Pyrometallurgical and Hydrometallurgical Research Equipment

**Pyrometallurgy**

- **Resistance Furnaces**: Our institute has several resistance furnaces at its disposal. Their set-up differs significantly from each other enabling suitable trial conditions for every research purpose. The equipment varies in terms of melt capacity up to 35 l, atmosphere, maximum temperature (up to 2000 °C) and movability (static, tiltable, rotary).

- **Induction Furnaces**: IME owns seven hot and cold wall induction furnaces, offers a melting capacity of approximately 1 500 l. The pilot-scale EAF has a transformer input of 1 MW, operates with AC or DC and with or without a carbon crucible. The pilot-scale EAF has a volumetric capacity of 6 l. The medium furnace has a volumetric capacity of 12 l and can operate under controlled (inert/protective gas) atmosphere. Both lab-scale furnaces run on DC-mode and a power range of 1 - 100 kW. The lab-scale furnaces set-up allows to perform experiments with or without a carbon crucible. The pilot-scale EAF has a transformer input of 1 MW, operates with AC or DC and offers a melting capacity of approximately 1500 l.

- **Electric Arc Furnaces (SAF/EAF)**: Our institute has several arc furnaces in three different sizes. The smallest furnace has a volumetric capacity of 6 l. The medium furnace has a capacity of 10 l and can operate under controlled (inert/protective gas) atmosphere. Both lab-scale furnaces run on DC-mode and a power range of 1 - 100 kW. The furnace's set-up allows to perform experiments with or without a carbon crucible. The pilot-scale EAF has a transformer input of 1 MW, operates with AC or DC and offers a melting capacity of approximately 1500 l.

- **Top Blown Rotary Converter (TBC)**: The TBC is a very flexible and versatile furnace. It is heated via oxygen/air-gas burner, lifts and rotates around its own axis allowing a thermal (continuous), feeding mechanism (dis-continuous) and process atmosphere (protection gas or vacuum).

**Hydrometallurgy**

- **IME's Hydro-Laboratory**: In the IME’s hydrometallurgical laboratory it is possible to leach primary and secondary materials in a fume cupboard, in order to assure a safe treatment of volatile or dangerous substances. Leaching can be performed with acids or by up to 5 litres of reaction volume. KPG-stirring can be provided during direct or indirect heating (water/oil bath or double wall container). The IME has the opportunity to perform experiments with feeding gas (e.g. N₂, Ar, O₂) and under the influence of ultrasonic waves or microwaves. Process atmosphere, pH, redox potential and oxygen concentration measurements are essential and ensure process parameter control, kinetic studies and evaluation of chemical behaviour.

- **Multi-Step Leaching Cascade**: The IME is equipped with a scale cascade leaching facility containing four stirred glass reactors (3 x 10 l, 1 x 8.5 l). This equipment is designed to study the use of aqueous solutions containing a lixiviant which brings valuable metals into solution from ores or other leaching substrates. In the following steps, pH and concentration of agent are controlled to remove dissolved metals from the solution as selectively as possible. With pH-measurements and pumps, continuous and automatic feeding of neutralizing agent (max. 4.5 l/h) is available. The maximum solution throughput is 10 l/h.

- **Top Blown Rotary Converter (TBRC)**: The TBRC is a very flexible and versatile furnace. It is heated via oxygen/air-gas burner, lifts and rotates around its own axis allowing a good temperature and chemical process control. The TBRC has the opportunity to perform experiments with feeding gas (e.g. N₂, Ar, O₂) and under the influence of ultrasonic waves or microwaves. Process temperature, pH, redox potential and oxygen concentration measurements are essential and ensure process parameter control, kinetic studies and evaluation of chemical behaviour.

**Our Commitment**

Metallurgical products are constantly increasing in complexity and underpin a strategic role in every composition in order to meet the growing requirements of the industry and application side. Therefore, continuously changing products require tailor-made solutions. Aside, high economic values and restricted availability of particular waste material components, as well as rising disposal costs and increasingly stringent environmental regulations are some of the many reasons for the quest and realization of recycling knowhow and technologies.

Our Institute for Process Metallurgy and Metal Recycling hence regards it as our task and duty to develop and prove solutions to overcome today’s challenges in metallurgy. We offer literature research, state of the art studies, thermocatalysis modeling, technical advice and survey service based on our profound experience in both pyrometallurgical and hydrometallurgical methods. Additionally, we are specialized in application-oriented research and development of innovative, cost-efficient and sustainable processes from lab-scale to pilot-scale. Our experimental work is not only dedicated to state-of-the-art processes and techniques but also considers novel approaches such as microwave technology applications. If you would like to know more about us, please visit our homepage or find us on ResearchGate.

**Pyrometallurgy / Hydrometallurgy**

**Fundamentals / Slag Design**

**Recycling of Metals**

**Pilot Scale**

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Thermochemical Modeling

In order to design effective recycling solutions - and for safety reasons - it is essential to understand and predict the occurring processes in advance. We use the commercial software FactSage® for thermochemical modeling. For pyrometallurgical purposes it enables us to predict equilibrium phases, melting temperatures, vapor pressures, favorable reaction pathways. For hydrometallurgical applications, simulations of pH-diagrams are possible, which are helpful to estimate necessary parameters for leaching and precipitation experiments.

Some metallurgical processes need preliminary thermal treatment with the objective of (partial) reduction of oxides, selective evaporation of specific metals and/or compounds as well as the removal of organics via pyrolysis. By using defined atmospheres like hydrogen, nitrogen, air or even vacuum; the chemical reaction can be controlled towards the desired direction.

Fundamental Research

As input materials become more and more complex, suitable data for thermochemical modeling is sometimes missing and requires systematic experimental investigations. Pyrometallurgical fundamental research is generally carried out in lab-scale and aims at the definition of metal/slag equilibria, evaluation of crucible material, determination of necessary process duration, investigation of the influence of melt movement, etc. These experiments can be performed under controlled atmosphere, online weight recording and temperatures up to 2000 °C. At IME, resistance and induction heated furnaces are most commonly used for fundamental research trials.

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Microwave-Metallurgy

Microwave technology is quite new to metallurgy. Consequently, the occurring interactions between a matter and a microwave are not fully understood yet. Depending on the substance’s properties, it can reflect or transmit a microwave or be stimulated by either the magnetic or electric field of a microwave. This results in the local generation of calorific energy. Due to the TBRC's high flexibility, it is not exclusively used for metal/slag interaction processes. For instance, research is conducted on the removal of titanium from aluminum via the use of reactive gases. A different method for refinement of metals with high volatile element concentration is vacuum distillation. Here, volatile elements are removed from a metallic melt by applying low pressures, therefore selectively vaporizing and condensing alloy components. Studies on the refinement of magnesium scraps and incineration ashes are currently under investigation at the IME.

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SAF/EAF-Metallurgy

Submerged and open arc furnaces respectively are widely used for primary metallurgy of ferro-alloys or recycling of iron scrap. For reasons of flexibility (high temperatures possible, mode of electrical operation, electrode positioning, etc.) the electric arc furnace is increasingly used for non-ferrous recycling purposes, few of which are listed below:

- recycling of NiMH and LiCo-batteries
- recovery of precious metals from spent catalysts
- recovery of Co/Fe/Ga from solar panels
- recovery of Fe/V/Ga from red mud

Unfortunately, most furnaces show a lack of the desired (non-turbulent) stirring effect which favors coagulation of the particles. For that purpose the IME offers a lab-scale, medium-scale and pilot-scale solution. They all base on the same principle: A vessel which rotates around its own axis and is adjustable in its tilting angle. The lab-scale unit is resistance heated while the medium- and pilot-scale furnaces (TBRCs) are heated by an oxyfuel-burner, achieving a good reproducibility of industrial processes.

Bath-Smelting/TBRC

Some processes are not suitable for induction furnaces or electric arc furnaces due to inability to couple with the magnetic field, high turbulence generated in the melt or localized high temperatures. Setting processes of metal containing slags as well as aluminum recycling under salt are perfect examples which require unagitated melt treatment. For these conditions resistance heated or gas fired furnaces are the only option.

Due to the TBRC’s high flexibility, it is not exclusively used for metal/slag interaction processes. For instance, an applicable oxygen-lance enables converting processes. Thus, our TBRC has been successfully used for various purposes. Some examples of application are given below:

- recovery of metal fines from oxide residues
- separation of matte and slag phase
- recycling of contaminated scraps (e.g. UBSCs)
- autothermal metal recovery from WEEE-scraps

Ceramic-Metallurgy

Research on innumerable recycling applications yet to be discovered. Recycling materials may need a multi-step leaching process to achieve successful treatment, for which example inhibits gel formation. Our cascade line enables to carry out a continuous process with four different treatment steps, each showing distinct effects (pH, temperature, stirring rate). Application examples are as follows:

- (metallurgical) waste water treatment
- selective neutralization of acid mine water
- selective neutralization of acid mine water

Pre-Conditioning

Most materials require pre-conditioning of physical or thermal nature to make it applicable for subsequent hydrometallurgical or pyrometallurgical treatments. Powdery input material (e.g. ore concentrate, off-gas dust) must be compacted prior to metallurgical treatment in furnaces, for example EAF, TBRC or rotary kilns. This can be done via pelletizing, cold briquetting, pressing or sintering. All the listed methods are available at IME. In order to design effective recycling solutions - and for safety reasons - it is essential to understand and predict the occurring processes in advance. We use the commercial software FactSage® for thermochemical modeling. For pyrometallurgical purposes it enables us to predict equilibrium phases, melting temperatures, vapor pressures, favorable reaction pathways. For hydrometallurgical applications, simulations of pH-diagrams are possible, which are helpful to estimate necessary parameters for leaching and precipitation experiments.

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