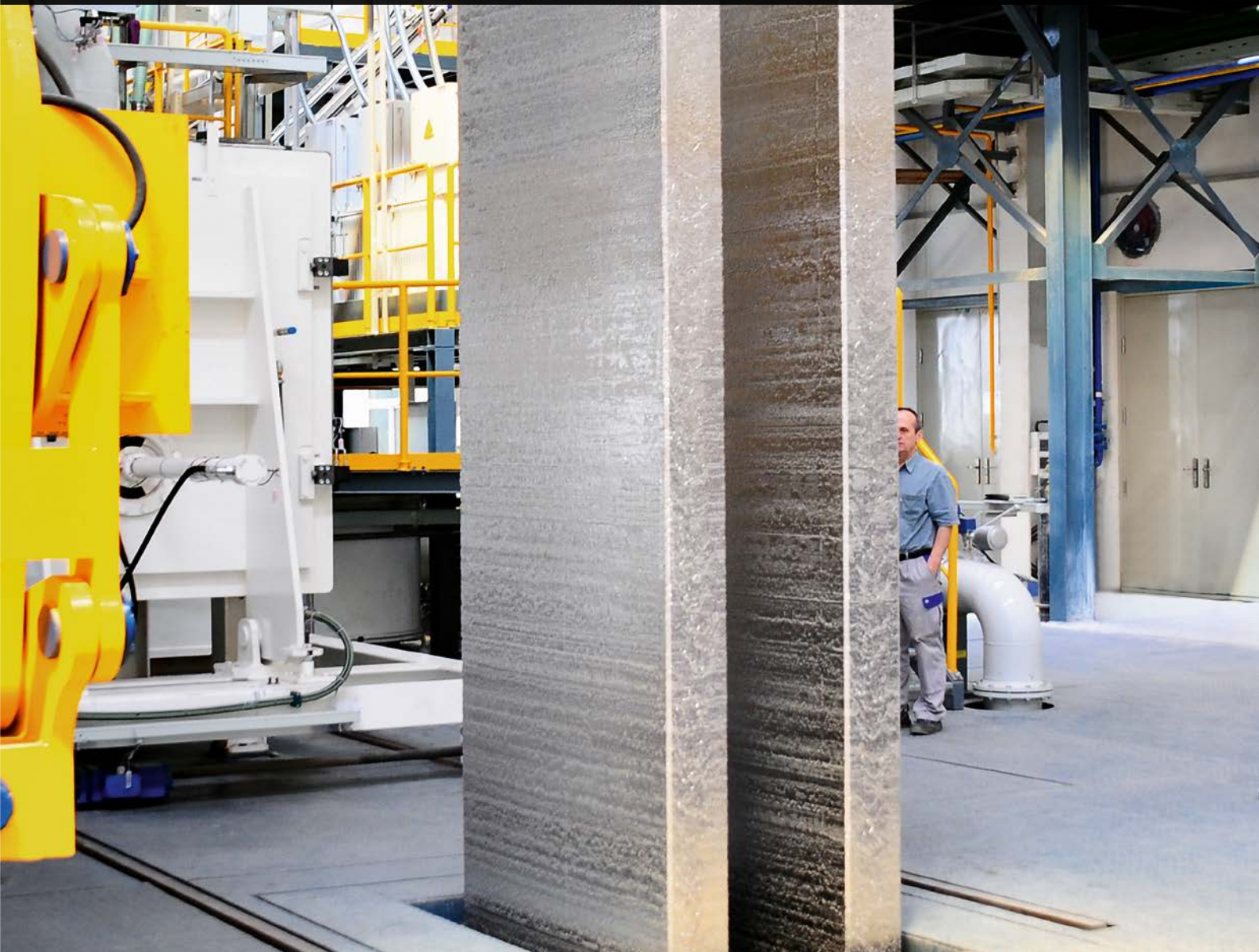


ALD Vacuum Technologies

High Tech is our Business

Electron Beam Melting (EB)

Electron Beam Melting Processes and Furnaces



Electron Beam Melting

Metallurgy of the Electron Beam Melting Process



Large EBCHR Furnace for Titanium

Electron beam melting is distinguished by

- superior refining capacity
- a high degree of flexibility
- the use of water cooled copper mold

It is ideal for remelting and refining under high vacuum of metals and their alloys like

- refractory metals (tantalum, niobium, molybdenum, tungsten, vanadium, hafnium)
- reactive metals (zirconium, titanium)

EB plays an important role in manufacturing

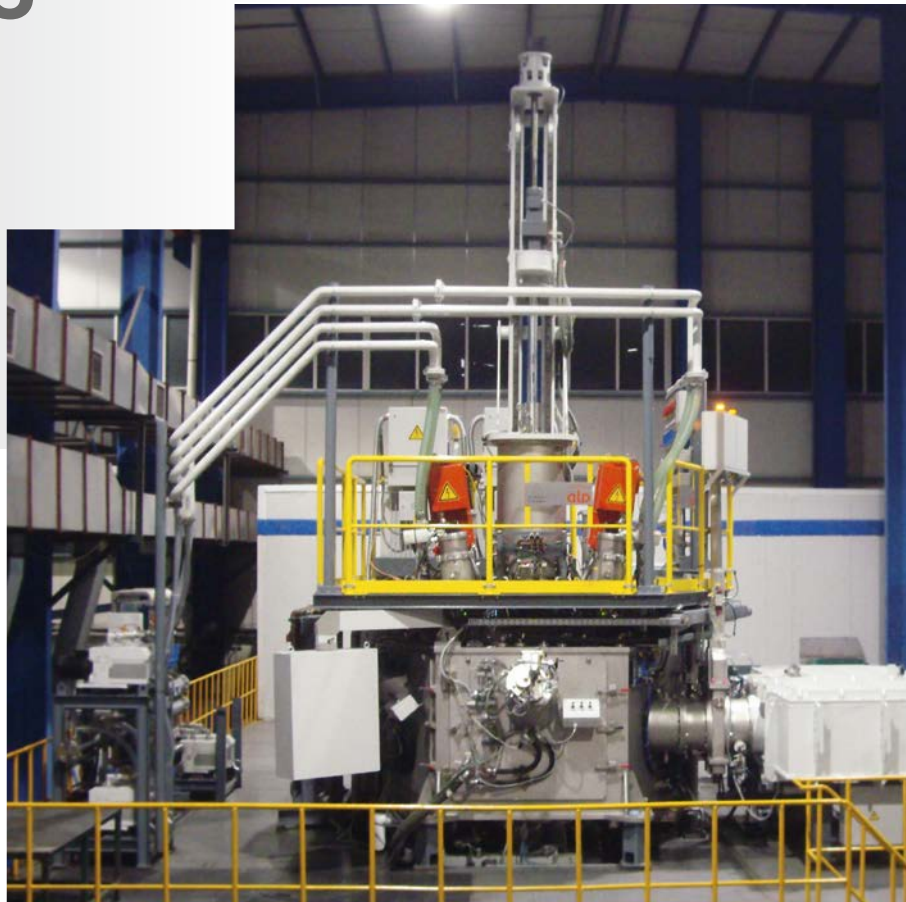
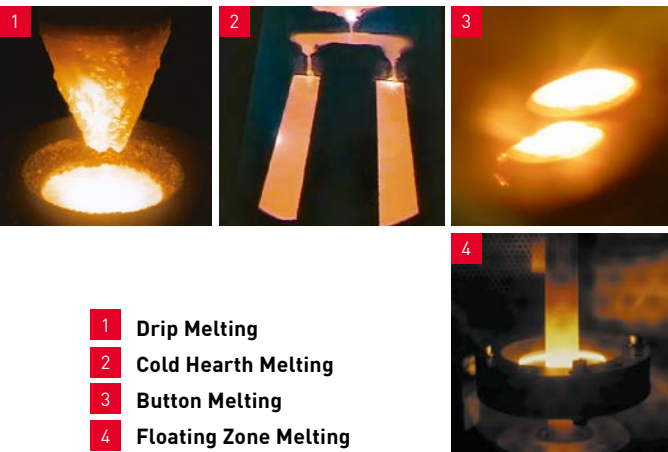
- of ultra-pure sputtering target materials
- electronic alloys and
- the recycling of titanium scrap.

Metallurgy of the Electron Beam Melting Process

- Electron beam guns are high temperature heat sources which are able to exceed the melting and even evaporation temperatures of all materials at their beam spot.
- By magnetic deflection and rapid scanning at high frequencies, the electron beam can be effectively directed at targets of multiple shapes. It is thus the most flexible heat source in remelting technology.
- The electron beam impinges on the target with typical power densities of 100 kW/cm^2 . Depending on the melt material, the power transfer efficiency ranges from approximately 50 to 80 %.
- Since EB melting is a surface heating method, it produces only a shallow pool at acceptable melt rates which positively effects the ingot structure regarding porosity, segregation, etc.
- The exposure of the superheated metal pool surface to the high vacuum environment at levels from 1 to 10^{-3} Pa results in excellent degassing of the molten material.
- Metallic and non-metallic constituents with vapor pressures higher than the base material are selectively evaporated thus generating the desired high purity of the ingot material.
- Process control allows reproducible power distribution for alloy control.

Electron Beam Melting

Process Variations



1200 kW EB Melting Furnace for Tantalum and Niobium

Process Variations

The high degree of flexibility of the EB heat source has spawned the development of several remelting and refining methods.

■ Drip Melting

- Classical method for processing refractory metals such as Ta and Nb among others.
- Raw material in form of bars is usually fed horizontally and drip-melted directly into the withdrawal mold.
- The liquid pool level is maintained by withdrawing the bottom of the growing ingot.
- Refining is based on degassing and selective evaporation.
- For repeated remelting, vertical feeding is applied.

■ Cold Hearth Refining

- EBCHR is of great importance for the processing and recycling of reactive metals.
- The feedstock is drip-melted in the rear part of a water-cooled copper hearth from where it overflows into the withdrawal mold.
- During the dwell time of the molten material in the hearth system gravity separation of high- and low-density inclusions (HDI, LDI) can be achieved in addition to the refining mechanisms described above.
- The hearth must be properly sized to provide sufficient dwell time of the molten metal in order to permit efficient gravity separation of HDIs and LDIs.

- Larger hearth melting systems are equipped with more EB guns to provide the required power and energy distribution.

■ Button Melting

- Button Melting is utilized for cleanliness evaluation of superalloy samples regarding type and quantity of low-density, non-metallic inclusions.
- The equipment features programmed automatic sample melting and controlled directional solidification.
- Low-density inclusions (normally oxides) float to the surface of the pool and are concentrated in the center, on top of the solidifying button.

■ Floating Zone Melting

- Floating zone melting is one of the oldest techniques for the production of metals with highest purity.

Electron Beam Melting

Process Control



Local operation panels

Remote control desk

Process Control

EB furnaces operate in a semi-automatic control mode. Even with highly skilled computer controlled process automation, operator supervision of the process and manual fine tuning is still possible.

Process automation includes:

- vacuum system;
- vacuum pressure control;
- material feed rate and ingot withdrawal rate;
- processor-based high voltage and emission current control;
- PC-based automatic beam power distribution; data acquisition and archiving.

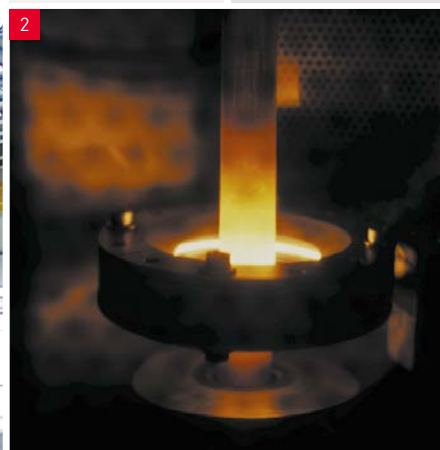
Beam Power Distribution

For process-specific power distributions, the beam deflection has to be controlled with respect to location and dwell time. For this purpose, ALD has developed a PC-based electron beam scan and control system “**ESCOSYS**” for simultaneous control of several EB guns. This system fulfills the highest requirements for complex beam power distribution which is defined in melt recipes by selecting suitable deflection patterns from a variety of available pattern shapes. These can be graphically edited in size and location on the melt geometry and visualized on the computer screen.

Patterns are automatically corrected for projected angular distortions on the targets. The active power fraction in each pattern is defined by the dwell time as part of the pattern parameter set. An operation mode for power distribution management is also included. Here, the actual beam pattern on the target is calculated by the computer, based on operator definitions. As part of the furnace commissioning a special teach-in program is evoked for the computer to learn about the melt geometry and its dependency on the deflection frequency. This way, electron beam excursions beyond the melt boundaries are recognized and automatically limited when editing deflection patterns.

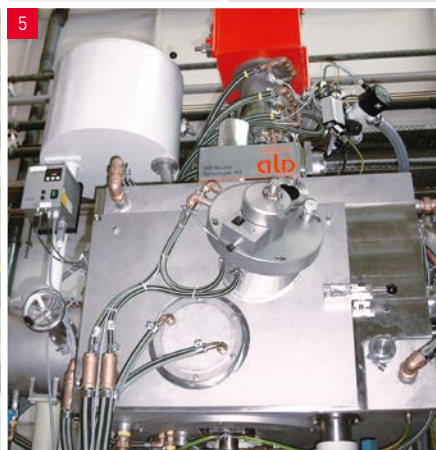
Electron Beam Melting

Melting Furnace Types



1 EB Cold Hearth Production Furnaces
Reactive metal ingots and slabs, including material recycling.
Ingot weights up to 20 t. Beam power up to 4,800 kW.

2 EB Floating Zone Melting Furnaces
Rods up to 20 mm in diameter and 300 mm length.



3 EB Drip-Melt Production Furnaces
Refractory metal ingots up to 500 mm \varnothing and 3,000 mm length. Beam power up to 1,800 kW.

4 EB Pilot Production Furnaces
Permitting both drip melting and cold hearth refining. Beam power up to 300 kW.

5 EB Laboratory Furnaces
For research and development or precious metal production.

6 EB Button Melting Furnaces
For button melting and material qualification.

TYPE OF GUNS – MAIN FEATURES

	K60	KSR 300	KSR 600	KSR 800
Maximum beam power	60 kW	300 kW	600 kW	800 kW
Beam power control range - Power control by bombardment power	1-100 %	1-100 %	10-100 %	10-100 %
Maximum acceleration voltage	30 kV	40 kV	45 kV	50 kV
Average life time of cathodes at maximum beam power	200-300 h	200-300 h	200-300 h	200-300 h
Focus lenses	1	2	2	2
Deflection system	1	1	1	1
Limiting frequency	150 hz	1200 hz	1200 hz	1200 hz
Maximum deflection angle	+/- 25 deg	+/- 45 deg	+/- 45 deg	+/- 45 deg
Pump capacity - Turbomolecular pump at beam generator housing - Turbomolecular pump at pressure stage housing	360 l/s -	360 l/s 1100 l/s	1100 l/s 1100 l/s	1100 l/s 1100 l/s



K60



KSR 300



KSR 600



KSR 800

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