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ELECTRON BEAM FURNACES

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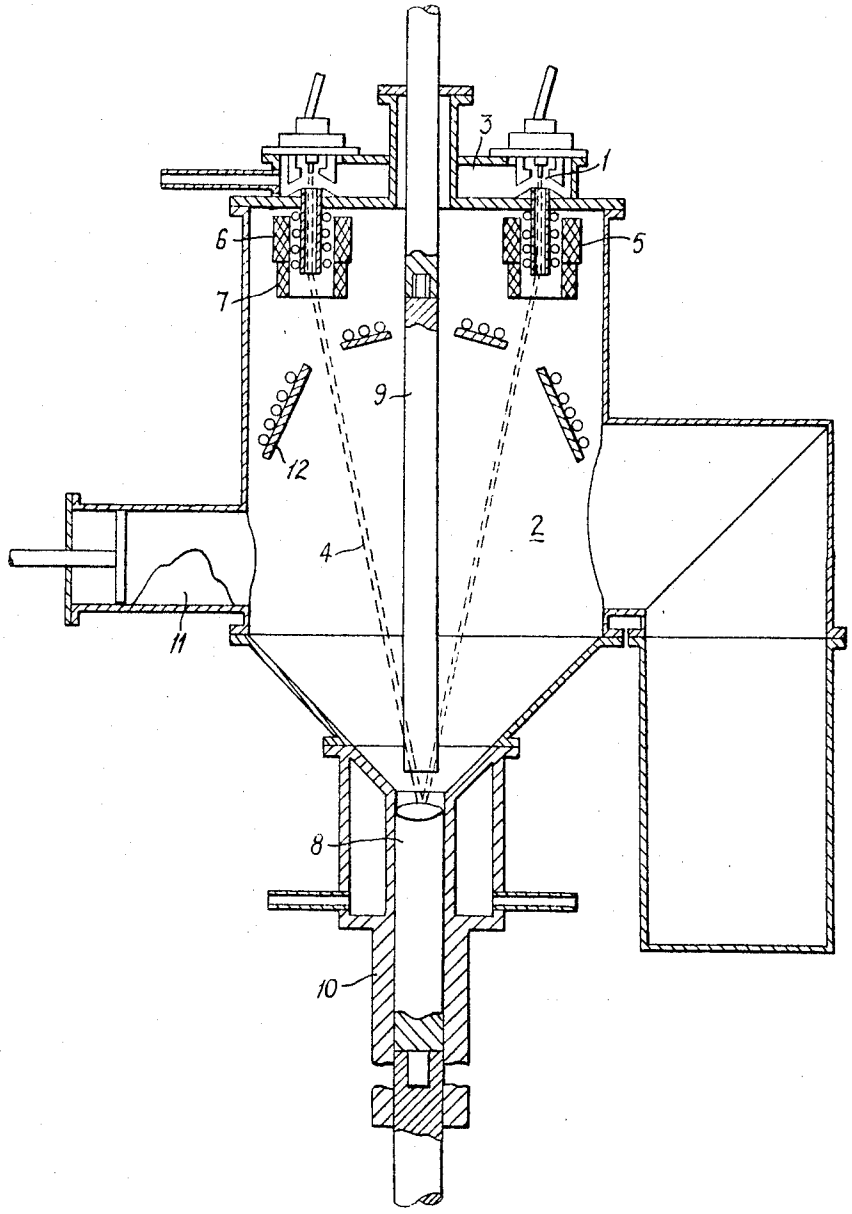

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ELECTRON BEAM FURNACES

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This invention relates to electron beam melting furnaces.

Electron beam melting furnaces can be employed for metals having a high melting point temperature, and for such elements as germanium and silicon and used for example for crystal production.

It is necessary, since an electron beam is used, to operate the furnace at a pressure below atmosphere. At the same time, owing to the high voltages employed with the gun it is necessary that the gun be at an appreciably higher vacuum than is necessary for the furnace.

Furthermore it is important to prevent the backward movement of positive ions along the beam which causes damage to the gun cathode.

The main object of the invention is to provide improved apparatus which satisfies these requirements.

According to the present invention an electron beam furnace comprises an evacuated melting chamber, a mould for an ingot at the lower end of the melting chamber, means for supporting a vertically extending feed rod over the ingot, and a plurality of electron guns located in a separate electron gun chamber which is adjacent to but evacuated to a lower pressure than the melting chamber, said electron gun chamber communicating with the melting chamber through beam ducts, there being a beam duct associated with each gun through which the beam passes into the melting chamber together with beam deflecting means whereby the electron beams entering the melting chamber are deflected out of alignment with the ducts to tend to trap positive ions from entering the beam ducts and so reaching the cathode.

The beam deflecing means may be electrostatic or electromagnetic. Preferably the electron guns have a line focus and are arranged to project electron beams downwards so that deflection of the beams perpendicularly to their greatest cross-section deflects the beams towards or away from the ingot.

Condensing surfaces may be arranged around the ingot on which vapour condenses and is reclaimed. The beams may pass through apertures in the condensing plates.

In order that the invention may be more clearly understood, reference will now be made to the accompanying drawing which shows a vertical sectional view of a furnace embodying the invention.

In the arrangement shown several electron guns **1** are mounted at the top of a melting chamber **2**. The guns are contained within a separately evacuated electron gun chamber **3** and each projects a line focus electron beam **4** which permits an efficient coverage of the ingot being melted. The power of the guns is controlled by the accelerating voltage applied, or the emission characteristics of the cathode. The beams pass into the melting chamber through water cooled ducts **5** which are of elongated cross-section to suit the line focus beams and are connected to, or below the anode. The ducts separating the melting chamber from the electron gun chamber allows a greater pressure differential to be obtained between the two chambers than an aperture in a plate.

Magnetic or electrostatic focussing coils **6** surround each of these ducts to focus the beams, while at the

end of the tubes magnetic or electrostatic deflection coils **7** are positioned to adjust the angle of incidence of the beams on the ingot **8**. This method allows easy control of the position of the heat input and allows various size ingots to be melted. Some of the beams can additionally be made to impinge on a feed rod **9** being melted, to drip melt the metal into the mould.

Moreover since the directions of the beam paths in the melting chamber are offset from the passages through the ducts, positive ions emitted from the bombarded surface and passing backwards along the beams are mainly deflected from the tube passages and hence the positive ions reaching the cathode are minimised.

A retractable water cooled copper mould assembly **10** is used to continuously produce an ingot whilst feeding the molten pool with metal to be melted. Additionally ingot feed may be by hopper feed **11** for feeding swarf powder or small scrap material.

Vapour condensing plates **12** are positioned in the chamber in optical line with the ingot on which volatilised metal can condense and thus the metal is not lost, and does not contaminate the chamber. These condensing plates would preferably be of the same material as the ingot being produced so that an efficient means is provided for reclaiming the volatilised metal, without the necessity for removing it from the separate condenser plates. The use of condensing plates of another metal is not precluded however. The main advantages of this invention can be summarised:

The use of deflection arrangements for the electron beam enables heat inputs of variable coverage to be obtained allowing various size moulds to be used, and the beams deflected to melt solid rod feed if required.

What I claim is:

1. An electron beam furnace comprising an evacuated melting chamber, an ingot mould, means for supporting a vertically extending feed rod over the ingot in said melting chamber, a plurality of electron guns located in a separate electron gun chamber and directed downwardly, said electron gun chamber being adjacent to said melting chamber, means for evacuating said gun chamber to a lower pressure than the melting chamber, beam ducts connecting the melting chamber and the electron gun chamber, there being a beam duct associated with each electron gun through which the beam passes into the melting chamber and beam deflecting means associated with each electron gun whereby the electron beams entering the melting chamber are deflected out of alignment with the beam ducts to tend to trap positive ions from entering the beam ducts and so reaching the cathode.

2. An electron beam furnace comprising an evacuated melting chamber, an ingot mould at the lower end of said chamber, means for supporting a vertically extending feed rod over the ingot in said melting chamber, a plurality of electron guns having a line focus located in a separate electron gun chamber and directed downwardly, said electron gun chamber being adjacent to said melting chamber, means for evacuating said gun chamber to a lower pressure than the melting chamber, beam ducts connecting the melting chamber and the electron gun chamber, there being a beam duct associated with each electron gun through which the beam passes into the melting chamber and beam deflecting means associated with each electron gun whereby the electron beams entering the melting chamber are deflected out of alignment with the beam ducts to tend to trap positive ions from entering the beam ducts and so reaching the cathode.

3. An electron beam furnace comprising an evacuated melting chamber, an ingot mould at the lower end of said chamber, means for supporting a vertically extending feed rod over the ingot in said melting chamber, a plurality of line focus electron guns located in a separate

electron gun chamber and directed downwardly, said electron gun chamber being adjacent to said melting chamber, means for evacuating said gun chamber to a lower pressure than the melting chamber, beam ducts connecting the melting chamber and the electron gun chamber, there being a beam duct associated with each electron gun through which the beam passes into the melting chamber and beam deflecting means associated with each electron gun whereby the electron beams entering the melting chamber are deflected out of alignment with the beam ducts to tend to trap positive ions from entering the beam ducts and so reaching the cathode, condensing surfaces for vapour around the upper part of the melting chamber and edges defining apertures in said condensing surfaces through which the beams pass.

4. The structure of claim 1, wherein an additional material feed duct is positioned in communication with said melting chamber.

5. An electron beam furnace comprising walling defining a melting chamber, means for evacuating said melting chamber, an ingot mould located in the lower part of said melting chamber, means for supporting a vertically extending feed rod over said ingot mould, walling defining an electron gun chamber located over the melting chamber, means for evacuating said electron gun chamber to a lower pressure than the melting chamber, electron beam ducts connecting the electron gun chamber with the melting chamber, a plurality of electron guns located in said electron gun chamber and directed downwardly to project electron beams through said electron beam ducts respectively on to an ingot in said mould and means for deflecting electron beams entering the melting chamber out of alignment with the beam ducts to deflect upwardly moving positive ions and prevent said ions entering the beam ducts and passing to the cathode.

6. An electron beam furnace comprising walling defining a melting chamber, means for evacuating said melting chamber, an ingot mould located in the lower part of said melting chamber, means for supporting a vertically extending feed rod over said ingot mould, walling defining an electron gun chamber located over the melting chamber, means for evacuating said electron gun chamber to a lower pressure than the melting chamber, electron beam ducts connecting the electron gun chamber with the melting chamber, a plurality of electron guns each having a line focus located in said electron gun chamber and directed downwardly to project electron beams through said electron beam ducts respectively on to an ingot in said mould and means for deflecting electron beams entering the melting chamber out of alignment with the beam ducts to deflect upwardly moving positive ions and prevent said ions entering the beam ducts and passing to the cathode.

7. An electron beam furnace comprising walling defining a melting chamber, means for evacuating said melting chamber, an ingot mould located in the lower part of said melting chamber, means for supporting a vertically extending feed rod over said ingot mould, walling defining an electron gun chamber located over the melting chamber, means for evacuating said electron gun chamber to a lower pressure than the melting chamber, electron beam ducts connecting the electron gun chamber with the melting chamber, a plurality of electron guns located in said electron gun chamber and directed downwardly to project electron beams through said electron beam ducts respectively on to an ingot in said mould, means for deflecting electron beams entering the melting chamber out of alignment with the beam ducts to deflect upwardly moving positive ions and prevent said ions entering the beam ducts and passing to the cathode and condensing surfaces for vapour around the upper part of the melting chamber and edges defining apertures in said condensing surfaces through which the beams pass.

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