

The Minerals, Metals & Materials Series

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Jerome P. Downey · Baojun Zhao ·
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Editors

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Symposium
on High-Temperature
Metallurgical Processing

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Preface

This book presents selected papers submitted for the 10th International Symposium on High-Temperature Metallurgical Processing organized in conjunction with the TMS 2019 Annual Meeting and Exhibition in San Antonio, Texas, USA. More than 120 abstracts were received. Among them, 90 were selected for oral presentation and 34 were provided with a poster presentation opportunity. After reviewing the submitted manuscripts, 75 were accepted for publication in this book.

As the title of symposium suggests, the interest of the symposium is on thermal processing of minerals, metals and materials that intends to promote physical and chemical transformations of materials to enable the extraction and production of valuable materials such as metals, alloys, ceramics and compounds. The symposium was open to participants from both industry and academia and focused on innovative high-temperature technologies including those based on non-traditional heating methods as well as their environmental aspects such as handling and treatment of emission gases and by-products. Because high-temperature processes require high energy input to sustain the temperature at which the processes take place, the symposium addressed the needs for sustainable technologies with reduced energy consumption and reduced emission of pollutants. The symposium also welcomed contributions on thermodynamics and kinetics of chemical reactions, phase transformations that take place at elevated temperatures, as well as simulation of high-temperature metallurgical processes. We hope the book will serve as a reference for both new and experienced metallurgists, particularly those who are actively engaged in exploring innovative technologies and routes that lead to more energy-efficient and environmentally sustainable solutions.

We would like to acknowledge the contributions from the authors of included papers, time and effort that reviewers dedicated to the manuscripts and help from the publisher. We also want to thank Dr. Elsa Olivetti and Dr. Camille Fleuriault for their help in identifying and screening manuscripts, and Dr. Mingjun Rao for his assistance in collating the submitted abstracts and manuscripts.

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About the Editors



Tao Jiang received his M.S. in 1986 and Ph.D. in 1990, both from Central South University of Technology. Then he joined the university and served as an assistant professor (1990–1992) and full professor (1992–2000). From 2000 to 2003, he was a Visiting Scientist in the Department of Metallurgical Engineering at the University of Utah. Since 2003, Dr. Jiang has been a Professor in the School of Minerals Processing and Bioengineering at Central South University. He was elected as Specially Appointed Professor of Chang Jiang Scholar Program of China in 2008 and has been the dean of the school since 2010.

His research interests include sintering, pelletizing and non-coke ironmaking of iron ores, and extraction of refractory gold ores. He has completed more than 50 projects from government and industry, including the National Science Fund for Distinguished Young Scholars Program. He and co-workers invented the direct reduction process of composite binder pellets, and three plants were set up in China based on the invention. He proposed the innovative composite agglomeration process of iron ore fines, which was put into production in Baotou Steel Company, China. He has been actively involved in the areas of utilization of non-traditional ferrous resources such as complex ores and various solid wastes. Dr. Jiang has published 320 technical papers, and 6 books including *Direct Reduction of Composite Binder Pellets and Use of DRI*, *Principle & Technology of Agglomeration of Iron Ores*, *Chemistry of Extractive Metallurgy of Gold*, and

Electrochemistry and Technology of Catalytical Leaching of Gold. He holds 42 patents and has more than 40 conference presentations.

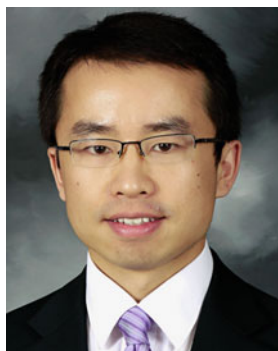


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Dean Gregurek has been a Senior Mineralogist in the RHI Magnesita Technology Center, Leoben, Austria, since 2001. Dr. Gregurek received his M.Sc. degree at the University of Graz in 1995 and his doctorate degree in Applied Mineralogy from the University of Leoben in 1999. Prior to RHI Magnesita, he worked two years for Luzenac Europe in the talc business. His current research interests and technical expertise are focused on chemical and mineralogical studies related to interactions between refractories, and molten metals and slags from pyrometallurgical furnaces. Dr. Gregurek has been a TMS member since 2012, was *JOM* advisor (2014–2017) and has been Chair of the Pyrometallurgy Committee and a co-organizer for the 7–10th International Symposium on High-Temperature Metallurgical Processing (TMS Annual Meetings 2016–2019).



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Dr. Peng has published 113 papers, including 80 peer-reviewed articles in multiple journals. He has served as an editor for *Cogent Chemistry* since 2018, a guest editor for *JOM* from 2013 to 2018, a member of editorial board of the *Journal of Minerals and Materials Characterization and Engineering* since 2012, and a reviewer for 41 journals. He received a TMS Travel Grant Award for the 141st TMS Annual Meeting and Exhibition, the Doctoral Finishing Fellowship and Dean's Award for Outstanding Scholarship of Michigan Technological University in 2012, and the Bhakta Rath Research Award of Michigan Technological University in 2013.

Dr. Peng is an active member of The Minerals, Metals and Materials Society (TMS). He has co-organized 8 TMS symposia (Characterization of

Minerals, Metals and Materials in 2013–2018, and the 9 and 10th International Symposia on High-Temperature Metallurgical Processing in 2018 and 2019) and co-chaired 16 TMS symposia sessions since 2012. He is a member of the Pyrometallurgy Committee and Materials Characterization Committee and is the Chair of the Continuing Education Sub-Committee of the Materials Characterization Committee. He was a winner of the TMS EPD Young Leaders Professional Development Award in 2014.



Jerome P. Downey earned his Ph.D. in Metallurgical and Materials Engineering at Colorado School of Mines and his B.S. and M.S. degrees in Metallurgical Engineering at Montana Tech. Dr. Downey is a registered professional engineer with active licences in Colorado and Montana. He has over 40 years of professional experience that includes industrial operations, applied process research and development, and corporate management. His technical expertise includes chemical and metallurgical thermodynamics, thermal processing, materials synthesis and processing, and hazardous materials treatment.

Dr. Downey is presently the Goldcorp Professor of Extractive Metallurgy at Montana Tech. He also serves as the Campus Director of the Montana University System Materials Science Ph.D. programme. Dr. Downey's research efforts are currently focused on the study of fundamental properties of slags, molten salts, and glasses; vapour phase extraction and refining of rare earth elements; and synthesis of non-oxide ceramic compounds for energy applications. Other research interests include pyro- and hydrometallurgical process development, polymer and biomass gasification, and wastewater treatment.



Baojun Zhao is Codelco-Fangyuan Professor in the School of Chemical Engineering at The University of Queensland, Brisbane, Australia. His primary fields of research are fundamental and applied investigations relevant to high-temperature processing of metals and materials. He has developed a number of novel research techniques to enable high-quality research to be carried out. He has received a number of international awards to demonstrate his leading research achievements. He has long-term collaborations with many international companies on metallurgy, materials and resources.



Onuralp Yücel completed his technical education with a Ph.D. in Metallurgical Engineering from Istanbul Technical University (ITU) where he currently holds the post of Professor since 2002. He was a Visiting Scientist at Berlin Technical University between 1987 and 1988. He carried out postdoctoral studies at New Mexico Institute of Mining and Technology, Socorro, USA, between 1993 and 1994. He has as many as 330 publications/presentations to his credit, which include topics such as technological developments in the production of a wide range of metals, ferroalloys, advanced ceramic powders, and application of carbothermic and metallothermic processes among others. He was the Vice Chairman of ITU, Metallurgical and Materials Engineering Department (MMED) between 2004 and 2007, and Director of ITU, Applied Research Center of Material Science and Production Technologies between 2006 and 2012. He has been the Chairman of ITU, MMED, since 2016. He is a member of the International Advisory Board of the International Symposium on Boron, Borides and Related Materials; International Symposium on Self-Propagating High-Temperature Synthesis; and International Metallurgy and Materials Congress (IMMC).

Dr. Yücel's areas of interest include:

Pyrometallurgy: Pretreatment of concentrates (production of WO_3 , Sb_2O_3 , As_2O_3 , MoO_3), smelting and reduction of slags, production ferroalloys, alloys and metals carbothermic and metallothermic processes in EAF or in ladle (copper, cobalt, vanadium, chromium,

ferroboron, cobalt boron, nickel boron, ferromolybdenum, ferromanganese, silicomanganese, ferrovandium, ferrotungsten, ferrochromium, nickel–chromium molybdenum–iron and aluminium–titanium–boron alloys)

Ceramic Powder Production and Processing: Production of carbide, nitride, boride powders and their processing by explosive consolidation or sintering techniques. (B_4C , TiB_2 , ZrB_2 , SiC , CrB_2).

Beneficiation of Industrial Wastes: Production of metals and compounds from galvanizing ash, brass production wastes and vanadium sludges produced aluminum production. Grit production from aluminium, copper and steel slags.



Ender Keskinilic earned his undergraduate degree from the Department of Metallurgical and Materials Engineering of Middle East Technical University (METU), Ankara (the capital city of Turkey), in 1999. He continued M.S. and Ph.D. studies in the same department. He worked as a Research Assistant in METU between 1999 and 2003. After receiving the master's degree in 2001, he progressed further in the field of extractive metallurgy. During the Ph.D. period, he moved to Eregli-Zonguldak in 2003 and worked in the Quality Metallurgy and RD Department of Eregli Iron and Steel Works Co. (ERDEMIR), which is the leading steel company in Turkey regarding the qualities produced and the production capacity. After earning his Ph.D. degree in 2007, he returned to university and to work in the Department of Metallurgical and Materials Engineering of Atilim University, Ankara, in 2008. He has been working as a faculty in Atilim since then. He was assistant professor between 2009 and 2014. He has been working as an associate professor since 2014. His primary field of interest is extractive metallurgy and more specifically pyrometallurgical processes such as iron- and steelmaking, ladle metallurgy, ferroalloy production and non-ferrous extractive metallurgy. He has been acting as the Chairman of the Department of Metallurgical and Materials Engineering of Atilim University since July 2018.



Rafael Padilla received his Ph.D. and M.Sc. degrees in Metallurgy from the University of Utah in 1984 and 1977, respectively, and Professional Engineering Title as Metallurgical Engineer from the Technical University of Oruro, Bolivia, in 1975. He joined the Department of Metallurgical Engineering, University of Concepcion, Chile, in 1986, where he currently holds the rank of Full Professor. His present research interest is on the vaporization of minor elements such as arsenic, antimony and bismuth from sulphide concentrates at roasting and smelting temperatures, and the removal and recovery of impurities from refractory chalcopyrite–enargite concentrates by pressure and atmospheric leaching.