

Improving the Property 'Portfolio' of Mg Alloys by a New Integrated Processing Technique

Yuri Estrin

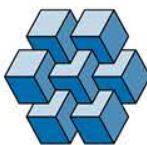
Centre for Advanced Hybrid Materials
Department of Materials Engineering
Monash University, Melbourne



Improving the Property 'Portfolio' of Mg Alloys by a New Integrated Processing Technique

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WCU Program,
Seoul National University, Korea



Australian Partnership for Light Metals Research



CAST Cooperative Research Centre



ARC Centre of Excellence
Design in Light Metals

Professor StJohn, Dr. Rajakumar, Prof. Muddle



MONASH University



Australian Partnership for Light Metals Research



CAST Cooperative Research Centre

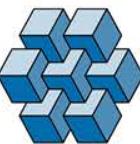


ARC Centre of Excellence
Design in Light Metals

Prof. Collins, Dr. Rajakumar, Prof. Muddle



MONASH University

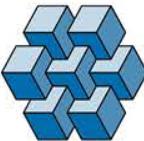


Australian Partnership for Light Metals Research



Prof. Collins, Mr Barnes, Prof. Muddle





Australian Partnership for Light Metals Research



CAST Cooperative Research Centre



Prof. Collins, Mr Barnes, Prof. Wu



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Australian Partnership for Light Metals Research



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Dr. Easton, Mr Barnes, Prof. Wu



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Titanium Technologies

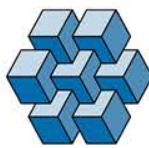
From Ore-to-More

John E. Barnes | Leader, CSIRO Titanium Technologies



- FUTURE MANUFACTURING FLAGSHIP
www.csiro.au





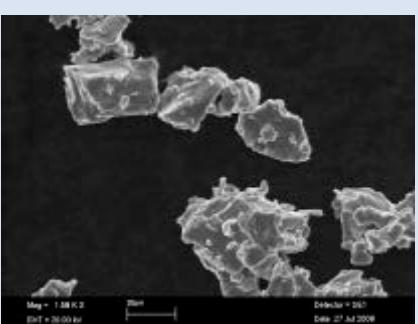
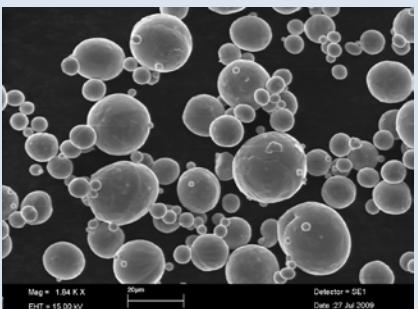
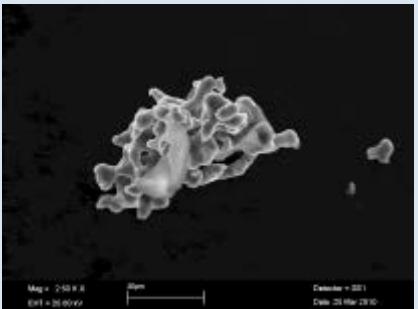
Maximising Australia's Natural Resources Potential

Titanium - from ore to *more*

-
- 1** Rank of Australian titanium ore reserves in the world
 - 0** Amount of Titanium metal produced in Australia
 - 90** Number of years until known ore is depleted
 - 100** The factor of economic value of metal over ore
 - 1%** Resource that could be used to yield the same revenue
 - 9,000** Years of resource left



Directly from Powder to Finished Product

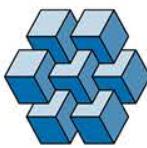


Titanium powder

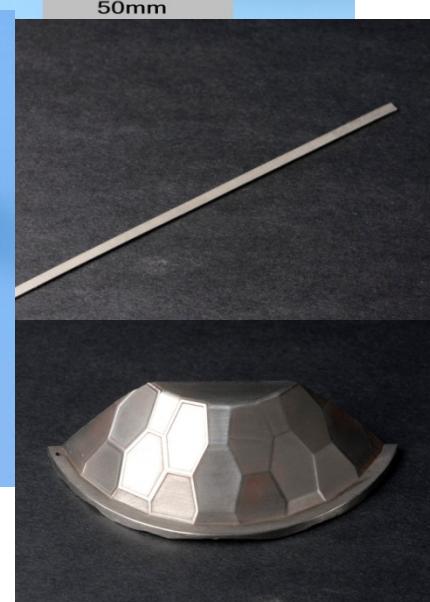
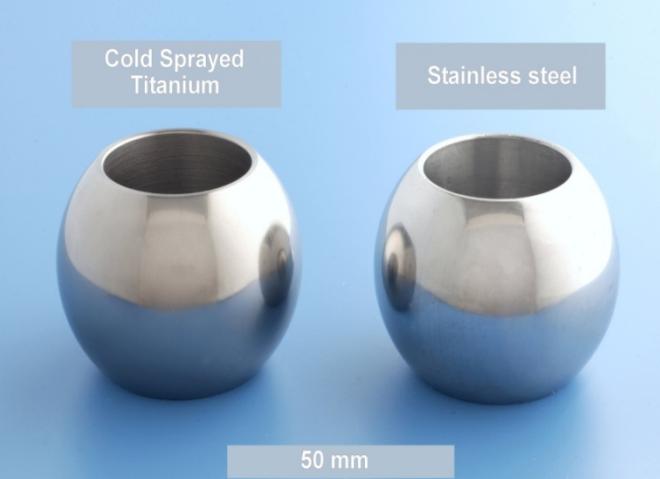


Cold Spray Titanium
Heat treated & etched





Cold Spray for Pre-forms

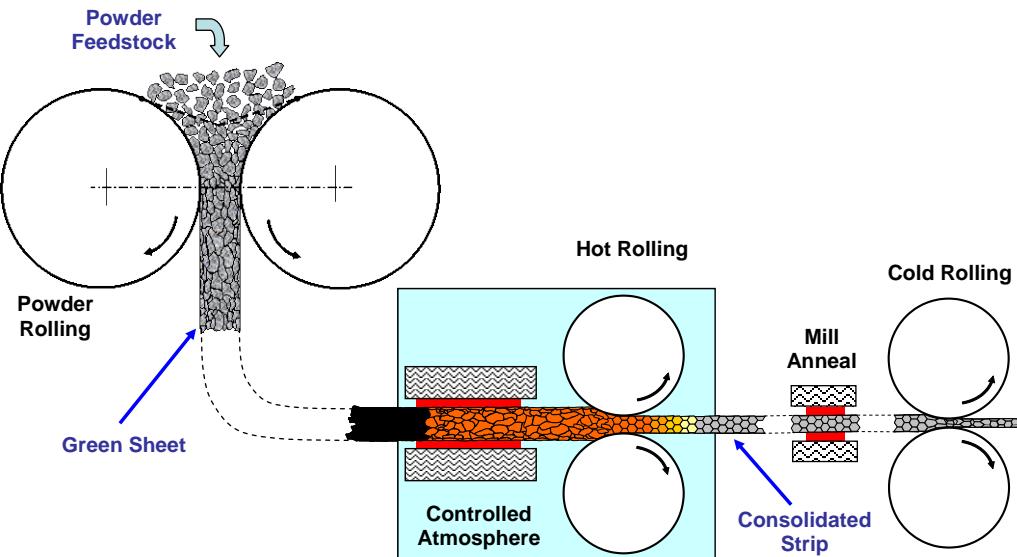




Continuous Sheet Production



Powder feedstock

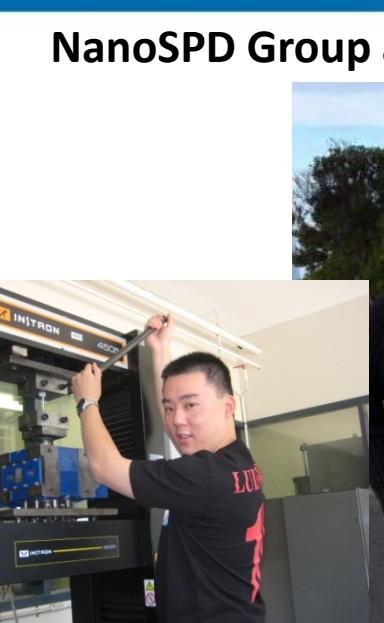
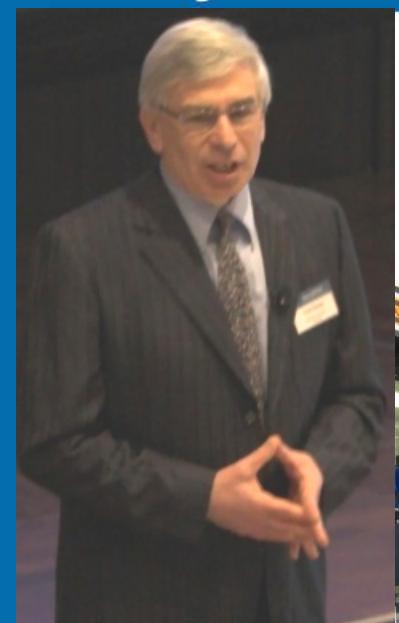
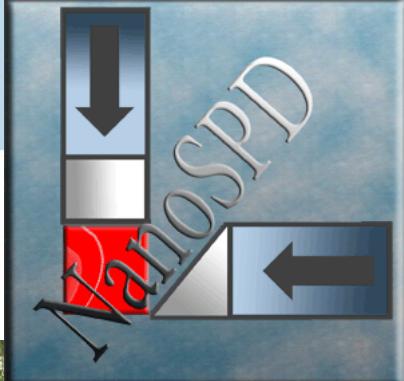


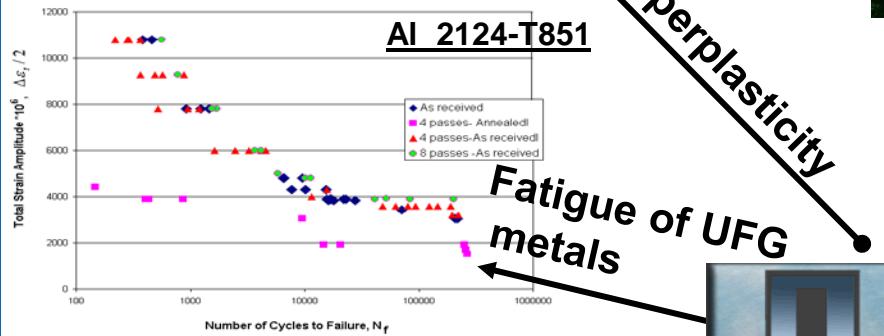
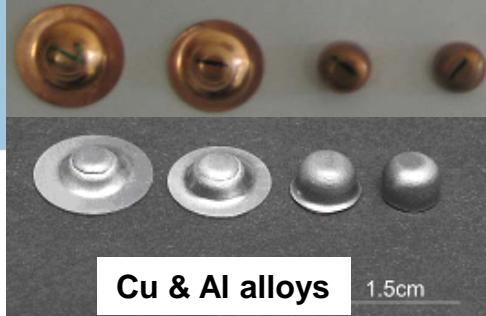
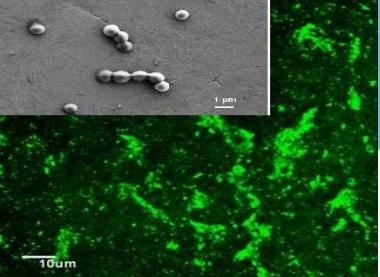


SEVERE PLASTIC DEFORMATION RESEARCH AT MONASH UNIVERSITY

Centre for Advanced Hybrid Materials

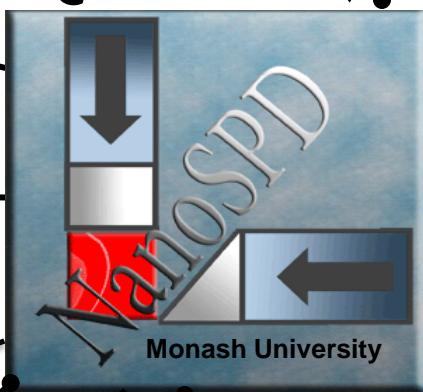
NanoSPD Group at Monash University (2000-2012)



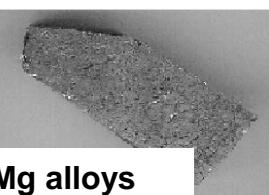


$$\dot{\varepsilon} - c \nabla^2 \varepsilon = f(\sigma, \varepsilon)$$

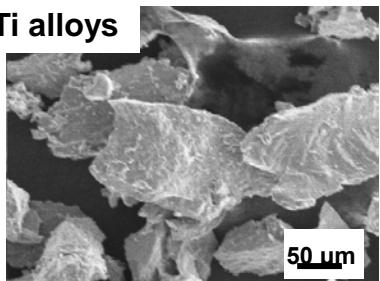
Modelling of UFG metals behaviour



Machining of CG and UFG Ti



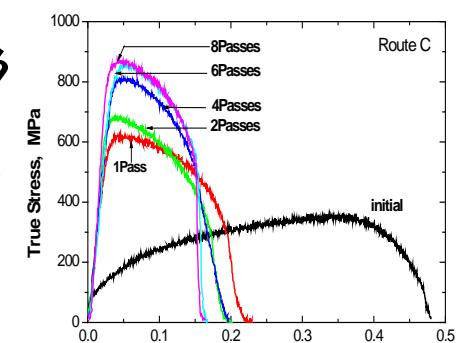
Ti alloys



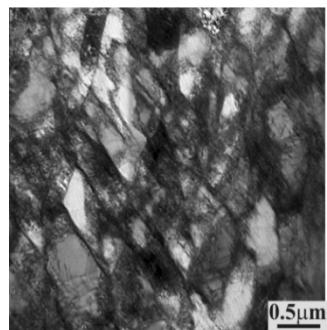
Mg alloys

Enhanced Strength and Ductility

Powder compaction



SPD of IF and TWIP steels



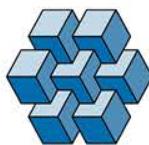
Swarf compaction

Fatigue of UFG metals

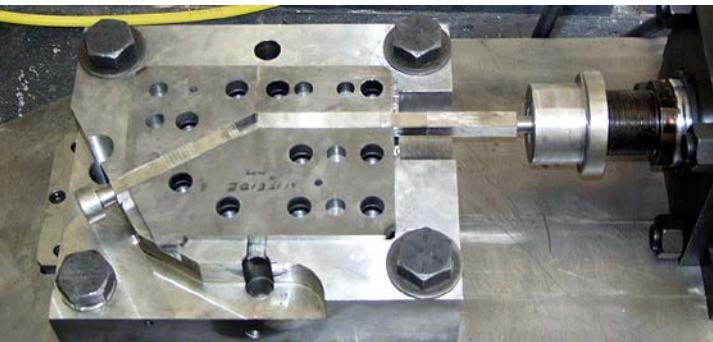
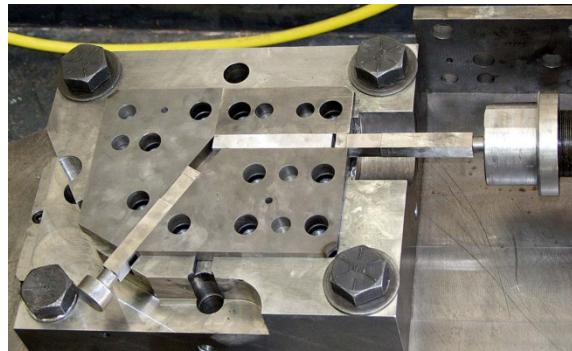
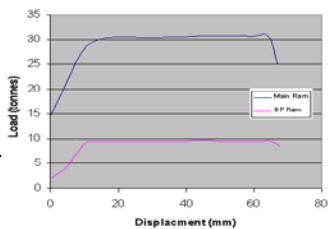
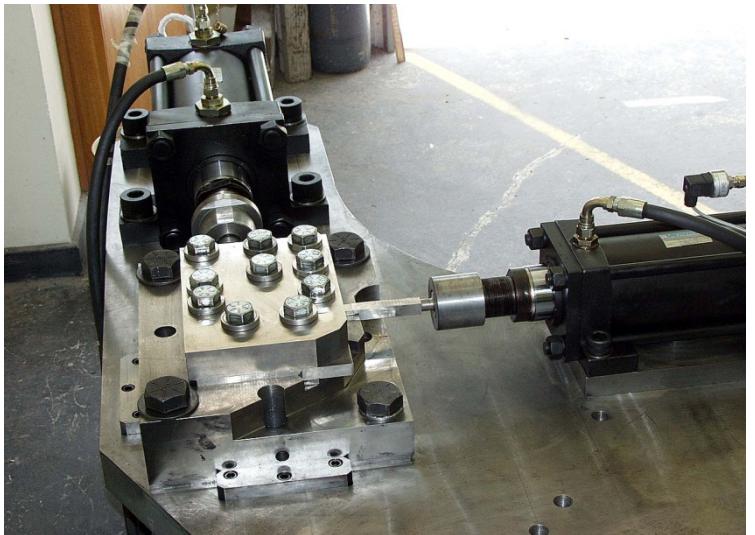
Bio-Medical Application

Microforming

Superplasticity



Room Temperature ECAP Rig



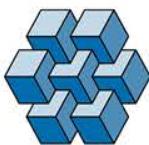


Elevated Temperatures ECAP Rigs



Isothermal ECAP Unit



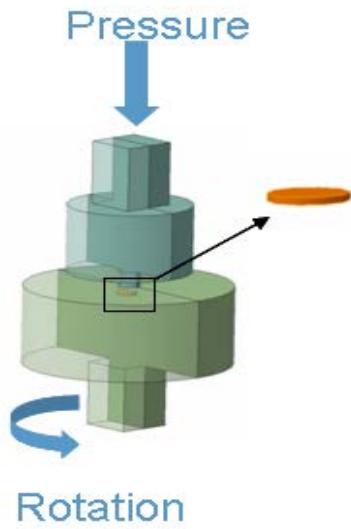


Asymmetric Rolling Mill

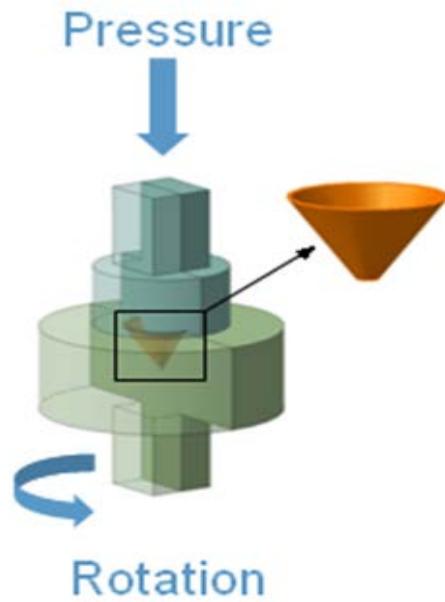




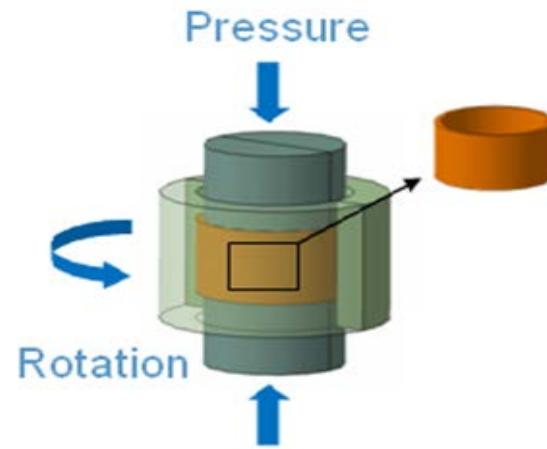
Severe Plastic Deformation Processes for Thin Samples



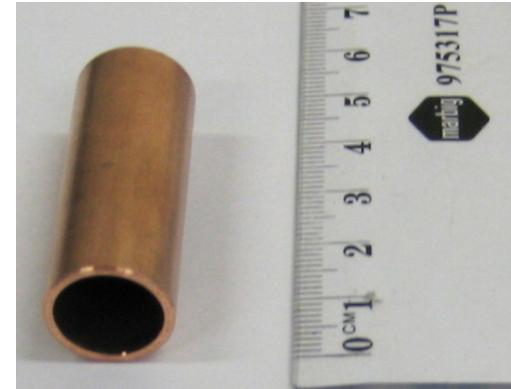
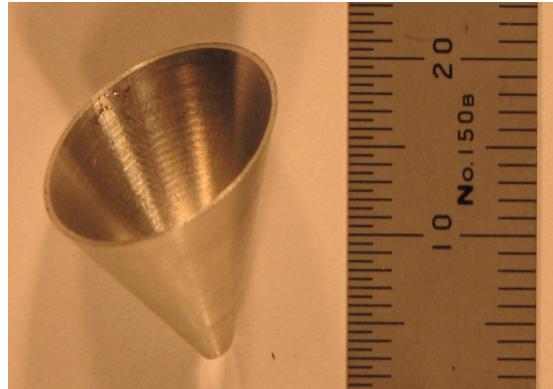
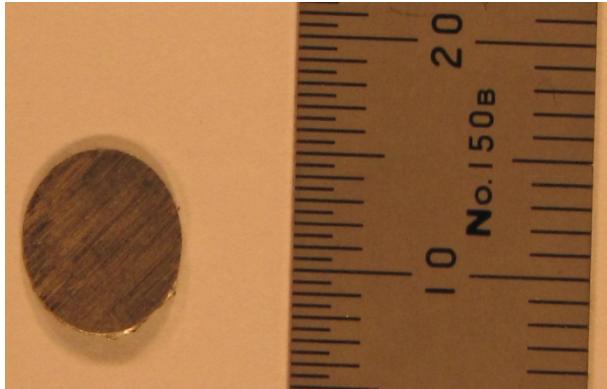
HPT - High Pressure Torsion

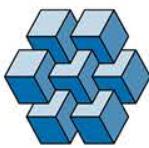


CCM - Cone-Cone Method

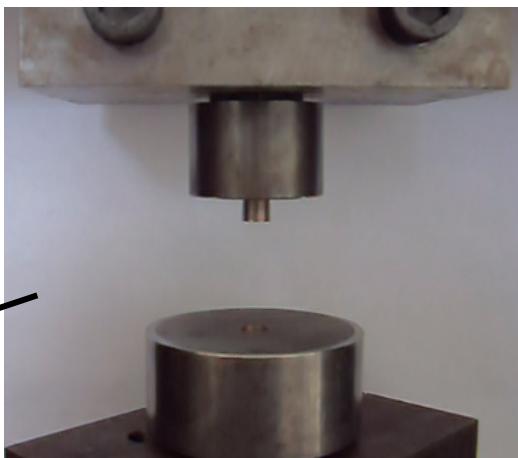
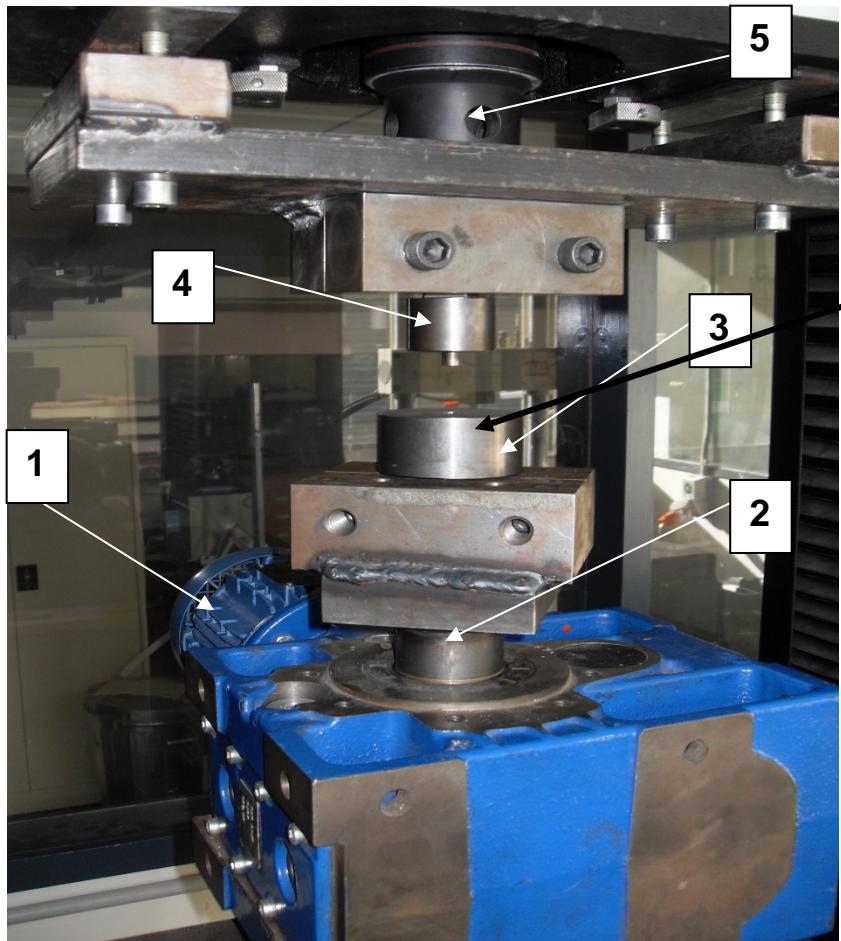


HPTT - High Pressure Tube Twisting





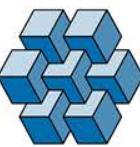
High Pressure Torsion



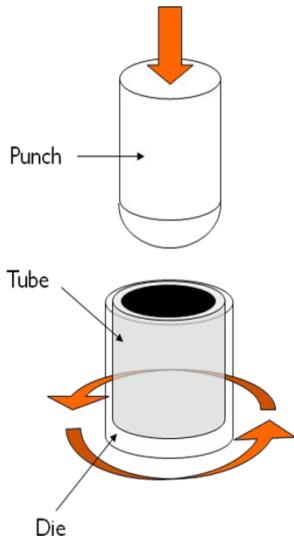
Cone - Cone



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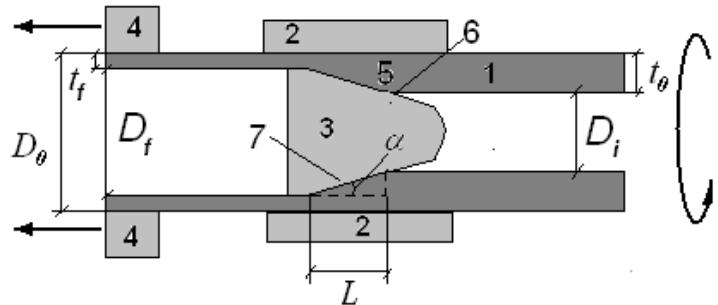


New Results: Strengthening of Metal Tubes

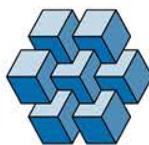


(i) Severe shear strain is imposed within the thickness of the sample due to the difference in magnitude of the material flow velocities at two surfaces resulted from different rotational velocities of the confining die and/or mandrel.

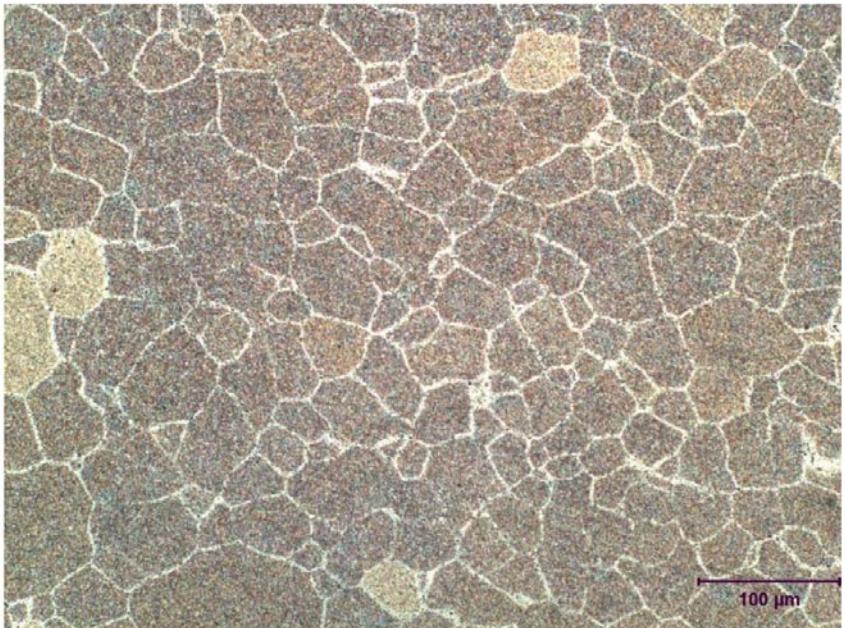
(ii) Processing involves friction forces acting on the surfaces and a high hydrostatic pressure within the deformation zone resulted from reduction of the wall thickness.



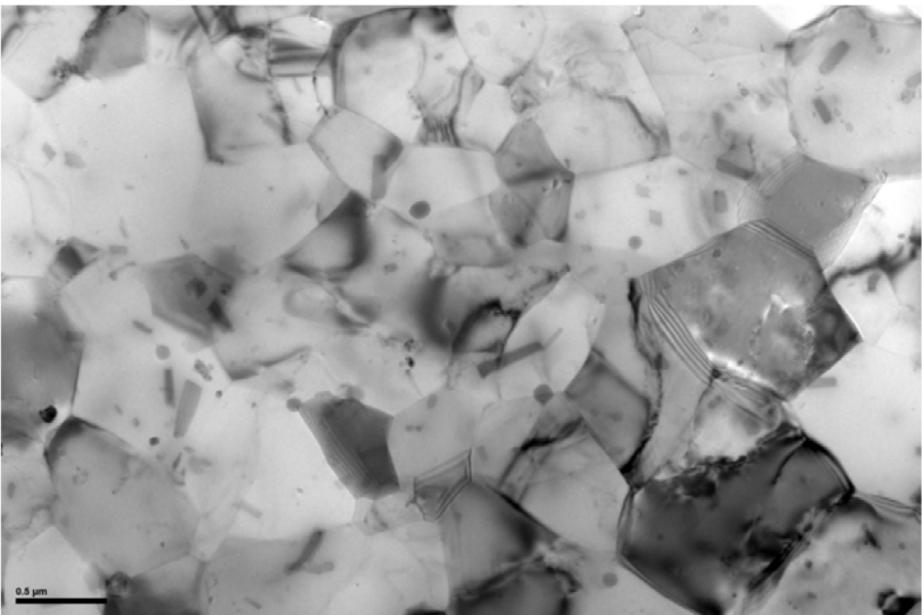
STRENGTHENED METAL TUBES
by Severe Plastic Deformation
(Patent Application US61/545921)



New Results: Microstructure of Processed Tube Sample (AA6060)



Initial microstructure
(annealed at 415° C)

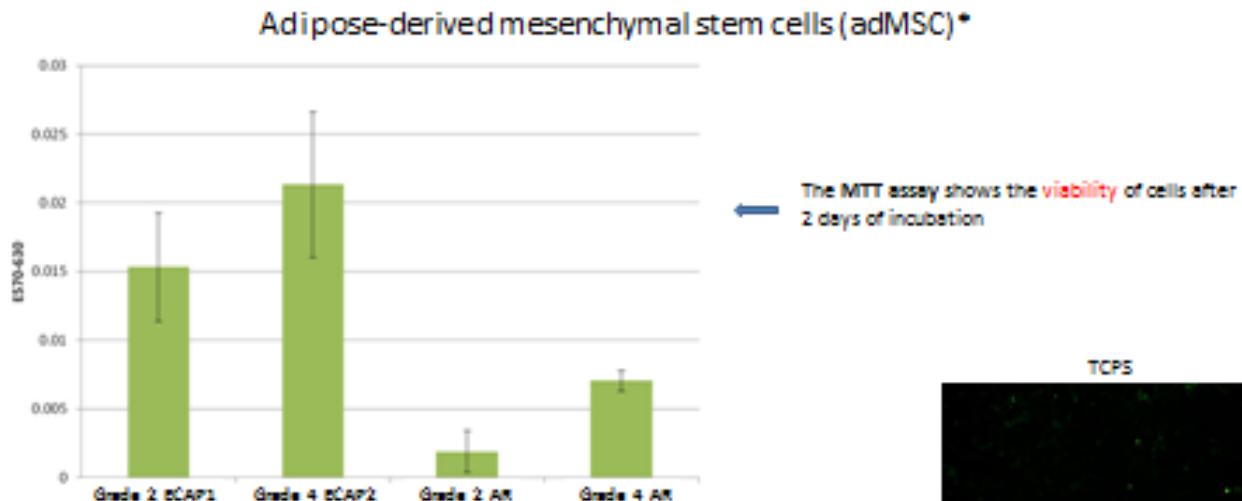
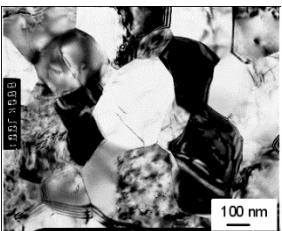
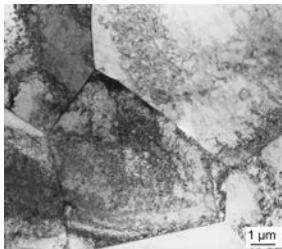


Microstructure after processing

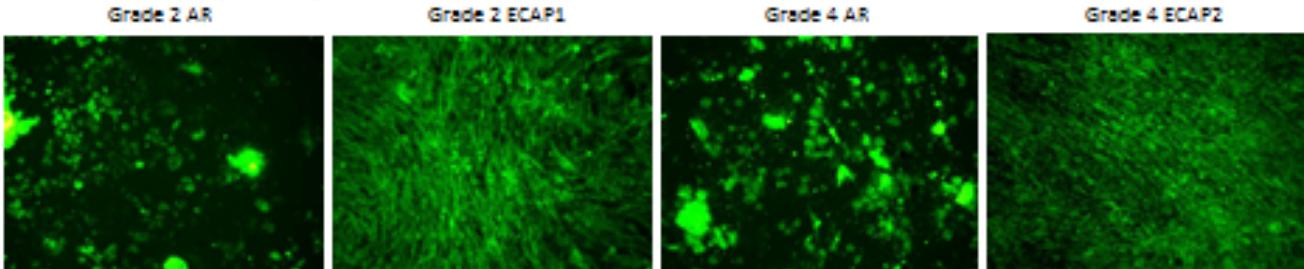




New Results: CP-Ti Bio-Implants

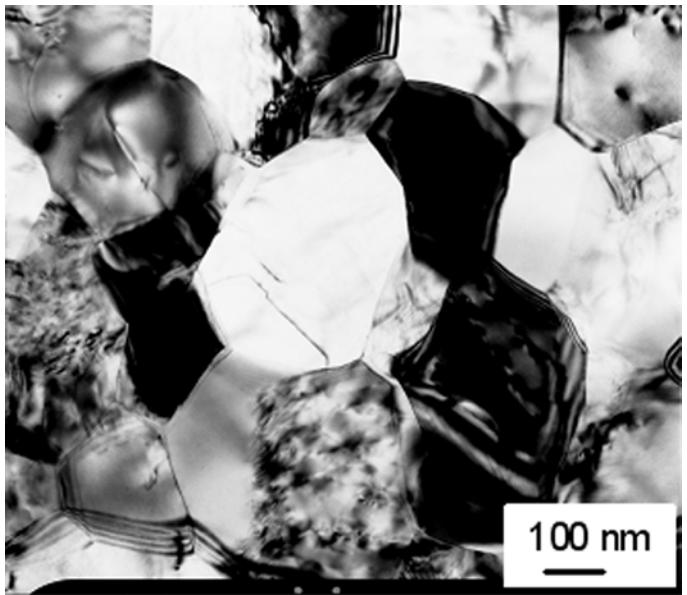


Calcein staining reveals the **amount of calcium** in ECM after 20 days of incubation. It describes the measure of mineralization of the extracellular matrix, which is necessary for formation of the bone in the vicinity of the implant.

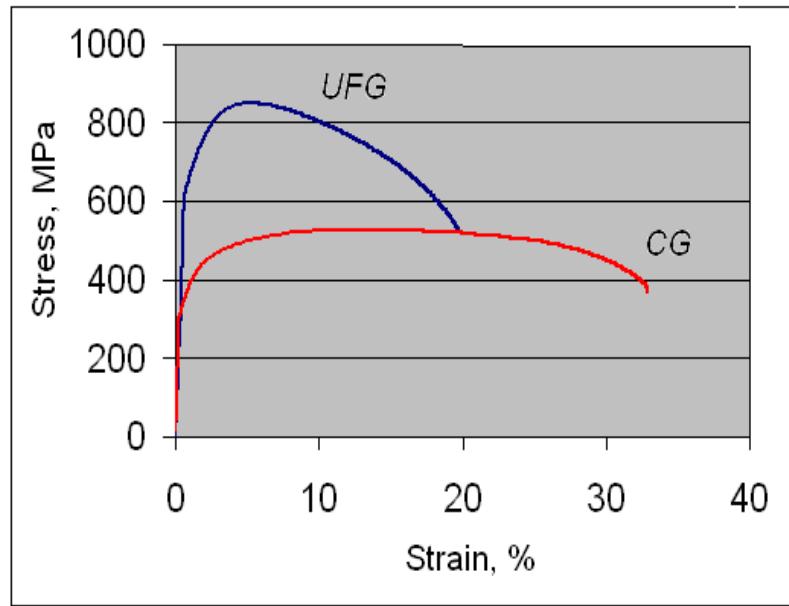




Grain refinement and mechanical property improvement of Grade 2 CP Titanium



Grain structure of ECAP-
modified titanium

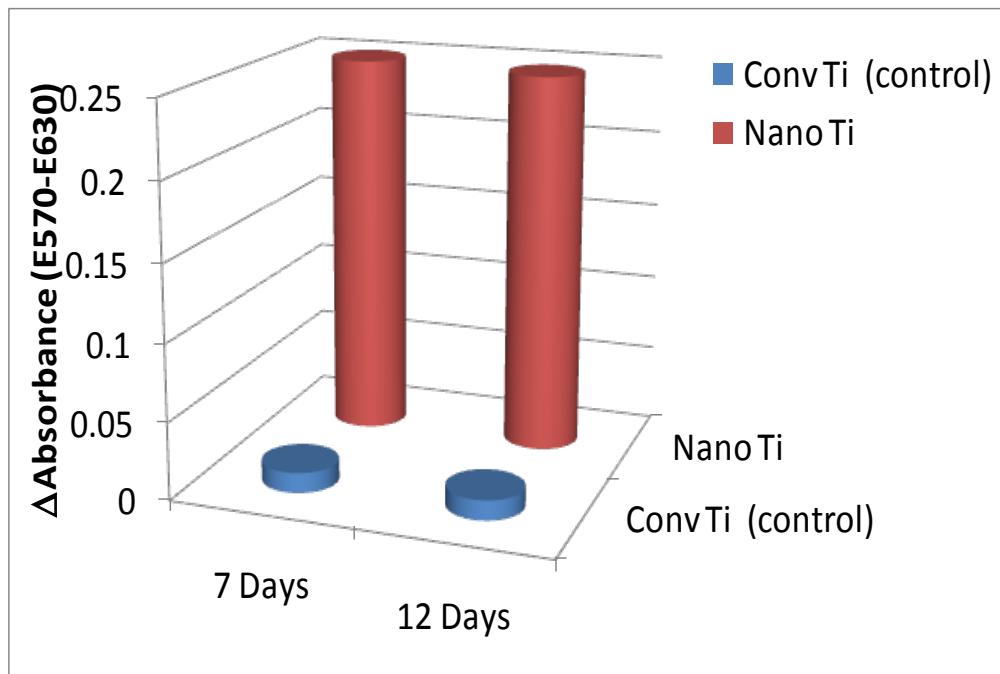


Tensile curves of coarse-grained
(CG) and ultrafine-grained (UFG)
titanium

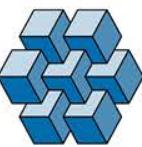


Nanostructured Ti Shows Distinctly Greater Preosteoblastic Cell Growth *in vitro*

MC3T3-E1 cells from mice embryos



Y. Estrin et al.
J. Biomed. Materials Res., 2008



*Integrated extrusion and ECAP
to improve the performance of
magnesium alloy ZK60*



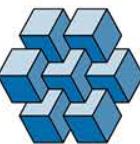
Collaborations

- Prof. Alexei Vinogradov, University of Togliatti, Russia and Osaka University, Japan
- Dr. Dmytri Orlov, Reitsumeikan University, Kyoto, Japan
- Dr. Daniele Pelliccia, Monash University, Australia
- Prof. Nick Birbilis, Monash University, Australia

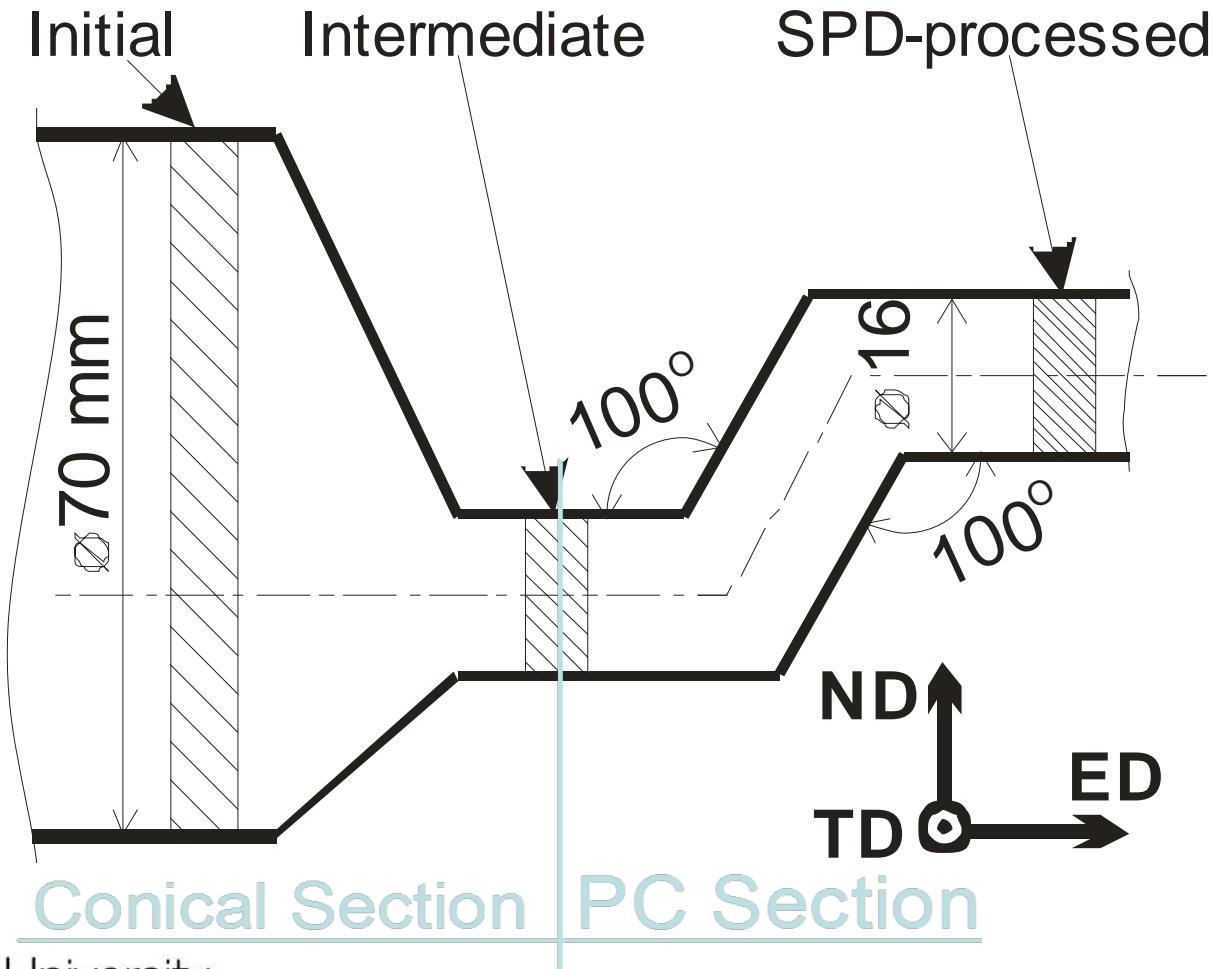


Aim

To improve performance of Mg-Zn-Zr alloy ZK-60 through microstructure control through an integrated process of *extrusion and equal channel angular pressing (ECAP)*.

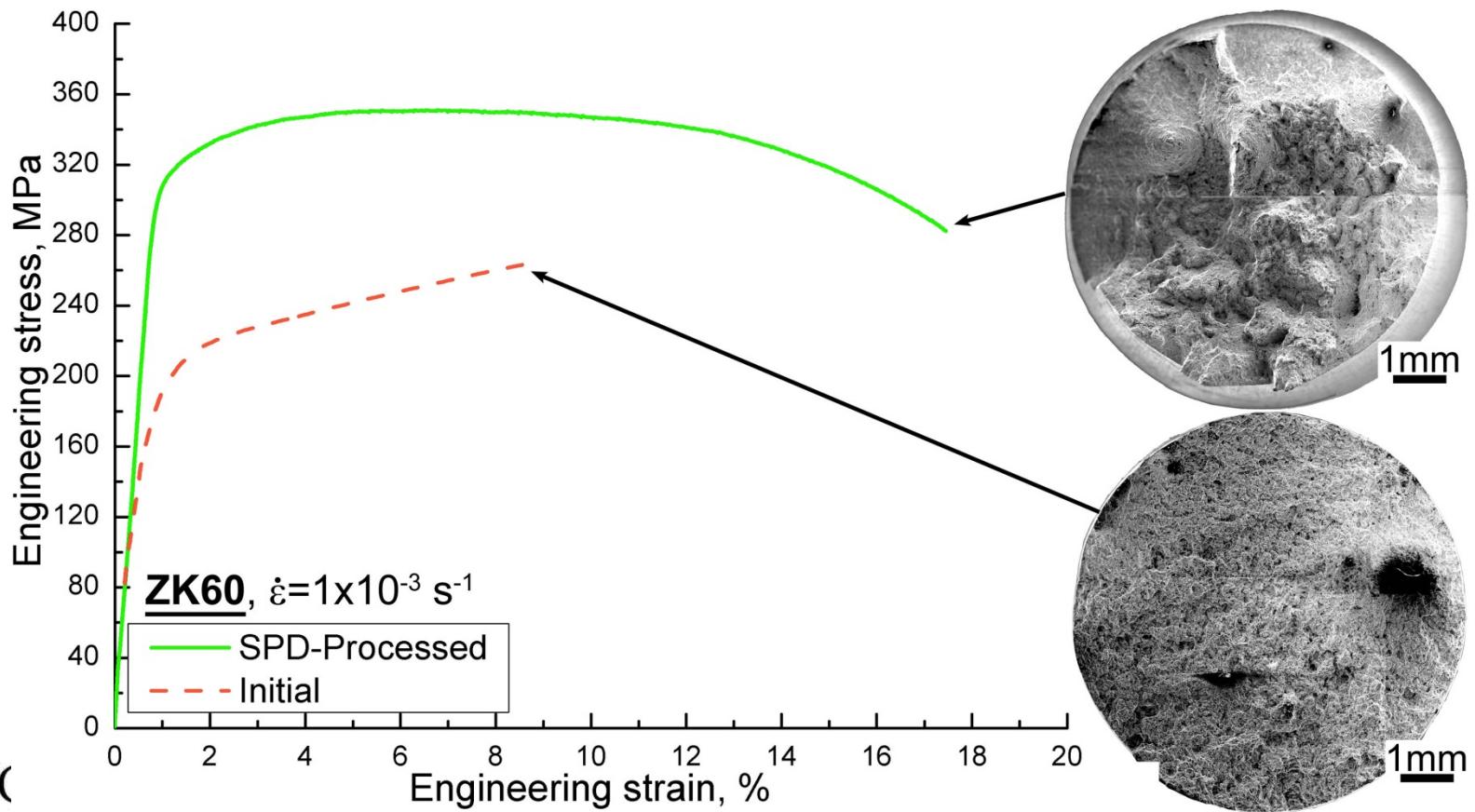


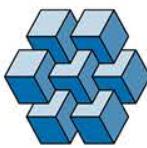
Integrating extrusion+ECAP



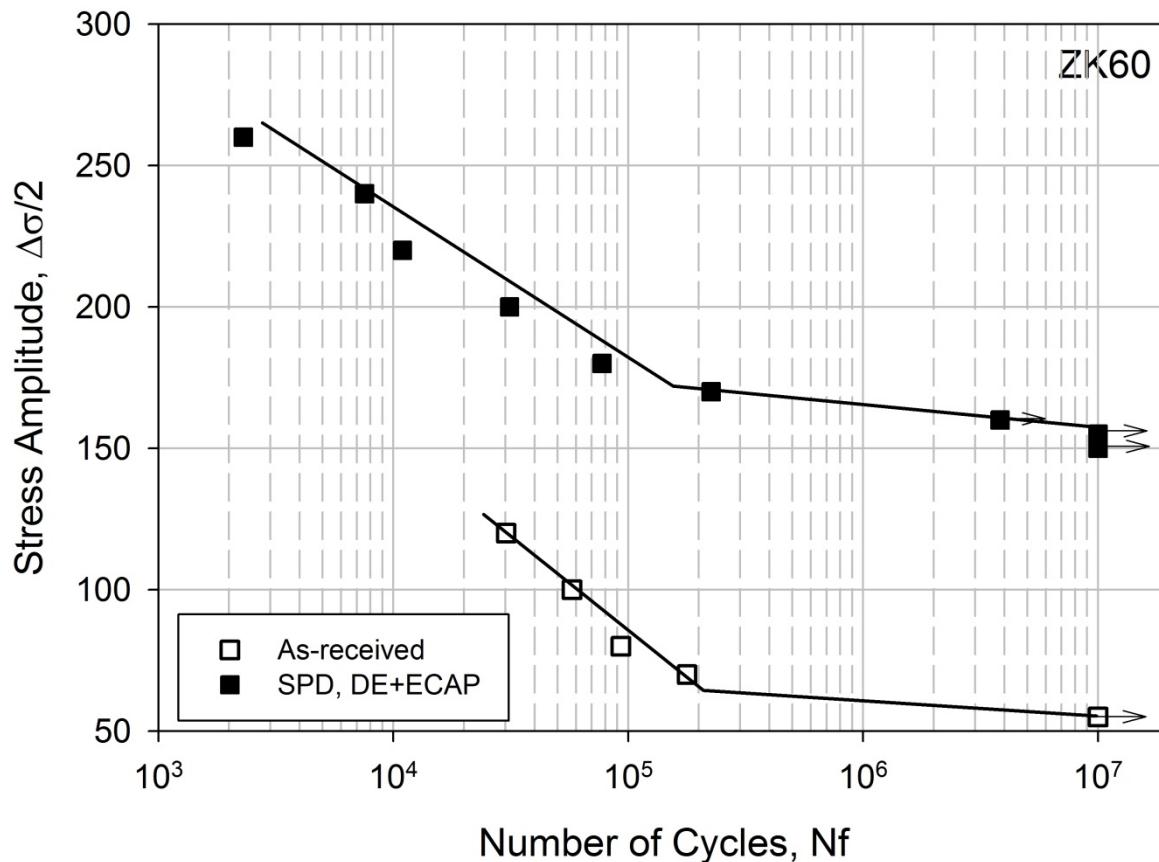


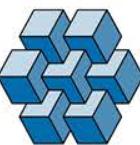
ZK60, Tensile Properties



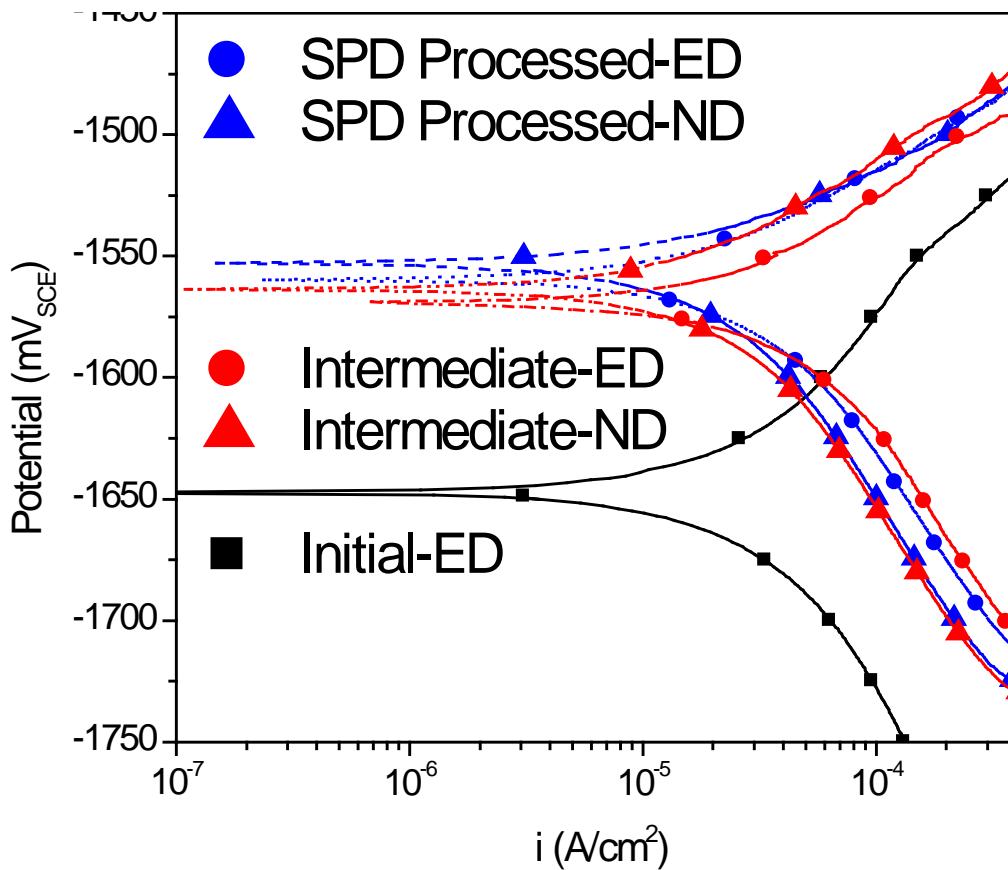


Mg ZK60, Fatigue Performance



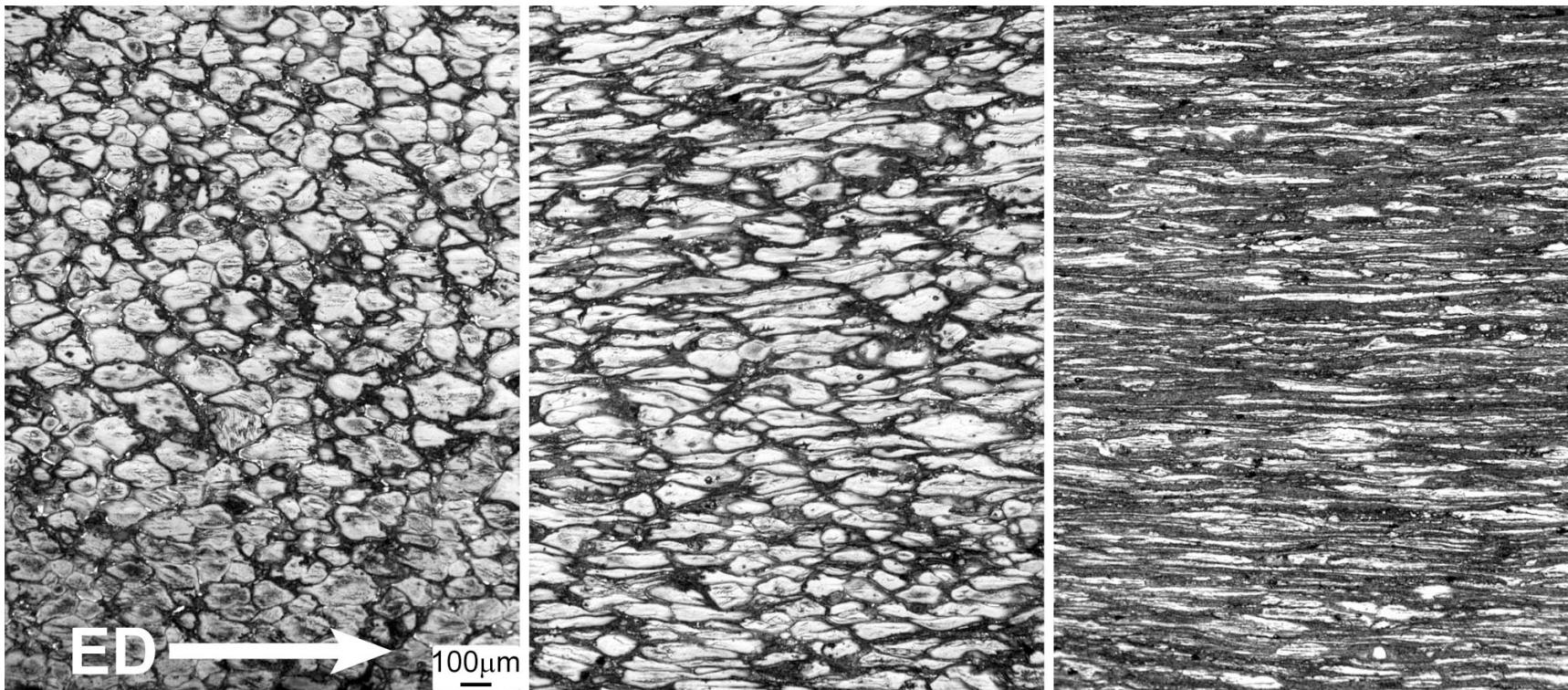


Mg ZK60, Corrosion Performance





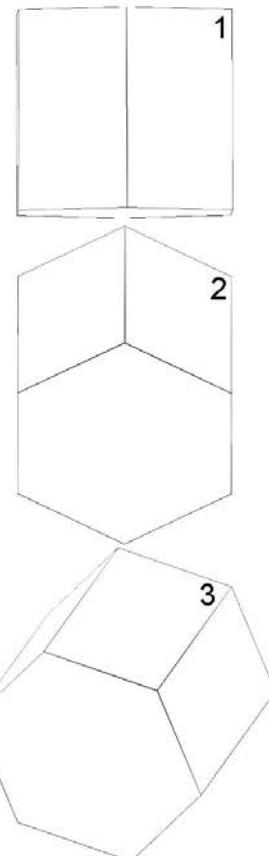
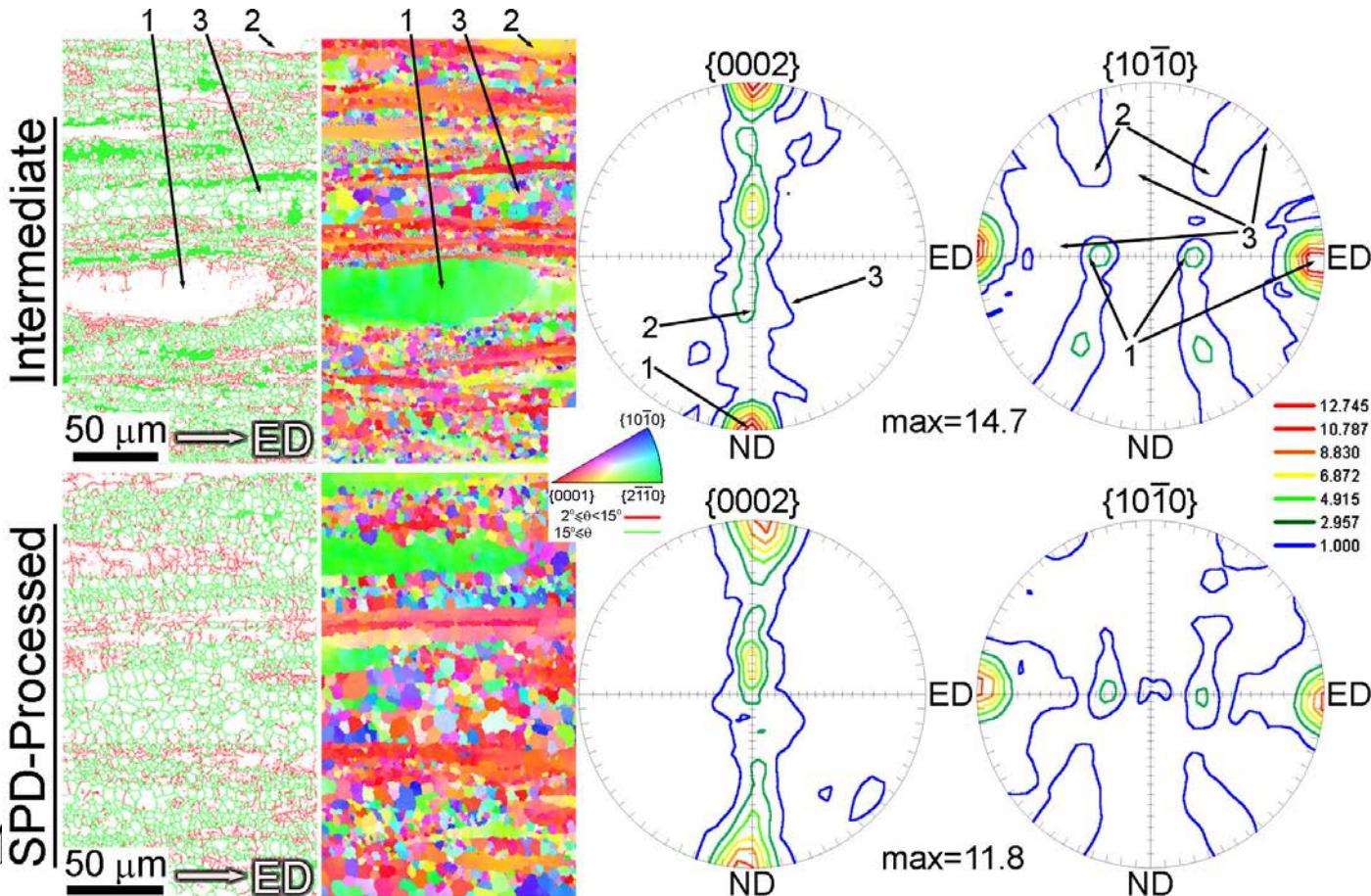
Mg ZK60, Microstructure Evolution along conical section of the die





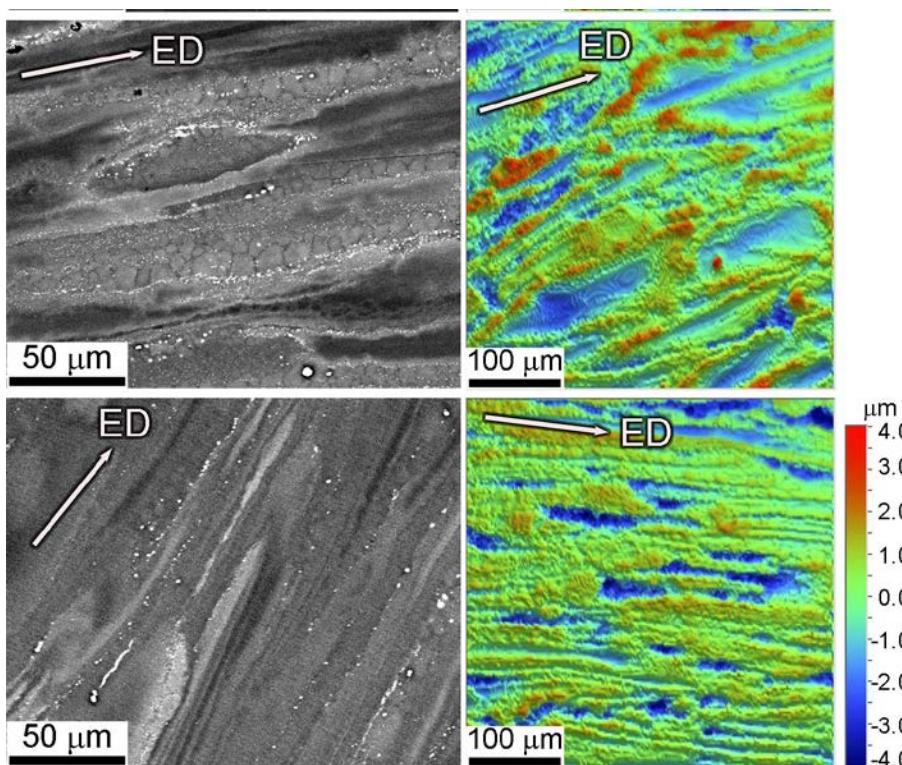
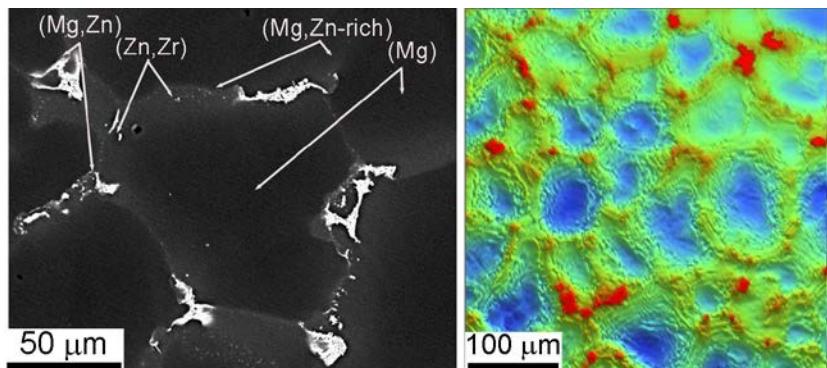
Mg ZK60, Microstructure Evolution by EBSD

in PC section of the die





Mg ZK60, Intermetallics Evolution by SEM and optical profilometry after exposure test

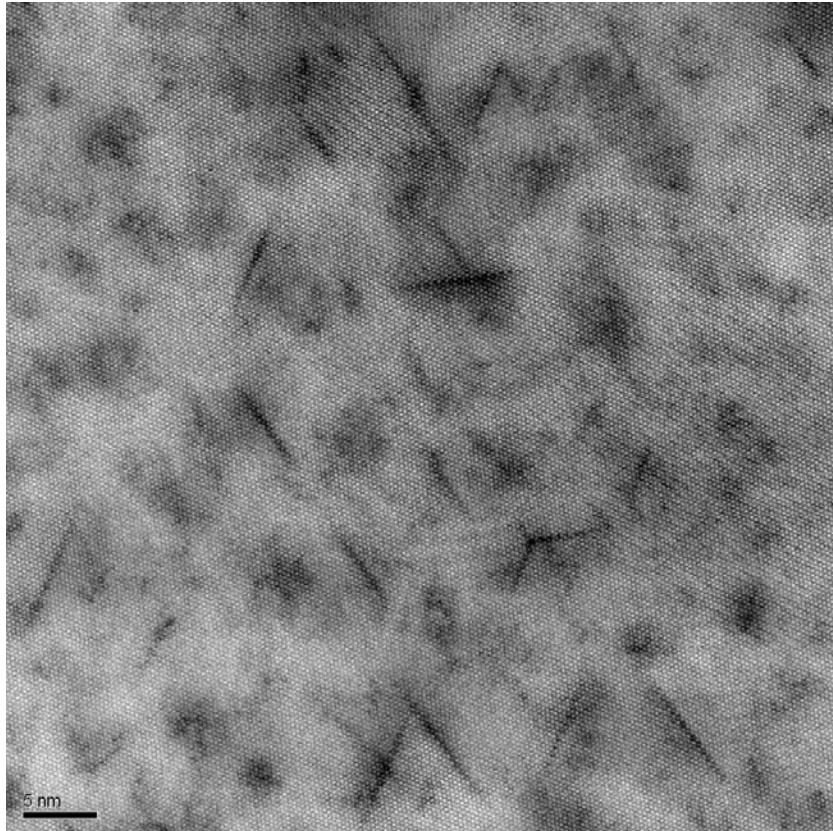
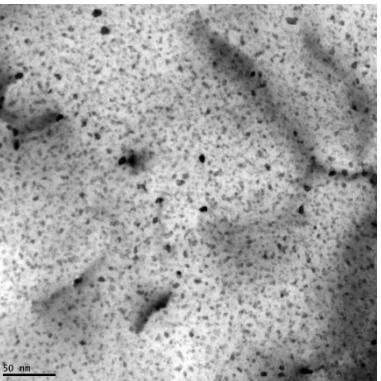
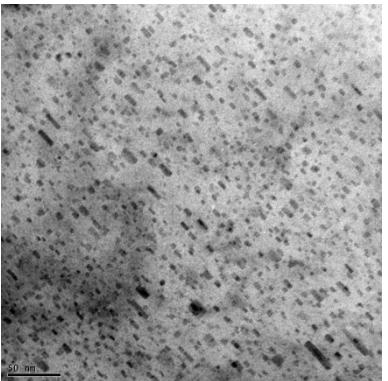




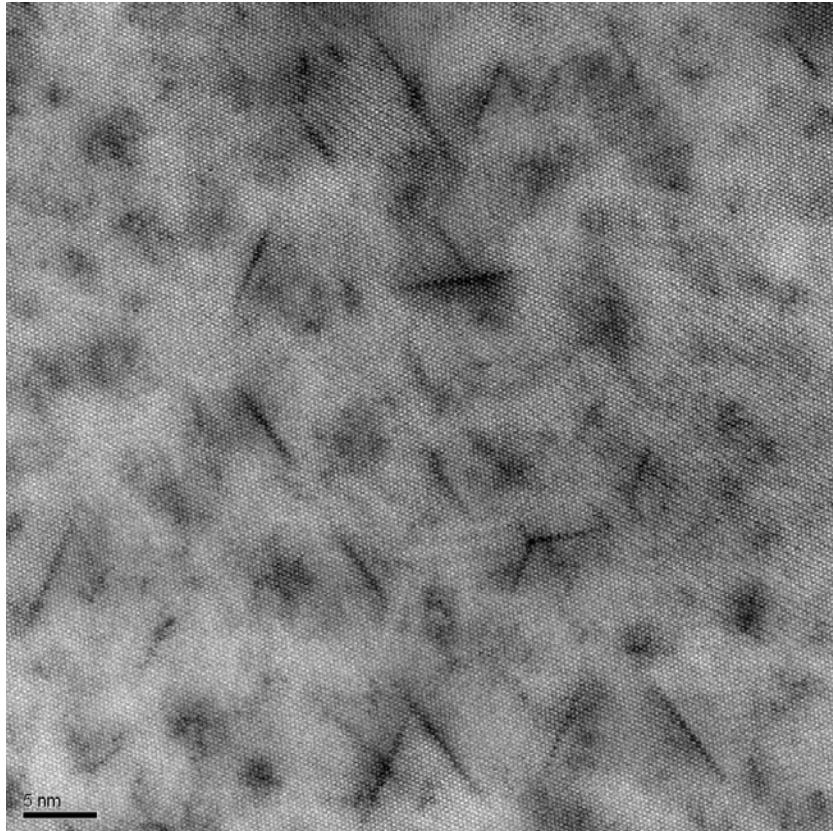
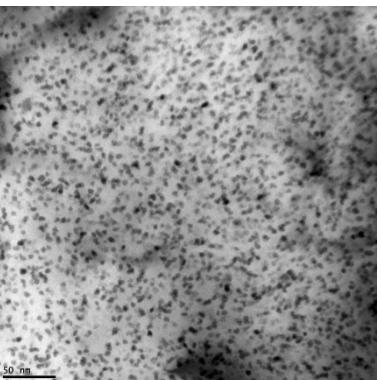
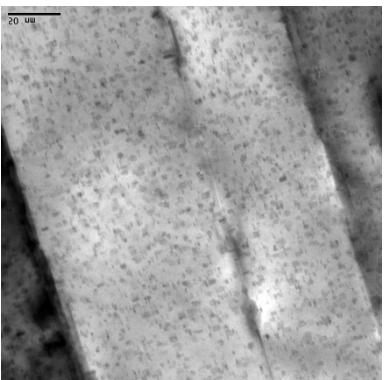
Mg ZK60, Intermetallics Evolution by HR-TEM

new deformation-induced particles discovered

Initial



SPD processed



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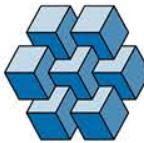
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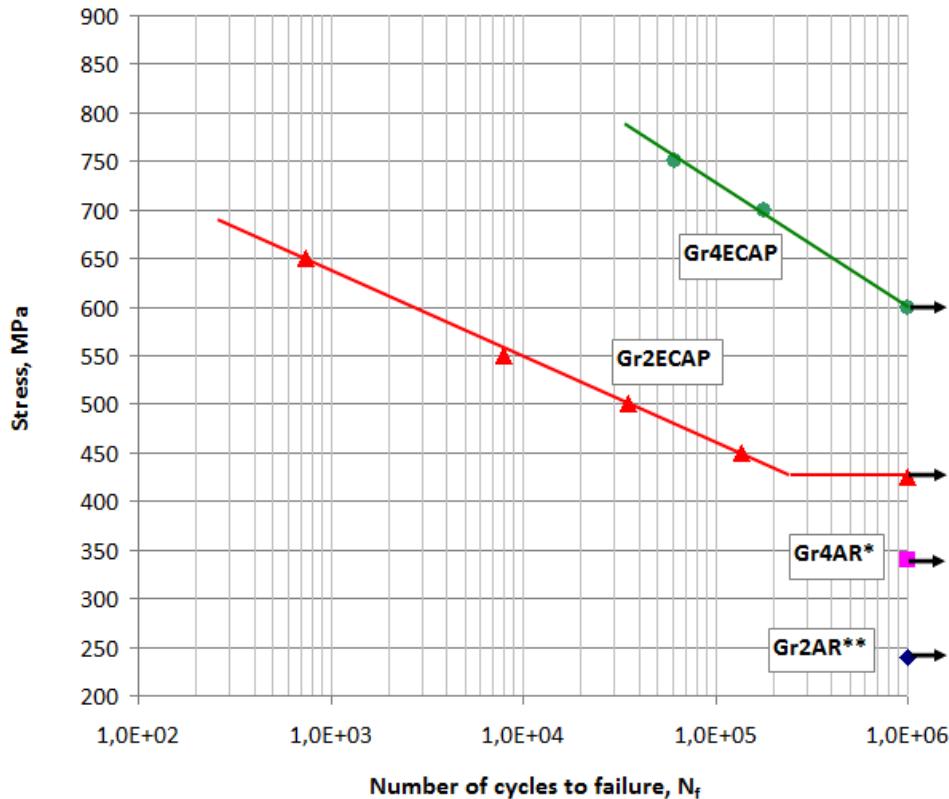
Summary

- Four meter long bars were manufactured by integrated extrusion and equal channel angular pressing.
- Tensile, fatigue and corrosion properties were simultaneously improved by such processing.
- Corrosion properties are controlled by particle redistribution, while mechanical properties depend primarily on microstructure and texture evolution.



Mechanical properties

Condition	UTS, MPa	YS, MPa	Elongation, %
Grade 2 AR	480	350	30
Grade 2 ECAP	850	750	20
Grade 4 AR	766	620	22
Grade 4 ECAP	1030	940	20



* R.Z. Valiev et al. , Advanced Engineering Materials, 10 (2008) B15-B17.

** W.-J. Kim, C.-Y. Hyun, H.-K. Kim, Scripta Materialia, 54 (2006) 1745-1750.



New Results: Bimetallic Tubes

