



# **3rd International Symposium on High-Temperature Metallurgical Processing**

**Edited by**

**Tao Jiang, Jiann-Yang Hwang, Patrick Masset,  
Onuralp Yucel, Rafael Padilla, and Guifeng Zhou**



**WILEY**

**TMS**

# **3rd International Symposium on High-Temperature Metallurgical Processing**

Proceedings of a symposium sponsored by  
the Pyrometallurgy Committee and  
the Energy Committee of  
the Extraction and Processing Division of  
TMS (The Minerals, Metals & Materials Society)

Held during the  
TMS 2012 Annual Meeting & Exhibition  
Orlando, Florida, USA  
March 11-15, 2012

*Edited by*

**Tao Jiang**  
**Jiann-Yang Hwang**  
**Patrick Masset**  
**Onuralp Yucel**  
**Rafael Padilla**  
**Guifeng Zhou**



A John Wiley & Sons, Inc., Publication

**TMS**

**Copyright © 2012 by The Minerals, Metals, & Materials Society.  
All rights reserved.**

**Published by John Wiley & Sons, Inc., Hoboken, New Jersey.  
Published simultaneously in Canada.**

---

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of The Minerals, Metals, & Materials Society, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

---

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

---

Wiley also publishes books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit the web site at [www.wiley.com](http://www.wiley.com). For general information on other Wiley products and services or for technical support, please contact the Wiley Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

---

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

**ISBN 978-1-11829-141-2**

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1



A John Wiley & Sons, Inc., Publication

**TMS**

# TABLE OF CONTENTS

## 3rd International Symposium on High Temperature Metallurgical Processing

Preface .....	xi
Editors.....	xiii

### 3rd International Symposium on High Temperature Metallurgical Processing

#### High Efficiency New Metallurgical Technology

A Laboratory Investigation of the Reduction of the Siderite Iron Ore to Iron Nugget .....	3
<i>N. Panishev, E. Redin, and V. Pilshchikov</i>	
Composite Agglomeration Process of Iron Fines .....	7
<i>T. Jiang, Y. Hu, G. Li, Y. Guo, Z. Yu, X. Fan, Y. Zhang, and Y. Yang</i>	
Investigation of Pyrometallurgical Nickel Pig Iron (NPI) Production Process from Lateritic Nickel Ores .....	17
<i>O. Yucel, A. Turan, and H. Yildirim</i>	
Novel Process for Utilizing Low-Grade Manganese Oxide Ores by Sulfur-Based Reduction Roasting-Acid Leaching .....	25
<i>T. Jiang, Z. You, Y. Zhang, D. Duan, and G. Li</i>	
Equipment for Pilot Scale Experiments of NO <sub>x</sub> Emissions from the Silicon Process .....	33
<i>I. Solheim, R. Jensen, and N. Eivind Kamfjord</i>	
Slide Gate Systems for Copper Tapping.....	41
<i>K. Gamweger</i>	
Recovery of Huangmei Limonite by Flash Magnetic Roasting Technique .....	49
<i>W. Chen, X. Liu, Z. Peng, and Q. Wang</i>	

Studies on Alternative Blast Furnace Burden Structure with High Proportion Sinter.....	59
--	----

*J. Fan, G. Qiu, T. Jiang, Y. Guo, Y. Yang, and M. Cai*

Hydrothermal Sulfidation of Carbonate-Hosted Zinc-Lead Ore with Elemental Sulfur .....	67
--	----

*C. Li, C. Wei, J. Liao, Z. Deng, H. Xu, Y. Song, X. Li, and M. Li*

## **Reduction and Titanium Production**

Preparation of Titanium Alloy from Titania-bearing Blast Furnace Slag.....	77
--	----

*R. Huang, C. Bai, X. Lv, and S. Liu*

Basic Research of Direct Pyrolysis Performance of MgCl <sub>2</sub> in Molten State .....	85
---	----

*Z. Ting'an, L. Guozhi, D. Zhihe, L. Yan, N. Liping, Z. Qiuyue, S. Lianxu, and H. Jicheng*

Chlorination of Titania Feedstocks.....	93
---	----

*S. Moodley, R. Eric, A. Kale, and C. Kucukaragoz*

Experimental Study on the Pulverization and Reduction Behavior of Sinter in Oxygen Blast Furnace.....	105
---	-----

*Y. Han, J. Wang, R. Lan, L. Wang, X. Zuo, and Q. Xue*

Formation of Ti(C,N) in Blast Furnace Slag Bearing High TiO <sub>2</sub> .....	113
--	-----

*S. Ma, G. Qiu, Q. Deng, and H. Wang*

Research on Carbonothermal Reduction Behavior of Ilmenite .....	121
---	-----

*Y. Guo, L. Chen, T. Jiang, W. Weng, and F. Chen*

Reduction Kinetics of Low Grade Hematite Ore.....	129
---	-----

*Y. Xiao, Z. He, T. Chun, D. Zhu, and J. Pan*

Viscosity Evolution of Blast Furnace Slag Bearing Titanium .....	137
--	-----

*H. Wang, G. Qiu, Q. Deng, and S. Ma*

## **Basic Research of Metallurgical Process**

Thermal Decomposition and Regeneration of Wüstite .....	147
---	-----

*Z. Peng, J. Hwang, Z. Zhang, M. Andriese, and X. Huang*

Competitive Precipitation and Growth of Spinel Crystals in Vanadium Slag ..	157
---	-----

*X. Zhang, B. Xie, J. Diao, and X. Li*

Expert System for Grate-Kiln Pellet Production Based on Mathematical Models of Temperature Field .....	165
<i>X. Fan, Y. Wang, and X. Chen</i>	
The Influence of Sodium Oxide on the Distribution Behavior of Some Elements at the S-Furnace of the Mitsubishi Process .....	175
<i>Y. Kimura, and K. Yamaguchi</i>	
Effect of Temperature on Equilibrium Phase Relation and Liquidus of CaO-SiO <sub>2</sub> -Al <sub>2</sub> O <sub>3</sub> -FeO <sub>x</sub> System.....	183
<i>N. Wang, Z. Zou, Z. Zhang, Y. Xiao, and Y. Yang</i>	
Viscosity Determination of the Freeze Slag in Reaction Shaft of Flash Smelting Furnace .....	189
<i>J. Wang, Y. Wu, L. Liang, and C. Zhang</i>	
Effect of MgO Content on Melting Features and Viscosity of SiO <sub>2</sub> -CaO-MgO-Al <sub>2</sub> O <sub>3</sub> -FeO Slag in Nickel Laterite Metallurgy .....	197
<i>X. Lv, C. Pan, C. Bai, G. Qiu, and M. Hu</i>	
Influence of Silicon Content in Hot Metal on Mineralogical Characterization and Physico-chemical Properties of Vanadium Slag .....	203
<i>C. Zhao, B. Xie, X. Zhen, Q. Huang, and X. Zhang</i>	
Analysis of Influence Factors on the Melting Point of the Freeze Slag Inside Flash Smelting Furnace Brickless Reaction Shaft .....	211
<i>J. Wang, and C. Zhang</i>	

## **Alloy and Materials Preparation**

Improving Hot Workability of Ledeburitic Tool Steels.....	221
<i>M. Fazarinc, G. Kugler, I. Perus, and M. Tercelj</i>	
Influence of Elements Segregation on Creep Properties of a Single Crystal Nickel-Based Superalloy .....	229
<i>C. Zhang, S. Tian, X. Yu, Z. Zeng, and C. Liu</i>	
Preparation of Titanium Ferrous Alloys with Low Oxygen Content Prepared by Reduction-SHS .....	237
<i>Z. Ting-an, D. Zhihe, Z. Hanbo, Z. Zhiqi, N. Liping, and H. Jicheng</i>	
Preparing Aluminum-Scandium Alloys Using Direct Hall Reduction Process.....	243
<i>C. Guan, J. Xue, J. Zhu, and Q. Liu</i>	

Production of NbAl <sub>3</sub> Powders through Sodium Reduction of Oxides in Molten Salts .....	251
<i>C. Du, N. Wang, Y. Zhang, S. Jiao, and H. Zhu</i>	
Recrystallization of L-605 Cobalt Superalloy during Hot-Working Process....	257
<i>J. Favre, Y. Koizumi, A. Chiba, D. Fabregue, and E. Maire</i>	
Research on Inclusions in CuCr Alloy Prepared by Thermit Reduction .....	265
<i>D. Zhihe, Z. Ting'an, Z. Zhiqi, N. Liping, L. Guozhi, L. Yan, and H. Jicheng</i>	
Settling of Inclusions in Top-cut Solar Grade Silicon SoG-Si Scraps under Electromagnetic Field.....	271
<i>L. Nana, W. Damodah, and L. Zhang</i>	
Study and Application of the Taphole Clay with High Strength and Environment-friendly in a New Blast Furnace with 3800M3 Volume .....	279
<i>G. Xu, Y. Wang, Y. Xiong, H. Li, and S. Li</i>	

## **Sintering and Synthesis**

Strengthening the Sintering of Iron Concentrate Fines by High Pressure Roller Grinding Pretreatment.....	291
<i>Y. Guo, K. Mu, T. Jiang, D. Su, and J. Zeng</i>	
Research on Sintering Properties of Vanadium-Titanium Magnetite Concentrate .....	299
<i>X. Fan, Q. Wang, X. Chen, M. Gan, L. Yuan, and S. He</i>	
Influence of Limonite Proportion on Sinter Quantity and Quality .....	307
<i>X. Fan, D. Su, G. Fu, X. Chen, M. Gan, T. Jiang, and Y. Guo</i>	
In Situ Observation of High Temperature Properties of Iron Ore during Sintering Process .....	315
<i>M. Zhao, Y. Pei, Z. Zhao, L. Ban, and Z. Ma</i>	
Air Leakage Online Monitoring and Diagnosis Model for Sintering .....	323
<i>F. Xiaohui, J. Lijuan, and C. Xuling</i>	
Investigation on the Interfaces of M42/45 Steel Bimetal Composites Sintered by Spark Plasma Sintering.....	331
<i>J. Xu, H. You, P. Jiang, Y. Lv, and Y. Cao</i>	

## **Energy and Environment**

Current Status of Heat Recovery from Granulated Slag .....	339
<i>S. Esfahani, and M. Barati</i>	
Contribution to the Energy Optimization in the Pyrometallurgical Treatment of Greek Nickeliferous Laterites.....	349
<i>K. Karalis, C. Zografidis, A. Xenidis, S. Tabouris, and E. Devlin</i>	
Strengthening Refractory Iron Ore Sintering with Biomass Fuel .....	357
<i>X. Fan, Z. Ji, M. Gan, X. Chen, W. Li, and Z. Yu</i>	
Combustion Behavior of Pulverized Coal Injection in Corex Melter Gasifier .....	365
<i>S. Zhang, F. Zhu, C. Bai, L. Wen, G. Qiu, X. Lv, M. Hu, and Y. Qin</i>	
Improved Short Coil Correction Factor for Induction Heating of Billets .....	373
<i>M. Kennedy, S. Akhtar, J. Bakken, and R. Aune</i>	
Liberation of Metallic-Bearing Minerals from Host Rock Using Microwave Energy.....	383
<i>M. Andriese, J. Hwang, and Z. Peng</i>	
Effects of Binders Additives on Compressive Strength of Hematite Pellets in Firing Process .....	391
<i>Y. Huang, G. Han, T. Jiang, G. Li, Y. Zhang, and D. Wang</i>	
Mechanisms of NO Formation during SiO Combustion.....	401
<i>N. Kamfjord, H. Tveit, E. Myrhaug, and M. Næss</i>	
Pilot Scale Measurements of NO Emissions from the Silicon Process.....	411
<i>N. Kamfjord, I. Solheim, and H. Tveit</i>	

## **Treatment and Recycling of Solid Slag/Wastes**

An Integrated Strategy for Whole Ecological Utilization of Typical Industrial Solid Wastes in China.....	421
<i>X. Xue, H. Yang, T. Jiang, and Y. Li</i>	
Chlorination Behaviors of Copper Phases by Calcium Chloride in High Temperature Oxidizing-Chloridizing Roasting .....	429
<i>D. Zhu, D. Chen, J. Pan, T. Chun, G. Zheng, and X. Zhou</i>	

Effect of Iron Containing Metallurgical Byproducts on Pulverized Coal Combustion Efficiency .....	439
<i>Z. Chong, W. Liangying, Z. Shengfu, B. Chenguang, and T. Xiuqin</i>	
Effect of SiO <sub>2</sub> Addition on Production of Fe-Si-Mn Alloy from Adjusted Converter Slag .....	447
<i>M. Chen, J. Dong, Z. Tian, and C. Huang</i>	
Solidification of EAF Stainless Steel Dust .....	453
<i>B. Peng, J. Peng, L. Chai, and D. Yu</i>	
Study on Cementing Material Making with Electrolytic Manganese Residue .....	461
<i>J. Wang, B. Peng, L. Chai, Q. Zhang, and Q. Liu</i>	
Study on the Desulfurization of Pyrite Cinder Pellets .....	473
<i>Z. Ruan, D. Zhu, T. Chun, and J. Pan</i>	
 <b><u>Pelletizing and Raw Materials Processing</u></b>	
Effects of Sodium Salts-Modified Paigeite on Dephosphorization of High-Phosphorus Oolitic Hematite during Reduction .....	483
<i>G. Li, T. Lei, T. Jiang, and M. Rao</i>	
Study of Certain Parameters in Laboratory-Scale Smelting of Sivrihisar Laterite Ores of Turkey.....	491
<i>E. Keskinkilic, S. Pournaderi, A. Geveci, and Y. Topkaya</i>	
Effect of Basicity and MgO on the Pelletizing of Specularite Concentrate .....	499
<i>D. Zhu, J. Zhang, and J. Pan</i>	
Effects of MHA Binder on Roasting Behaviors of Oxidized Pellets from Specularite Concentrate .....	507
<i>Y. Zhou, Y. Zhang, T. Jiang, G. Li, and D. Zhang</i>	
A Study of Carbon-Burdened and Cold-Bonded Pelletizing-Electrosmelting Process Disposing Low-Grade Manganese Ore.....	515
<i>Z. Qiang, N. Shun-ming, C. Wen, T. Sanchuan, L. Zhao-jia, and W. Hong-qiang</i>	
Author Index .....	523
Subject Index .....	527