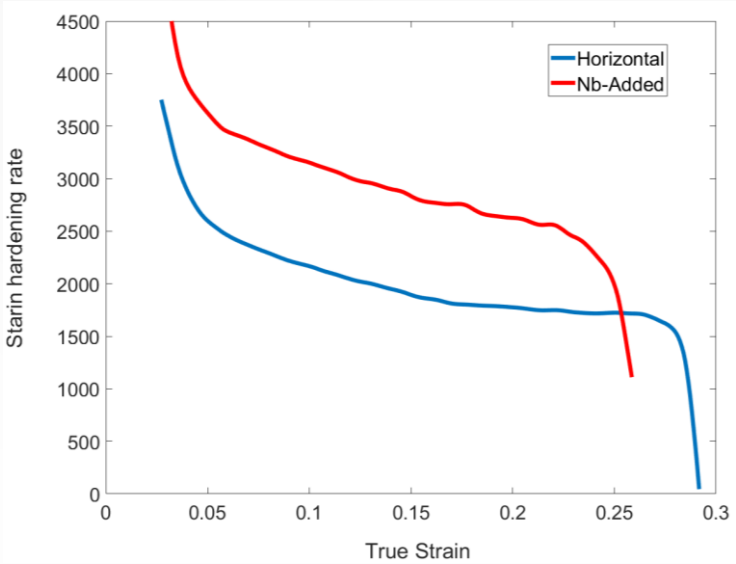


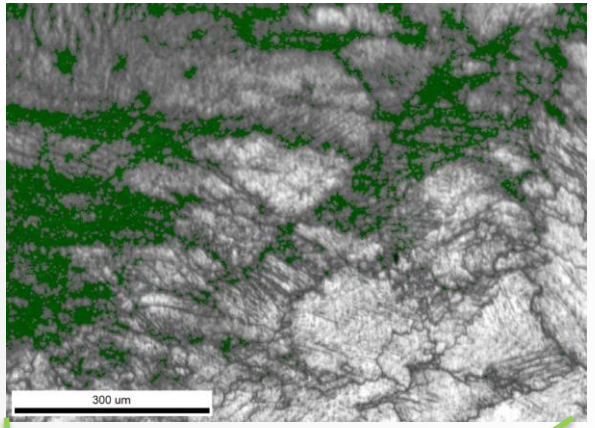
Twinned

Not Twinned

Nb addition

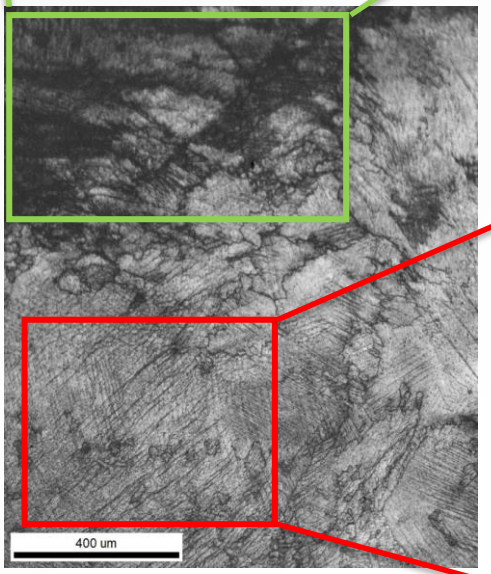




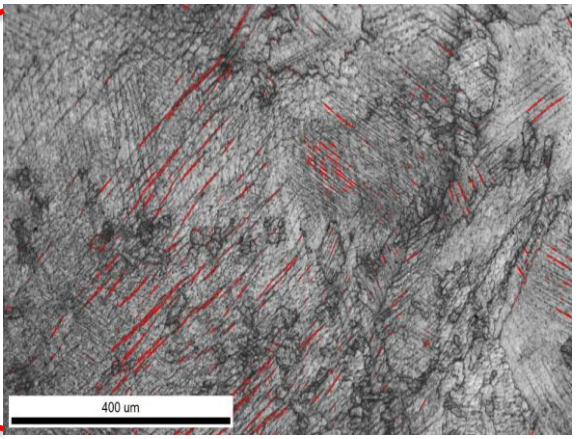


HCP

TRIP effect



TWIP effect



Summary

- Strong anisotropic behavior of LMDed high entropy alloy
- Uniaxial tension in <111> direction leads to higher strength compared to the one along <001> direction.
- The dominant deformation mechanism in the horizontal sample with <111>// TD is twining, whereas the vertical sample with <001>//TD deforms via slip.
- A novel structure-property relationship for large metal components made layer-by-layer with laser powder deposition
- This can be employed to determine microstructural features required to obtain desired properties and to improve the mechanical integrity of LMD products.

Thank you