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2012**

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Mg Magnesium Technology 2012

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The Minerals, Metals & Materials Society (TMS)

Held during
TMS 2012 Annual Meeting & Exhibition
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Edited by

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PREFACE

“The market for magnesium may be expected to develop along lines similar to those along which aluminum developed, but whether to anything like the same extent is entirely problematic. The market is somewhat unacquainted with many of the special qualities of the metal, and increased sales are largely a matter of education and research whereby a demand will be created and developed hand in hand with production. [...] The importance of a metal with properties similar to that of aluminum, but nearly half as light in these days of enormous automobile and aircraft expansion hardly needs much argument.”

- 1919 United States Bureau of Mines Bulletin

In 1920, the television was not invented yet, and radio was king, with Louis Armstrong and Duke Ellington playing their legendary jazz in living rooms everywhere. The prohibition of alcohol began in the U.S.A. ushering in an era of organized crime (most famously, Al Capone) and of homemade whisky. The average daily wage for a male was US\$5.00 per day; the average car cost US\$265.00; a gallon of milk was US\$.56, and a gallon of gas was US\$.22. It was clearly a different time, but as this quote illustrates, some things are jarringly as valid today as they were 90 years ago. While the length of time since the bulletin may indicate the resilience of the Mg community, it also points to the fact that our mission is far from done; we must continue to support education and research for Mg and its alloys to reach their full potential.

It is this mission that supports the continued propagation of the Magnesium Technology Symposium, which is held yearly under the auspices of the TMS Light Metals Division's Magnesium Committee at the TMS Annual Meeting and Exhibition. This year is the 13th edition of this meeting, and will be held in Orlando, FL (USA) from March 11-15, 2012. The symposium is arranged into an opening plenary session, a poster session, and a number of technical sessions which address the full scope of Mg research and development. These sessions include, deformation mechanisms, primary production, casting and solidification, alloy and microstructural design, corrosion and coating, high temperature processing and properties, processing-microstructure-property relationships, advanced processing and joining, and new applications in biomedical and energy.

This proceedings volume represents the proceedings of these symposia. They represent contributions from 19 countries spanning the globe. The largest contribution for the 2012 proceedings comes from the United States (30%), followed by Canada (19%), China (14%) and Japan (11%). All submissions were thoroughly peer-reviewed by volunteer referees acting on the behalf of the Magnesium Committee. These reviewers are critical to the success of this volume, and are commended in the following pages. Some of the symposium contributions related to Mg surface science will be published in an upcoming JOM special issue sponsored by the Magnesium Committee, titled “Magnesium: Engineering the Surface” in June 2012, and to be edited by Michele Manuel (University of Florida, USA), and Chamini Mendis (Helmholtz-Zentrum Geesthacht, Germany).

Additionally, a one-day, invited speaker mini-symposium will be held on the specific topic of “Phase Transformation and Deformation in Magnesium Alloys”, and is organized by Jianfeng Nie (Monash University, Australia), Sean Agnew (University of Virginia, USA) and Suveen Mathaudhu (U.S. Army Research Office, USA). These sessions are co-sponsored by the TMS/ASM Phase Transformation Committee, and aim to examine the current understanding on phase transformations and roles of phase transformation products in controlling the deformation behavior of commercially and strategically important magnesium alloys, and to provide a platform for rational design of microstructures for better mechanical properties and formability. The submissions to this mini-symposium will be published in a forthcoming Special Issue of *Metallurgical and Materials Transactions A*.

Lastly, 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. Chris Wood for her tireless patience and hard work.

Over the past 12 years, the Magnesium Technology Proceedings, through its high quality technical content, has become the primary proceedings for the magnesium industry and technical community. We would hope that this year’s volume will serve you just as well.

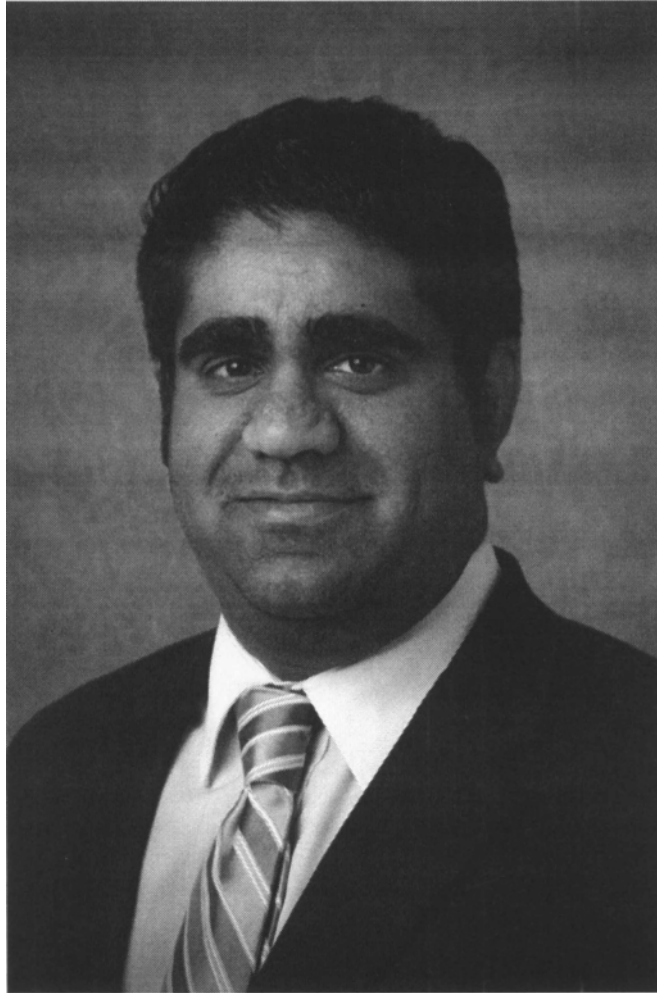
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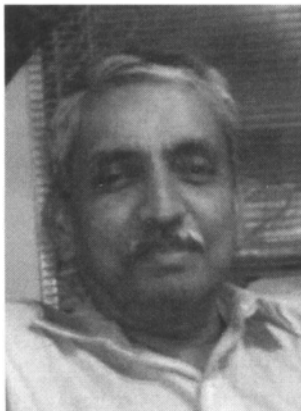
SUVEEN NIGEL MATHAUDHU
MAGNESIUM TECHNOLOGY 2012 EDITOR

Suveen Nigel Mathaudhu (1975) 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 50 technical publications in these areas.

ABOUT THE ORGANIZERS



Wim H. Sillekens (1963) is a Senior Scientist at the Netherlands Organization for Applied Scientific Research (TNO), where he is involved in national and European research projects. He obtained his Ph.D. from Eindhoven University of Technology, Netherlands, on a subject relating to metal-forming technology. Since he has been engaged in light-metals research (aluminum and magnesium), amongst others on (hydro-mechanical) forming, (hydrostatic) extrusion, forging, recycling/refining, and more recently on biomedical applications. His professional career includes positions as post-doc researcher at his alma mater and as a research scientist / project leader at TNO. International working experience covers a placement as a research fellow at the Mechanical Engineering Laboratory (AIST-MITI) in Tsukuba, Japan, and – more recently – shorter stays as a visiting scientist at GKSS in Geesthacht, Germany, and at PNNL in Richland WA, USA. He has co-authored a variety of journal and conference papers (about 50 entries to date). Current research interests are in the physical and mechanical metallurgy of light metals in general and magnesium wrought alloys in particular.



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, 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, Recycling Committee and 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 was a member of LMD council. He received the LMD Distinguished Service Award in 2010. He has been a co-editor of the Energy Technology symposium. Dr. Neelameggham holds a doctorate in extractive metallurgy from the University of Utah.



Norbert Hort (1964) 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 already got involved in magnesium research since the early 1990ties. His diploma thesis (1994) was dealing 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 PhD 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 additionally the development of new magnesium alloys for biodegradable implants in a close collaboration with biologists and clinicians. He is co-author of more than 60/120 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 is also the chairman of the technical committee “Magnesium” of the German Society of Materials (DGM).

TMS Magnesium Technology 2012 – Session Chairs (*provisional*)

Plenary Session – Monday AM

- Suveen N. Mathaudhu (US Army Research Office, USA)
- Wim Sillekens (TNO, Netherlands)
- Norbert Hort (Helmholtz-Zentrum Geesthacht, Germany)

Primary Production – Monday PM

- Neale Neelamegham (IND LLC, USA)
- Adam Powell (Metal Oxygen Separation Technologies Inc., USA)

Deformation Mechanisms – Monday PM

- Bin Li (Mississippi State University, USA)
- Alok Singh (National Institute of Materials Science, Japan)

Casting and Solidification – Wednesday AM

- Norbert Hort (Helmholtz-Zentrum Geesthacht, Germany)
- Yongho Sohn (University of Central Florida, USA)

Alloy and Microstructural Design – Wednesday AM

- Jian-Feng Nie (Monash University, Australia)
- Nack Kim (POSTECH, South Korea)

Corrosion and Coating – Wednesday PM

- Guang-Ling Song (General Motors, USA)
- Michele Manuel (University of Florida, USA)

High Temperature Processing and Properties – Wednesday PM

- Paul E. Krajewski (General Motors, USA)
- Warren Poole (University of British Columbia, Canada)

Processing-Microstructure-Properties I – Thursday AM

- Hidetoshi Somekawa (National Institute of Materials Science, Japan)
- Kyu Cho (U.S. Army Research Laboratory, USA)

Advanced Processing and Joining – Thursday AM

- Tyrone Jones (U.S. Army Research Laboratory, USA)
- Brian Jordan (University of Alabama, USA)

Processing-Microstructure-Properties II – Thursday PM

- Alan Luo (General Motors, USA)
- Fabrizio D'Errico (Politecnico di Milano, Italy)

Energy and Biomedical / Primary Production – Thursday PM

- Wim Sillekens (TNO, Netherlands)
- Neale Neelameggham (IND LLC, USA)

Poster Session

- Eric A. Nyberg (Pacific Northwest National Laboratory, USA)

TMS Magnesium Technology 2012 – Reviewer Pool

The completion of this volume would not have been possible without the volunteer assistance of these fine individuals from 11 different countries. Their commitment to the advancement of Mg research and science is to be commended. They are presented here in last-name alphabetical order:

John Allison
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Deakin University (Australia)

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Geesthacht (Germany)*

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*University of Queensland
(Australia)*

Gokhan Demirci
Aselsan Inc. (Turkey)

Fabrizio D'Errico
*Polytechnico di Milano
(Italy)*

Kevin Doherty
*U.S. Army Research
Laboratory (USA)*

David Foley
Texas A&M University (USA)

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Vipin Jain
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