

Mg Magnesium **Technology** **2010**

Proceedings of a symposium sponsored by the
Magnesium Committee of the Light Metals Division of
The Minerals, Metals & Materials Society (TMS)

Held during
TMS 2010 Annual Meeting & Exhibition
Seattle, Washington, USA
February 14-18, 2010

Edited by

Sean R. Agnew
Neale R. Neelameggham
Eric A. Nyberg
Wim H. Sillekens

A Publication of

TMS

TABLE OF CONTENTS

Magnesium Technology 2010

About the Editor.....	xv
About the Organizers	xvi

Magnesium Technology 2010

Poster Session

Corrosion Resistance of Graphite Anode for Magnesium Electrolyzers.....	3
<i>B. Li, J. Lou, C. Zhan, and J. Yu</i>	

Plenary Session

Magnesium Alloys in Aerospace Applications - Flammability Testing and Results	13
<i>B. Gwynne</i>	
A Possible Route to Making Magnesium Fit for Hydrogen Storage in Automotive Applications	15
<i>V. Skripnyuk, E. Rabkin, Y. Estrin, and R. Lapovok</i>	
Precipitation Strengthening in Magnesium Alloys Containing Rare Earth Elements	17
<i>X. Zeng, W. Ding, Y. Wu, and L. Peng</i>	
Thermodynamics and Constitution of Mg-Zn-Ce Alloys	23
<i>C. Chiu, A. Kozlov, J. Groebner, and R. Schmid-Fetzer</i>	
Magnesium Alloys in U.S. Military Applications: Past, Current and Future Solutions.....	27
<i>S. Mathaudhu, and E. Nyberg</i>	

ICME I

Integrated Computational Materials Engineering for Magnesium in Automotive Body Applications	35
<i>J. Allison, B. Liu, K. Boyle, L. Hector, and R. McCune</i>	
Thermodynamic and Elastic Properties of La-X (X=Al,Mg) Intermetallic Compounds from First Principles Calculations	41
<i>L. Hector, J. Wrobel, and K. Kurzydowski</i>	
Numerical Simulation of Direct Extrusion of Magnesium Alloys	49
<i>W. Misiolek, and L. DePari</i>	

Transmutation and Accommodation Effects by Glide Twinning	51
<i>A. Oppedal, and H. ElKadiri</i>	
Plasticity in a Rod-Textured Extruded Mg AM30 Alloy.....	57
<i>Q. Ma, and H. ElKadiri</i>	
Extracting Post-uniform Constitutive Behavior from High Temperature Tensile Test Data	63
<i>C. Dreyer, L. Hector, C. Engledrum, and S. Agnew</i>	
Strain Field Measurement during Bending of Extruded Magnesium Alloys	69
<i>A. Ben-Artzy, L. Hector, and P. Krajewski</i>	
Cyberinfrastructure for Integrated Computational Material Engineering	77
<i>T. Haupt</i>	

Primary Production and Flammability Issues

The Magnesium Industry Today...The Global Perspective	85
<i>G. Patzer</i>	
Magnesium: Bridging Diverse Metal Markets	91
<i>S. Slade</i>	
Development Of Recyclable Mg-Based Alloys AZ91D And AZC1231 Phase Information Derived From Heating/Cooling Curve Analysis.....	97
<i>A. Gesing, N. Reade, J. Sokolowski, C. Blawert, D. Fechner, and N. Hort</i>	
Preparation of Al-Mg Alloys from MgO by Molten Salt Electrolysis Method.....	107
<i>S. Yang, F. Yang, X. Hu, Z. Wang, Z. Shi, and B. Gao</i>	
Effect of KCl on Conductivity of BaF ₂ -LiF-MgF ₂ Molten Salts	111
<i>S. Yang, F. Yang, G. Wang, X. Hu, Z. Wang, Z. Shi, and B. Gao</i>	
Powder Metallurgy of Magnesium: Is it Feasible?	115
<i>P. Burke, and G. Kipouros</i>	
Fireproof Evaluation of CaO added Mg-3Al, Mg-6Al, and Mg-9Al Mg Cast Products.....	121
<i>J. Lee, and S. Kim</i>	
Effect of Ca(OH) ₂ on Oxidation and Ignition Resistances of Pure Mg	129
<i>D. Jang, and S. Kim</i>	
Research on the Oxidation Behavior of AZ91D-based Magnesium Alloys.....	135
<i>H. Luo, T. Li, Y. Liu, and G. Yao</i>	

Coatings and Corrosion

A Novel Method for the Preparation of Electroless Coating on Magnesium Alloys	141
<i>H. Zhao, Z. Huang, P. Li, and J. Cui</i>	
Galvanic Corrosion and Stress Corrosion Cracking of Steel and Aluminum Bolts in Magnesium Die Cast Alloy AZ91	145
<i>G. Gerstmayr, G. Mori, and W. Eichlseder</i>	
Characterization Of A Multilayer Coating Prepared By Combining Plasma Electrolytic Oxidation, Electroless Copper And BTA Passivity On A Magnesium Alloy	151
<i>Y. Jiang, and Y. Bao</i>	
Enhanced Corrosion Resistance of AZ91 Mg Alloy by Plasma Electrolytic Oxidation with $Kmno_4$	155
<i>D. Shin, I. Hwang, K. Shin, K. Lee, and B. Yoo</i>	
Laser Surface Alloying of a Creep Resistant Magnesium Alloy MRI 230D with Al and Al_2O_3	161
<i>G. Rapheal, S. Kumar, C. Blawert, and N. B. Dahotre</i>	
Corrosion Phenomenon Evaluation of Mg Alloys Using Surface Potential Difference Measured by SKPFM.....	169
<i>R. Takei, H. Fukuda, H. Imai, J. Umeda, and K. Kondoh</i>	
A Study of Corrosion Film Growth on Pure Magnesium and a Creep-Resistant Magnesium Alloy in an Automotive Engine Coolant.....	173
<i>Z. Shi, P. Mallick, R. McCune, S. Simko, and F. Naab</i>	
Improving Corrosion Performance of AZ31B Mg Alloy Sheet by Surface Polishing.....	181
<i>G. Song, and Z. Xu</i>	
Microstructure and Corrosion of AZ91D with Small Amounts of Cerium.....	187
<i>D. Zander, M. Heilig, N. Hort, G. Klaus, A. Buehrig-Polaczek, J. Gröbner, and R. Schmid-Fetzer</i>	
Effect of Neodymium Addition on Corrosion Resistance of Mg-Li Alloy	193
<i>M. Li, G. Yao, Y. Liu, and H. Ji</i>	

Creep, Relaxation, Recovery, and Recrystallization

Effect of Aluminum Addition on the Strengthening and High Temperature Deformation Behavior of Mg-3Sn-2Ca Alloy.....	201
<i>K.. Rao, Y. Prasad, N. Hort, and K. Kainer</i>	

Atomistic Simulation of Grain Boundary Sliding in Mg during High Temperature Deformation	207
<i>H. Zhang</i>	
Grain Size Effect on the Dome-Forming Limit and Deformation Mechanism of AZ31B Magnesium Alloy Sheets	209
<i>H. Kim, W. Bang, and Y. Chang</i>	
Approaching Bolt Load Retention Behaviour of AS41 through Compliance and Creep Deformation	215
<i>O. Anopuo, Y. Huang, N. Hort, H. Dieringa, and K. Kainer</i>	
Elevated Temperature Tensile Behavior of Extruded Magnesium Sheets	221
<i>P. Krajewski, and A. Ben-Artzy</i>	
Elevated-Temperature Tensile Behavior of a Rapidly Solidified and Reverse Extruded Mg-Zn-Y-Ce-Zr Alloy	227
<i>J. Carter, P. Krajewski, and D. Shechtman</i>	
Microstructure, Tensile Properties and Creep Resistance of Binary Mg-Rare Earth Alloys	233
<i>M. Gibson, S. Zhu, M. Easton, and J. Nie</i>	
The Role of Strain on the Recrystallization Behaviour of Hot Worked and Annealed Magnesium Alloy Mg-3Al-1Zn.....	239
<i>A. Beer</i>	
The Relationships between Grain Boundary Sliding and Anisotropic Dislocation Plasticity in AZ31 Magnesium Alloys at Room Temperature.....	245
<i>D. Ando, Y. Sutou, and J. Koike</i>	
Texture Change in Pure Mg and Mg-1.5wt%Mn Casting Alloy During Compressive Creep-Deformation	249
<i>M. Celikin, D. Sediako, and M. Pekguleryuz</i>	

Fatigue, Failure, and Wear

Effect of Shot Peening on High Cycle Fatigue Performance of Mg-10Gd-3Y-0.5Zr Magnesium Alloy.....	255
<i>W. Liu, J. Dong, P. Zhang, L. Jin, and W. Ding</i>	
Monotonic and Multiaxial Cyclic Behavior of the Extruded AZ31B Magnesium Alloy.....	261
<i>J. Albinmousa, H. Jahed, and S. Lambert</i>	
Fatigue Evaluation of Friction Stir Spot Welds in Magnesium Sheets	267
<i>J. Jordon, M. Horstemeyer, J. Grantham, and H. Badarinarayan</i>	

Atomistic Simulations of Fatigue Crack Growth and the Influence of Temperature on Fatigue Behavior in Magnesium Crystals.....	273
<i>T. Tang, S. Kim, and M. Horstemeyer</i>	
Structure-Property Evaluation of Fatigue Damage in a Magnesium AM30 Alloy	281
<i>J. Bernard, J. Jordon, M. Horstemeyer, and H. ElKadiri</i>	
Very High Cycle Fatigue Property of Magnesium Alloy in Axial Loading and Rotating Bending.....	287
<i>T. Sakai, Y. Nakamori, N. Ninomiya, and M. Ueda</i>	
Numerical Modeling of Failure in Magnesium Alloys during Crush Simulations.....	293
<i>J. Rossiter, K. Inal, and R. Mishra</i>	
Dry Sliding Wear Behavior of AE44 Magnesium Alloy Reinforced with Saffil Alumina Fibers.....	297
<i>B. Hu, L. Peng, B. Powell, M. Lukitsch, and A. Sachdev</i>	
Influence of Cerium on Stress Corrosion Cracking in AZ91D.....	305
<i>M. Heilig, D. Zander, D. Olson, B. Mishra, N. Hort, G. Klaus, A. Buehrig-Polaczek, J. Gröbner, and R. Schmid-Fetzer</i>	

Mg-RE (Rare Earth) Alloys

Development of High Ductility Magnesium-Zinc-Cerium Extrusion Alloys	313
<i>A. Luo, R. Mishra, and A. Sachdev</i>	
Effect of extrusion temperature on microstructure and mechanical properties of Mg-8.5Gd-2.3Y-1.8Ag-0.4Zr alloy solid state recycled by hot extrusion	319
<i>J. Chen, Q. Wang, T. Peng, Z. Zhao, and W. Ding</i>	
Structure of β -1' Precipitates in Mg-Zn Based Alloys: Co-existence of MgZn ₂ and Mg ₄ Zn ₇ phases.....	323
<i>A. Singh, J. Rosalie, H. Somekawa, and T. Mukai</i>	
Rheological Behavior of Semi-solid Mg-Y Alloys	329
<i>Q. Peng, Y. Huang, N. Hort, and K. Kainer</i>	
Computer Modeling Of DC Casting Magnesium Alloy WE43 Rolling Slabs	333
<i>M. Turski, J. Grandfield, T. Wilks, B. Davis, R. DeLorme, and K. Cho</i>	
Effects of extrusion conditions on the microstructure and mechanical properties of Mg Zn Y RE alloys.....	339
<i>J. Kim, and Y. Kawamura</i>	
Effect of Cerium on the Deformation Behavior of Two Mg-Ce Alloys.....	343
<i>L. Jiang, X. Quelennec, J. Jonas, and R. Mishra</i>	

Structural Relationships Between Monoclinic and Laves Phase Precipitates in Mg-Zn-Y Alloys.....	347
<i>J. Rosalie, H. Somekawa, A. Singh, and T. Mukai</i>	
Exploiting Low Levels of Rare Earth Addition in Mg Extrusion Alloys.....	353
<i>M. Barnett, A. Beer, and N. Stanford</i>	
Thermodynamic Database Development of Mg Alloys with RE Elements and Its Applications to Mg Alloy Design.....	359
<i>Y. Kang, L. Jin, I. Jung, A. Pelton, P. Chartrand, and C. Fuerst</i>	

Casting and Cast Alloys

Effects of Section Thicknesses on Tensile Properties of Permanent Mould Cast Magnesium Alloy AJ62.....	367
<i>J. Burns, L. Han, H. Hu, and X. Nie</i>	
Growth Restriction Factor Effects Near the Surface of High Pressure Die Cast Mg-Al Binary Alloys.....	373
<i>A. Nagasekhar, C. Caceres, and M. Easton</i>	
Strengthening Mechanisms in Mg-Al-Sn Based Alloys.....	377
<i>S. Avraham, A. Katsman, and M. Bamberger</i>	
Numerical Simulation and Experimental Study of Squeeze Casting Magnesium Alloy AM50.....	383
<i>Z. Sun, H. Hu, and A. Yu</i>	
Section Thickness and the Skin Effect in a High Pressure Die Cast Mg-12%Al Alloy.....	391
<i>K. Yang, A. Nagasekhar, and C. Caceres</i>	
Investigations on Microstructure and Properties of Mg-Sn-Ca Alloys with 3% Al Additions.....	395
<i>F. ElSayed, T. Abuleil, A. El-Aziz, K. Kainer, and N. Hort</i>	
Simulation of Stresses during Casting of Binary Magnesium-Aluminum Alloys.....	401
<i>M. Pokorny, C. Monroe, C. Beckermann, Z. Zhen, and N. Hort</i>	
Study on the Microstructure Changes during the in situ Tensile Processes of as-cast and Aged Specimens of High-vacuum Die-cast Mg-9Al-1Zn Alloy.....	409
<i>J. Song, and S. Xiong</i>	
Structure-Property Relationships for Die-Cast Magnesium Alloys.....	413
<i>J. Wood, J. Weiler, J. Jekl, and R. Berkmortel</i>	

Grain Refinement of Mg-Al Alloys by Carbon Inoculation.....419
Y. Huang, X. Zheng, B. Liu, O. Anopuo, N. Hort, K. Kainer, and G. Kim

A Systematic Study of the Grain Refinement of Magnesium by Zirconium.....425
P. Saha, K. Lokies, S. Viswanathan, A. Gokhale, and R. Batson

Deformation Mechanisms

The Evolution of In-Grain Misorientation Axes (IGMA) During Deformation of Wrought Magnesium Alloy AZ31433
Y. Chun, and C. Davies

Influence of Deformation Processing on the Tensile/Compressive Asymmetry in Wrought Mg-3Al-Zn Alloy.....439
R. Liu, D. Yin, J. Wang, and J. Zhao

Importance of Crystallographic Texture of AZ31B on Flow Stress Anisotropy and Tension-Compression Asymmetry445
M. Al-Maharbi, D. Floey, I. Karaman, I. Beyerlein, T. Hartwig, L. Kecskes, and S. Mathaudhu

Mechanical Behavior of AZ31 Due to Texture and Microstructure.....451
D. Foley, M. Al-Maharbi, K. Hartwig, I. Karaman, L. Kecskes, and S. Mathaudhu

Tensile Mechanical Properties and the Ductile-To-Brittle Transition Behavior of the Mg-Li-Al-Zn Alloy.....455
C. Yang, T. Lui, and L. Chen

The Influence of Sn and Pb Addition on the Tensile Properties of Mg Alloys.....461
W. Gao, and H. Liu

Room Temperature Tensile Anisotropy of Extruded Magnesium Plates467
P. Krajewski, A. Ben-Artzy, and R. Mishra

Mechanical Properties and Microstructural Analysis of AXJ530 Magnesium Alloy Reinforced with Alumina Fibers.....473
B. Hu, L. Peng, B. Powell, and A. Sachdev

Very High Strain Rate Deformation of AZ31b Mg Alloys Using Split Hopkinson Pressure Bar481
M. Sanjari, A. Farzadfar, S. Yue, and E. Essadiqi

Effects of Heat Treatment and Casting Process

On Mechanical Properties and Microstructures of TTMP Wrought Mg Alloys	489
<i>J. Huang, T. Arbel, L. Ligeski, J. McCaffrey, S. Kulkarni, J. Jones, T. Pollock, R. Decker, and S. LeBeau</i>	
The Effect of Thermomechanical Processing on the Tensile and Fatigue Behavior of Thixomolded® AM60	495
<i>Z. Chen, B. Kuhr, A. Ritter, J. Huang, R. Decker, S. LeBeau, and C. Boehlert</i>	
Influence of the Heat Treatment on Mechanical Properties and Microstructure in LPSO Mg-Zn-Y Alloys	501
<i>M. Noda, T. Mayama, and Y. Kawamura</i>	
The Effect of Zn Additions on Precipitation Hardening of Mg-Ca Alloys	505
<i>B. Langelier, and S. Esmaeili</i>	
Recent Developments in Mg-Sn based Alloy Thermodynamic Database.....	511
<i>M. Paliwal, J. Kim, D. Kang, and I. Jung</i>	
Influence of Zn Additions on Age Hardening Response and Microstructure of Mg-0.3at.%Ca Alloys	517
<i>K. Oh-ishi, C. Mendis, R. Watanabe, and K. Hono</i>	
Implementation of the Anisotropy of Plastic Flow in Inverse Parameter Calculations of the Deformation Behavior of AZ31 Magnesium Alloy.....	521
<i>T. Ebeling, C. Hartig, and R. Bormann</i>	
Effect of Aging and Thermomechanical Processes in Twin Roll Cast Mg AZ91 Alloy Sheet.....	527
<i>O. Duygulu, S. Ucuncuoglu, G. Oktay, O. Yucel, and A. Kaya</i>	
Experimental Studies on the As-Cast Microstructure of Mg-Al Binary Alloys with Various Solidification Rates and Compositions	533
<i>D. Kang, M. Paliwal, E. Essadiqi, and I. Jung</i>	
Impurity and Tracer Diffusion Studies of Magnesium and its Alloys.....	537
<i>S. Brennan, A. Warren, K. Coffey, Y. Sohn, N. Kulkarni, and P. Todd</i>	
Effect of Alloying and Solidification Rates on Microstructure of Hot Rolled and Annealed Micro-Alloyed Az31 Sheet.....	539
<i>E. Essadiqi, A. Javaid, M. Shehata, T. Muller, S. Yue, and R. Verma</i>	

Forming and Welding

Test Results and FEA Predictions from Magnesium AZ31 Sheet Beams in Bending and Axial Compression.....	547
<i>D. Wagner, S. Logan, K. Wang, and T. Skrzek</i>	
Microstructure and Mechanical Properties of Magnesium Extrusion Alloys AM30, AZ31, and AZ61	553
<i>A. Luo, J. Forsmark, X. Sun, S. Shook, W. Misiolek, and R. Mishra</i>	
Texture Development in a Twin Roll Cast and Warm Rolled ZK60 Magnesium Alloy	559
<i>H. Chen, H. Yu, S. Kang, and G. Min</i>	
Cruciform Geometries for Elevated Temperature Biaxial Testing of Mg AZ31B	563
<i>F. Abu-Farha, and L. Hector</i>	
Characterization of Continuous-Cast AZ31B Magnesium Alloy Sheets and Lubricants for Warm-Forming - Friction Effects	573
<i>A. Rohatgi, D. Herling, and E. Nyberg</i>	
High Strength ZK60 Mg Plate Produced by Grain Refinement and Precipitation during Alternate Biaxial Reverse Corrugation (ABRC) Process and Friction Stir Process (FSP)	579
<i>B. Mansoor, S. Mukherjee, and A. Ghosh</i>	
Formability of Mg Alloys at Room Temperature	587
<i>D. Kim, D. Kang, S. Kim, G. Bae, K. Kim, and N. Kim</i>	
Dynamic Blankholder Control for the Enhanced Forming Limit of Magnesium Sheets	589
<i>W. Bang</i>	
Accumulative Roll Bonding of Wrought Magnesium Alloy	593
<i>H. Nayaka, B. Daniel, and G. Chaudhari</i>	

ICME II and Biomedical Applications

Two- and Three-Dimensional Cellular Automaton Models for Simulating Dendrite Morphology Evolution of Cast Magnesium Alloys.....	601
<i>L. Huo, Z. Han, and B. Liu</i>	
Elemental Partitioning and Microstructure of Mg-Al-Ca-Sn Quaternary Alloys.....	607
<i>J. TerBush, O. Chen, J. Jones, and T. Pollock</i>	
Numerical Simulation of Flow-Induced Air Entrapment Defects in the High Pressure Die Casting Process	613
<i>S. Li, S. Xiong, B. Liu, M. Li, and J. Allison</i>	

ESPEI: Extensible, Self-optimizing Phase Equilibrium Infrastructure for Magnesium Alloys.....	617
<i>S. Shang, Y. Wang, and Z. Liu</i>	
Modeling Casting and Heat Treatment Effects on Microstructure in Super Vacuum Die Casting (SVDC) AZ91 Magnesium Alloy.....	623
<i>M. Li, R. Zhang, and J. Allison</i>	
Experimental and Computational Simulation of the Post-Warm Forming Constitutive Behavior of AZ31	629
<i>F. Polesak, B. Raeisinia, and S. Agnew</i>	
Assessing and Modeling the Impact of Initial Microstructure on Dynamic Recrystallization of Sheets.....	635
<i>F. John Polesak III, Babak Raeisinia, and Sean R. Agnew</i>	
Modified AZ80 Magnesium Alloys for Biomedical Applications.....	641
<i>M. Erinc, X. Zhang, and W.H. Sillekens</i>	
The Dissolution Behavior of a Mg-Zn-Ca Alloy for Biomedical Applications	647
<i>M. Manuel, and H. Brar</i>	
Author Index	651
Subject Index	655