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Mechanical Behavior and Active Deformation Mechanisms in Thin Film Mg

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Background & Motivation

- Interest in Mg has gained traction for application in
  - Light weight structural alloys, low density but pure Mg relatively weak
  - Hydrogen storage (metal hydrides) for alternative energy
- Possible improvements from length scale reduction
  - Small grains →Hall-Petch strengthening
  - Small thickness→ Shorter pathways for improved diffusion

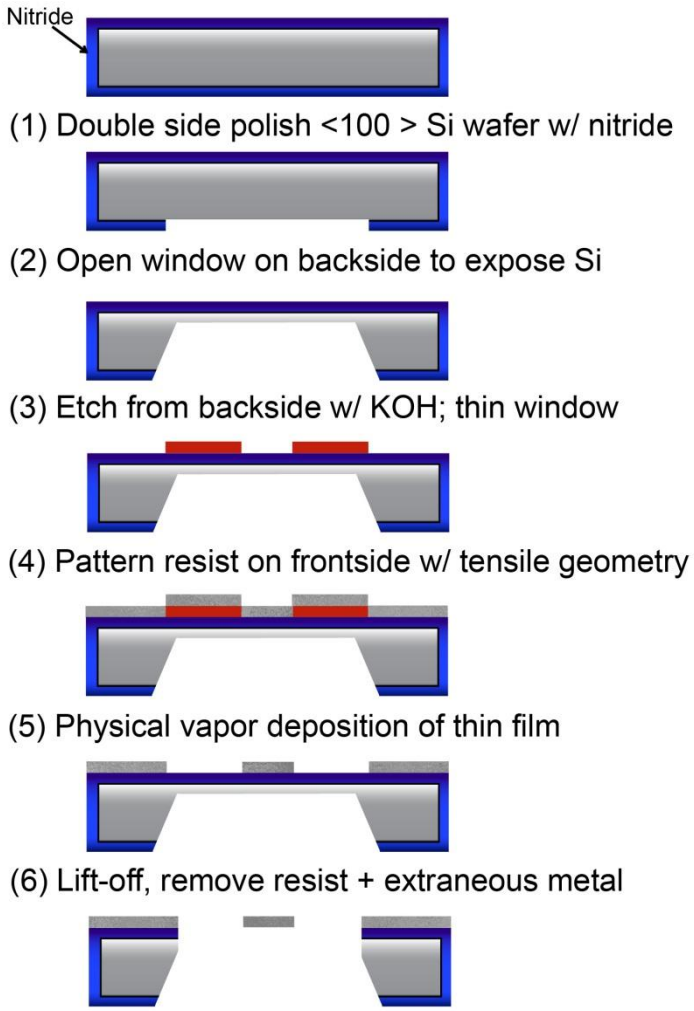
KEY QUESTIONS

- How do small grains affect the mechanical properties of Mg?
- What deformation mechanisms are active?

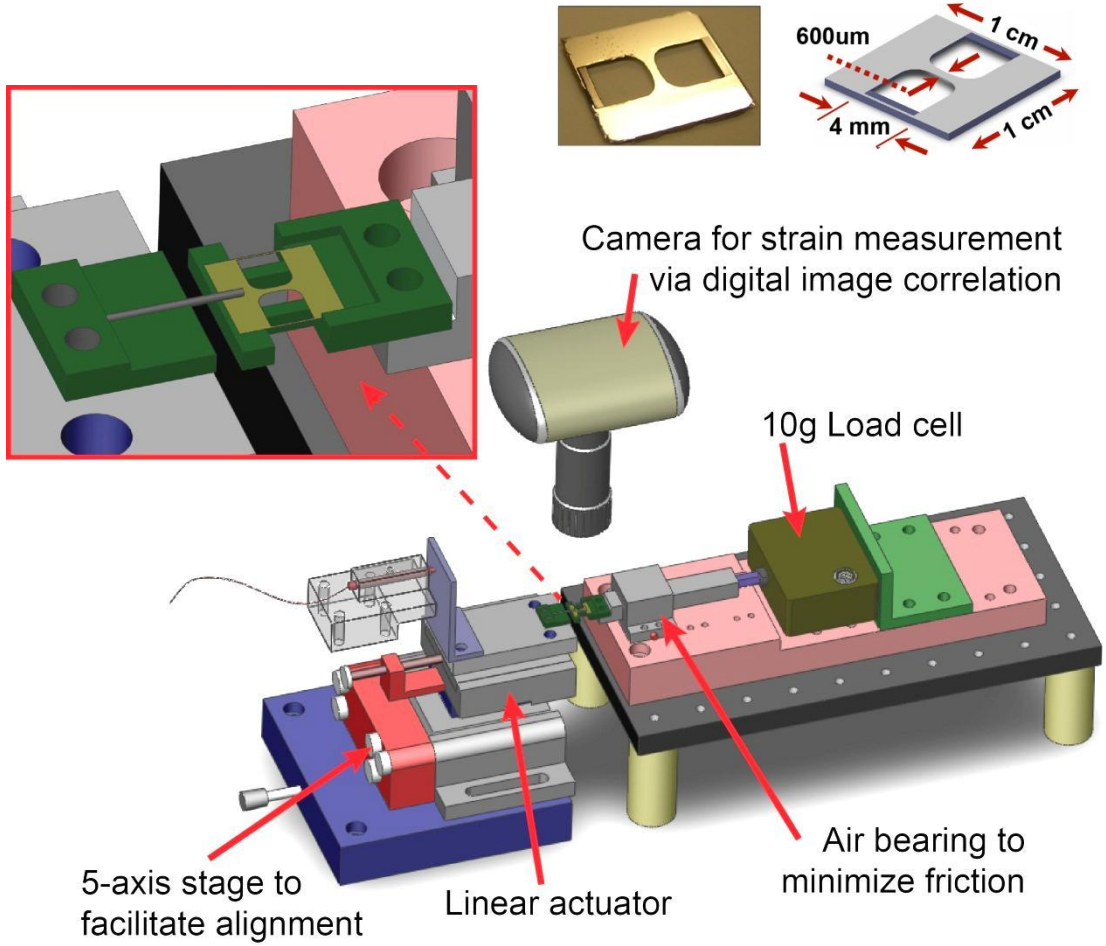
Film Synthesis & Testing

Sandia National Laboratories

Fabrication Flow



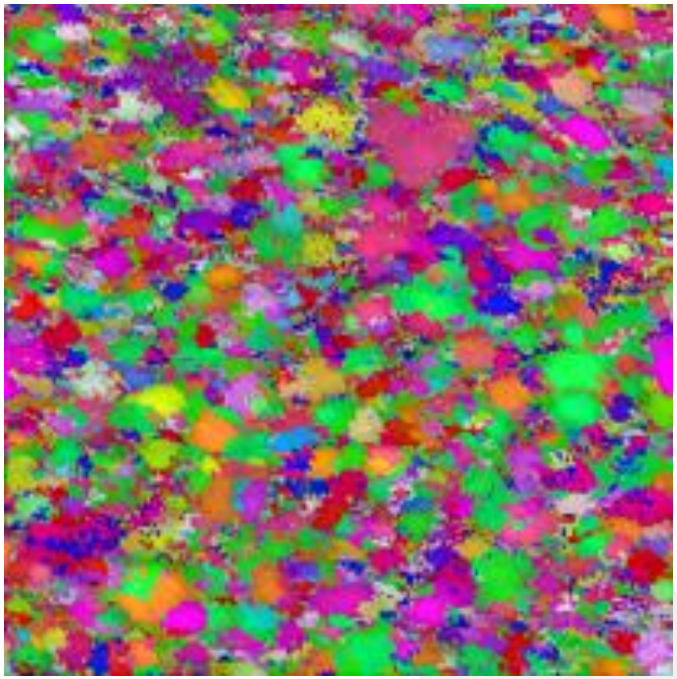
Mechanical Testing

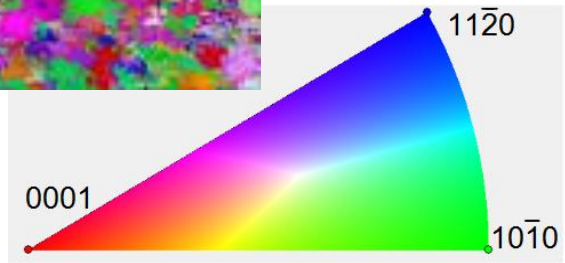


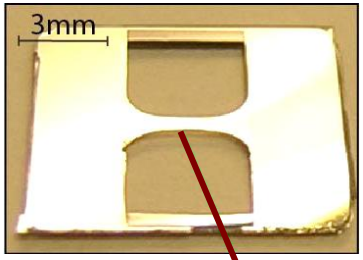
D.S. Gianola, et. al ; TMS Letters; 1 (2004)

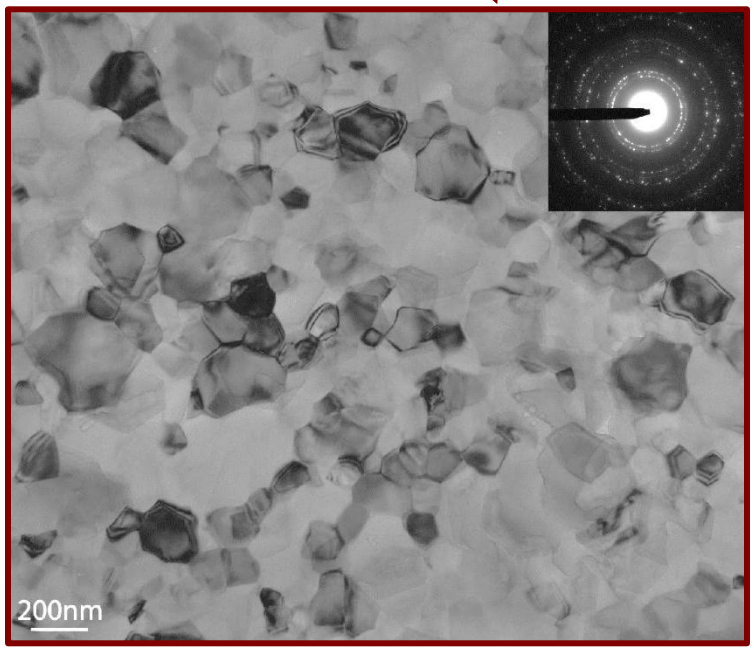
As-deposited Test Specimens

- 250nm thick films, 99.999% pure Mg e-beam evaporated under a base pressure of 8 x 10^{-7}Torr
- Dislocation free grains, 197nm in size









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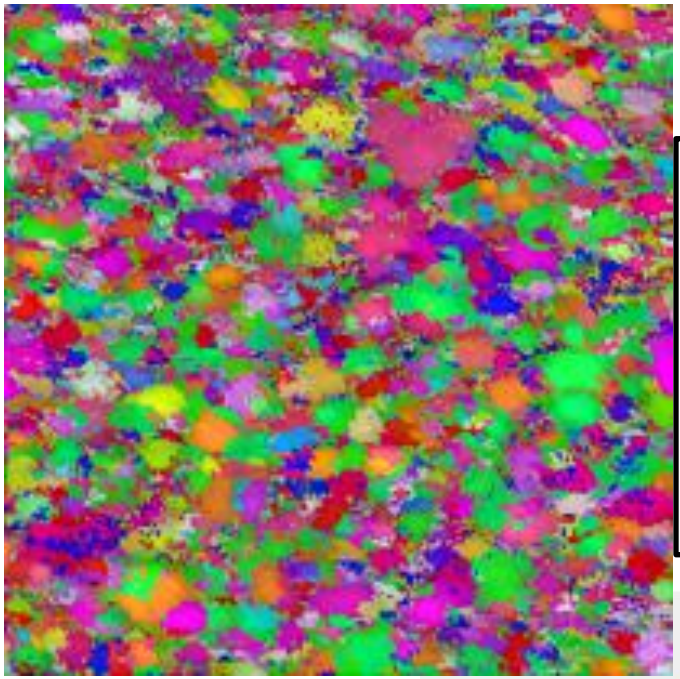
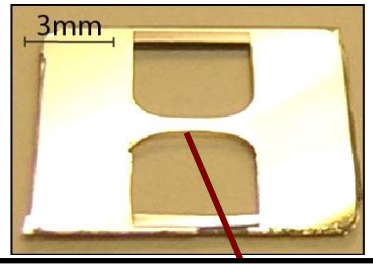
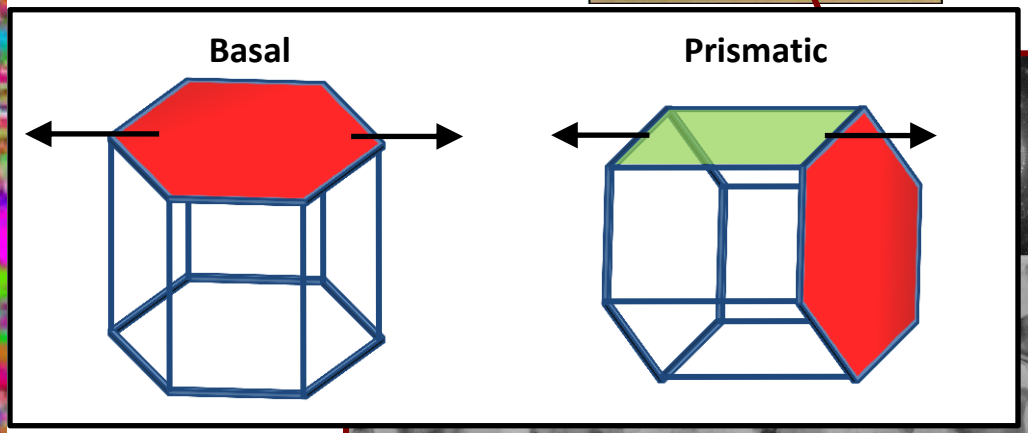
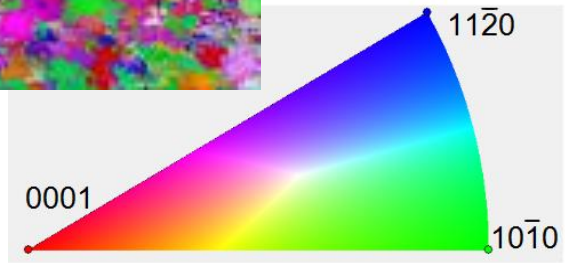
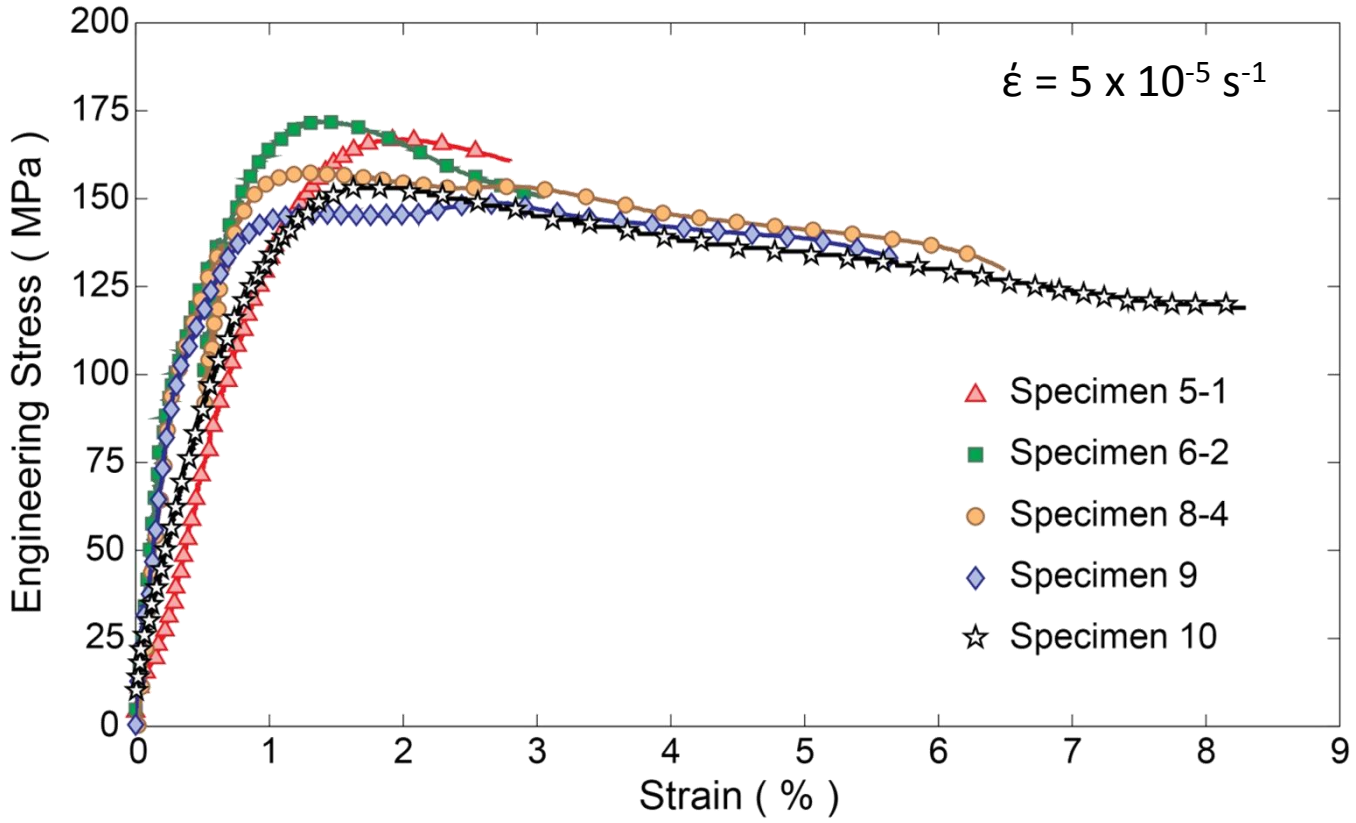






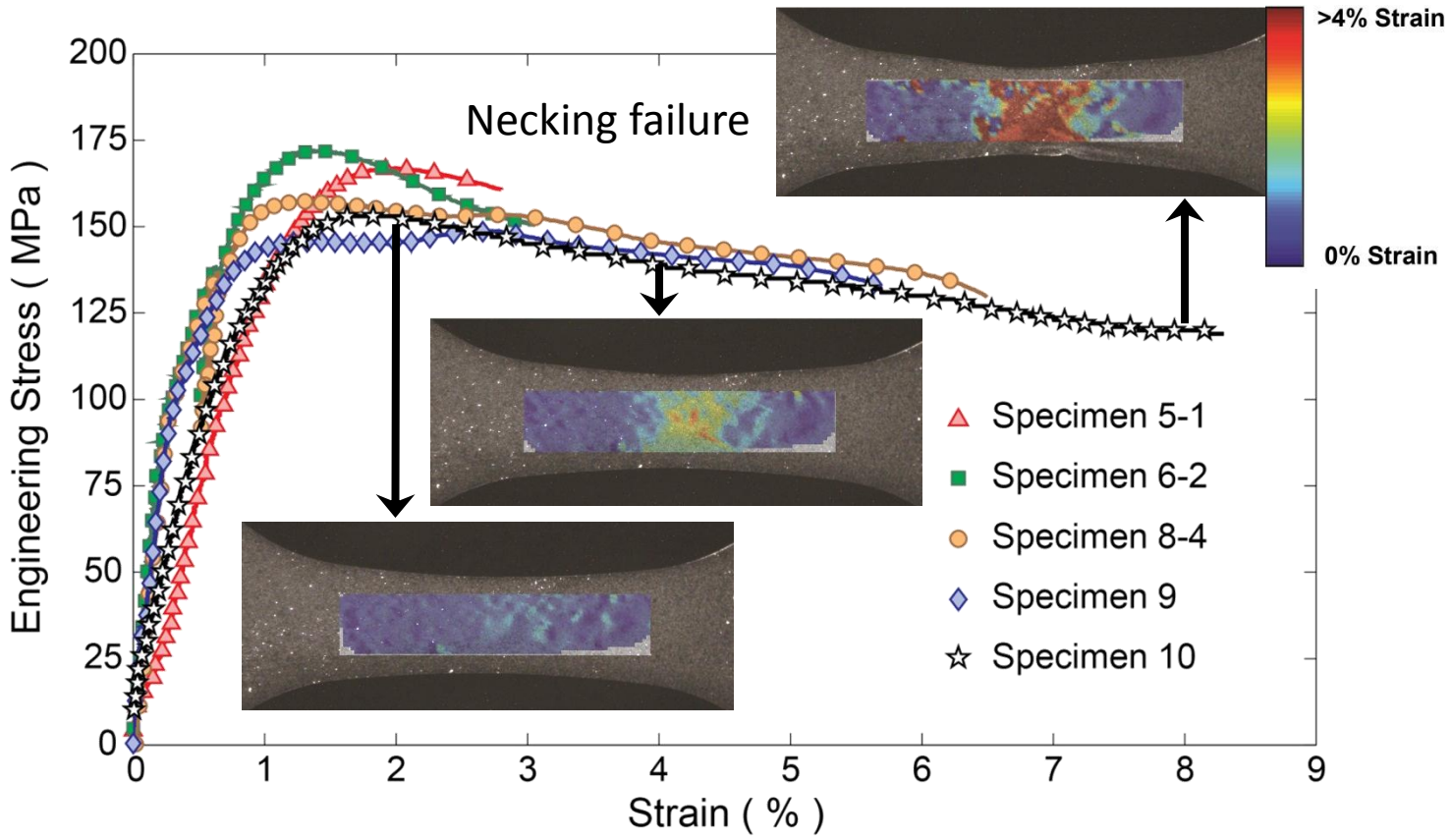


Mechanical Response



- Response similar to coarse grained Mg
  - Strengths of 160-195 MPa and elongations of 3 – 15%

Mechanical Response



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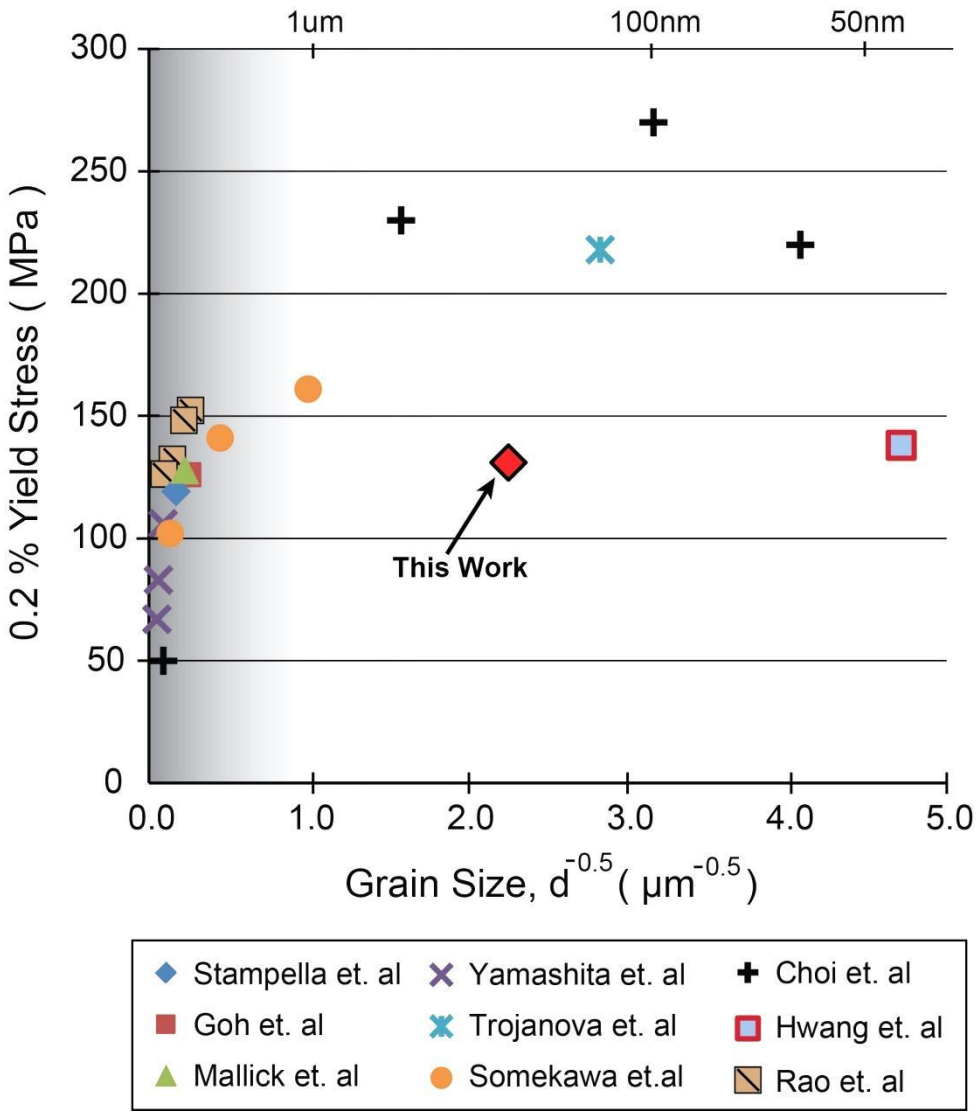
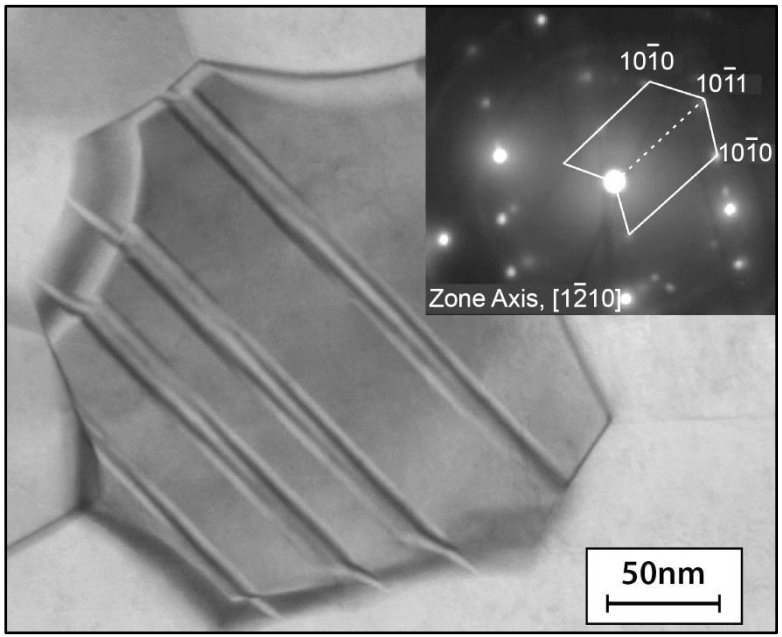
Strengthening ?

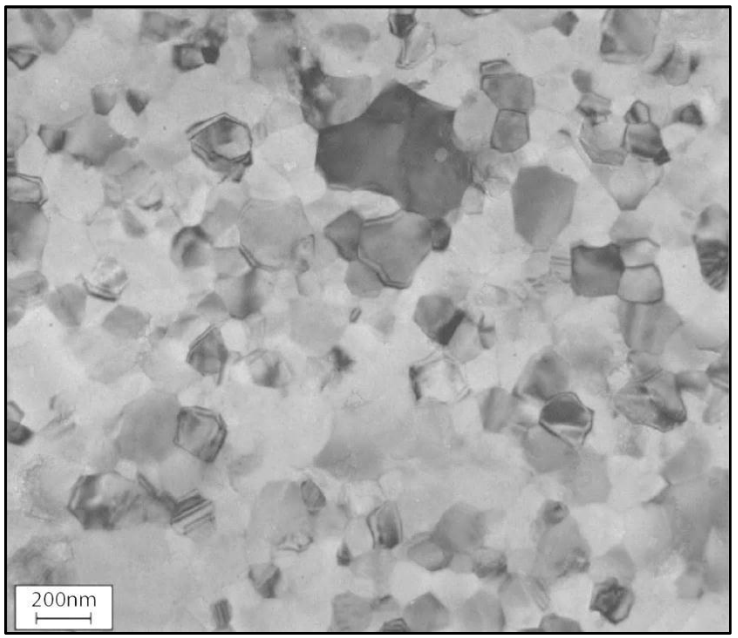


- "Bulk" yield point for the Mg films of this study
- Yield stress affected by
  - Purity
  - Texture
  - Processing
- Differences in these factors preclude a direct comparison of all data

Deformation Mechanisms

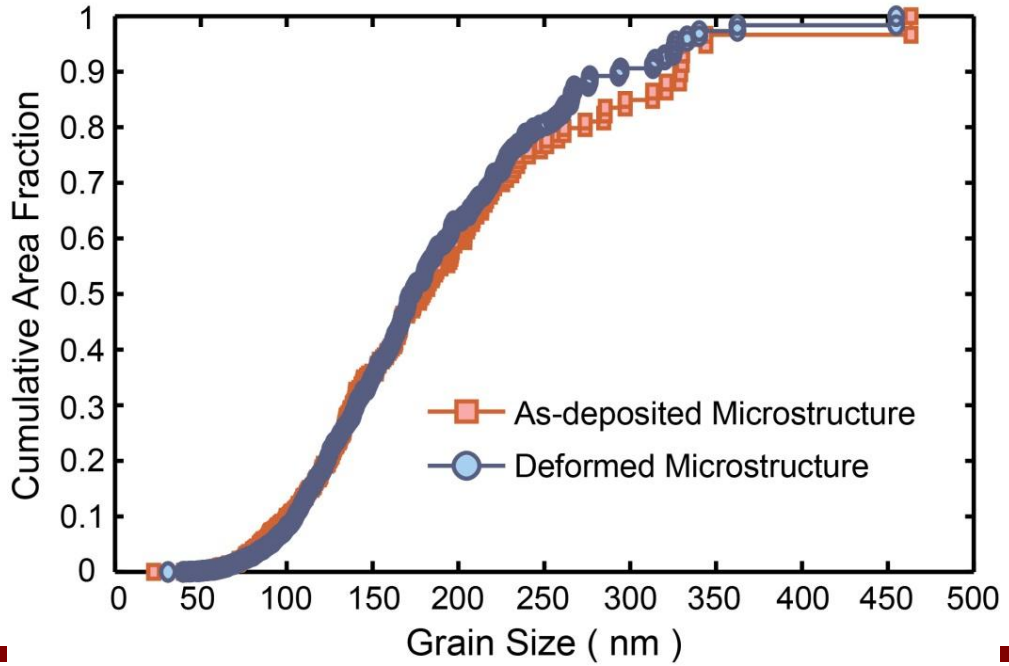
- No storage of dislocations
  - Possible nucleation & absorption of dislocations at GBs
- $\{10\bar{1}1\}$ $<10\bar{1}\bar{2}>$ twins
  - Deformation twins on pyramidal plane, bulk like yielding not likely from this twin system as Basal,τ_{crss} < Prismatic,τ_{crss} < Pyramidal,τ_{crss}





Deformation Mechanisms

- No change in the grain size, no extensive GB migration or rotation events
- GS distribution reveals many grains ≈ film thickness,
  - Grains with <10$\bar{1}$1> normal to film surface would have ~50MPa of resolved shear on basal plane (Basal,τ_{crss} = 0.77 MPa)
  - Yielding of such unconstrained grains will manifest on stress-strain response



Summary

- At 200nm GS, twinning is active with a lack of dislocation pile up

- "Bulk" yield point stems from yielding of grains spanning the full film thickness

Future Work

- In-situ TEM experiments to determine extent of dislocation and GB related processes

- Explore impact of purity and oxide on strength