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Effect of Prior Texture and Solute Content on the Deformation of Magnesium

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Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

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Outline

- Introduction to wrought magnesium alloys
- Strategies to develop improved alloys
- Experimental method
- Results and analysis
- Conclusions

Wrought Magnesium Alloys

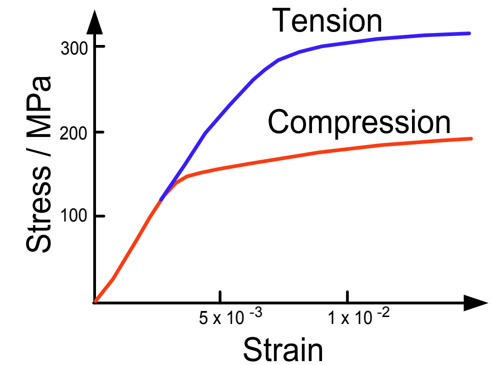
- Mg attractive for weight critical applications (ρ_{Mg} is 2/3 ρ_{Al}, 1/4 ρ_{Steel})
- Wrought Mg alloys currently only a small fraction (<15%) of total Mg alloy usage



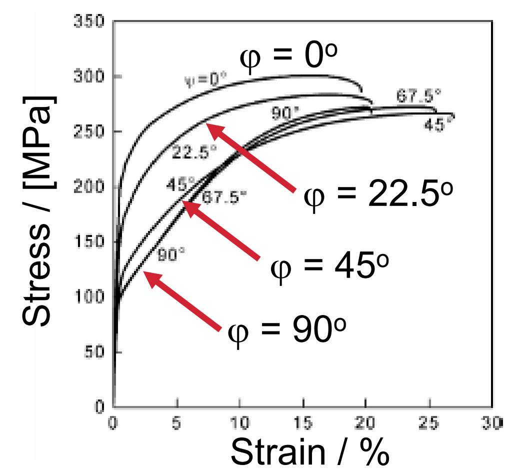
- Potential of wrought Mg to reduce vehicle weight large
  - needs new approaches to alloy design and processing

Wrought Mg Alloys - Challenges

- Asymmetry of compressive/tensile yield strength after deformation



- Anisotropy of properties with respect to axes of deformation

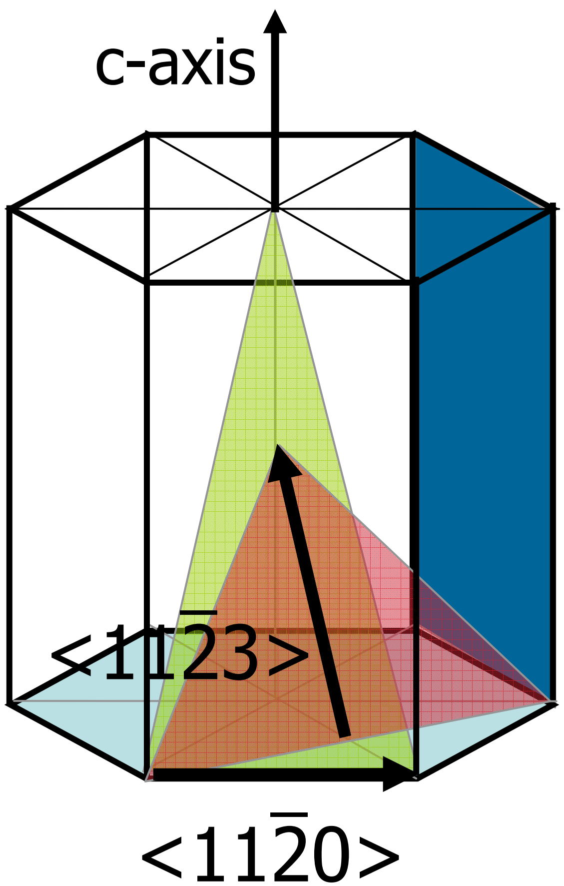


- Limited room temperature ductility

Improving Wrought Mg-Alloys

- Strategies for developing better mechanical properties in wrought-Mg
  - Refine grain size
  - Alloying to change deformation mode
  - Optimize texture
- Certain alloying additions (eg Li, Y) influence slip system activity
  - Promote additional slip modes to increase ductility

Magnesium – Slip Systems



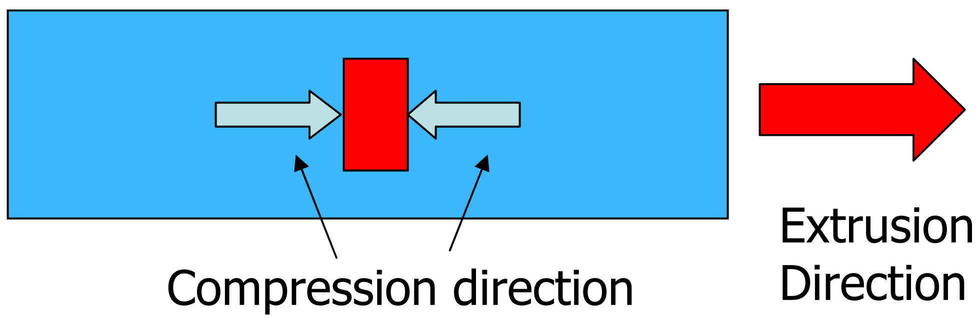
Slip mode	Relative CRSS (at 100^{o}C)	Independent slip systems
Basal	1	2
Prismatic	40	+2
Pyramidal	50	+4

Twinning occurs when slip is difficult. Common twin is c-axis tension twin

Only pyramidal <c+a> slip can produce c-axis compression

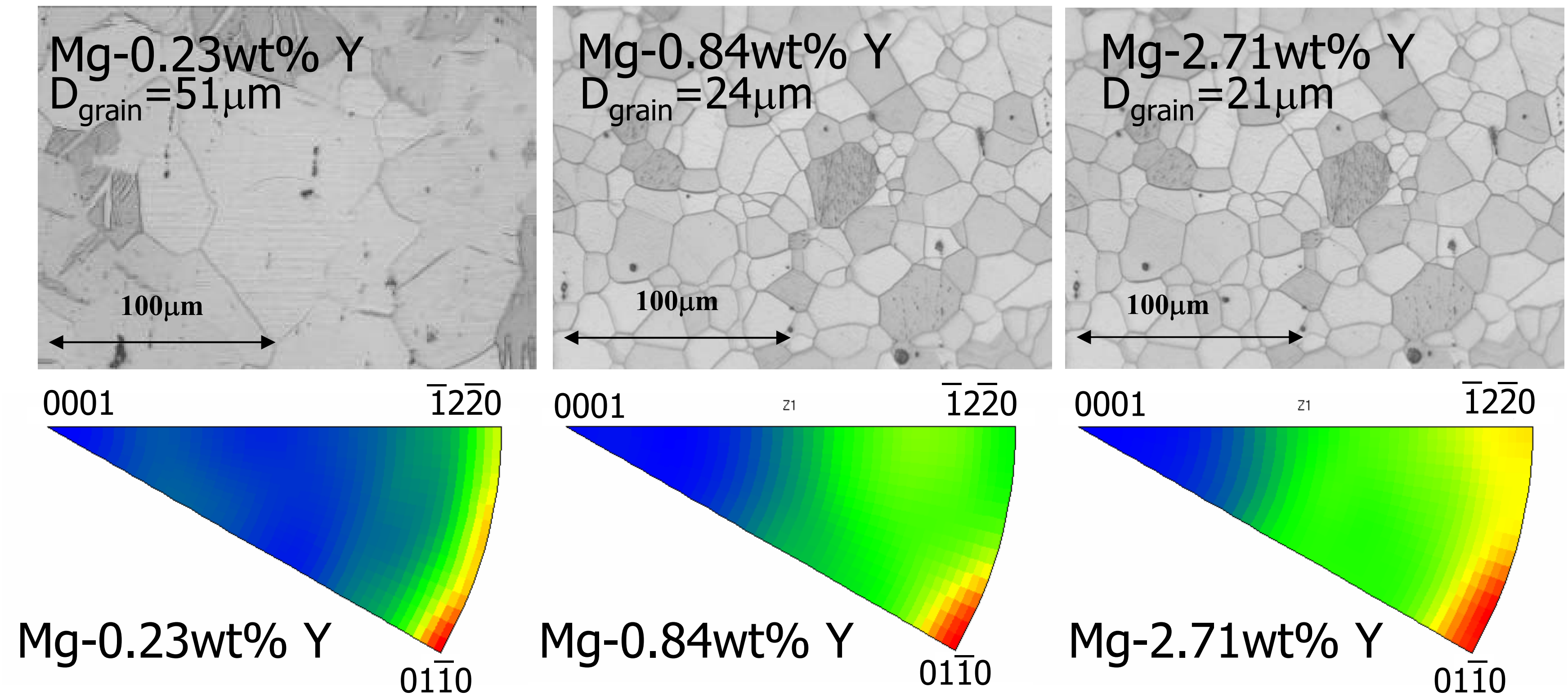
Experimental

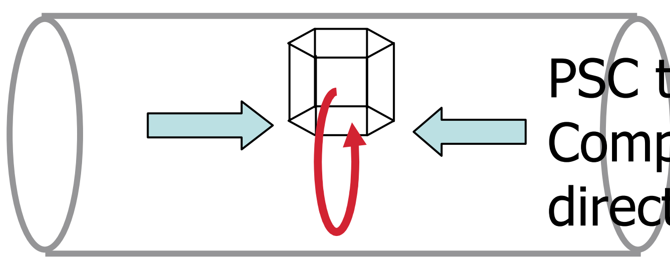
- Alloys
  - Commercially pure Mg, Mg-0.23Y, Mg-0.84Y, Mg-2.71Y (wt%)
- Plane strain compression (channel die) specimens cut from bar extruded (400°C, 2:1)



- Compress at 200, 250, 300, 350°C
- Measure stress/strain response and %DRX

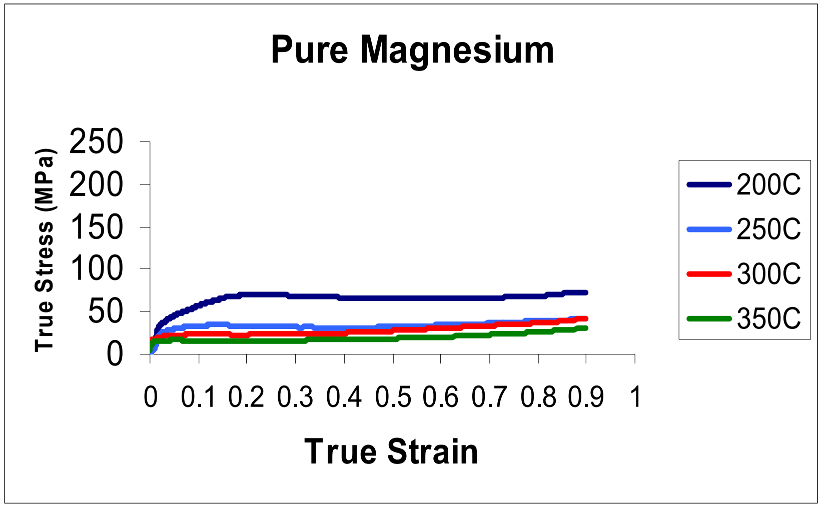
Initial Microstructure

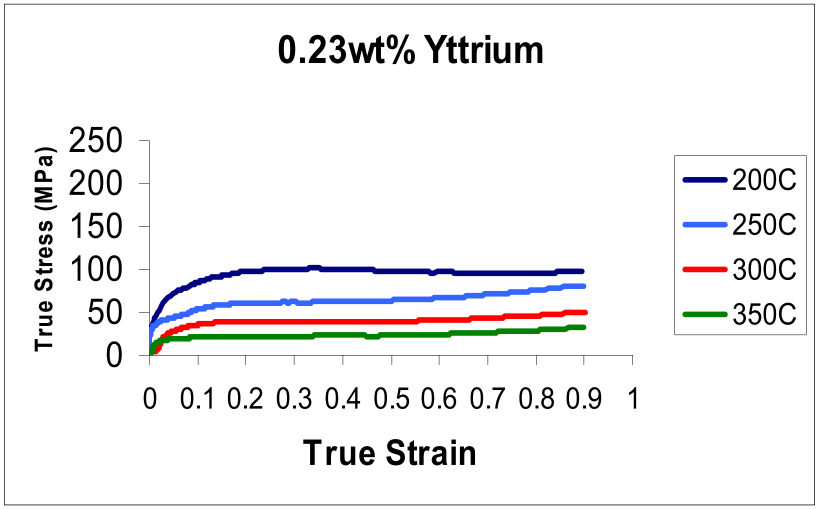


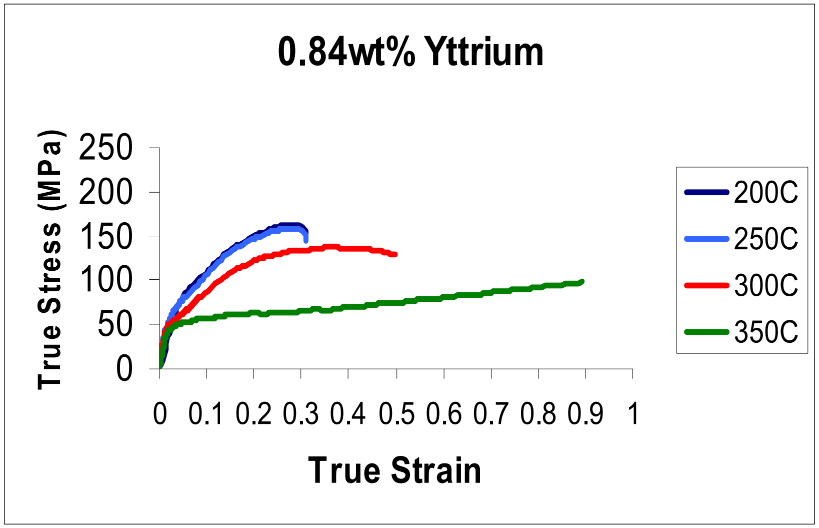


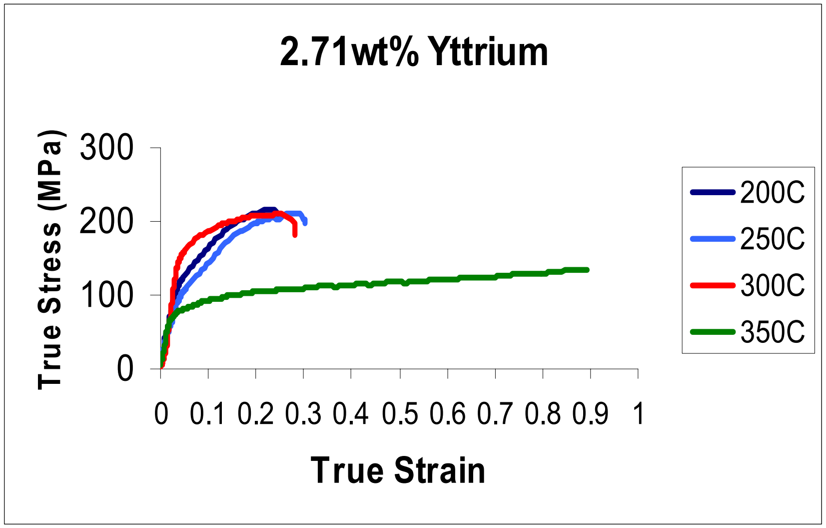
Mechanical Properties

Effect of Temperature



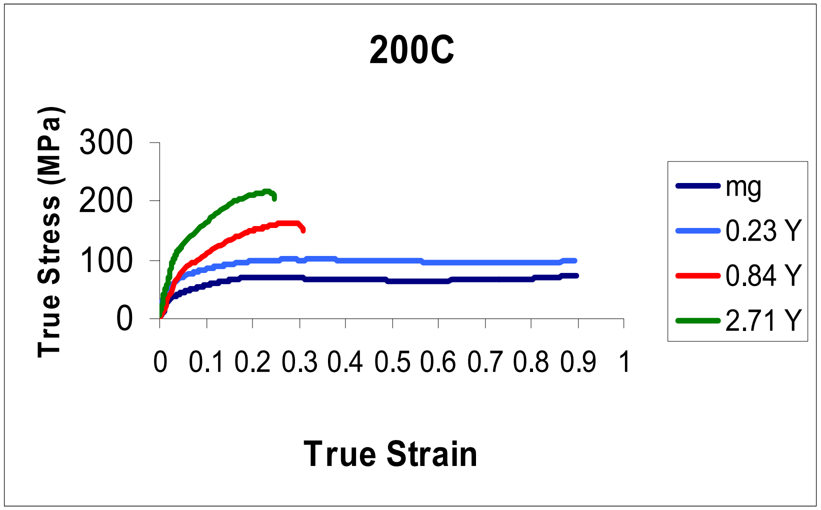


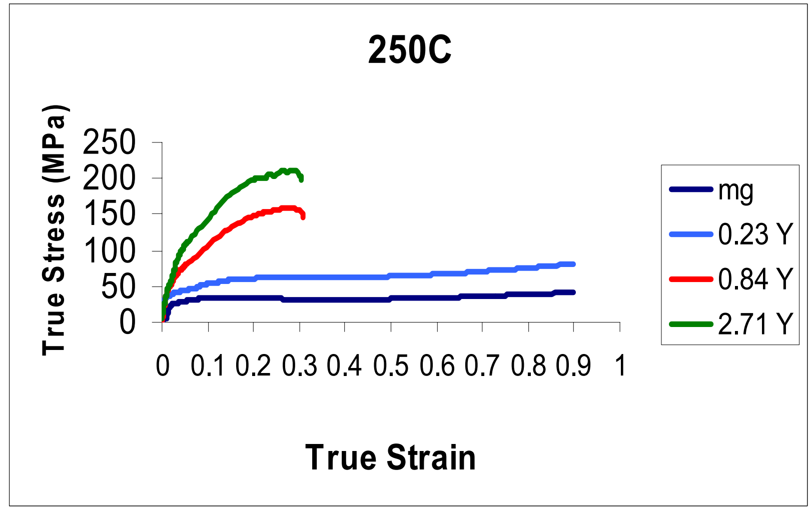


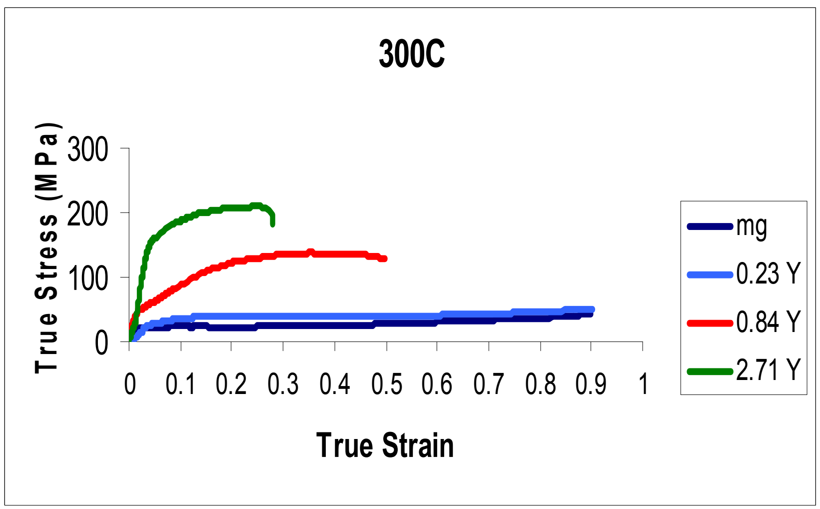


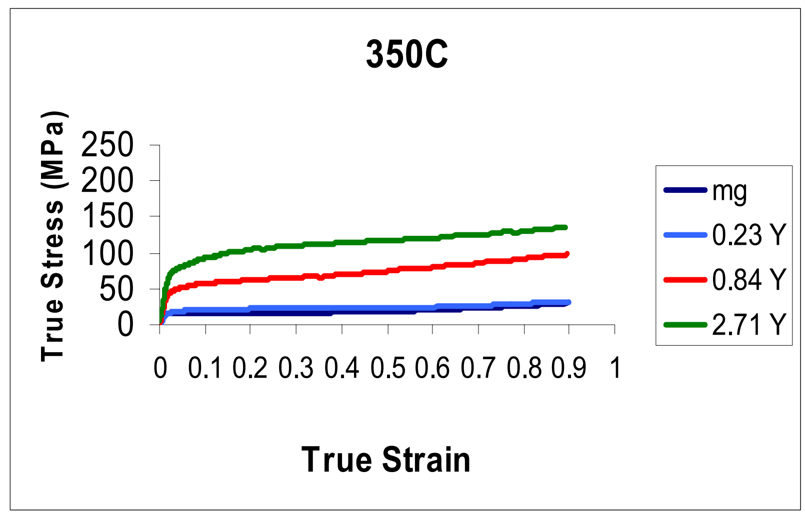
Mechanical Properties

Effect of Composition



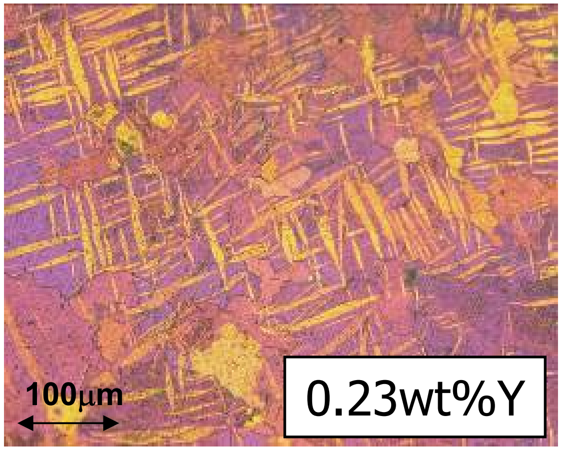


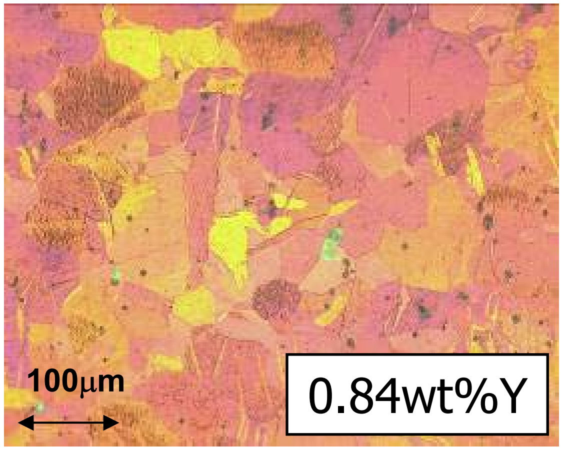


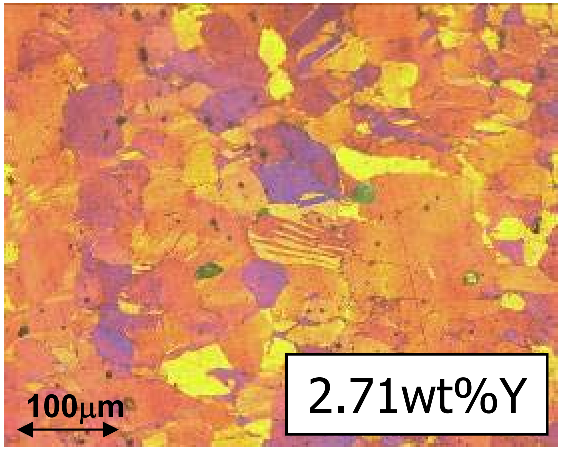


Microstructures (constant strain)

- e.g. deformed 300°C, true strain 0.3



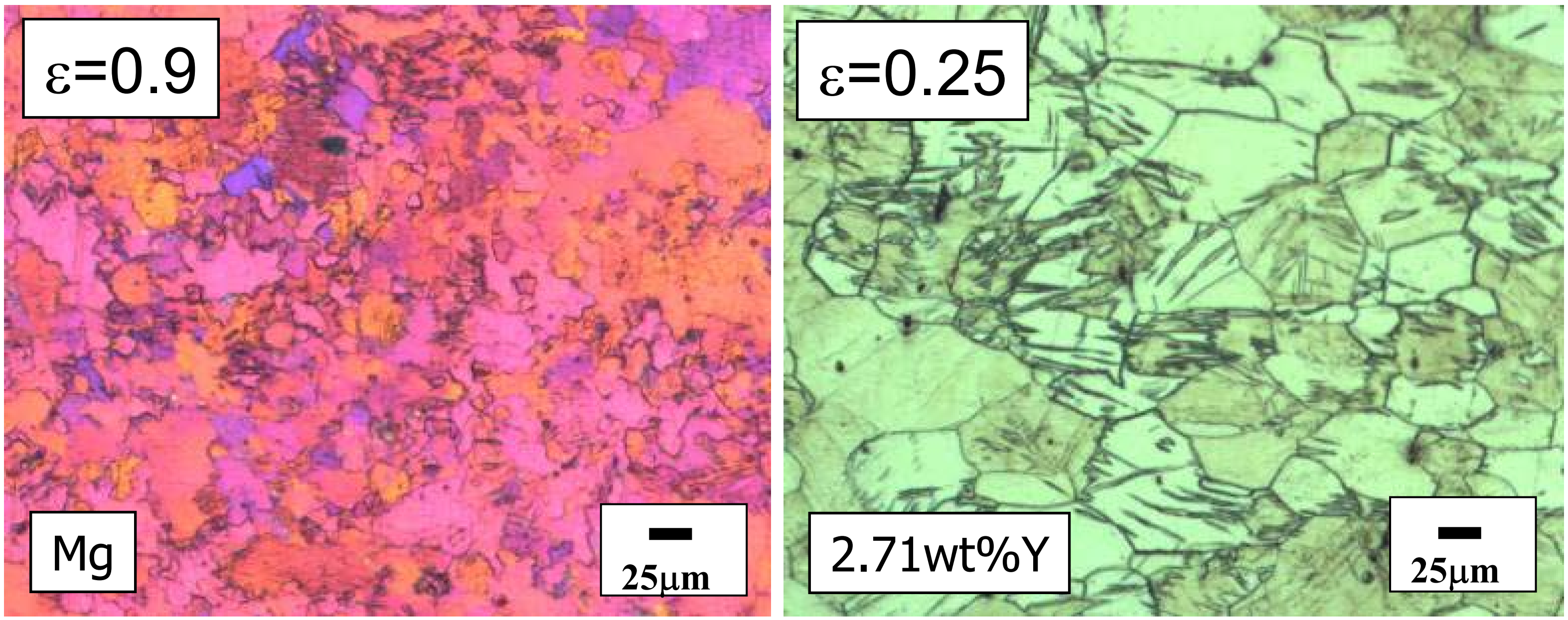




- Mg and Mg-0.23wt%Y
  - High fraction of twinned grains
  - DRX at grain boundaries
- Mg-0.84wt%Y and Mg-2.71wt%Y
  - Fewer twinned grains
  - No DRX observed

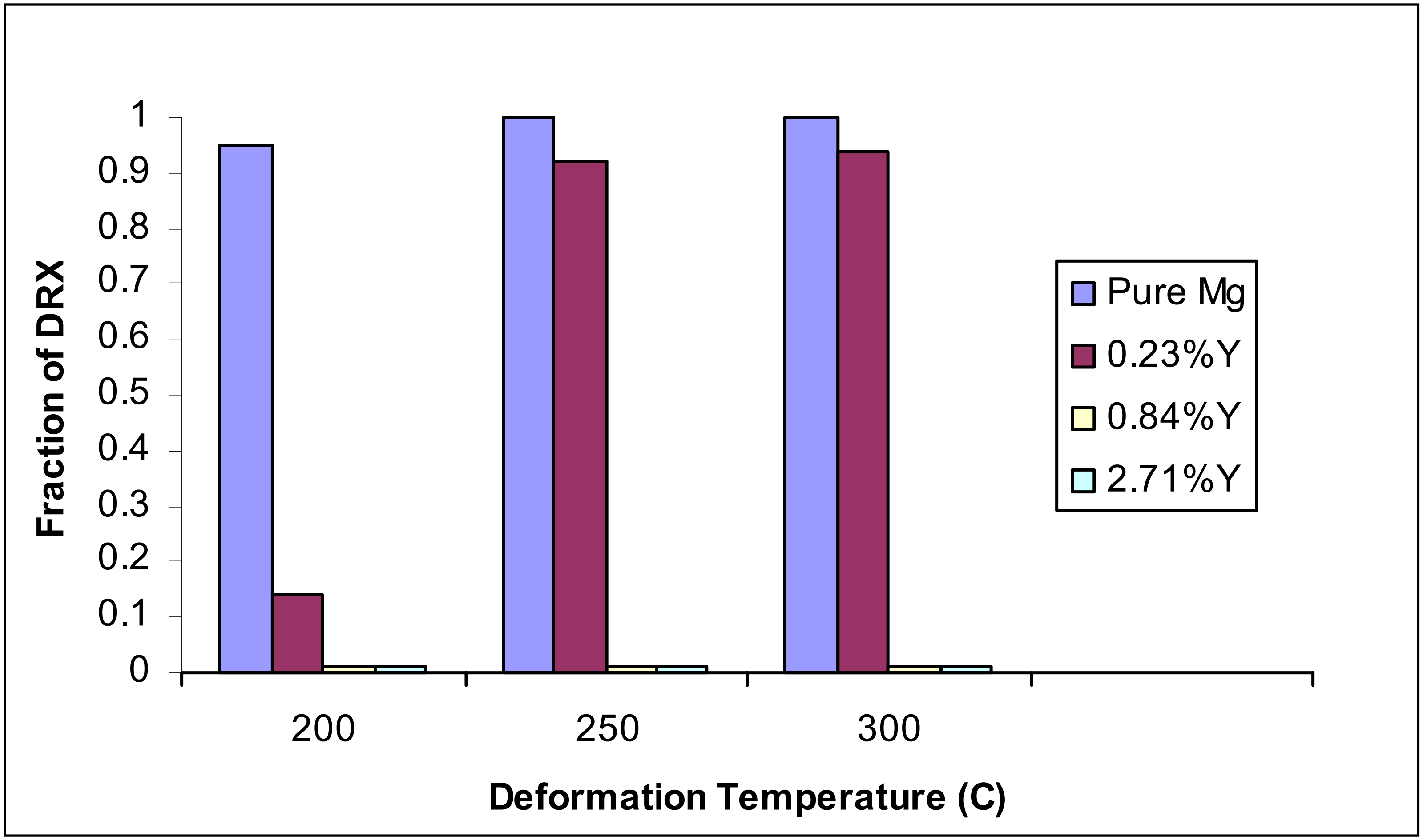
Microstructures (end of test)

- e.g. deformed 200°C

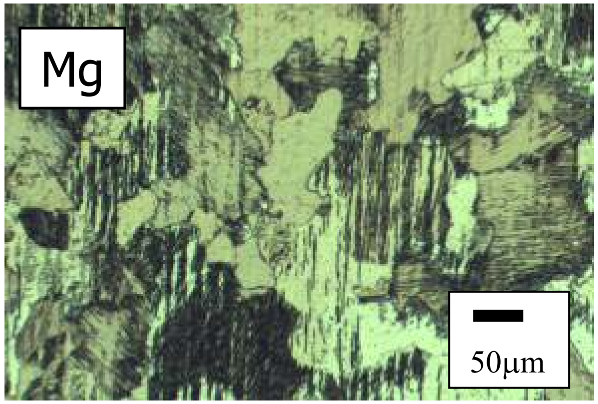


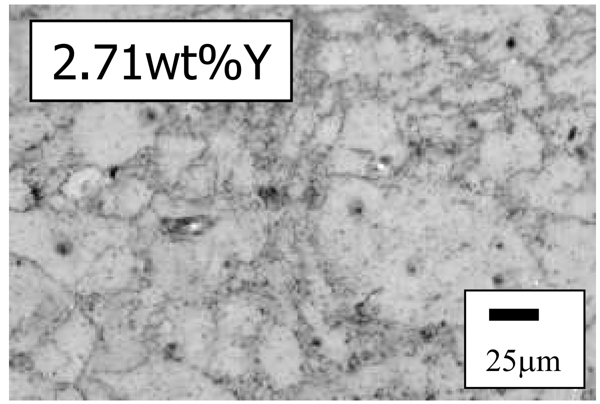
- Mg and Mg-0.23wt%Y
  - Heavily twinned structure replaced by fully DRX structure
  - High ductility
- Mg-0.84wt%Y and Mg-2.71wt%Y
  - Twinning observed, no DRX
  - Lower ductility

DRX fraction (end of test)



Deformation at 350^{o}C

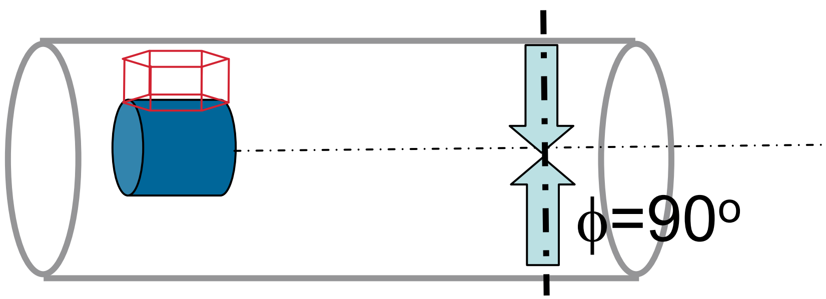




- Pure Mg and Mg-0.23wt% Y
  - Extensive DRX/twinning
  - High ductility: DRX/twinning remain important deformation mechanisms
- Mg-0.84wt% Y and Mg-2.71wt% Y
  - No twinning
  - Little DRX
  - High ductility: attribute to enhanced non-basal slip

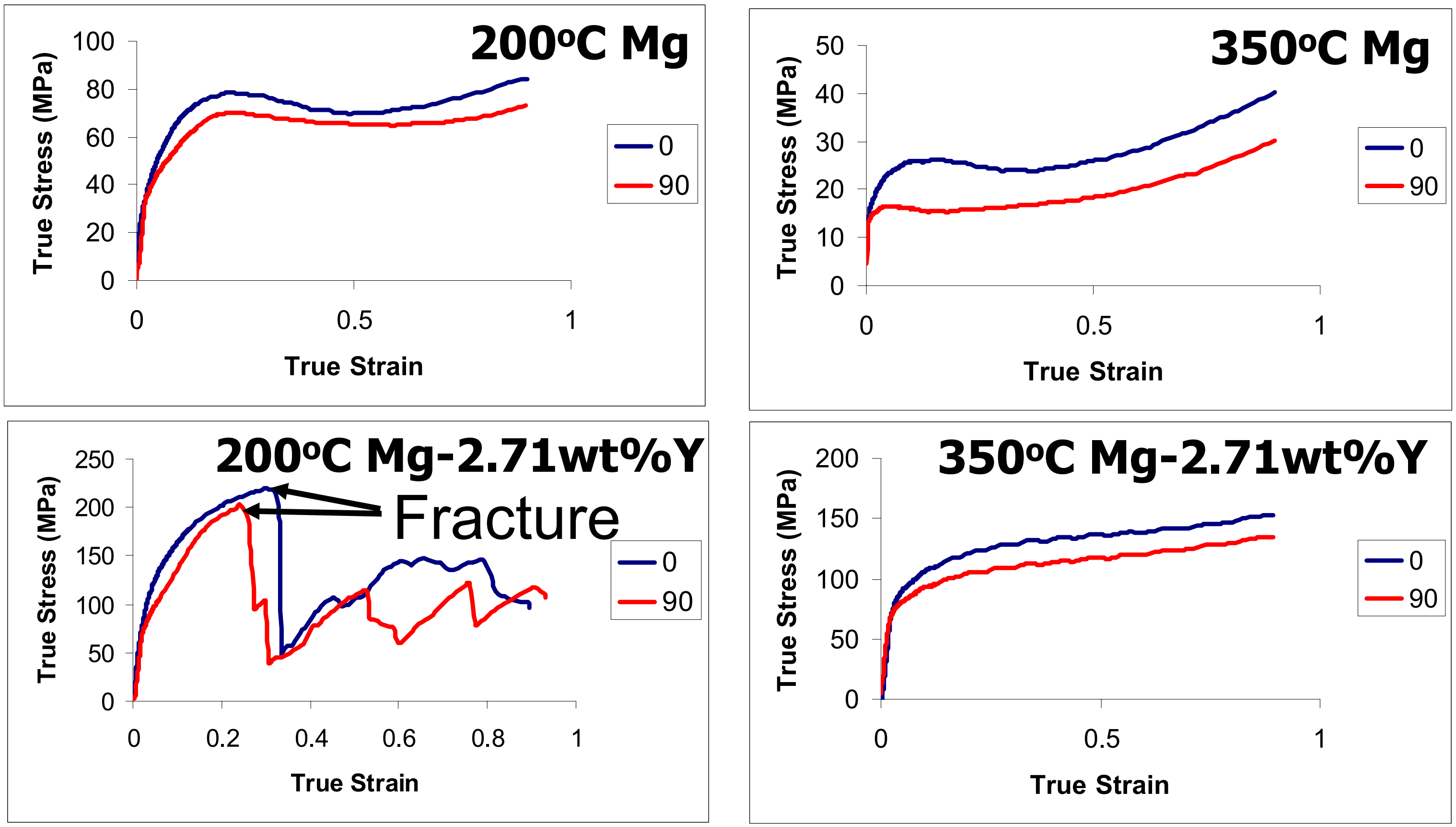
Anisotropy of Properties

- Test with specimen at 90^o to extrusion axis



- Unlike ϕ=0^o, for ϕ=90^o some grains favourably oriented for basal slip

Mechanical Properties



- Anisotropy observed in all alloys across all temperatures despite differences in deformation mode

Summary

- Additions of Yttrium >=0.84wt% suppress DRX strongly and reduce twinning
- DRX appears critical to obtaining high ductility in pure Mg and Mg-0.23wt% Y. When DRX is suppressed, ductility is reduced
- At 350^{o}C ductility of higher Y alloys greatly improves (without DRX or twinning)
- Expected anisotropy is observed in all alloys and at all temperatures
- Anisotropy is reduced but not eliminated in high Y alloys despite different deformation behaviour (suppression of twinning)
- <u>Y added in sufficient quantity radically changes the twinning and DRX behaviour of magnesium influencing microstructural evolution and mechanical properties during deformation</u>