

E-Beam Deposition

E-beam evaporators



THEVA Smart E-vaporator series

E-beam evaporation is the established industrial vacuum deposition technique for continuous long term thin film production.

In principle, an electron beam is extracted from a heated filament and focused onto a target by electron optics. Due to the intense heat input, even materials with a high melting or evaporation point can be annealed or transferred into the gas phase.

THEVA has designed the **Smart E-vaporator** series to supply a versatile e-beam heating and evaporation tool with superior reliability, long term operating capability, flexibility, and easy maintainability.

The Smart E-vaporator concept allows high rate deposition of metals and multi-component oxide materials. Its efficient heating of a small volume minimizes the heat load on delicate substrates and the vacuum system, reducing the cooling effort and extending the life of all components.

The THEVA concept

General features and benefits

The electron beam is highly efficient in delivering thermal energy to a small, compact volume to evaporate the material irrespective of melting point or vapor pressure.

The intense heating power allows very high deposition rates from small deposition material samples. The small spot size reduces radiation and heat load on delicate substrates such as plastic foil.

Electron optics allow fast scanning or deflection of the e-beam to give a well-defined heating area and profile.

The deposition technique does not require specially prepared targets, but evaporates material from very simple and economic embodiments (e.g., wire, granulate).

Separation of crucible and e-gun

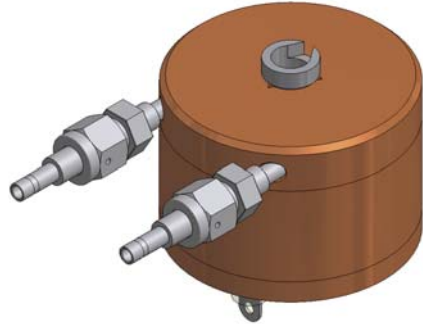
The basic concept of the Smart E-vaporator is the spatial separation of the deposition material and the e-beam source.

Since these core components can be designed and arranged independently from each other, they guarantee maximum flexibility in optimizing the deposition equipment.

An additional benefit of the spatial separation is a considerably increased lifetime since the e-gun and filament are not contaminated and can even be differentially pumped when reactive gas is used in the process. Therefore, this approach permits long, uninterrupted operation without servicing.

Crucible Evaporator

E-beam heated crucible



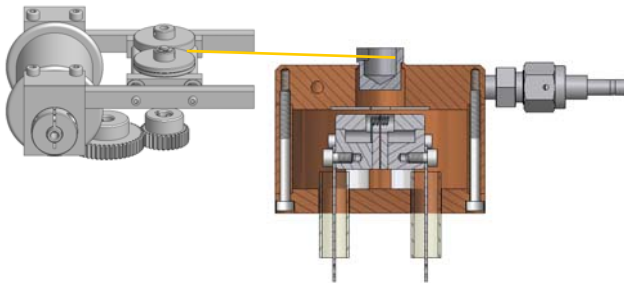
Crucible evaporator

The best arrangement for evaporating metals and alloys is a crucible heated by an electron beam from the bottom. Unlike resistively heated boats, the evaporation rate and heating power does not depend on the filling level and there is no creeping of the metal onto hot current leads. The uniform crucible heating from the bottom results in stable convection within the liquid metal and a calm surface. The absence of turbulence and overheating reduces splashing and undesired droplets on the substrate.

The e-beam transfers heat very efficiently into the crucible and due to the surround water cooling heat radiation only originates from the small area of the liquid metal. Consequently, the heat load on the substrate is very small. At high deposition rates, radiation is negligible compared to vapor condensation energy.

The standard crucible is made of tungsten; ceramic or graphite liners can be inserted to avoid alloying reactions.

Wire feeding



Wire feeding

Although the capacity of the crucible is limited, the system allows continuous, long term operation. A wire feeding system can supply kilometers of the evaporation material from a payout spool. This approach includes a deposition material supply feedback loop that controls the evaporation rate; therefore, no additional rate control is required.

Modular assembly and long service life

The THEVA Smart E-vaporators have a modular design that allows easy exchange or adaptation of the individual components.

- HV power supply
- Filament power supply
- Control electronics (CAN bus interface)
- E-beam heated crucible (water – cooled housing)
- Wire feeding system

Since the e-beam source is completely encapsulated in a water cooled housing, there is no contamination by evaporated material which guarantees an extremely long service life.

Pierce E-Gun

Pierce e-gun concept



Pierce e-gun

To allow for maximum flexibility THEVA designed a stand-alone pierce electron beam source and electron optics to focus and deflect the e-beam onto the desired target.

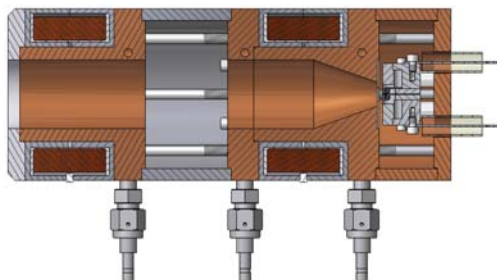
This e-gun is a versatile tool for fast and concentrated heating.

It is the core component of the Smart E-vaporator system. The electron optics and electronic beam deflection control provide precise shaping and positioning of the hot spot on the crucible for optimum evaporation results.

Due to beam deflection there is no direct line-of-sight between the evaporation source and e-gun. This approach reduces contamination to a minimum and increases the filament lifetime.

Optional differential pumping of the filament section allows operation even at high pressure and reactive gas ambient.

E-beam heating



E-beam heating

The pierce e-gun is an efficient and rapid heater in vacuum. Due to the short penetration depth of electrons into solid and liquid materials, heat can be deposited skin deep exactly where it is needed.

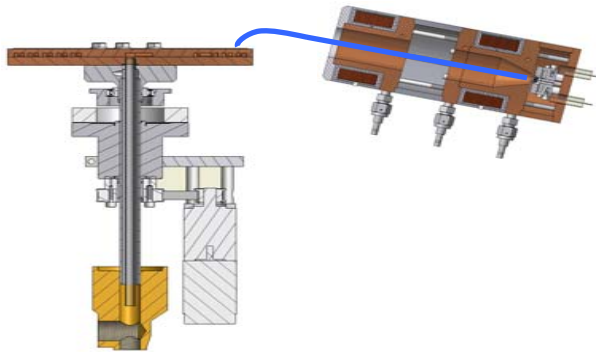
In addition to vacuum deposition techniques, the e-gun supports a wide range of rapid thermal surface treatment applications, including:

- vacuum annealing of metal surfaces (hardening of tools)
- removal of scale layers
- desorption of contaminations
- melting of ingots
- heating of floating nano-particles (in a reactor)

The electron optics accurately control the location and intensity of the applied heating energy.

Pierce E-Beam Evaporator

E-beam evaporation



Pierce e-beam evaporator

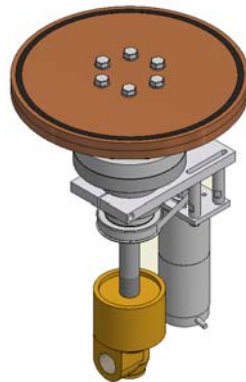
In conjunction with a crucible, the pierce e-gun forms the Smart E-vaporator system, which covers the power range up to 6 kW.

Modular design

The THEVA Smart E-vaporators have a modular design that provides flexible and easy adaptation and service of the components.

- HV power supply
- Filament power supply
- Control electronics (CAN bus interface)
- Pierce e-gun
- Magnetic beam deflection
- Custom designed crucible
- Funnel feeding system

Crucible design



Custom designed crucible stages

In the Smart E-vaporator the crucible containing or supplying the deposition material is completely independent of the e-beam source. Therefore, it can be designed to exactly meet the customer's needs.

Crucibles or liners may hold a certain volume of material or can be continuously refilled. A water-cooled turntable can extract granular material from a funnel and deliver it to the hot spot of the impinging electron beam for flash evaporation.

The latter arrangement greatly preserves the chemical composition in the evaporation process of complex compounds containing components with largely differing vapor pressures. It is a THEVA proprietary development that has been used for long-term deposition of high temperature superconductors (e.g., $\text{YBa}_2\text{Cu}_3\text{O}_7$).

Technical Specs

Crucible evaporators

EB-C series

Type	Power (W)	Voltage (kV)
EB-C	600	6
EB-C	1200	6
EB-C	1800	6

Crucibles and liners

THEVA will custom design Tungsten crucibles with wire feeding or liners (e.g., graphite, alumina, zirconia) to meet customer requirements.

Operating conditions

Gas pressure	$< 4 \times 10^{-4}$ mbar
Water cooling	> 2 l/min @ 20 °C (max. 3 bar)
Evaporation material	metals
Material feeding	metal wire (0.5 – 1 mm diameter) from payout coil; several kg or km capacity
Deposition rates (@ 30 cm distance)	0.1 - 50 nm/s
Heat load	very low, since high rates can be realized with low power; excellent heating power/radiation ratio
Operating period	very long $\gg 100$ h (at high vacuum)
Servicing	visual control of filament and crucible; easy exchange
Contamination	none, e-beam source encapsulated

Pierce e-gun

EB-L series

Type	Power (W)	Voltage (kV)
EB-L	1800	6
EB-L	3000	6
EB-L	4500	6

Crucibles

THEVA offers customer support in implementing the Smart E-vaporator into a vacuum system. THEVA will design water-cooled evaporation stages or crucibles that meet the requirements of the customer.

Operating conditions

Gas pressure	$< 4 \times 10^{-4}$ mbar (custom-made, e.g. differential pumping)
Water cooling	(4 + 10) l/min @ 20 °C (max. 4 bar) e-gun + crucible 10 l/min with water-cooled turntable
Evaporation material	complex compounds (e.g., $YBa_2Cu_3O_7$) ; simple oxides (e.g., MgO), metals
Material feeding	grains or powder (0.1 – 10 mm)
Deposition rates (@ 30 cm distance)	0.1 - 100 nm/s
Heat load	very low for granulate (0.1 – 0.3 mm)
Operating period	long > 100 h (depending on processing gas); differential pumping available
Servicing	easy exchange of filament or filament block
Contamination	low, due to separation of beam generation and evaporation source, no direct line-of-sight