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Mg Magnesium Technology 2013

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

Held during the
TMS 2013 Annual Meeting & Exhibition
San Antonio, Texas, USA
March 3-7, 2013

Edited by
Norbert Hort
Suveen N. Mathaudhu
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TMS

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Published simultaneously in Canada.**

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Library of Congress Cataloging-in-Publication Data is available.

ISBN 978-1-11860-552-3

Printed in the United States of America.

10987654321



A John Wiley & Sons, Inc., Publication



TABLE OF CONTENTS

Magnesium Technology 2013

Preface	xi
About the Editor	xiii
About the Organizers	xiv
Session Chairs	xvii

Magnesium Technology 2013

Plenary

A Brief History of the Development of Grain Refinement Technology for Cast Magnesium Alloys.....	3
<i>D. StJohn, P. Cao, M. Qian, and M. Easton</i>	

Creep

Compressive Creep Properties of Wrought High Temperature Magnesium Alloys in Axial and Transverse Orientation - A Neutron Diffraction Study	11
<i>D. Sediako, L. Bichler, M. van Hanegem, and S. Shook</i>	
Creep Behaviour of Mg Binary Solid Solutions	17
<i>S. Abaspour, and C. Cáceres</i>	
Influence of Yttrium on Creep Behavior in Nano-Crystalline Magnesium Using Molecular Dynamics Simulation.....	21
<i>M. Bhatia, and K. Solanki</i>	
Aging Behavior and Microstructural Evolution in Mg-3Nd-0.2Zn-0.5Zr Alloy	27
<i>A. Zadeh, X. Xia, A. Luo, J. Jakes, and D. Stone</i>	

Cast Materials

FE Modelling of Tensile and Impact Behaviours of Squeeze Cast Magnesium Alloy AM60	35
<i>S. DiCecco, W. Altenhof, and H. Hu</i>	
High Temperature Deformation of Magnesium Alloy TX32-0.4Al-0.8Si	41
<i>C. Dharmendra, K. Rao, N. Hort, and K. Kainer</i>	

Primary Production and Shaping

Doing Projects in a Foreign Language - Communications Management, Issues and Strategies	49
<i>D. Xian</i>	
Impact of Site Elevation on Mg Smelter Design	55
<i>P. Baker</i>	
Purification of Highly Contaminated Magnesium Melt	59
<i>B. Moon, B. You, and K. Koh</i>	

Selective Laser Melting of Magnesium and Magnesium Alloys	65
<i>M. Gieseke, C. Noelke, S. Kaierle, V. Wesling, and H. Haferkamp</i>	
Evolution of the Magnetherm Magnesium Reduction Process	69
<i>J. Sever, and M. Ballain</i>	
Research on New Type Materials Preparation for Magnesium Production by Silicothermic Process	75
<i>M. Wen, T. Zhang, Z. Dou, X. Ren, R. Zhang, and L. Zhou</i>	

Texture and Twinning

Effect of Grain Size and Basal Texture on Tensile Properties and Fracture Characteristics of Extruded AZ31 Alloy	83
<i>H. Chen, T. Lui, and L. Chen</i>	
Interaction between a Mg ₁₇ Al ₁₂ Precipitate and {1012} <1012> Twin Boundary in Magnesium Alloys	89
<i>B. Li, and S. Mathaudhu</i>	
Microstructure and Texture Evolution in a Magnesium Alloy during Extrusion at Various Extrusion Speeds	95
<i>Q. Ma, S. Horstemeyer, B. Li, Z. McClelland, P. Wang, and M. Horstemeyer</i>	
The Texture and Microstructure Evolution of Mg-Zn-Ce Alloys	101
<i>M. Sanjari, A. Farzadfar, T. Sakai, H. Utsunomiya, E. Essadiqi, I. Jung, and S. Yue</i>	
Twin Boundary Migration Creating Zero Shear Strain: In-Situ TEM Observations and Atomistic Simulations	107
<i>B. Liu, B. Li, and Z. Shan</i>	
Microstructure Characterization of Weakly Textured and Fine Grained AZ61 Sheet	113
<i>T. Berman, W. Donlon, C. Hung, P. Milligan, R. Decker, T. Pollock, and J. Jones</i>	

Wrought Materials I

Flow Behavior and Hot Workability of Pre-Extruded AZ80 Magnesium Alloy	121
<i>L. Gao, A. Luo, S. Wang, and X. Zeng</i>	
Inverse Strain Rate Sensitivity of Bendability of an AZ31 Sheet in Three-Point Bending	127
<i>B. Li, S. Horstemeyer, A. Oppedal, P. Wang, and M. Horstemeyer</i>	
Annealing of Cold and Warm Rolled AZ31B Magnesium Alloy Sheets	133
<i>L. Catorceno, and D. Lopes</i>	
Gas-Pressure Bulge Forming of Mg AZ31 Sheet at 450°C	139
<i>A. Carpenter, J. Carter, L. Hector Jr., and E. Taleff</i>	

Corrosion I

Efficiency of a New Hexavalent Chromium-Free Chemical Pickling Process Based on Organic and Inorganic Acids on Magnesium Alloys Mg-Y-RE-Zr and Mg-Zn-RE-Zr	147
<i>H. Ardelean, A. Seyeux, S. Zanna, P. Marcus, S. Pettier, N. Le Pottier, and D. Lecuru</i>	
Galvanic Corrosion of Mg-Zr Alloy and Steel or Graphite in Mineral Binders	153
<i>D. Lambertin, A. Rooses, and F. Frizon</i>	
The Influence of Mg-Zr Master Alloy Microstructure on the Corrosion of Mg	157
<i>D. Gandel, M. Easton, M. Gibson, T. Abbott, and N. Birbilis</i>	

The Use of AC-DC-AC Methods in Assessing Corrosion Resistance Performance of Coating Systems for Magnesium Alloys.....	163
<i>R. McCune, V. Upadhyay, Y. Wang, and D. Battocchi</i>	

Corrosion Behavior of Cerium-Based Conversion Coatings on Magnesium Alloys Exposed to Ambient Conditions.....	169
<i>C. Castano, S. Maddela, and M. O'Keefe</i>	

Nanostructured Materials

Thermal Stability of Ultra-Fine Grained Magnesium Alloy Processed by Extrusion and ECAP.....	175
<i>J. Vrátná, and M. Janeček</i>	

Corrosion II

Formation of Vanadate Conversion Coating on AZ31 Magnesium Alloy	183
<i>S. Salman, K. Kuroda, and M. Okido</i>	

Joining and Friction Processing

Microstructure Modification and Performance Improvement of Mg-RE Alloys by Friction Stir Processing.....	191
<i>Y. Wu, L. Peng, F. Zheng, X. Li, D. Li, and W. Ding</i>	

A Multi-Stage Approach for Predicting Fatigue Damage in Friction Stir Spot Welded Joints of Mg AZ31 Alloy ..	197
<i>H. Rao, and J. Jordan</i>	

Wrought Materials II

Recrystallization Behavior of a MgAlCa Alloy during Thermomechanical Processing and Subsequent Heat Treatment.....	205
<i>V. Miller, and T. Pollock</i>	

The Influence of Deformation Mechanisms on Rupture of AZ31B Magnesium Alloy Sheet at Elevated Temperatures	211
<i>A. Antoniswamy, A. Carpenter, J. Carter, L. Hector, and E. Taleff</i>	

Effect of the Extrusion Conditions on the Microstructure and Mechanical Properties of Indirect Extruded Mg-Zn-Y Alloy with LPSO Phase	217
<i>J. Kim, and Y. Kawamura</i>	

Investigation of Mechanical Properties and Deformation Behavior of CaO Added Mg-6Zn-1.2Y Sheets.....	221
<i>H. Lim, Y. Yoon, and S. Kim</i>	

Phase Formation

Bounds to Hardening by Solid Solution, Precipitation and Short Range Order in Mg Binary Alloys	227
<i>C. Cáceres, and S. Abaspour</i>	

A New Magnesium Alloy System: TEXAS	231
<i>B. Wiese, C. Mendis, C. Blawert, E. Nyberg, K. Kainer, and N. Hort</i>	

Effect of Sn Additions on the Age Hardening Response, Microstructures and Corrosion Resistance of Mg-0.8Ca (wt%) Alloys	237
<i>C. Mendis, D. Tolnai, C. Blawert, and N. Hort</i>	
Thermodynamics of Phase Formation in Mg-La-Ce-Nd Alloys.....	243
<i>R. Schmid-Fetzer, J. Gröbner, A. Kozlov, M. Hampl, M. Easton, S. Zhu, M. Gibson, and J. Nie</i>	
Phase Stability Investigation of the Mg-Zn-Sm System.....	249
<i>X. Xia, A. Zadeh, C. Zhang, X. Zeng, D. Stone, and A. Luo</i>	
In Situ Synchrotron Diffraction of the Solidification of Mg-RE Alloys	253
<i>D. Tolnai, C. Mendis, A. Stark, G. Szakács, B. Wiese, K. Kainer, and N. Hort</i>	
Nucleation Kinetics of the γ -Phase in a Binary Mg-Al Alloy	259
<i>M. Lalpoor, J. Dzwonczyk, N. Hort, and S. Offerman</i>	

Solidification

Computational Multi-Scale Modeling of the Microstructure and Segregation of Cast Mg Alloys at Low Superheat	265
<i>L. Nastac, and N. El-Kaddah</i>	
Effect of Casting Defects Distribution on the Beginning of Tensile Fracture in Semi-Solid Injected Magnesium AZ91D Alloy	271
<i>Y. Murakami, K. Miwa, N. Kanetake, and S. Tada</i>	
Effect of Inoculation Method of Refiner on the Grain Refinement of AZ91 Alloy	275
<i>J. Bae, Y. Kim, C. Yim, H. Kim, and B. You</i>	

Nanocomposites and Metal Matrix Composites

Nanoparticle Addition to Enhance the Mechanical Response of Magnesium Alloys Including Nanoscale Deformation Mechanisms.....	283
<i>M. Paramsothy, and M. Gupta</i>	
Properties of Extruded Disintegrable Metal Composites.....	289
<i>B. Salinas, Z. Xu, and J. Welch</i>	
Effect of Fiber Volume Fractions on Corrosion Resistance of Mg AM60 Alloy-based Composites in NaCl Solutions.....	293
<i>X. Zhang, X. Niu, and H. Hu</i>	
Synthesis of Disintegrable Metal Composite for Oilfield Applications	299
<i>Z. Zhang, B. Salinas, C. Newman, and Z. Xu</i>	

Wrought Materials III

Effect of Precipitation on Dynamically Recrystallized Grain Size in a Magnesium Alloy	307
<i>A. Kabir, J. Su, I. Jung, and S. Yue</i>	
Texture Development in an Extruded Magnesium Alloy during Compression along the Transverse Direction.....	313
<i>D. Sarker, and D. Chen</i>	
Evolution of Microstructure during Caliber Rolling of AZ31 Alloy	317
<i>A. Singh, H. Somekawa, T. Inoue, and T. Mukai</i>	

Increasing Volume Fraction of Precipitates and Strength of a Mg-Zn-Y Alloy by Pre-Aging Deformation	323
<i>J. Rosalie, H. Somekawa, A. Singh, and T. Mukai</i>	
Mapping the Mechanical Properties of Alloyed Magnesium (AZ 61).....	329
<i>J. Hay, and P. Agee</i>	

Microstructure

Effects of Alloying Elements and Cooling Rate on Morphology of Phases in CaO Added Mg-Al-Si Alloys.....	335
<i>Y. Jung, H. Lim, Y. Yoon, S. Kim, and D. Kim</i>	
Microstructure and Mechanical Properties of Die Cast Magnesium-Aluminum-Tin Alloys	341
<i>A. Luo, P. Fu, X. Zeng, L. Peng, B. Hu, and A. Sachdev</i>	
Study on Microstructure and Mechanical Property of Squeeze Casting AZ91D Magnesium Alloy	347
<i>Y. Li, Z. Han, A. Luo, A. Sachdev, and B. Liu</i>	
Tailoring Precipitates in Mg-6Zn-2Gd Based Alloy Subjected to High Pressure Torsion.....	351
<i>J. Li, and P. Schumacher</i>	
Microstructure and Phase Evolution in Mg-Gd and Mg-Gd-Nd Alloys with Additions of Zn, Y and Zr	357
<i>S. Khawaled, M. Bamberger, and A. Katsman</i>	

Twin Roll Casting

Influence of Temperature and Rolling Speed on Twin Roll Cast Strip	365
<i>G. Kurz, J. Bohlen, L. Stutz, D. Letzig, and K. Kainer</i>	
Mathematical Modeling of the Effect of Roll Diameter on the Thermo-Mechanical Behavior of Twin Roll Cast AZ31 Magnesium Alloy Strips.....	371
<i>A. Hadadzadeh, and M. Wells</i>	
Author Index.....	377
Subject Index	379

PREFACE

Magnesium was produced first in 1808, more than 200 years ago, by Sir Humphry Davy. It took a few decades to develop and establish stable production processes, and in the middle of the 19th century magnesium was available in larger quantities and ready to be used. In fact it met a new technology at these times: photography. Magnesium was utilized in flashlights and this endured until the end of the 20th century. Of course, flashlights are not a structural application. But with time, in the first years of the 20th century again a step in the technical development took place: the Wright brothers started to fly. It was found out early that wooden airplanes would not do their job at all. Light metal alloys had to be used, and magnesium alloys were part of aeronautics from the beginning. In fact an engine for aircrafts made out of a magnesium alloy was shown 1909 in Frankfurt, Germany, at the first "Internationale Luftschiffahrt Ausstellung," the first international aerospace exhibition. While magnesium was important for aerospace 100 years ago, today it is still looking for acceptance in aerospace industries.

In difference to the slight acceptance in aerospace, magnesium alloys are fairly well accepted in automotive industries as well as for consumer, computer, and communication applications. Due to its excellent specific properties magnesium alloys can compete especially in transportation with aluminium and even with steel leading to tremendous weight savings. This directly leads either to an increase in payload or a fuel reduction (saves money for the end user), or reduces green house gas emissions. Today automotive industries are showing lots of examples for the use of magnesium alloys in various applications, but an average standard car only contains a few kilograms of magnesium alloys. To enhance the use of magnesium even in this field it is still necessary to develop alloys and to optimize processes.

The development of processes for primary production, alloy development and the processing routes started in the early 20th century and continued over the years. Several authors compiled the state of the art. Among them are J. L. Haughton and W. E. Prytherch (1938), A. Beck (1939, reprinted 2001), L. M. Pidgeon, et al. (1946), W. H. Gross (1949), G. V. Raynor (1959), C. S. Roberts (1960), E. F. Emley (1966), R. S. Busk (1986), and in recent years M. A. Avedesian and H. Baker (1999), C. Kammer (2000), K. U. Kainer (2003), and H. E. Friedrich and B. L. Mordike (2004). In all of these books the state of the art is shown and the progress in magnesium alloy and technology development is described. But these books only present a view into the past.

The first Magnesium Technology symposium at the TMS meetings took place at the TMS Annual Meeting in Nashville, Tennessee, 2000. Since this time the symposium is showing the lively research of the active magnesium community in the world and it presents also a look into the future. This year is the 14th edition of this meeting, and it will be held in San Antonio, Texas, from March 3-7, 2013. The symposium is arranged into an opening plenary session and a number of technical sessions which address the full scope of Magnesium research and development. These sessions include primary production, casting and solidification, deformation mechanisms and texture, alloy and microstructural design, corrosion, high temperature behaviour, processing-microstructure-property relationships, and advanced processing and joining

Last, the organizing of these proceedings would not have been possible without the dedication and assistance of TMS staff. In particular, we would like to recognize Ms. Patricia Warren for her tireless patience and hard work.

Over the past 13 years, the Magnesium Technology proceedings, through its high quality technical content, has become the primary proceedings for the magnesium industry and technical community. We hope that this year's volume will serve you just as well.

Norbert Hort (Helmholtz-Zentrum Geesthacht, Germany)
Suveen N. Mathaudhu (U.S. Army Research Office, USA)
Neale R. Neelameggham (IND LLC, USA)
Martyn Alderman (Magnesium Elektron, UK)

ABOUT THE LEAD EDITOR



Norbert Hort
MAGNESIUM TECHNOLOGY 2013 LEAD EDITOR

Norbert Hort is the head of the Magnesium Processing Department at the Magnesium Innovation Centre (MagIC) within the Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung, Geesthacht, Germany (formerly the GKSS Research Centre). Concurrently he is lecturer at the Leuphana University, Lüneburg, Germany. He studied Materials Sciences at the Clausthal University of Technology (CUT), Germany, where he has been involved in magnesium research since the early 1990s. His diploma thesis (1994) dealt with gas-atomized, hot-extruded magnesium alloys. During 1994-95 he worked as a researcher at the Institute of Materials Sciences (CUT) and he joined the HZG in 2000. He got his Ph.D. degree in Materials Sciences in 2002 from the Clausthal University of Technology. In the MagIC he is responsible for the development of new creep resistant magnesium alloys, grain refinement and the castability of magnesium alloys (viscosity and density of melts, fluidity, and mould filling). A major focus of his research is the development of new magnesium alloys for biodegradable implants in a close collaboration with biologists and clinicians. He is co-author of more than 150 peer reviewed journal papers and contributions to conference proceedings. In recent years he was involved in the organizing committees of the conference series “Magnesium Alloys and their Applications” and of the conference “Light Metal Technologies 2011.” - Since 2009 he also has been the chairman of the technical committee “Magnesium” of the German Society of Materials (DGM).

ABOUT THE EDITORS



Suveen Nigel Mathaudhu serves as the Program Manager for Synthesis and Processing of Materials with the U.S. Army Research Office (ARO), Materials Science Division. He received his B.S.E. in Mechanical Engineering from Walla Walla University in 1998, and Ph.D. in Mechanical Engineering from Texas A&M University in 2006. In his current position, he manages programs which focus on the use of innovative approaches for processing high performance structural materials reliably and at lower costs. He also concurrently serves as an Adjunct Assistant Professor in the Department of Materials Science and Engineering at North Carolina State University, where his research interests include ultrafine-grained and nanostructured materials by severe plastic deformation, consolidation of metastable particulate materials and processing-microstructure-property relationships of refractory metals and lightweight metals, and thermally stable nanocrystalline materials. He has co-authored over 60 technical publications in these areas.



Neale R. Neelameggham is 'Guru' at IND LLC, involved in technology marketing and consulting in the field of light metals and associated chemicals, [boron, magnesium, titanium, lithium and alkali metals], rare earth elements, battery and energy technologies, etc. He has over 38 years of expertise in magnesium production technology from the Great Salt Lake brine in Utah. He was involved in Process Development of its startup company, NL Magnesium, through the presently known US Magnesium LLC, and was its Technical Development Scientist from where he retired. Dr. Neelameggham's expertise includes all aspects of the magnesium process, from solar ponds through the cast house including solvent extraction, spray drying, molten salt chlorination, electrolytic cell and furnace designs, lithium ion battery chemicals and by-product chemical processing. In addition, he has an in-depth and detailed knowledge of alloy development as well as all competing technologies of magnesium production, both electrolytic and thermal processes worldwide. Dr. Neelameggham holds 13 patents and a pending patent on boron production, and has several technical papers to his credit.

As a member of TMS, AIChE, and a former member of American Ceramics Society, he is well-versed in energy engineering, bio-fuels, rare-earth minerals and metal processing, and related processes. Dr. Neelameggham has served in the Magnesium Committee of LMD since its inception in 2000, chaired it in 2005, and has been a co-organizer of the Magnesium symposium since 2004. In 2007 he was made a permanent co-organizer for the Magnesium symposium. He has been a member of the Reactive Metals Committee and Recycling Committee, and a Programming Committee representative of LMD. In 2008, LMD and EPD created the Energy Committee following the symposium on CO₂ Reduction Metallurgy symposium initiated by him. Dr. Neelameggham

was selected as the inaugural Chair for the Energy Committee with a two-year term. He received the LMD Distinguished Service Award in 2010 and has been a co-editor of the Energy Technology symposium proceedings volume. Dr. Neclameggham holds a doctorate in extractive metallurgy from the University of Utah.



Martyn Alderman is Divisional Director of Technology for the Magnesium Elektron Group Worldwide. He obtained a Masters Degree in Material Science from the University of Cambridge (United Kingdom) in 1979 and for the next 20 years he worked in aluminium rolling mills producing and developing Al-Cu-Zr, Al-Mn, Al Mg-Mn, Al-Zn-Mg, and Al-Li-Cu alloys for Superplastic forming. He also has significant operational experience direct chill casting and in the extrusion of high strength aluminium alloys.

In 2003 he joined Magnesium Elektron during the acquisition of their large Madison, Illinois rolling operation in the United States. For the next few years he was travelling between the United States and Europe encouraging the wider use of magnesium sheet in transport applications, in particular by use of superplastic forming, and later in managing the post acquisition integration of the Revere North American Graphic Arts business. He chaired the 2010 International Magnesium Association Conference in Hong Kong, and for the past two years had been involved in editing and producing a 270 page *Handbook on Designing with Magnesium Alloys*.

As a member of TMS, SAE, and AMS, he is a regular attendee at worldwide magnesium conferences keeping abreast of global technology development with the aim of maintaining the Magnesium Elektron's position as a world leader in magnesium alloys and their end use applications.

MAGNESIUM TECHNOLOGY 2013

Session Chairs

Plenary	Norbert Hort Helmholtz-Zentrum Geesthacht
Primary Production and Casting	Neale Neelameggham Ind LLC Adam Powell Metal Oxygen Separation Technologies
Mechanical Properties	Alan Luo General Motors Global Research & Development Menahem Bamberger Technion
Corrosion	Liming Peng Shanghai Jiaotong University Carlos Caceres The University of Queensland
Texture and Wrought Materials	Martyn Alderman Magnesium Elektron Alok Singh National Institute for Materials Science
Wrought Materials II	Julian Rosalie National Institute for Materials Science Jennifer Hay Agilent Technologies
Grain Refinement, Twinning, and Composites	Karl Kainer Helmholtz-Zentrum Geesthacht Suveen Mathaudhu U.S. Army Research Office
Phase Formation	Alok Singh National Institute for Materials Science Alan Luo General Motors Global Research & Development
Poster Session	Eric Nyberg Pacific Northwest National Laboratory