The Solution

Electron Beam Melting (EB)

Electron Beam Melting Processes
and Furnaces

Electron Beam Melting

Electron beam melting is distinguished by its superior refining capacity and offers a high degree of flexibility of the heat source. Thus, it is ideal for remelting and refining of metals and alloys under high vacuum in water-cooled copper molds. Today the process is mainly employed for the production of refractory and reactive metals (tantalum, niobium, molybdenum, tungsten, vanadium, hafnium, zirconium, titanium) and their alloys. It plays an important role in manufacturing of ultra-pure sputtering target materials and electronic alloys and the recycling of titanium scrap.

Metallurgy of the Electron Beam Melting Process

Electron beam guns represent 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 and 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.

EB cold hearth refining.

Electron beam floating zone melting.

Depending on the melt material, the power transfer efficiency ranges from approx. 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 of 1– 0.001 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. In other cases, however, this can create loss of desired alloy constituents which must be accounted for.

Process Variations

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

■ **Drip Melting**
is the 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 as described above. Mostly repeated remelting of the first melt ingots is required to achieve the final quality. For repeated remelting, vertical feeding is applied.

■ **Electron Beam Cold Hearth Refining (EBCHR)**
is of great importance for 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 the hearth in order to permit efficient gravity separation of HDIs and LDIs. Larger hearth melting systems are equipped with a larger number of EB guns to provide the required power and energy distribution.

500 kW EB Melting Furnace.

■ **Button Melting**
is utilized for cleanliness evaluation of super-alloy 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.

Process Control

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

Process automation includes:

- vacuum pump system scheme;
- 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.

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.

Front access door of EB Melting Furnace.

Local operation panels.

The active power fraction in each pattern is defined by the dwell time as part of the pattern parameter set. An operation mode for the so-called 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 Guns and Melting Furnace Types

The following systems are available:

■ **Electron Beam Guns**
a series of EB guns with 60, 300 and 600-kW beam power at 25–45 kV.

■ **EB Drip-Melt Production Furnaces**
for production of refractory metal ingots up to 400 mm in diameter and 3,000 mm length, beam powers up to 2 MW with 2, 3 or 4 guns.

■ **EB Cold Hearth Production Furnaces**
for production of reactive metal ingots and slabs, including material recycling. Ingot weights up to 10 tons, total beam power up to 3 MW with up to 6 guns.

■ **EB Pilot Production Furnaces**
permitting both dripmelting and cold hearth refining, equipped with all facilities to conduct these processes. Total beam power 200–500 kW with 2 guns.

■ **EB Laboratory Furnaces**
for research and development.

■ **EB Button Melting Furnaces**
for producing test buttons of 30 mm Ø; 8 mm height; 0.7 kg weight (Ni-based superalloys), required EB-power 30 kW.

■ **EB Floating Zone Melting Furnace**
rods up to 20 mm in diameter and 300 mm length can be treated. An annular electron beam system of 10 kW is employed.

EB Lab 100.

EB Features

- ALD offers electron beam guns of 60, 300 and 600 kW power with highly advanced beam deflection controls;
- System designs are implemented with melting powers above 2,000 kW;
- Ceramic-free melting process for circular, square and rectangular ingot shapes.

EB Applications

- Remelting of high-purity materials such as Nb and Ta;
- Titanium production for the chemical and aerospace industries;
- Zirconium production for the chemical industry;
- Production of high-purity metals for electronic applications (e.g., sputtering targets).

The Solution

ald

ALD Vacuum Technologies GmbH

Wilhelm-Rohn-Strasse 35
D-63450 Hanau, Germany
Phone: +49 (0) 6181- 307-0
Fax: +49 (0) 6181- 307-3290

e-mail: info@ald-vt.de
Internet: www.ald-vt.de

China
ALD Liaison Office
c/o C&K Development Co., Ltd.
Rm. 1102, South Office Tower
Hong Kong Plaza
283 Huai Hai Zhong Rd.
Shanghai, 200021
Phone: +86 (21) 63 85 - 55 00
Fax: +86 (21) 63 84 - 03 11
e-mail: cnkchina@online.sh.cn

Far East
ALD Thermo Technologies Far East Co., Ltd.
Shinjuku Nomura Building, 6 F.
1-26-2 Nishi-Shinjuku, Shinjuku-Ku
Tokyo 163-0558, Japan
Phone: +81 (3) 33 40 37 26
Fax: +81 (3) 33 40 37 27
e-mail: kpk@zero-japan.co.jp

Great Britain
ALD Vacuum Technologies Ltd.
The Frensham Suite
13-21 High Street
Guildford, Surrey GU1 3DG
Phone: +44 (1483) 45 44 34
Fax: +44 (1483) 30 66 41
e-mail: ald.vactech@btclick.com

USA / Canada
ALD Vacuum Technologies, Inc.
18, Thompson Road
East Windsor CT 06088
Phone: +1 (860) 386 - 72 27
Fax: +1 (860) 386 - 72 20
e-mail: rschumann@ald-usa.com

MetaCom/EB_e/04.03/2000/Dr