Relating Texture and Thermomechanical Processing Variables in Mg–Zn–Ca Alloys

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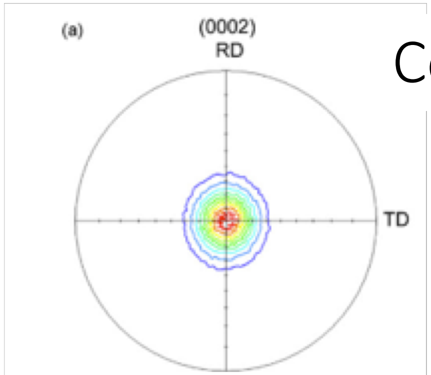
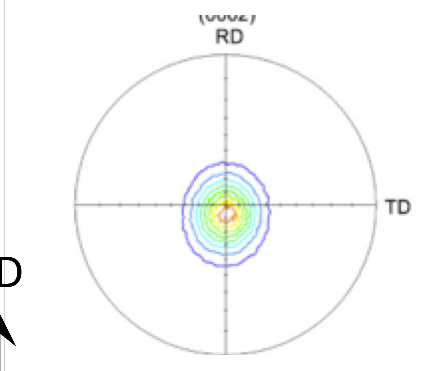
Both composition and TMP affect texture & formability

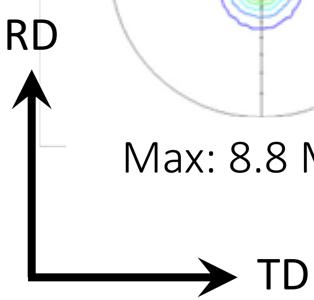
AZ31B



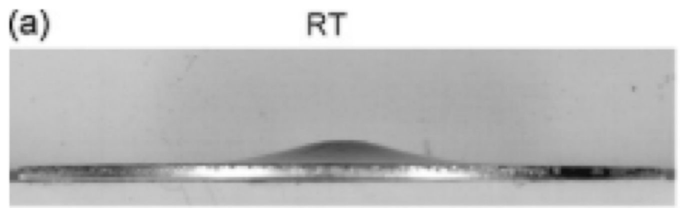
Max: 10.6 MRD



Max: 8.8 MRD

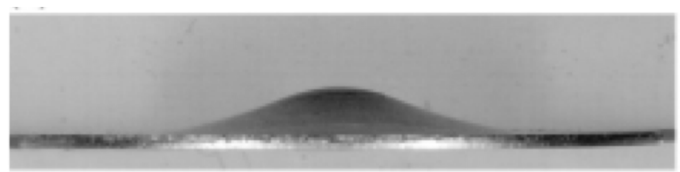


Conventionally Rolled



IE: 2.6

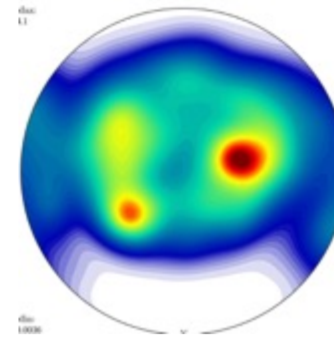
DSR



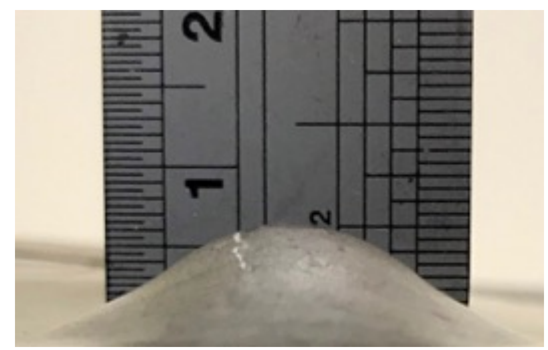
IE: 4.0

[Huang2009]

ZXEM2000 (sheet provided by OSU)



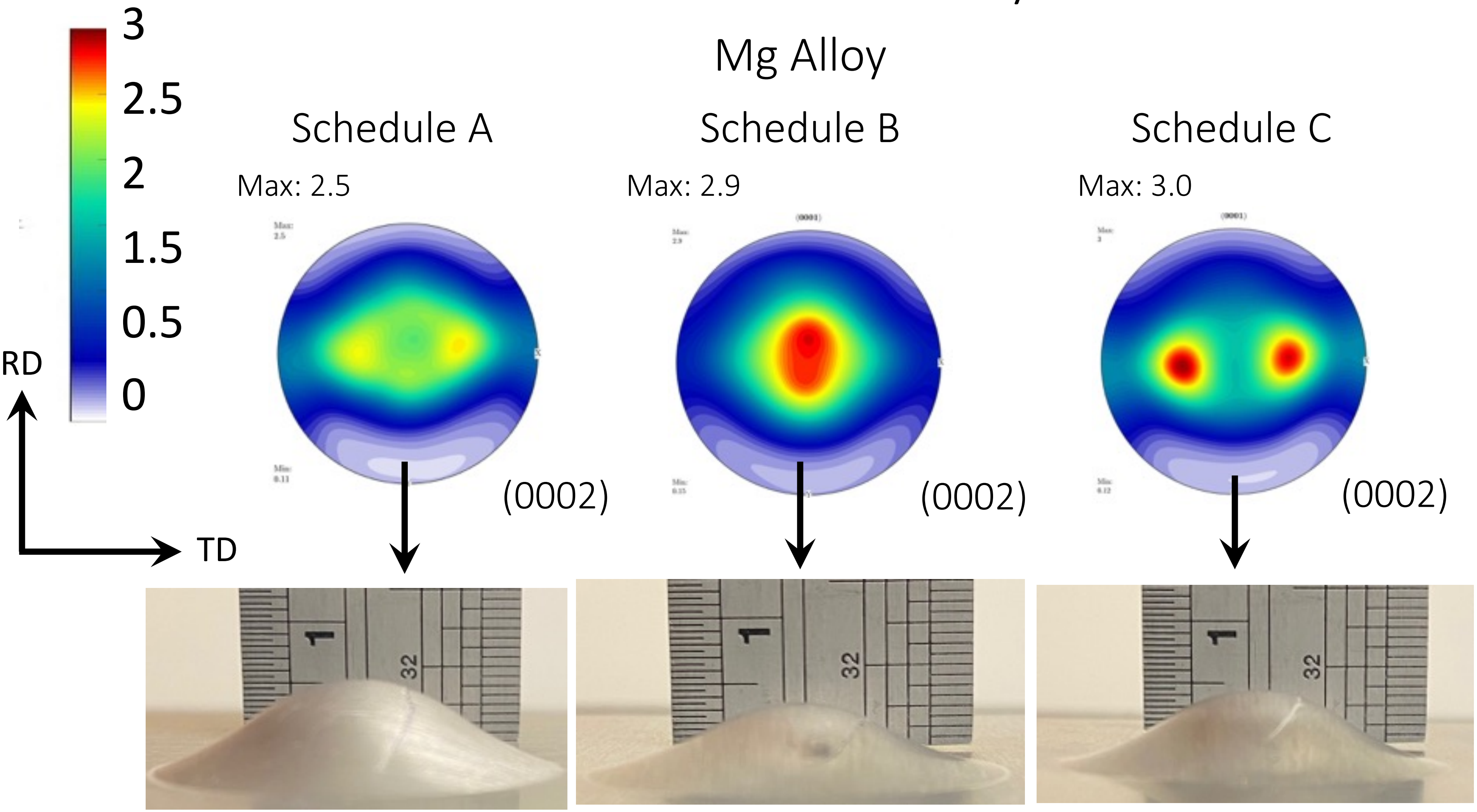
Max: 3.1 MRD



IE: 6.5

Huang XS, Suzuki K, Watazu A, et al (2009) Improvement of formability of Mg–Al–Zn alloy sheet at low temperatures using differential speed rolling. J Alloys Compd 470:263–268

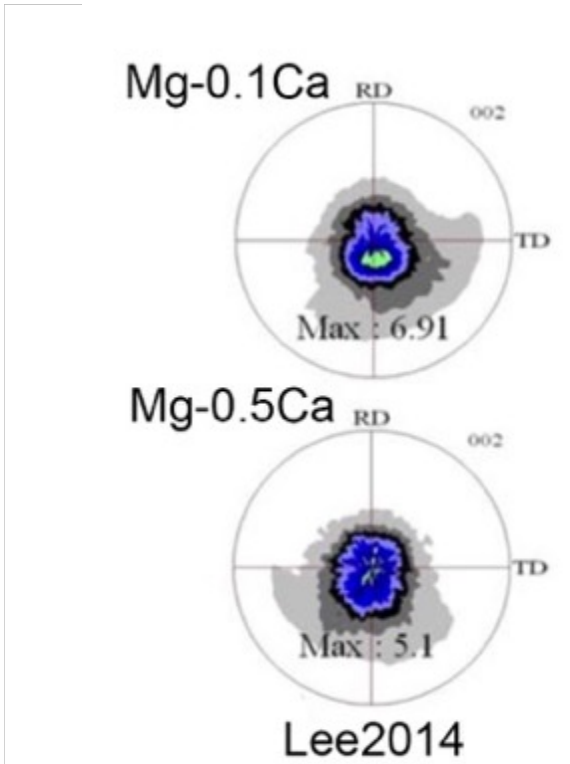
A promising alloy can have different textures (and formability) based on the TMP history

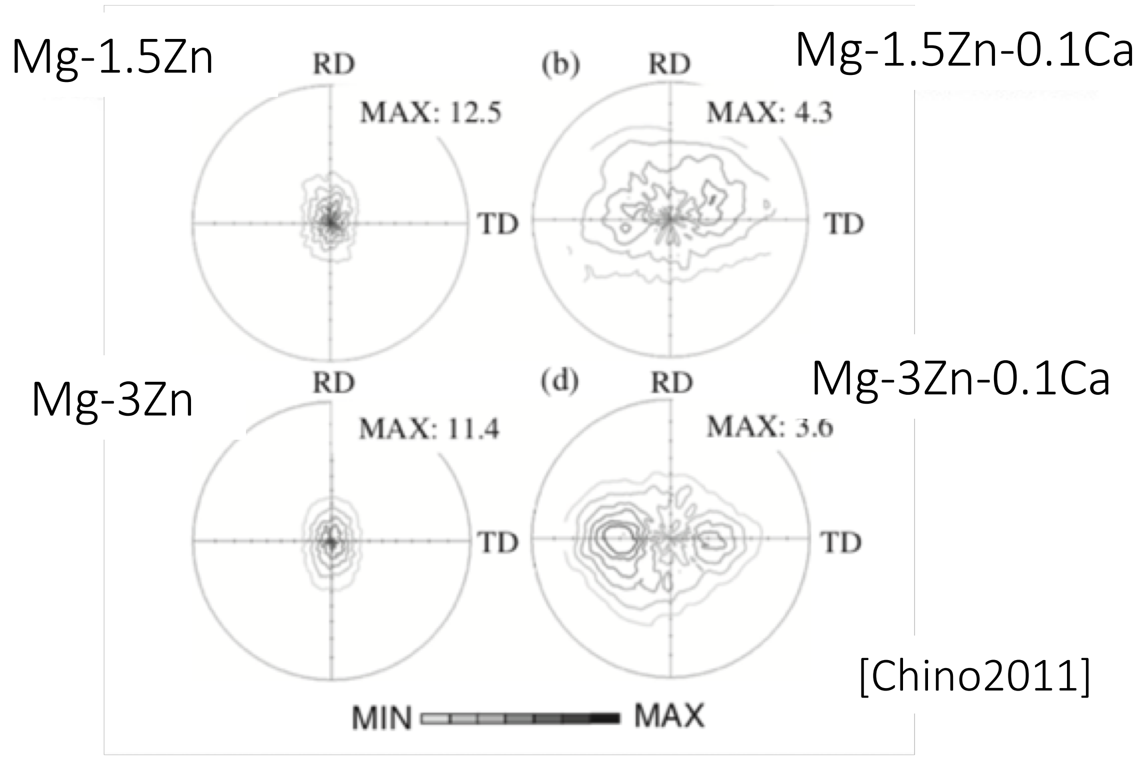


IE: 6.2 +/- 0.6 | IE: 4.6 +/- 0.4 | IE: 6.5 +/- 0.4

Berman and Allison

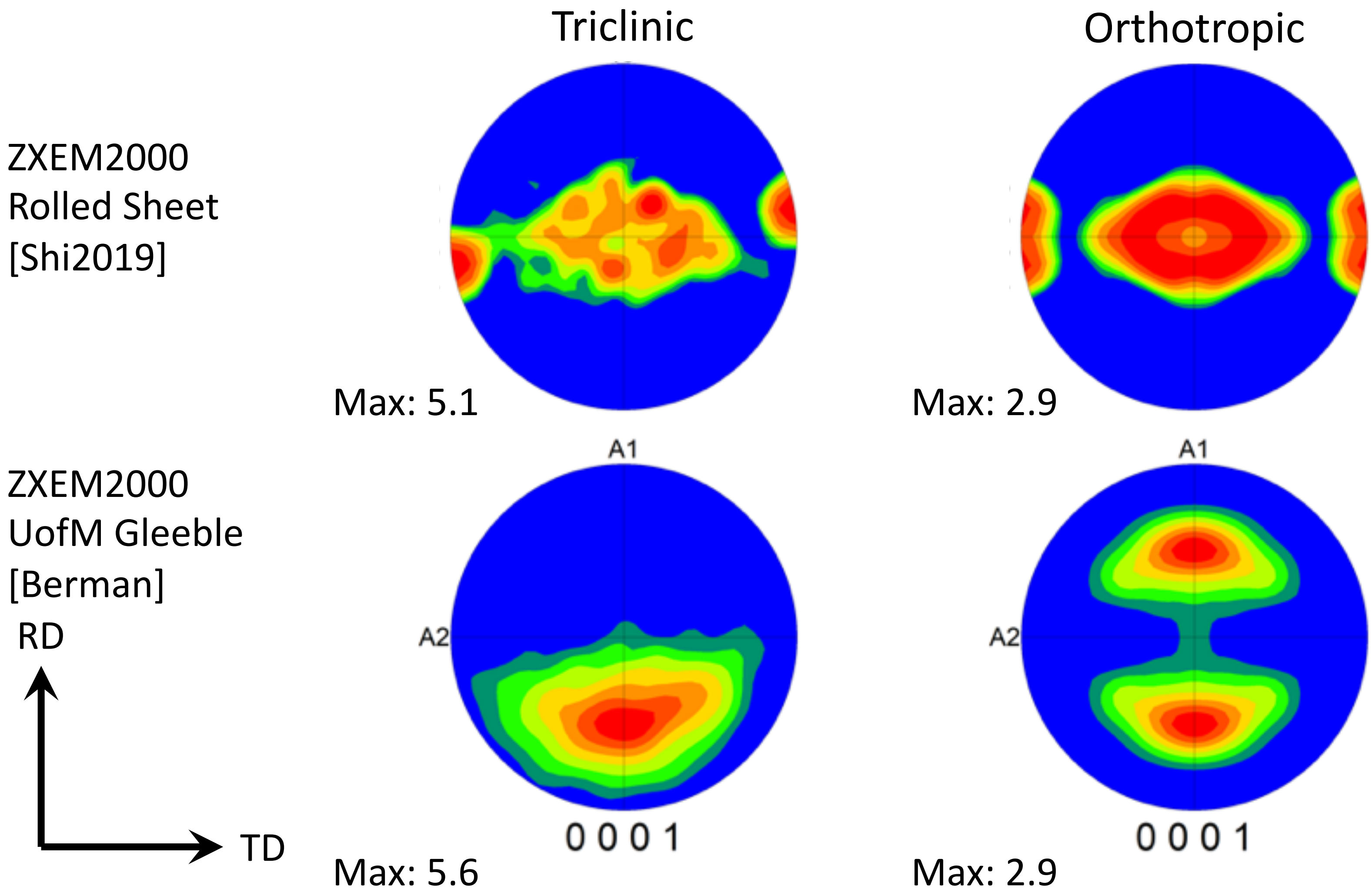
Mg-Zn-(RE,Ca) alloys can lead to weaker textures, but it can be difficult to reproduce TMP history from literature





- Lee JY, Yun YS, Kim WT, Kim DH (2014) Twinning and texture evolution in binary Mg-Ca and Mg-Zn alloys. Met Mater Int 20:885–891.
- Chino Y, Ueda T, Otomatsu Y, et al (2011) Effects of Ca on Tensile Properties and Stretch Formability at Room Temperature in Mg-Zn and Mg-Al Alloys. Mater Trans 52:1477–1482.

It can also be quite difficult to compare pole figures in the literature



Shi R, Miao J, Luo AA (2019) A new magnesium sheet alloy and its multi-stage homogenization for simultaneously improved ductility and strength at room temperature. Scr Mater 171:92–97.

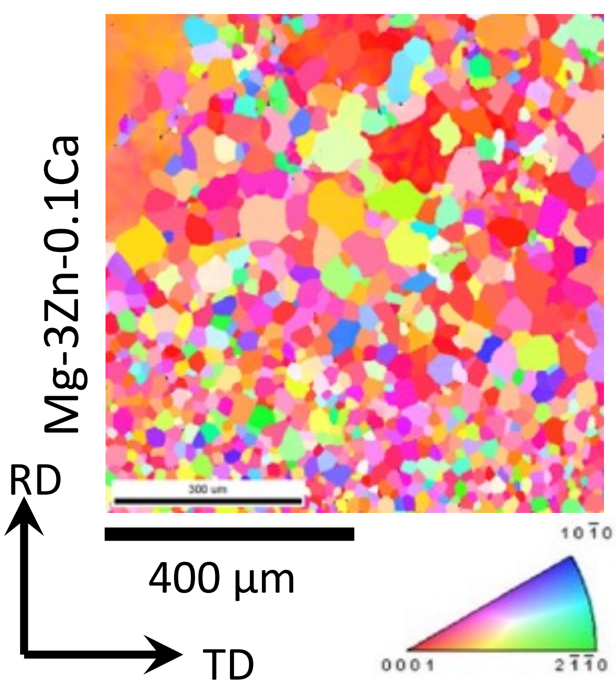
Approach

- Cast ingot provided by Prof. Manuel's group at University of Florida (Initial focus on Mg-3Zn-0.1Ca –ZX30)

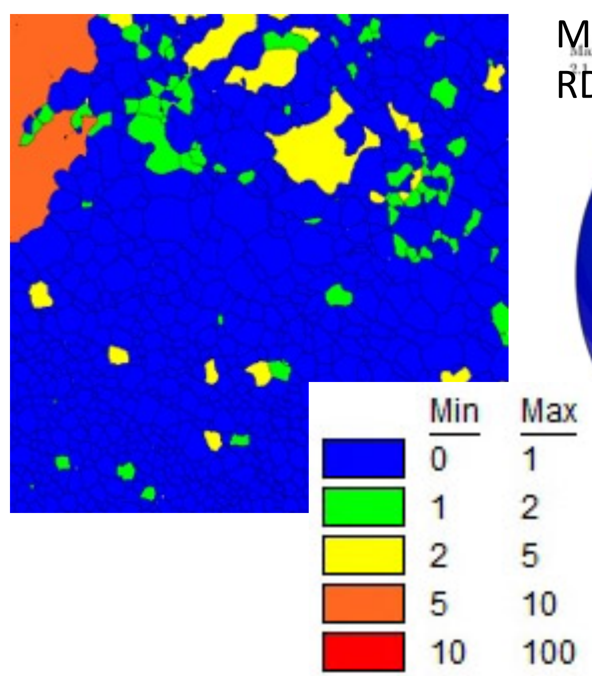
- Gleeble Plane Strain Compression (PSC) + Electron Backscatter Diffraction (EBSD)

- TMP (and alloying) vs. texture

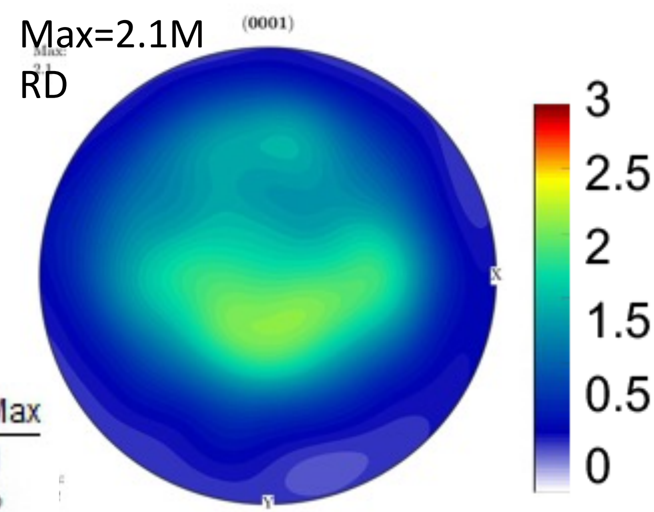
IPF map



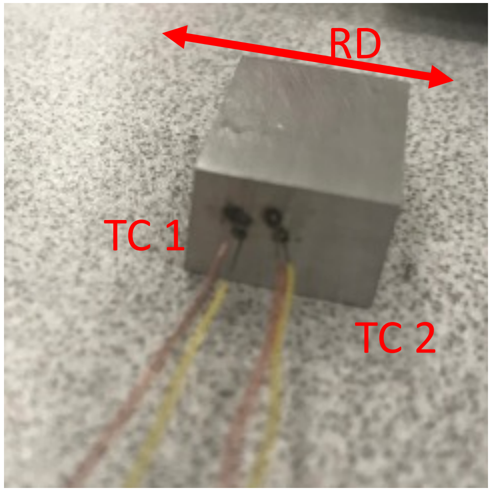
GOS map



0001 PF

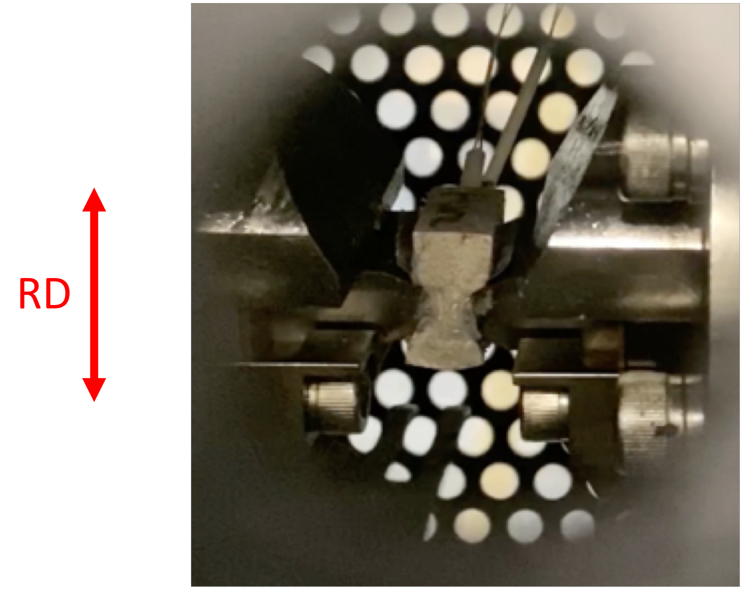


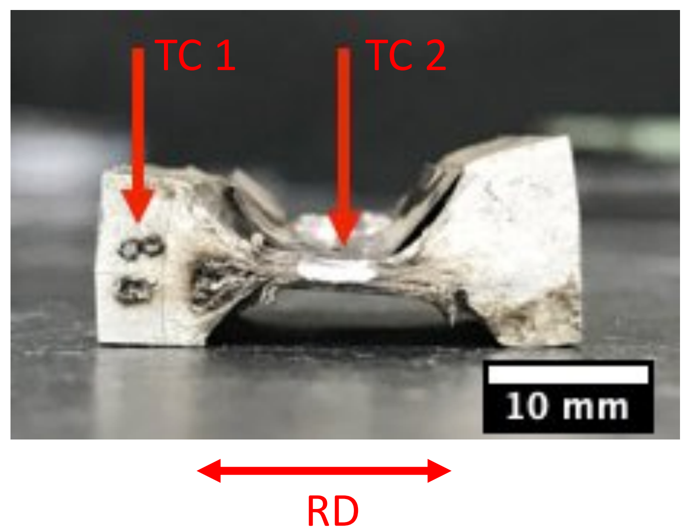
Careful control of TMP using Gleeble Thermomechanical Simulator



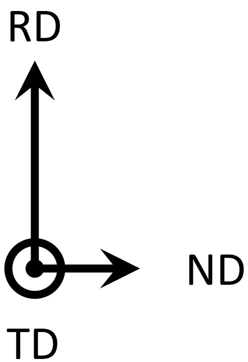
TC 1 is used as the control thermocouple (less likely to fall off during compression)

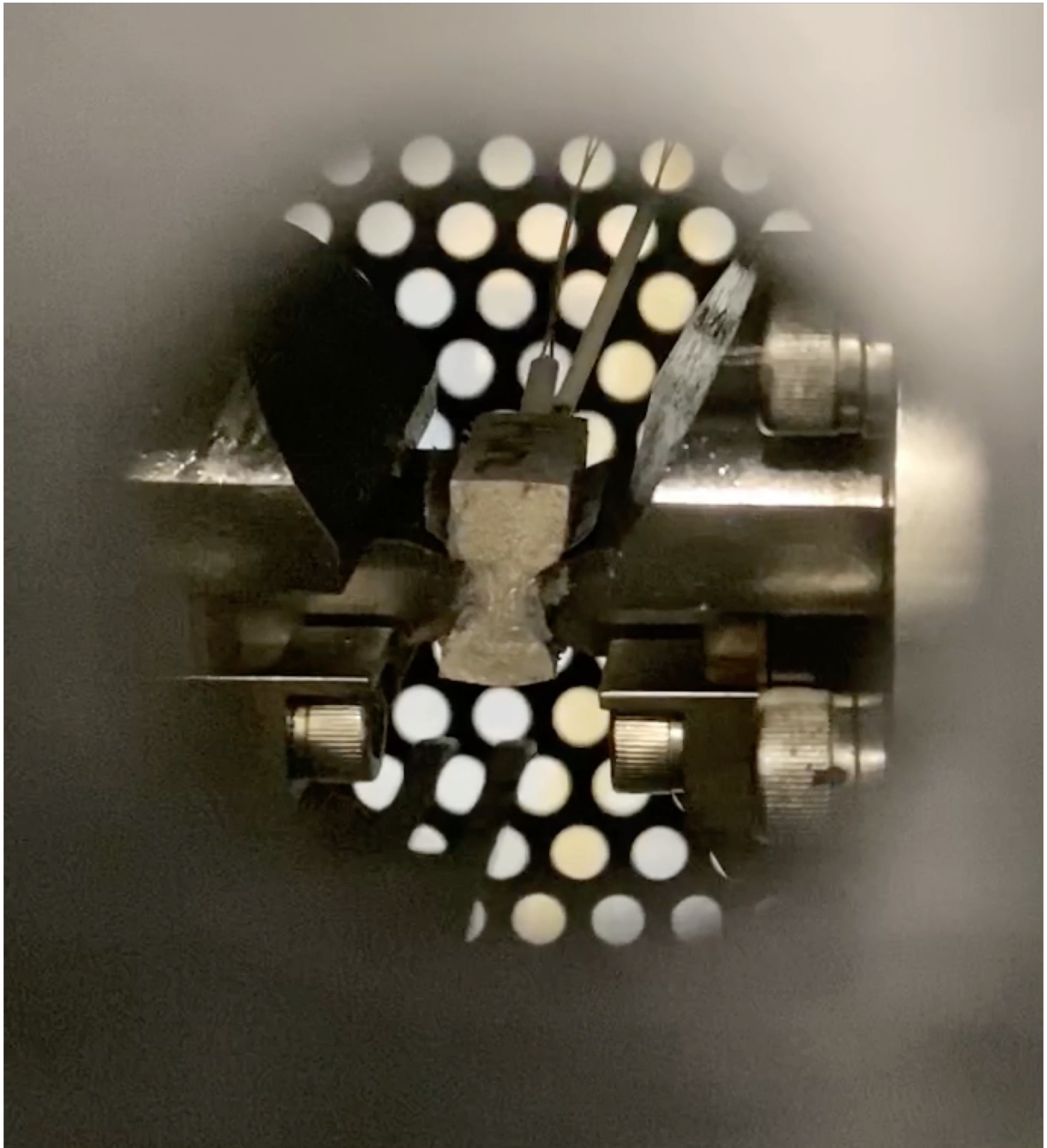
- Temperature
- # of passes
- Strain per pass: variable or constant
- Strain rate
- Annealing between passes
- Final anneal (time and temp)





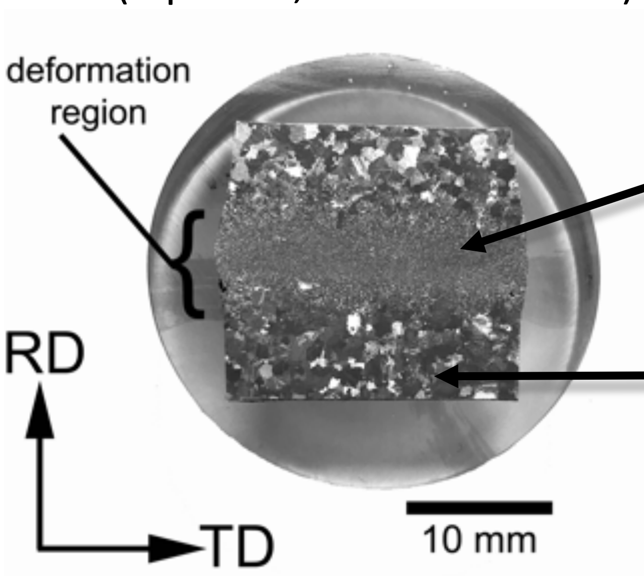
Gleeble Plane Strain Compression (PSC)

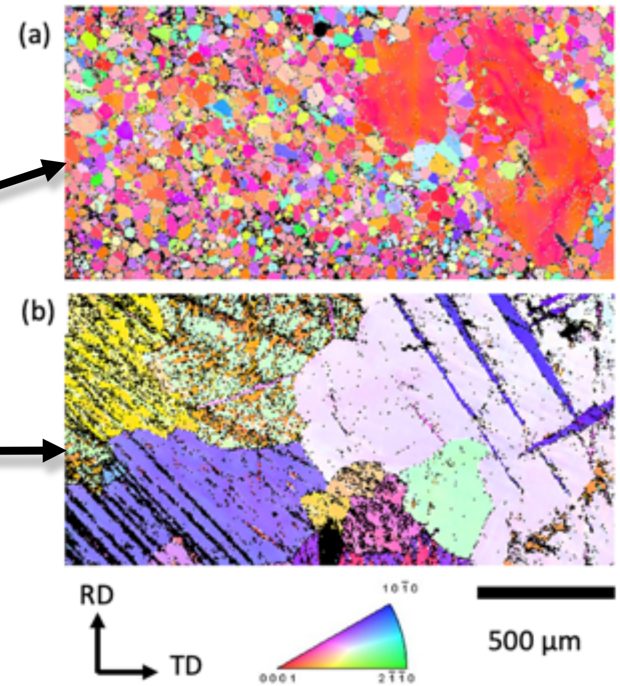




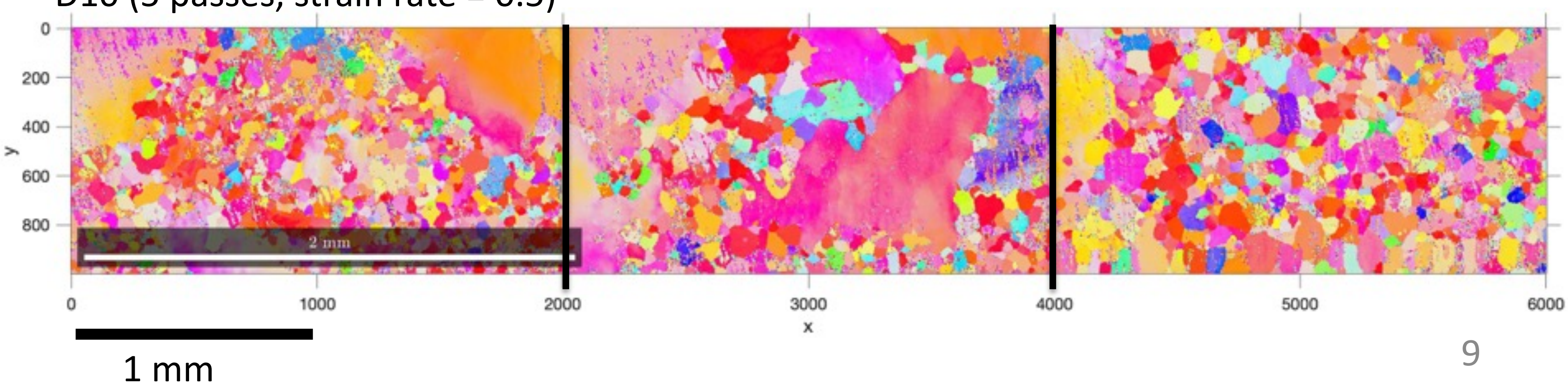
TMP Processing leads to obvious grain refinement. More passes leads to a more uniform microstructure…

D06 (5 passes, strain rate = 0.1)



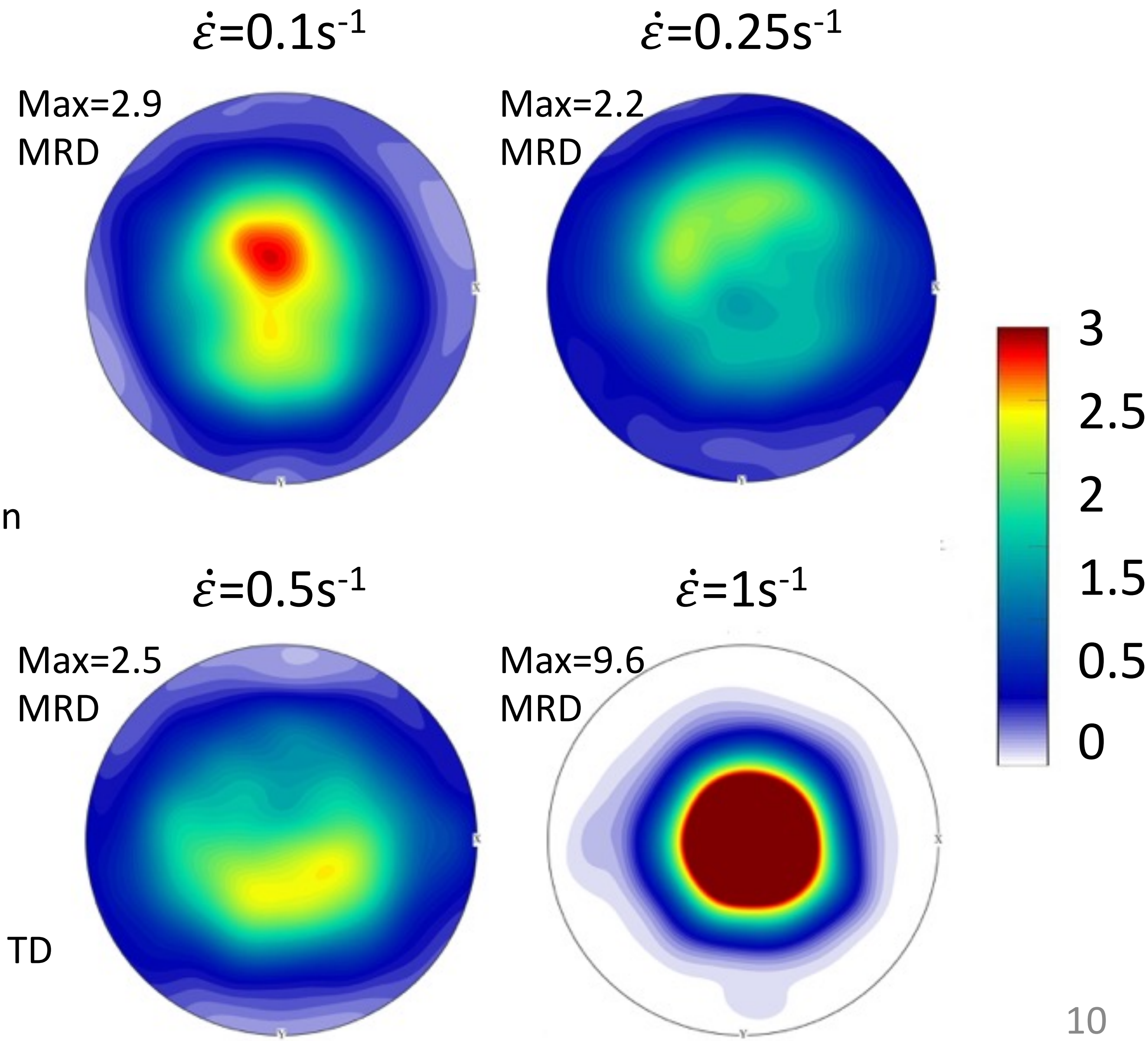


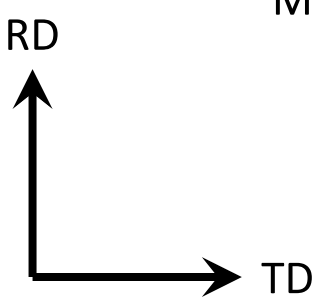
D10 (5 passes, strain rate = 0.5)



Intermediate strain rates lead to spreading in TD

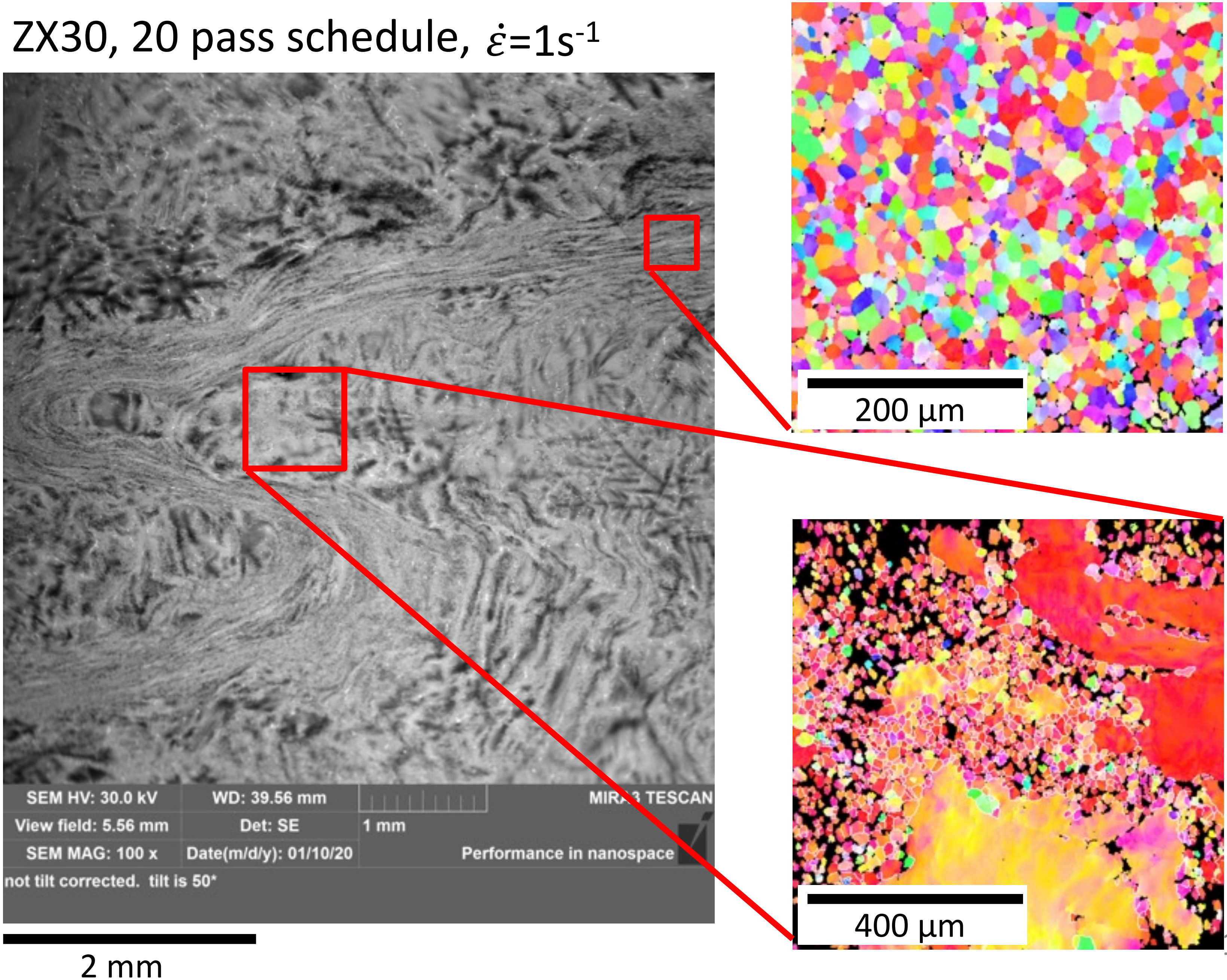
Alloy: Mg-3Zn-0.1Ca
Temp: 350ºC
# of passes: 10
Strain per pass: 0.2
Strain rate: varied
Final anneal: 350ºC/10min



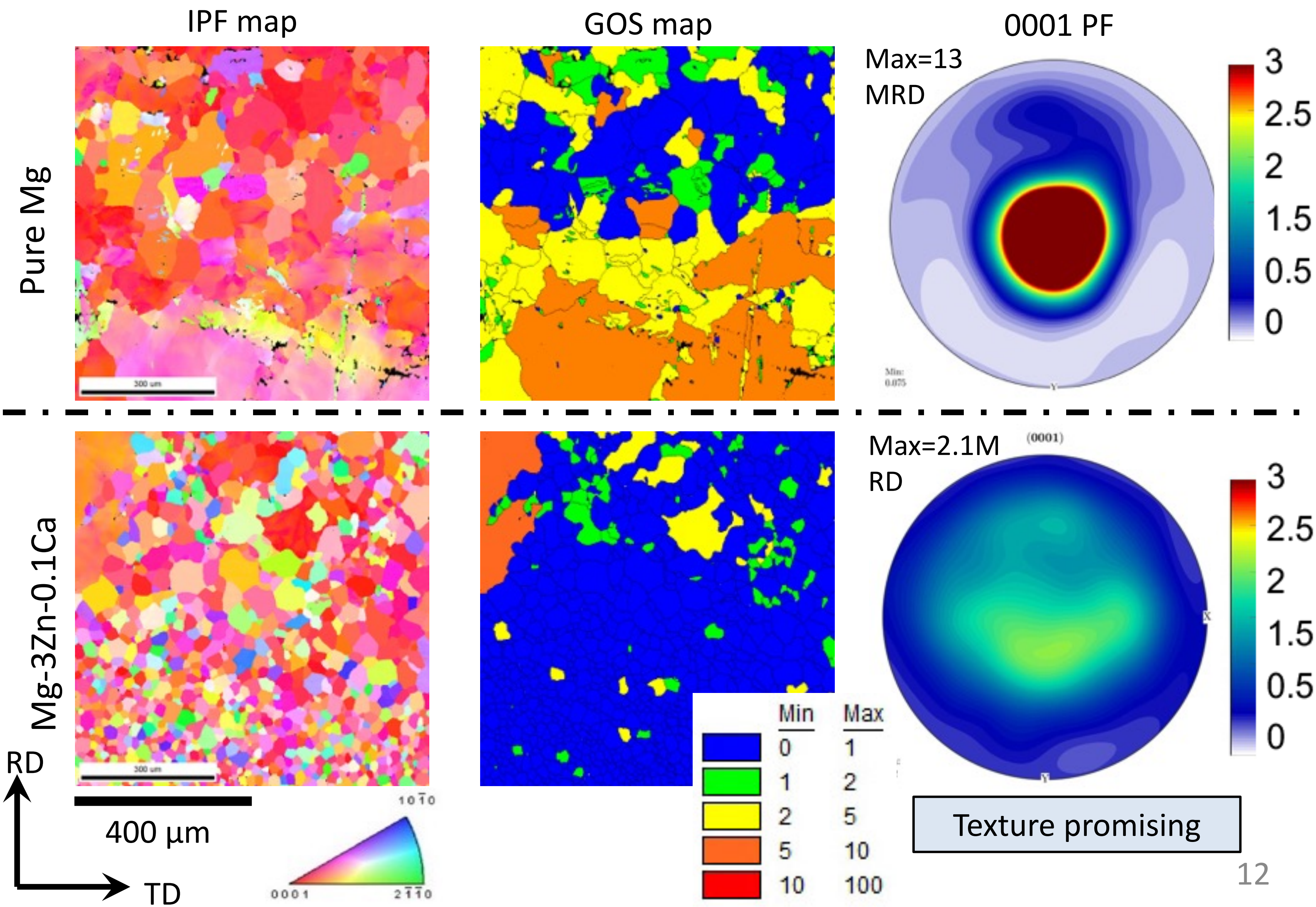


High strain rates can lead to strain localization

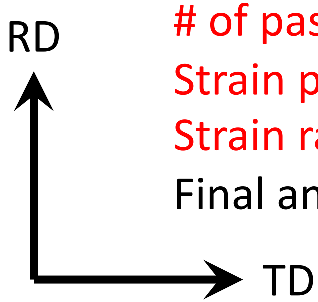
ZX30, 20 pass schedule, $\dot{\varepsilon}$=1s^{-1}



20 pass schedule resulted in inhomogeneous microstructure

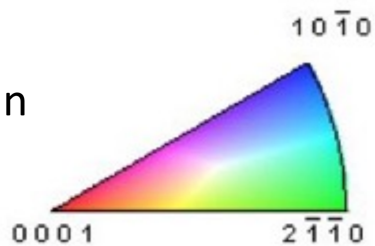


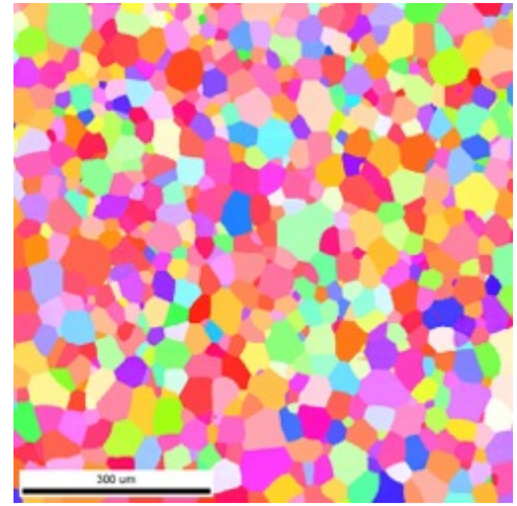
An additional processing route was identified that produces more homogenous microstructure



Alloy: Mg-3Zn-0.1Ca
Temp: 350ºC
# of passes: 10
Strain per pass: 0.2
Strain rate: 0.5/s
Final anneal: 350ºC/10min

IPF map

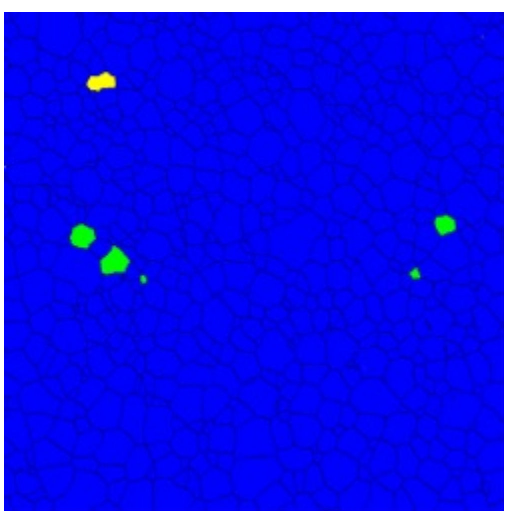




400 µm

Mean grain diameter: 24 µm

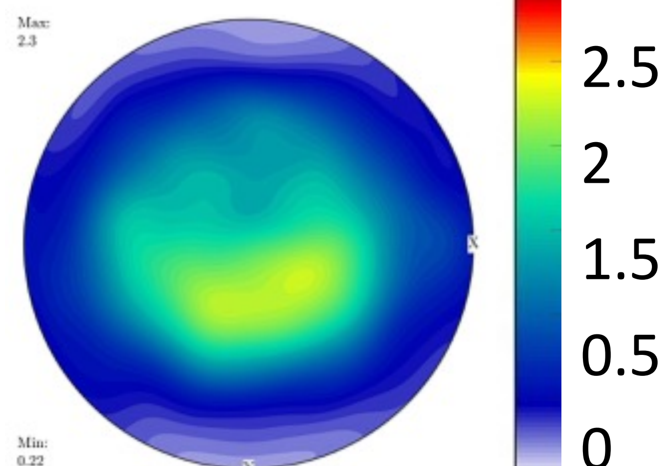
Grain Orientation Spread (º)



400 µm

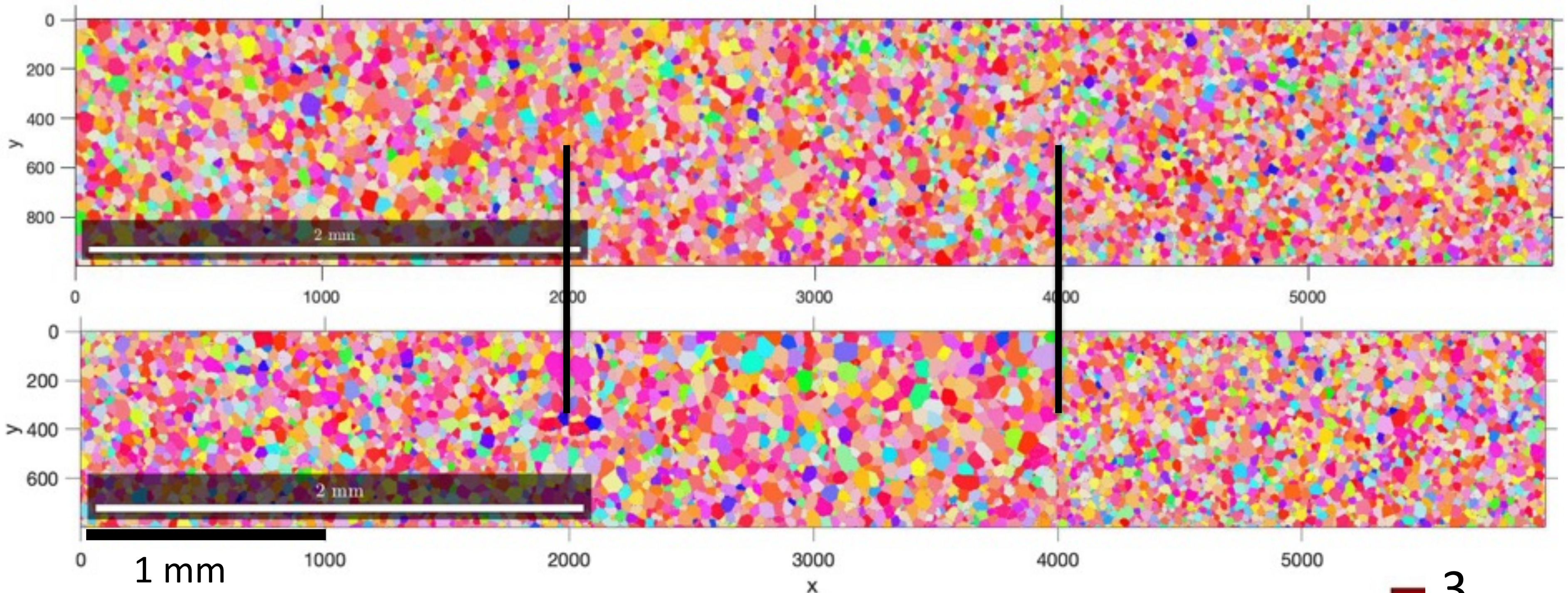
	Min	Max	Total Fraction	Partition Fraction
Blue	0	1	0.992	0.992
Green	1	2	0.006	0.006
Yellow	2	5	0.002	0.002
Orange	5	10	0.000	0.000
Red	10	100	0.000	0.000

(0001)

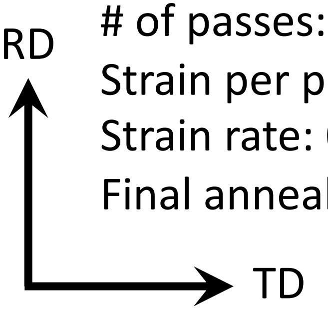


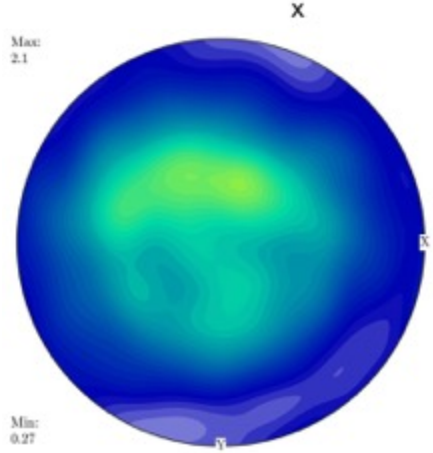
Max: 2.3 MRD

Texture data is generated by merging several scans and repeat tests result in consistent microstructure

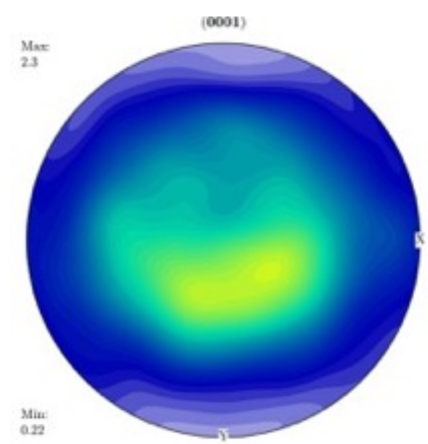


Alloy: Mg-3Zn-0.1Ca
Temp: 350ºC
# of passes: 10
Strain per pass: 0.2
Strain rate: 0.5/s
Final anneal: 350ºC/10min

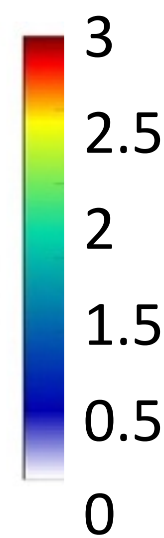




Max: 2.1 MRD



Max: 2.3 MRD



Currently exploring the affect of alloying on texture

Alloy	ST temp (ºC)	ST time (hr)
Pure Mg	N/A	N/A
Mg - 0.1Ca	500	24
Mg - 0.5Ca	500	24
Mg-1.8Zn-0.5Ca	350	24
Mg-3Zn-0.1Ca	350	24
Mg-3Zn-0.5Ca	350	24

- Fixed TMP
- Equivalent EBSD collection and analysis for all alloys

Conclusions

- Comparison between alloys/processing in literature is difficult as the TMP history is often incomplete

- Gleeble PSC testing allows for precise measurement and control of TMP, but it was important to determine an appropriate TMP schedule

- When starting with large, cast grains, at least 10 passes were required for uniform grain refinement

- High strain rates can lead to strain localization, making it difficult to relate TMP and texture

- A TMP schedule was arrived at that leads to a uniform, reproduceable texture and microstructure in ZX30

Thank You!

- USAMP team (Bita Ghaffari & Anil Sachdev)
  - OSU (Luo group) – ZXEM2000 sheet and Gleeble specimen, rolling schedule input
  - University of Florida (Manuel group) – cast ingots (Mg-Zn-Ca)

- Undergraduate Assistants: Olga Kim, Yana Beeker, Mayme Philbrick

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