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Characterization of Tri-Lab Tantalum Plate

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Tri-Lab Tantalum plate

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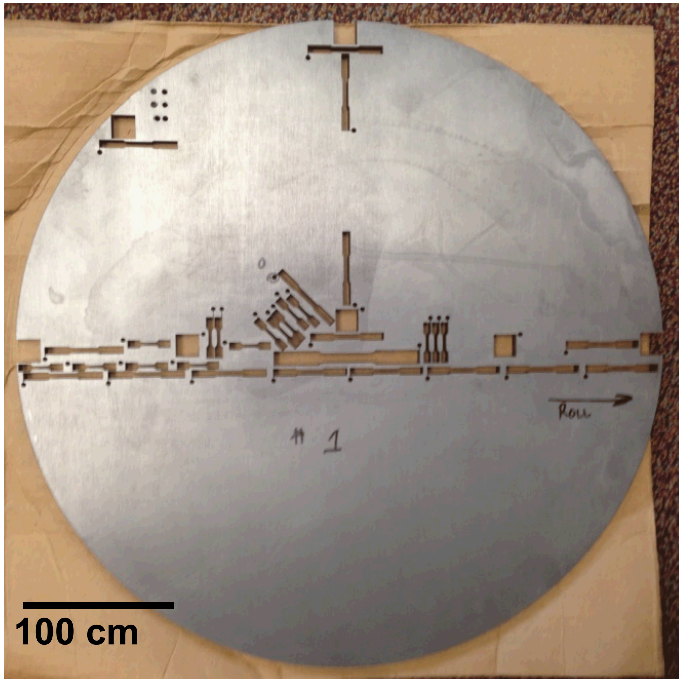
-manufactured by HCStark Inc.

A typical plate:



0.4 in. thick by 17.5 in. dia.

- 9 plates, 3 to each laboratory (LLNL, LANL, SNL)
- Microstructural banding and crystallographic texture notoriously difficult to control during processing of BCC metals.
- Homogeneity within a plate and plate-to-plate uniformity achieved through a specialized method of clock rolling and tilt rolling of the stock material.

Chemistry:

- Most significant measured impurities are O (16 PPM), N (8 PPM), C (5 PPM) and H (1 PPM).
- Conforms to specification provided by ASTM B-708-05

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Through thickness and in-plane Microstructure and Mechanical Properties Variation

Variability in Processed Ta material

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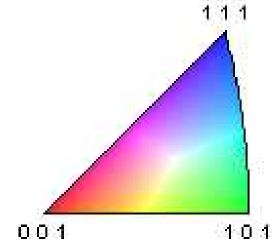
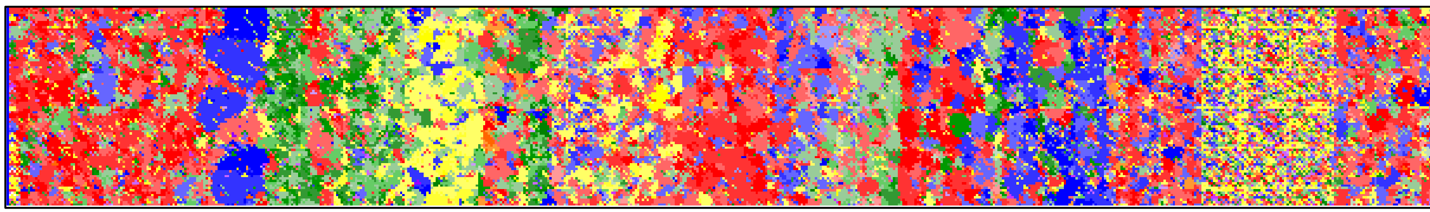
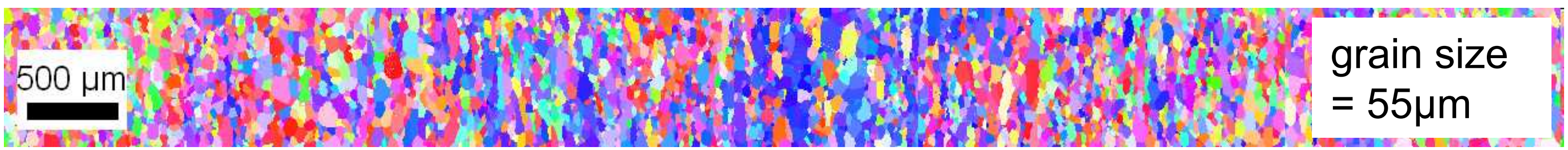


Through-Thickness Direction

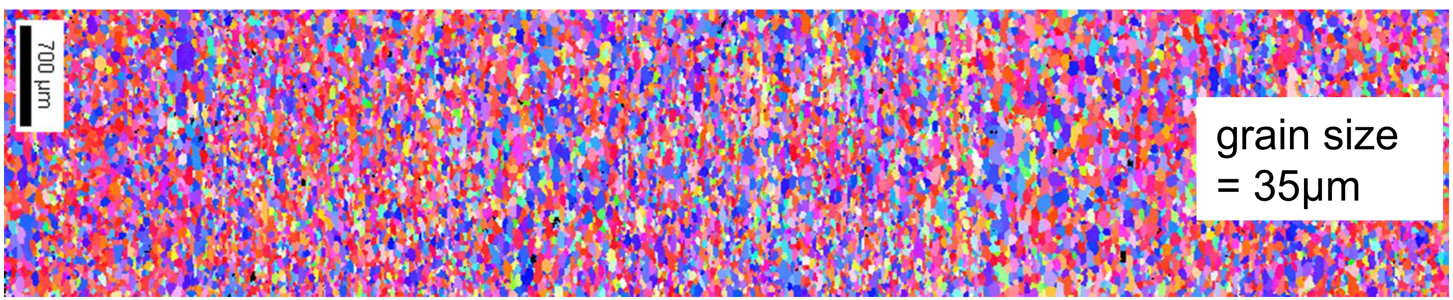
Vintage Bar



Previous Plate (A)



New Plate (B)



HC Starck Inc.

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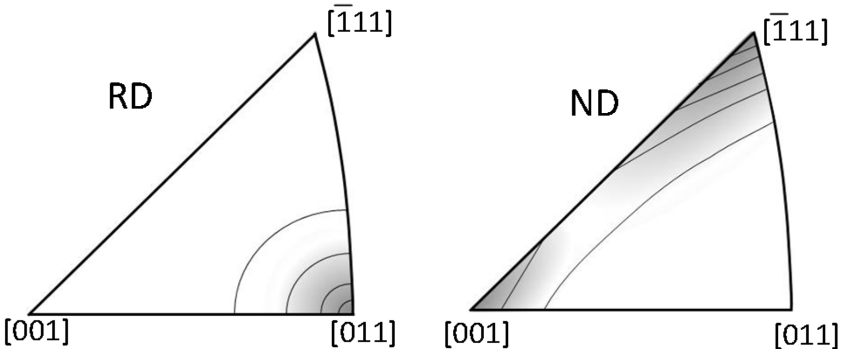
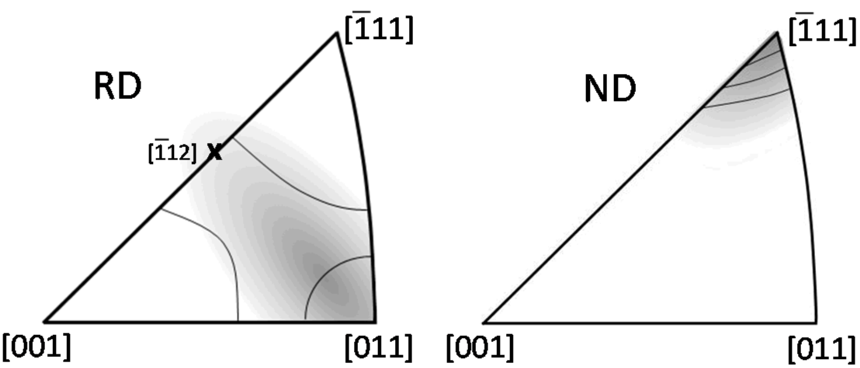
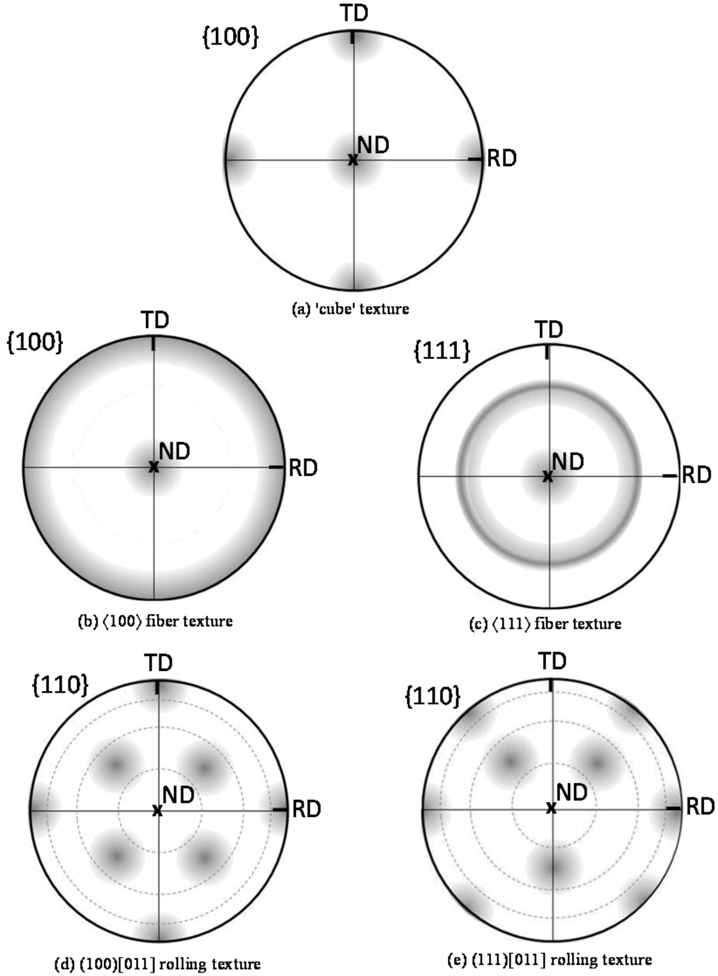
Representation of typical rolling textures in BCC metals



⟨ - texture

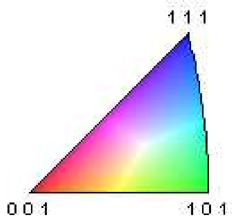


γ- texture



γ- texture

⟨ - texture



Typical IPF representation of EBSD data

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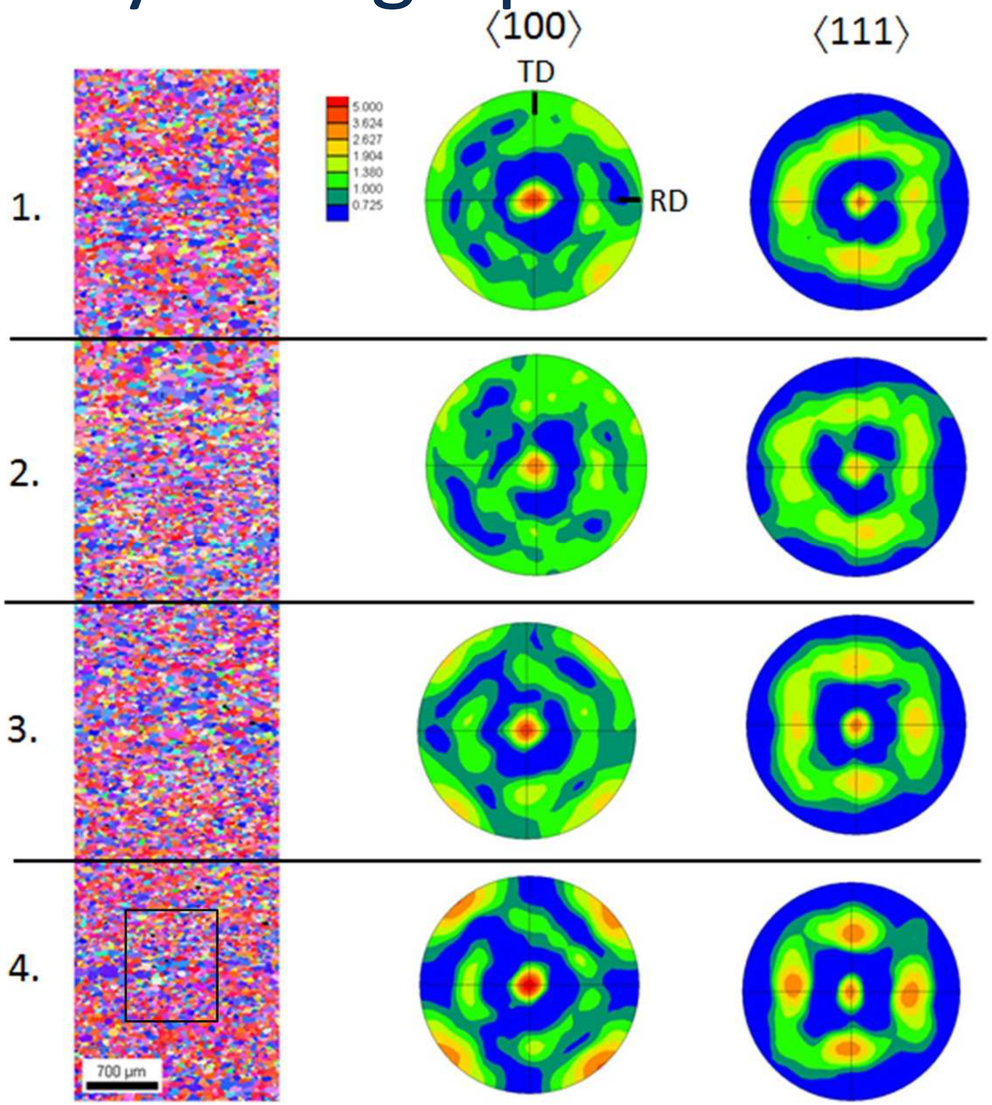
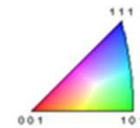
The α- fiber component characterizes the crystallographic texture of the plate





Quartile	⟨001⟩/⟨111⟩ ratio	Grain Size (µm)
1	1.24	38
2	0.957	36
3	1.05	35
4	1.39	34

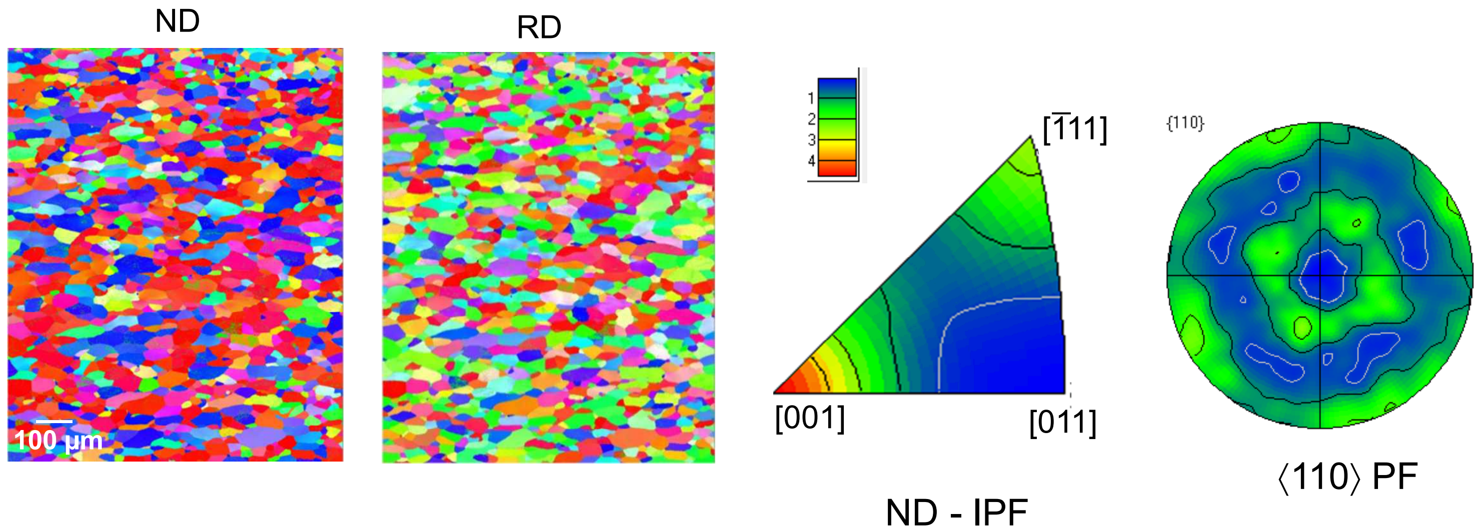
No clear evidence of banding or other microstructure inhomogeneity

pixel spacing

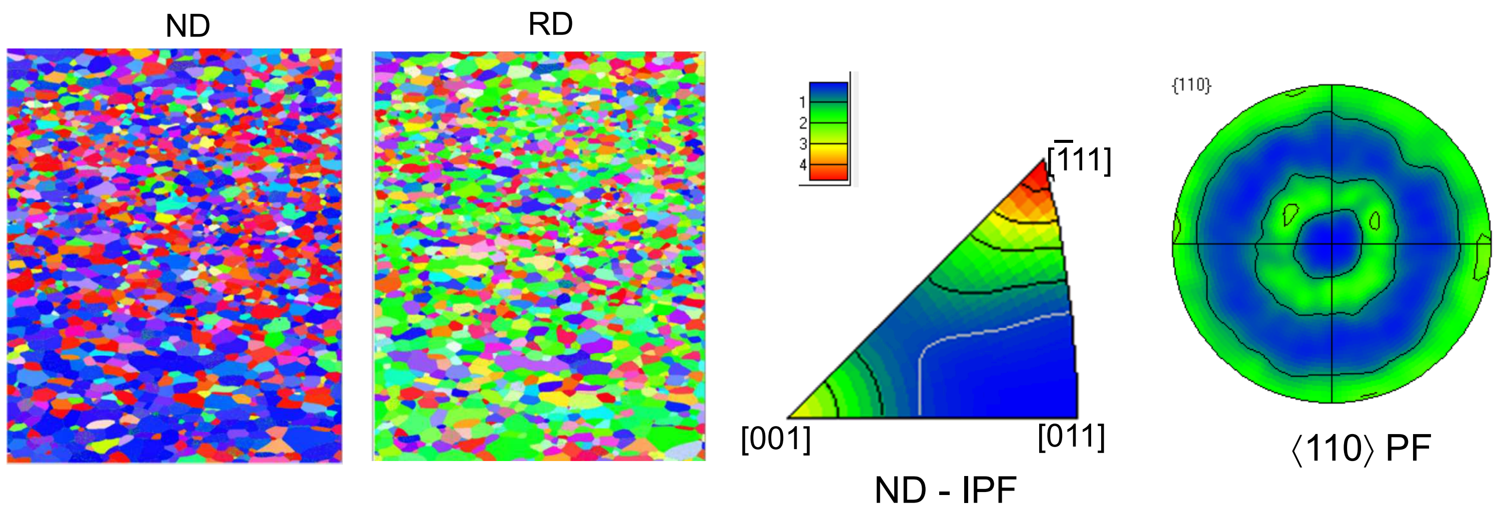
High Resolution EBSD maps from the center of the plate

1 µm pixel spacing

Near plate surface



Near plate center



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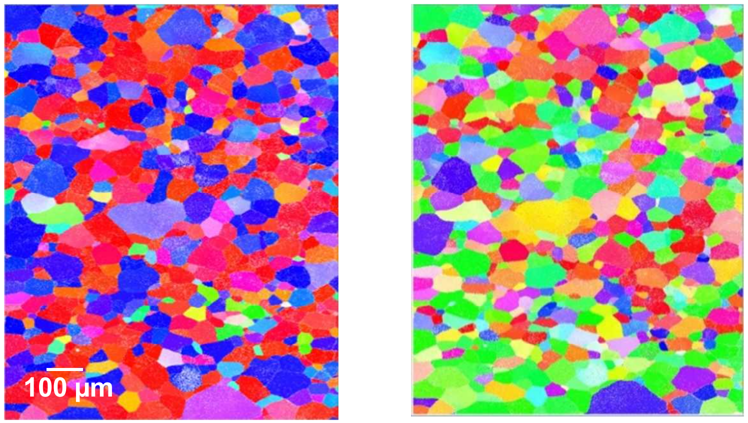
- Partial ⟨110⟩ fiber texture along RD and ⟨001⟩/⟨111⟩ ratio changes from center to surface along ND

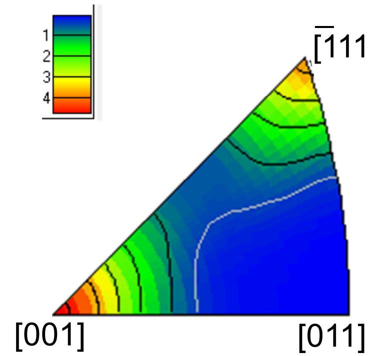
High Resolution EBSD scans from the end of the plate

Near plate surface

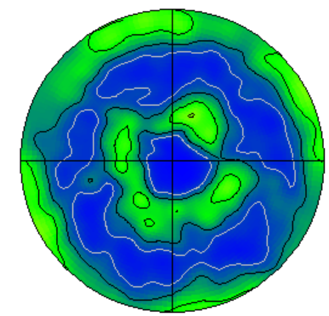
ND RD



EBSD maps



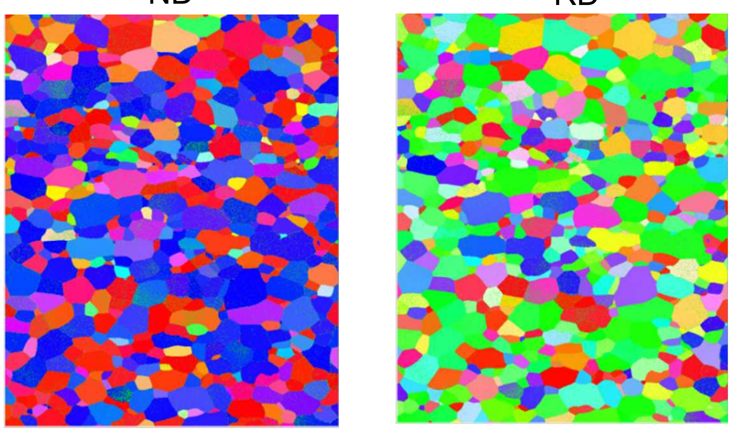
ND - IPF



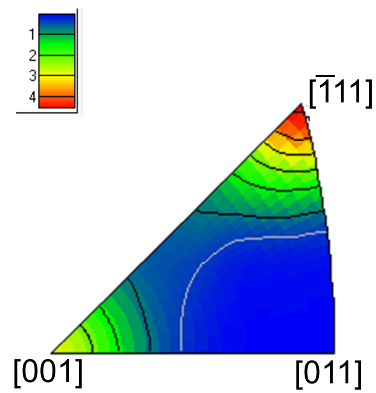
⟨110⟩ PF

Near plate center

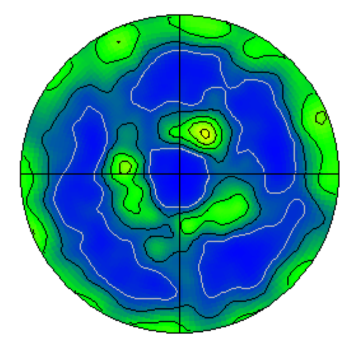
ND RD



EBSD maps



ND - IPF



⟨110⟩ PF

- Increased grain size near end of plate

Summary Tables from EBSD maps

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Through Thickness scan

Quartile	⟨001⟩/⟨111⟩ ratio	Grain Size (μm)
1	1.24	38
2	0.957	36
3	1.05	35
4	1.39	34

High Resolution scans

Location	⟨001⟩/⟨111⟩ ratio	Grain Size (um)	Aspect Ratio
Center Top Edge	3.99/2.17 (1.83)	27.1	1.63
Center Middle	2.89/4.29 (0.67)	23.7	1.60
End Top Edge	5.16/4.07 (1.26)	38.3	1.12
End Middle	3.87/6.00 (0.64)	39.7	1.07

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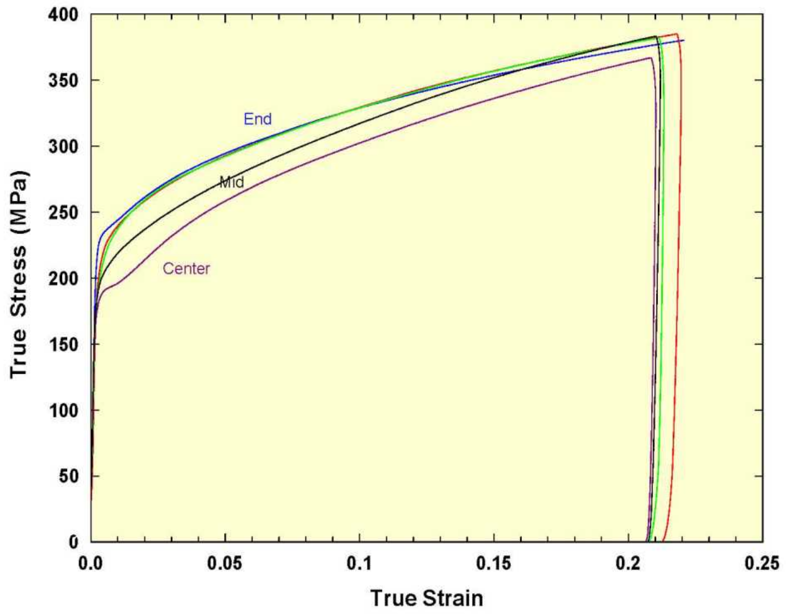
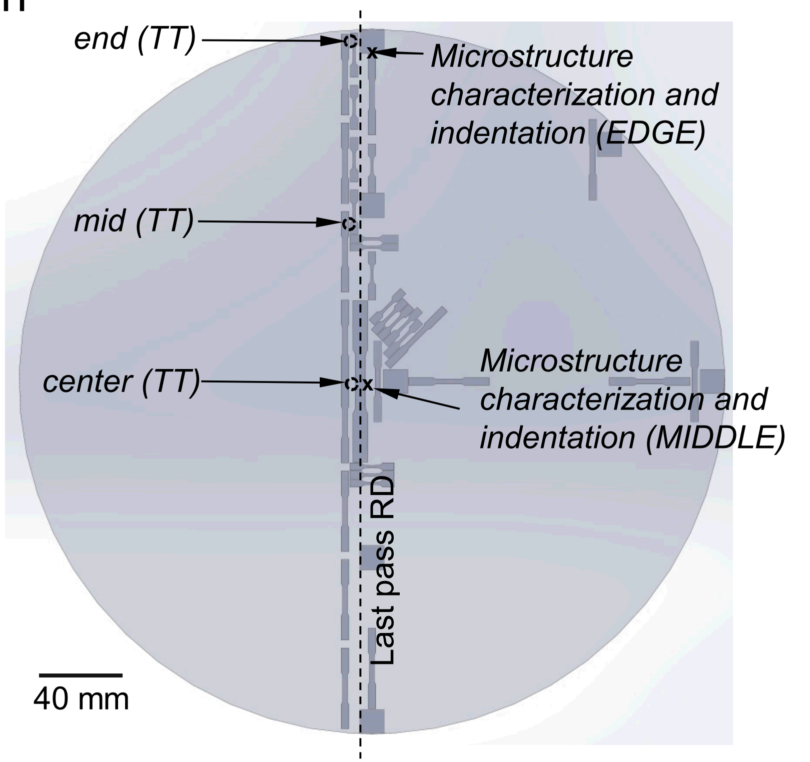
TT Compression Testing suggested a trend of increasing strength from center to end of plate

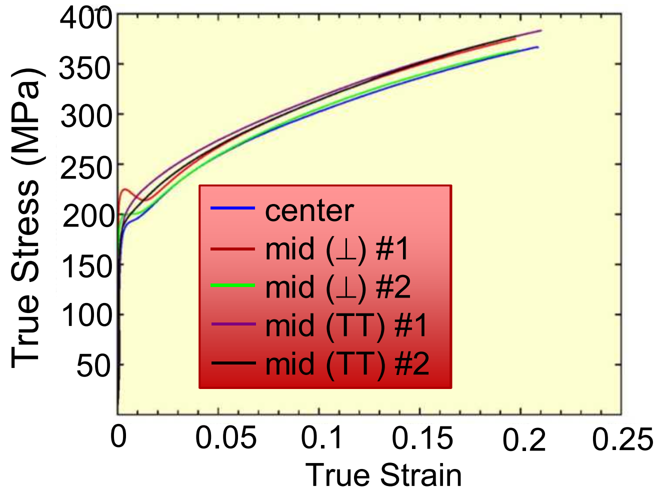
- Along the last pass rolling direction

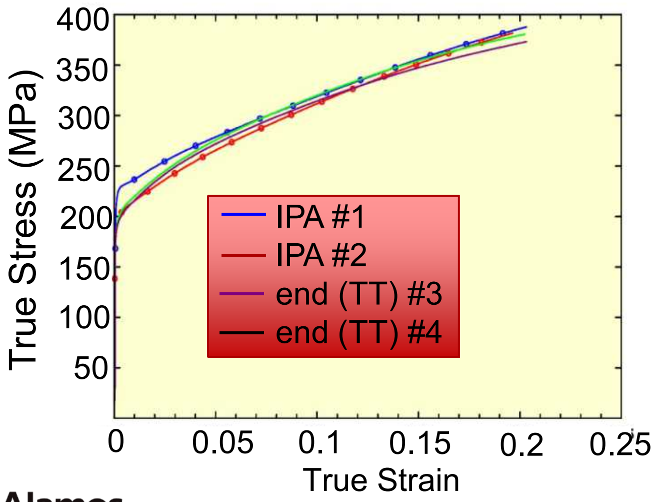


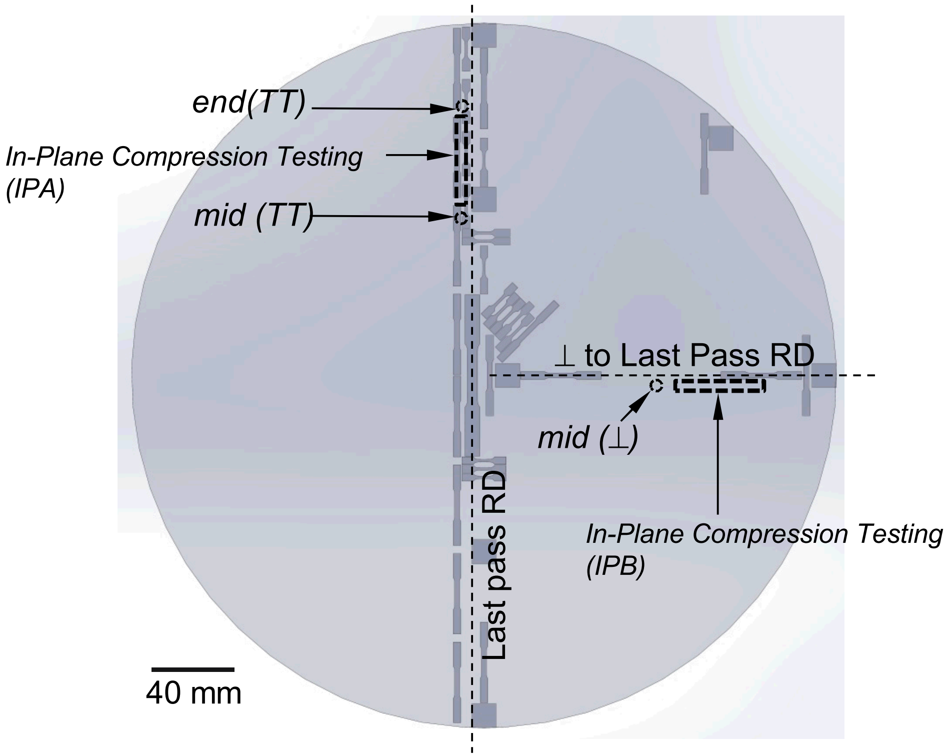


- Compression test Cylinders: 5mm dia. X 5 mm height
- Center/end difference consistent to a strain of 1.1
- Rationalized in terms of texture variation

Compression testing suggested minimal directional and in-plane variation in mechanical properties







- Slightly different work hardening response in IPA compression test results

Negligible Plate-to-Plate variation demonstrated

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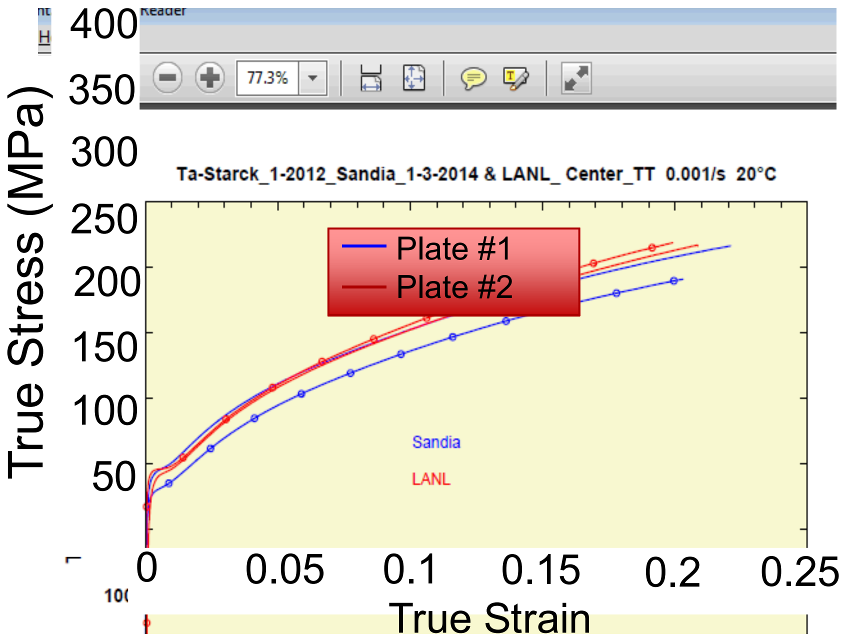

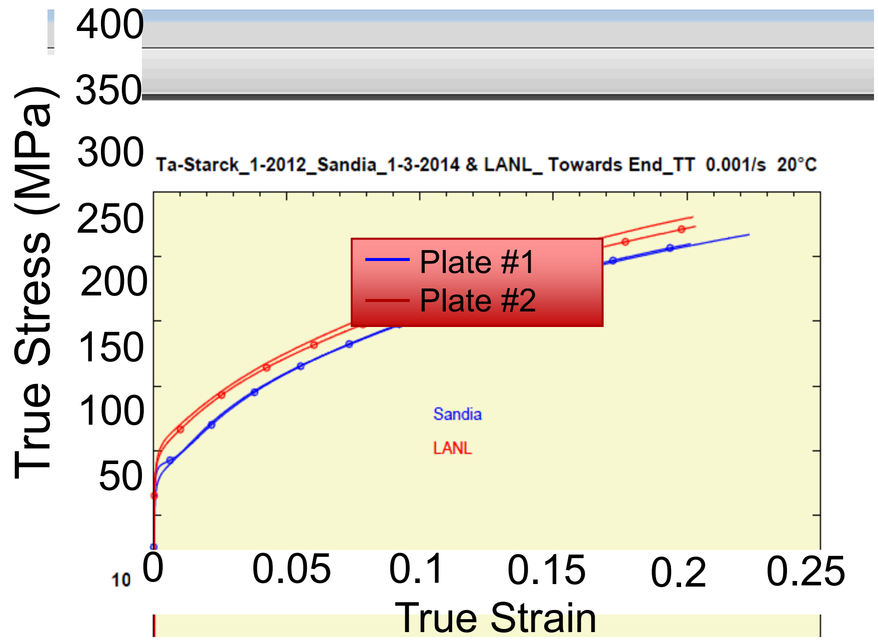

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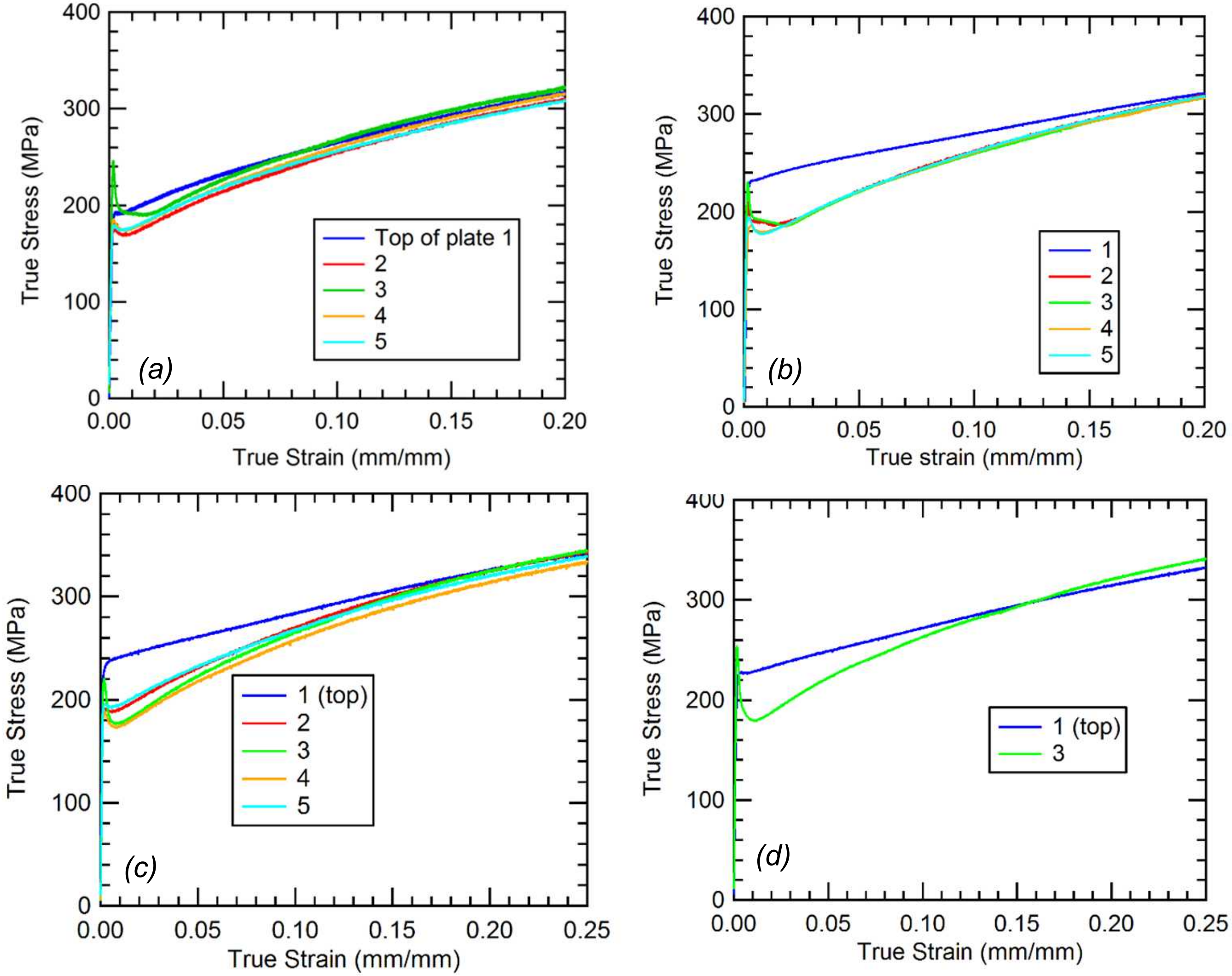
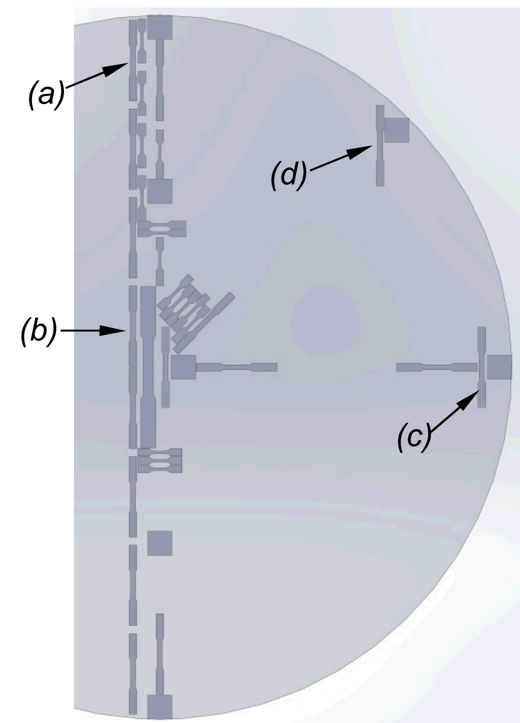
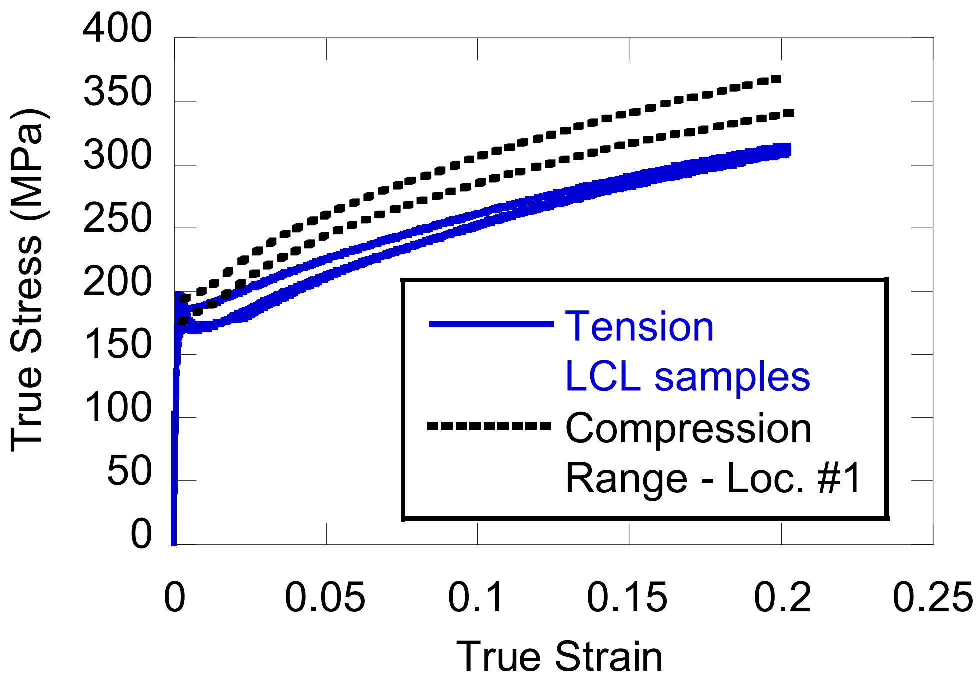
Stored work near the plate surface suppressed yield point effects





ASTM ½ sub-size:
thickness = 0.063 in.

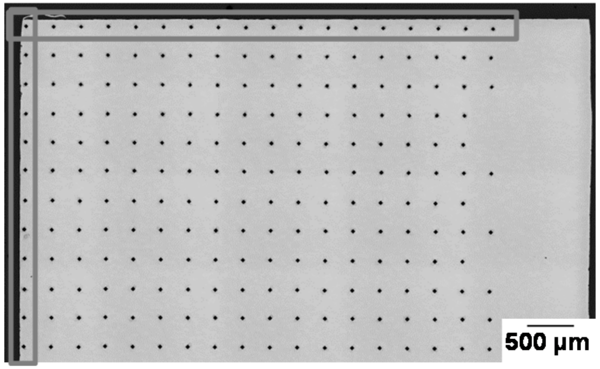
Work hardening rates differed in compression tests vs. tension tests

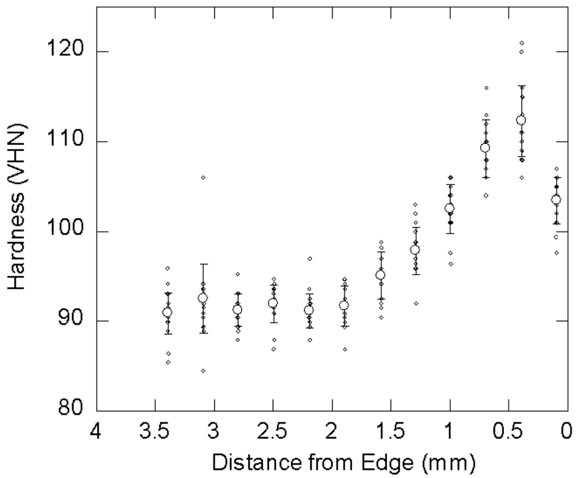


- Tension compression asymmetry in BCC metals
- Different geometry of test samples
- Orientation hardening

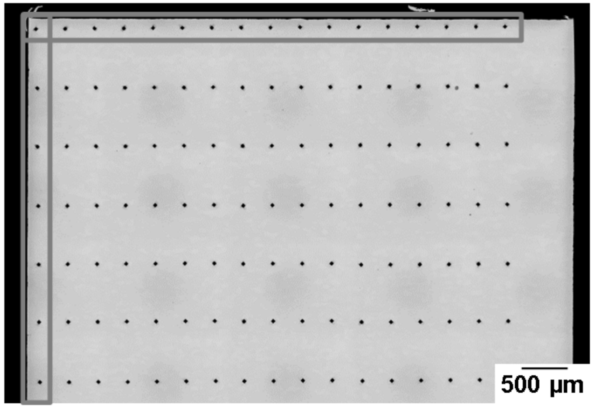
Micro-Indentation showed increased hardness near the surface of the plate

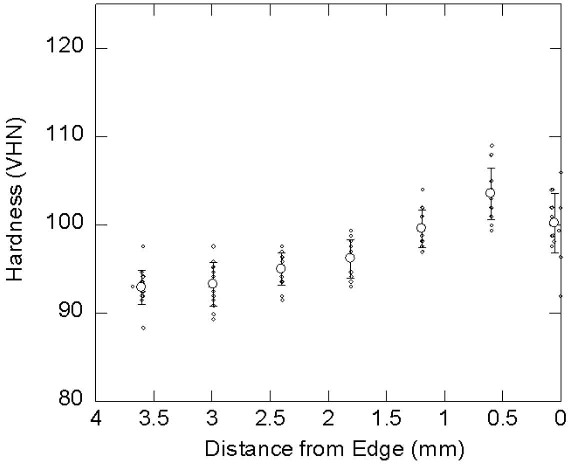
center of plate





end of plate





Evidence of stored work near top of plate

Instrumented Indentation reveals similar 15% increase in hardness near edge of plate

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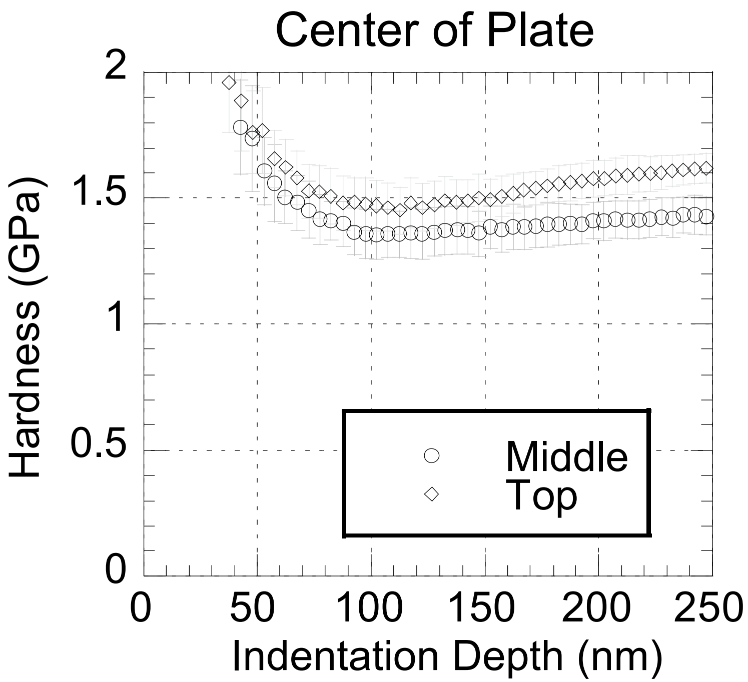

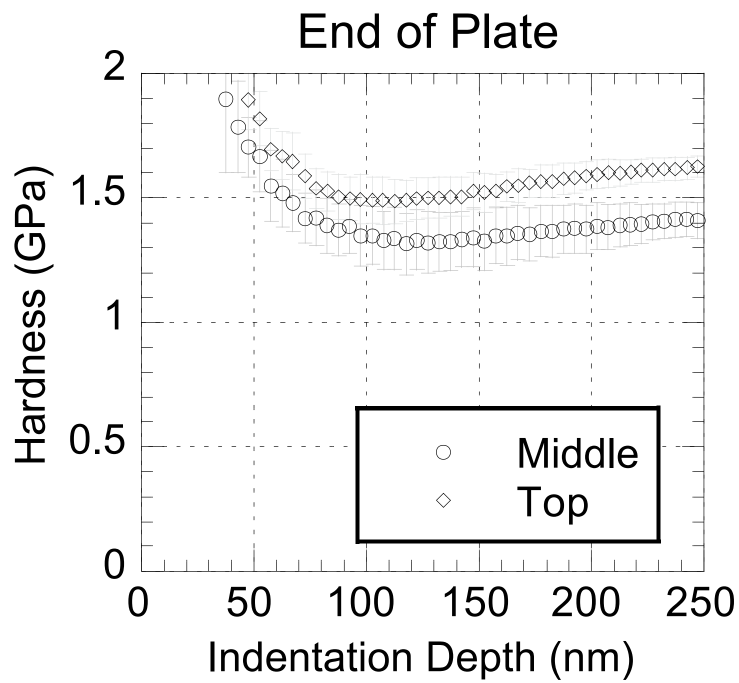

Different scale experiment vs. microindentation

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Summary

- DOE Ta has uniform crystallographic texture, far superior that what can usually be achieved for a polycrystalline BCC metal. Variation in <001>/<111> ratio near end of plate.
- Evidence of stored work near top and bottom surfaces of the plate and a small increase in grain size (from 25 um to 39 um) near the end of the plate.
- No clear evidence of microstructure banding.
- Compression cylinder testing revealed a measurable increase in strength near the end of the plate.

Recommendation: Do not use material 25 mm from the end of the plate and 2mm from the top and bottom of the plate for ACP testing