SIMULATION OF SUSTAINABLE METALLURGICAL PROCESS **

Prof. Dr. Markus REUTER

Work load: 75h Theory (lectures), 105h Self-studies.
Number of credits: 6 ECTS
Course code: SSMP MA. / Examination number: 51119

► *Course contents:*

Reactor types in process metallurgy and minerals processing (e.g. TSL, Kaldo, flash smelting, QSL, flotation cells etc.) will be compared using simulation cases, evaluated and optimised for metal and minor metal recovery. The environmental footprint as also the economic performance of each reactor type will be compared with each other to establish best options for reactor flotation types as a function of feed types. The student will understand minerals processing and metallurgical reactor technology better and also be in a better position to create more sustainable industry and society.

Process design cases will be performed by the students to optimally process different feed types. By using a wider range of reactor types the student will be able to simulate complete flowsheets, provide mass and energy balances at the same time also determine the environmental footprint as well as economic analysis. This course will also examine the impact of product design on the recycling of various end-of-life products such as mobile phones etc. Thus, not only will natural resources be processed in the simulated systems but also materials from the "urban mine". Therefore, this course will also use this rigorous simulation basis to critically discuss environmental legislation as well as communicate these results to all stakeholders.

► *Intended Learning Outcomes:*

1. Simulation of reactor types
    - Modelling and simulation of hydro- and pyrometallurgical reactors for primary and secondary resources and determination of mass and energy balances as well as minerals processing
    - Determination of ecological and economic footprint of reactors

2. Modelling of processing flowsheets
    - Develop processing flowsheets for non-ferrous metal containing resources
    - Modelling and simulation of hydro- and pyrometallurgical processing plants for primary and secondary non-ferrous resources as well as minerals processing

- Determination of mass and energy balances of the complete flowsheet and determine optimal processing routes
- Determination of ecological and *economic footprint of complete* flowsheets

3. Methods and tools
   - Use of simulation tools such as HSC Sim 9.0, FACTSAGE etc. and environmental software tools such as GaBi to evaluate different processing options
   - Create process designs and communicate results to a client and/or stakeholders e.g. NGOs.

► *Prerequisites and co-requisites:*

Recommended:
Basic thermodynamic, thermodynamic and kinetic knowledge in process metallurgy

► *Planned learning activities and teaching methods:*

S1 (SS): Block course / Lectures (1 SWS)
S1 (SS): Block course / Seminar (2 SWS)
S1 (SS): Block course / Practical Application (2 SWS)

► *Mode of delivery (face-to-face; distance-learning):*

- The course takes place as a 2 week block course in September.
- Face-to-face discussions with young researchers in the field. Supportive learning during practical lessons by working on datasets both in group and individually.

► *Recommended or required readings:*

E. Worrell, M.A. Reuter (2014): Handbook of Recycling, Elsevier BV, Amsterdam, 595p. (ISBN 978-0-12-396459-5).

M.A. Reuter, R. Matusewicz, A. van Schaik (2015): Lead, Zinc and their Minor Elements: Enablers of a Circular Economy World of Metallurgy – ERZMETALL 68 (3), 132-146.

M.A. Reuter, A. van Schaik, J. Gediga (2015): Simulation-based design for resource efficiency of metal production and recycling systems, Cases: Copper production and recycling, eWaste (LED Lamps), Nickel pig iron, International Journal of Life Cycle Assessment, 20(5), 671-693.

M.A. Reuter, I. Kojo (2014): Copper: A Key Enabler of Resource Efficiency, World of Metallurgy – ERZMETALL 67 (1), 46-53 (Summary of plenary lecture Copper 2013).

S. Creedy, A. Glinin, R. Matusewicz, S. Hughes, M.A. Reuter (2013): Outotec® Ausmelt Technology for Treating Zinc Residues, World of Metallurgy – ERZMETALL, 66(4), 230-235.

M.A.H. Shuva, M.A. Rhamdhani, G. Brooks, S. Masood, M.A. Reuter (2016): Thermodynamics data of valuable elements relevant to e-waste processing through primary and secondary copper production - a review, J. Cleaner Production, 131, 795-809.

M.A. Reuter (2016): Digitalizing the Circular Economy – Circular Economy Engineering defined by the metallurgical Internet of Things-, 2016 TMS EPD Distinguished Lecture, USA, Metallurgical Transactions B, 47(6), 3194-3220 (http://link.springer.com/article/10.1007/s11663-016-0735-5).

I. Rönnlund, M.A. Reuter, S. Horn, J. Aho, M. Päällysaho, L. Ylimäki, T. Pursula (2016): Sustainability indicator framework implemented in the metallurgical industry: Part 1-A comprehensive view and benchmark & Implementation of sustainability indicator framework in the metallurgical industry: Part 2-A case study from the copper industry, International Journal of Life Cycle Assessment, 21(10), 1473-1500 & 21(12), 1719-1748.

► *Assessment methods and criteria:*

For the award of credit points it is necessary to pass the module exam. The module exam contains:
AP: Report of simulation
The student should solve a case/example and hand in the computer file as a document.

The Grade is generated from the examination result(s) with the following weights (w):
AP: Report of simulation [w: 1]

► *Contribution to EIT's Overarching Learning Outcomes:*

(EIT OLO1, OLO3, OLO6): This course is about determining of ecological and economic footprint of reactors and complete flowsheets; using simulation and environmental software tools to evaluate different processing options. Additionally, the course focuses on creating simulation process designs and communicating results to a client and/or stakeholders, e.g. NGOs. Students are involved in modelling and simulation of hydro- and pyrometallurgical reactors for primary and secondary resources.