

Process Development in Laboratory & Pilot Scale

- recycling of Li containing Al scrap by vacuum distillation: recovery of metallic lithium and Al master alloy
- recycling of NiCd batteries by vacuum distillation: recovery of Cd metal and Fe-Ni alloy
- recycling of Cu-Zn-Sn scrap by vacuum distillation: recovery of metallic Zn and bronze alloy
- development of a procedure avoiding evaporation losses of alloy elements by electron beam melting
- recycling of superalloy scrap by VIM and ESR
- processing of aluminothermic TiAl and TiAl scrap by VIM and ESR:
- homogenisation, refining and directional solidification
- processing of ATR vanadium & niobium using EBM: removal of oxygen and aluminium
- refining of silicon by fractional crystallisation

Small-Scale Production & Customer Oriented Research

The IME know-how and equipment allows the in-house production of almost all kinds of special metallic products. Possible production routes are:

- VIM/ESR/VAR/EBM/VIM-EBM
- VIM-ESR or VIM-VAR or VIM-ESR-VAR
- casting of flakes for hydrogenation and powderization

We prepare customised products like:

- iron/nickel/cobalt-based superalloys
- titanium alloys
- intermetallic phases
- refractory metal alloys
- light metal alloys
- dental alloys
- metallic powders
- ultra pure aluminium

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- **Vacuum and Pressure Induction Melting Furnaces:**
 - melt volume: 0.1-100 l
 - power supply: 40-300 kW, 150 Hz, 1.5 kHz, 10 kHz
 - oxide or non-oxide ceramic crucibles or graphite crucibles- vacuum or protection gas atmosphere up to 3 bar total pressure
- **Vacuum Arc Furnace:**
 - max. electrode dimension: Ø 160x1400 mm
 - mould dimensions: Ø 120, Ø 160, Ø 200 mm
 - max. ingot weight: 200 kg
 - power supply: 450 kVA, 7.5 kA, 70 V, DC
 - vacuum ($5 \cdot 10^{-4}$ mbar) or protective gas atmosphere
- **Pressure Electroslag Furnace:**
 - max. electrode dimension: Ø 110x1340 mm
 - mould dimensions: Ø 160 mm
 - power supply: max. 6 kA, max. 80 V, 50 Hz
 - working mode:
 - protective gas (max. 50 bar overpressure)
 - vacuum (<math><10</math> mbar)
- **Electron Beam Furnace:**
 - max. electrode dimension: Ø 100x350 mm
 - mould dimensions:
 - slabs 90x35x350 mm
 - ingots Ø 50x350 mm, Ø 100x350 mm
 - button and tongue shaped crucibles
 - centrifugal casting device
 - power supply: max. 60 kW, max. 30 kV, max. 2 A
 - working pressure: $8 \cdot 10^{-4}$ - $3 \cdot 10^{-6}$ mbar
- **Zone Refining Equipment:**
 - power supply: 80 kW, 10 kHz
 - ingot dimensions: max. Ø 100x1000 mm
 - melting rate: 35 kg Al / 24 hours
 - vacuum or protective gas operation
- **Hydrogen Embrittlement Retorts:**
 - treatment volume: 1-200 l
- **Vacuum Inductive Distillation Furnaces:**
 - power supply:
 - 600 kVA, max. 300 kW, min. 80 kW, 150 Hz
 - 40 kW, 10 kHz
 - melt volume:
 - 1.5 l, 10 kg Fe
 - 100 l, 800 kg Fe
 - vacuum: <math><1</math> mbar
- **Vacuum Treatment Furnaces:**
 - induction furnace:
 - max. product dimension: Ø 100x500 mm
 - resistant furnace:
 - max. product dimension: 30x30x20 mm
 - max. temperature: 1550°C



- Vacuum Induction Melting (VIM)
- Vacuum Arc Remelting (VAR)
- Electro Slag Remelting (ESR)
- Electron Beam Melting (EBM)
- Zone Refining (ZR)
- Powder Synthesis (HDH)

Department and Chair of



IME Opportunities in Vacuum Process Metallurgy

Metallic materials require high precision in terms of their composition and homogeneity. The control of the desired alloying elements and the unwanted impurities is the crucial task during alloy production especially when oxygen sensitive elements like titanium, zirconium, aluminium, magnesium and rare earth metals are present in the melt. Procedures of melting and melt treatment in vacuum or protective gas atmosphere are well established in small-scale for special products and industrial-scale (e.g. steel). The know-how and the available equipment at the IME offers the opportunity for experiments in all versions of vacuum and protective gas metallurgy. At the IME new procedures can be evaluated and existing routes can be technologically and economically improved.

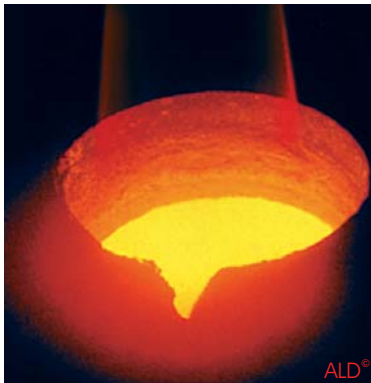
Alloying



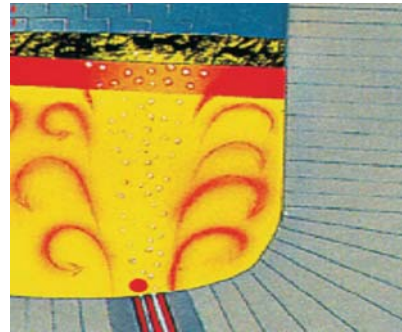
Complex alloys with a maximum batch size of 200 kg are synthesised by using VIM, ESR, VAR or EBM. The intelligent combination of those technologies, the knowledge of suitable VIM-crucibles and raw materials, as well the know-how of process control is the basis for a successful small-scale production of high-tech materials. Examples therefor are magnet and battery alloys, getter materials as well as memory, air craft and watch alloys.

Distillation

The separation of metals from each other or the removal of impurities using their different partial pressures is often required for the production of high-purity materials or in the splitting of complex recycling materials. Depending on the specific problem, either vacuum induction furnaces or electron beam furnaces can be used for distillation applications.



Gas Purging / Degassing



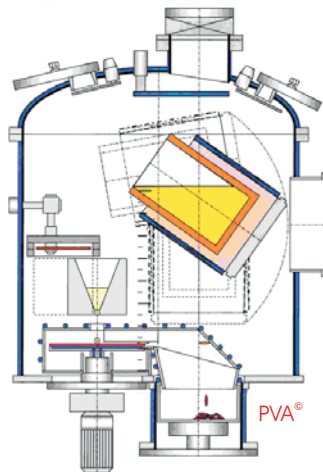
Vacuum assisted gas purging treatments allow a very quick removal of dissolved gases due to the generating of high turbulent melt stirring. Either porous ceramic plugs, rotating impellers or injection lances can be used to immerse purging gases like argon or nitrogen into the melt.

Electro Slag Remelting

Refining by ESR is a well-established technology for homogenising and refining of steel. Thus the transfer of this technology to the processing of reactive metals (e.g. titanium) or rendering the advantages of slag metallurgy in vacuum induction melting using reactive slag are challenging and open new perspectives to manufacture high-tech metals.



Solidification/Grain Design



In addition to the conventional casting into steel, water-cooled copper or ceramic moulds, VIM-melts can be poured on a water-cooled rotating disc to form flakes for further powder synthesis using the HDH method. VIM-melts can likewise be treated by moving the rotating crucible downwards through an indirect water-cooling section to constitute directional solidification.

Zone Refining



For the production of ultra pure materials zone refining can be applied. A small zone of a metal bar becomes liquid in a tube furnace by a moving induction coil. The liquid zone migrates through the metal bar very slowly and a front of impurities

is pushed ahead. The contaminated end of the bar is finally cut. Using this technology the manufacturing of e.g. ultra pure Al (> 99,99995 %) for electronic applications is possible.

Vacuum Heat Treatment

Homogenising, hardening and annealing, solution annealing or stress relief heat treatment under vacuum and/or protection gas by inductive or resistance heating provides the desired material properties. No oxidation, decarbonising or nitration takes place during the heat treatment. Applications are found in processing e.g. titanium or nickel alloys.



Powder Synthesis



Powders based on hydride forming metals can be produced by using the hydrogenation-dehydrogenation method (HDH). Hydrogenation is an exothermic process by absorbing hydrogen. The product phase is a very brittle hydride, which is subsequently crushed. Dehydrogenation is an endothermic reaction and takes place under vacuum conditions and elevated temperature. The powder is nearly oxygen-free, sinter active and usually shows sizes of 50-150 µm.