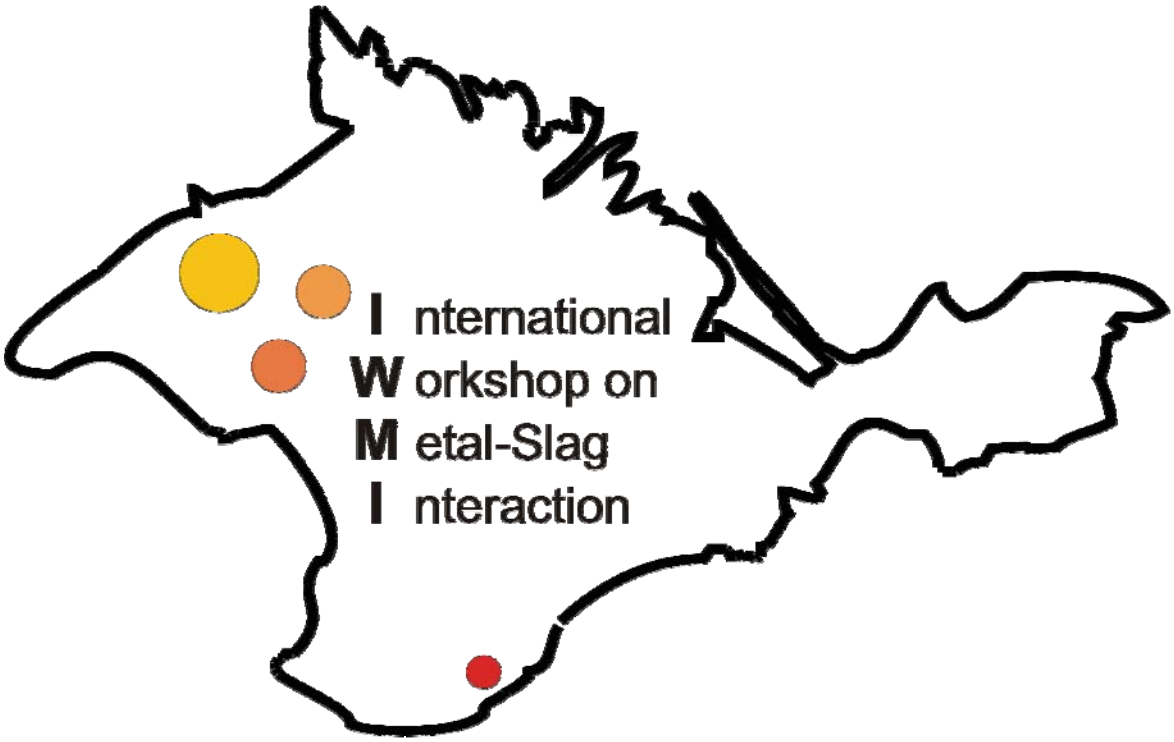

SLAGS AND FLUXES IN MODERN METALLURGY

Proceedings

of the

International Workshop on Metal-Slag Interaction

September 14th to 19th 2010 in Yalta, Crimea - Ukraine

IME Process Metallurgy and Metal Recycling - RWTH Aachen University
Aachen – Germany

Donetsk National Technical University
Donetsk - Ukraine

Schriftenreihe des IME

Band 28

B. Friedrich and O.A. Troyansky

Slags and Fluxes in Modern Metallurgy

Shaker Verlag

Aachen 2011

Foreword

There is much more to modern metallurgy than just the metal itself. It is often forgotten that slags and fluxes play an important role in the processes that we use to obtain the materials which are meanwhile an integral part of our technical society. Without slags there would be no copper production and no recycling of aluminium. Slags enable the metallurgist to treat complex raw materials, such as spent lithium ion batteries or electronic scrap. The understanding of their structure, composition and application is the key to establish new processes for these activities.

An extensive scientific community has dedicated their research capacities towards the investigation of thermophysical properties of slags while others focus intensively on the processing, solidification and forming of the target metals and materials. However, for the design and optimisation of metallurgical processes it is very often necessary to have an equally close look at both phases and to focus on the interaction that happens directly at the metal-slag interface. During the past decade, various activities have been initiated at the Department of Electrometallurgy of Donetsk National Technical University and IME Process Metallurgy and Metal Recycling at RWTH Aachen University in order to understand metal-slag interaction in depth. This research ranges from basic interfacial phenomena to the design and application of new slag compositions for modern metallurgical processes with special regard to the thermochemical interaction of the slag with other present phases as well as the kinetics of the occurring reactions.

Using the chemical reactions in metal-slag interaction as an analogy, two internationally renowned research teams were brought together in a workshop in Yalta with the goal to exchange ideas and findings, compare methodologies and gain a deeper understanding of the field of expertise across the boundaries of geographical distance and language.

We gratefully acknowledge the support of the German and the Ukrainian Ministry of Education and Research and our German industrial sponsor for bringing the heat to our “reaction”.

Aachen, April 2011

Prof. Dr.-Ing. B. Friedrich

Prof. O. A. Troyansky

Technical foreword

Since the 1960s electroslag remelting (ESR) has been established as an indispensable metallurgical process for the production of high-performance materials in today's most demanding technical applications, such as special steels for energy conversion or nickel-based superalloys for aerospace applications. Continuous research on all aspects of this refining process, especially on solidification conditions and process parameters, have taken ESR to a level of stable control and high reproducibility as demanded for safety relevant materials.

Even though the process seems to be well studied and standardized, new information was received by Ukrainian and German researchers in the last years. Investigations conducted at the Department of Electrometallurgy of Donetsk National Technical University and IME Process Metallurgy and Metal Recycling at RWTH Aachen University have revealed evidence of new possibilities for ESR with regards to metal and alloy refining principles. This research is directed towards detailed investigation of refining possibilities of ESR under controlled atmosphere in a chamber furnace using calcium-containing fluxes (so called "active slags").

Both the institutes have done research on the chemistry of an ESR process which exploits the possibilities of uncommon slag systems. One example for this successful work relates to the behaviour and control of oxygen and nitrogen in titanium which is possible through the application of active slags. With this workshop we decided to extend the findings obtained from our studies of ESR to other metallurgical processes, such as copper refining or lithium ion battery recycling in order to obtain a more general understanding of the challenges, possibilities and research opportunities that metal-slag-interaction has to offer from a scientific but also from a technical point of view. The papers presented in this proceedings reflect an interesting cross-section of the research presently conducted in Aachen and Donetsk and will serve as a starting point for further cooperation on metal-slag science in metallurgy.

Yalta, September 2010

Prof. A. D. Ryabtsev J. Reitz

List of Authors

Akbari, Semiramis – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Besson, Sandra – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Böhlke, Jörn – Scientific Engineer
Aurubis AG, Hüttenwerke Kayser, Lünen - Germany

Chilikin, Oleksiy – Prof. Director, Head of Department
Department of Management, Donetsk State University of Management, Donetsk – Ukraine

Degel, Rolf Dr.-Ing.
SMS Demag, Düsseldorf - Germany

Friedrich Bernd – Prof. Director
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Kostetsky, Yuriy – Associate Prof.
Department of Electrometallurgy, Donetsk National Technical University, Donetsk - Ukraine

Lenz, Anne – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Leoha, Fedor – Ph. D. Student
Department of Electrometallurgy, Donetsk National Technical University, Donetsk - Ukraine

Maurell-Lopez, Sebastian – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Morscheiser, Johannes – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Pashynskyi, Volodymyr – Prof. Head of Scientific & Research Department
Department of Physical Material Science, Donetsk National Technical University, Donetsk - Ukraine

Pichat, Anne – R-D Engineer
Alcan Centre de Recherches de Voreppe, Voreppe Cedex - France

Reitz, Jan – Scientific Engineer
Schott AG, Mainz - Germany

Ratiev, Sergey – Assistant, Scientist
Department of Electrometallurgy, Donetsk National Technical University, Donetsk – Ukraine

Ryabtsev, Anatoliy – Prof. Head of Department
Department of Electrometallurgy, Donetsk National Technical University, Donetsk - Ukraine

Snizhko, Olga – Ph. D. student
Department of Physical Material Science, Donetsk National Technical University, Donetsk - Ukraine

Stopic, Srecko – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Troyanskyy, Oleksandr – Prof. First Vice-Rector, Head of Department
Department of Electrometallurgy, Donetsk National Technical University, Donetsk - Ukraine

Vest, Mathias – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Weyhe, Reiner – Dr.-Ing.
ACCUREC Battery Recycling GmbH, Mülheim a.d. Ruhr - Germany

Xolin, Elodie – R-D Engineer
Alcan Centre de Recherches de Voreppe, Voreppe Cedex - France

Zander, Marko – Scientific Engineer
IME Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen - Germany

Zervos, Johannes – Scientific Engineer
Trimet Aluminium AG, Hamburg - Germany

Index

B. Friedrich; J. Böhlke: Lead and Zinc Recovery from Metallurgical Slags.....13

M. Zander; B. Friedrich; R. Degel: Heavy Metal Recovery from Slags of Copper Production via SAF Techniques.....21

S.M. Ratiev; A.D. Ryabtsev: Copper Recovery from Fire-Refining Furnaces Slags.....35

Y.V. Kostetsky: Refining of Iron-Carbon Melts by Sulfide Fluxes in Order to Remove Excessive Copper During Steel Scrap Recycling 43

S. Maurell-Lopez; A. Lenz; B. Friedrich: Slag Design for Electronic Waste Recycling in TBRC Reactors 51

S. Besson; A. Pichat; E. Xolin; B. Friedrich: Salt-Metal Interaction in Aluminium Recycling 61

S. Akbari; B. Friedrich: Salt-Metal Interaction in Magnesium Recycling 71

M. Vest; J. Zervos; R. Weyhe; B. Friedrich: Slag Design for Lithium Recovery from Spent Batteries 97

S. Stopić; B. Friedrich: State of the Art of Ni-Production in the Balkan Region with Special Focus on Ni-Loss in Slags 111

J. Morscheiser; B. Friedrich: Refining Potentials of the Electroslag Remelting Process Regarding Sulphur in Ni-Based Superalloys.....121

V.V. Pashynskyi: Microstructure Transformations in Titanium Alloys During Refining from Nitrogen-Rich Inclusions by Chamber Electroslag Remelting (ChESR) 132

O.A. Snizhko; S.M. Ratiev; F.L. Leoha: Structure and Properties of Titanium, Alloyed by Oxygen.....145

O.A. Troyanskyy: Investigation of Mass Transfer Processes Between Metal and Slag at Film Stage of ESR Process 153

J. Reitz; B. Friedrich: Metal-Slag Interaction During PESR of Titanium Alloys 161

A.D. Ryabtsev: The Refining and Alloying of Titanium in the Process of Chamber Electro-Slag Remelting.....179