

[54] **EMITTER BLOCK ASSEMBLY**

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[51] Int. Cl. .... **H05b 7/00**

[58] Field of Search ..... **13/31**

[56] **References Cited**

**UNITED STATES PATENTS**

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[57]

**ABSTRACT**

An emitter block assembly of an electron beam furnace includes a base maintained at a ground potential and a pair of spaced cathode blocks maintained at a high voltage of negative polarity with respect to the ground potential. A filament is electrically connected between the blocks. An alternating voltage of adjustable magnitude applied between the blocks controls a current through the filament. This current determines a rate at which electrons form an electron beam for the furnace. Ions impinging on surfaces of the blocks and of parts adjacent thereto tend to form conductive films thereon. To prevent such films from shorting the blocks to each other, each of the blocks mounted separately to high voltage insulators extending from the base in areas removed from the main path of the ions. Additionally, the insulators are shielded by spaced metal jackets to prevent a conducting film from forming on the insulators.

**7 Claims, 2 Drawing Figures**

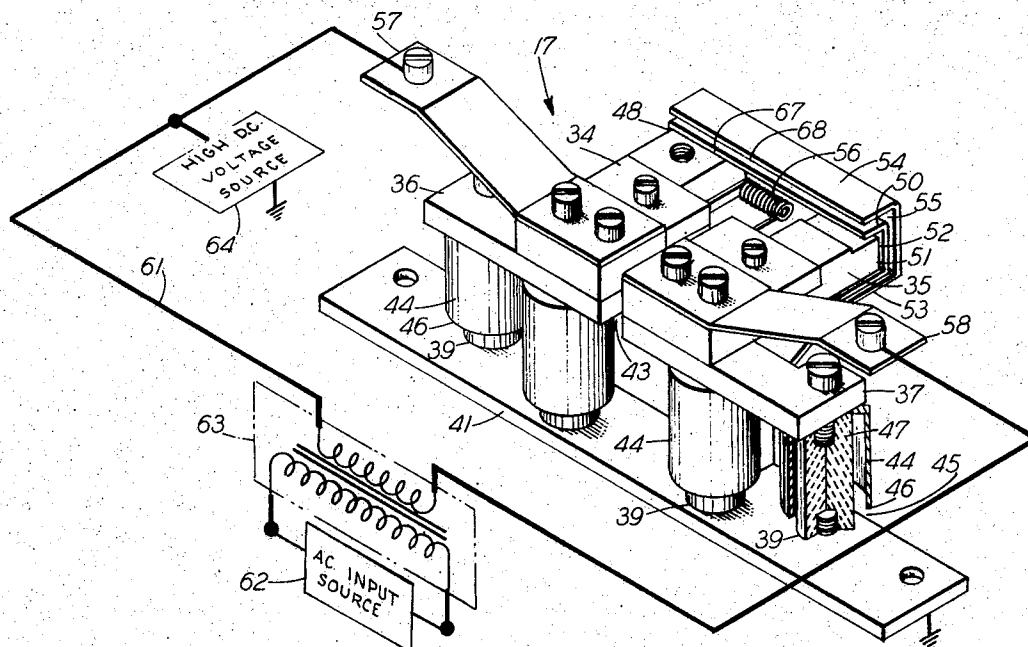


FIG.-1

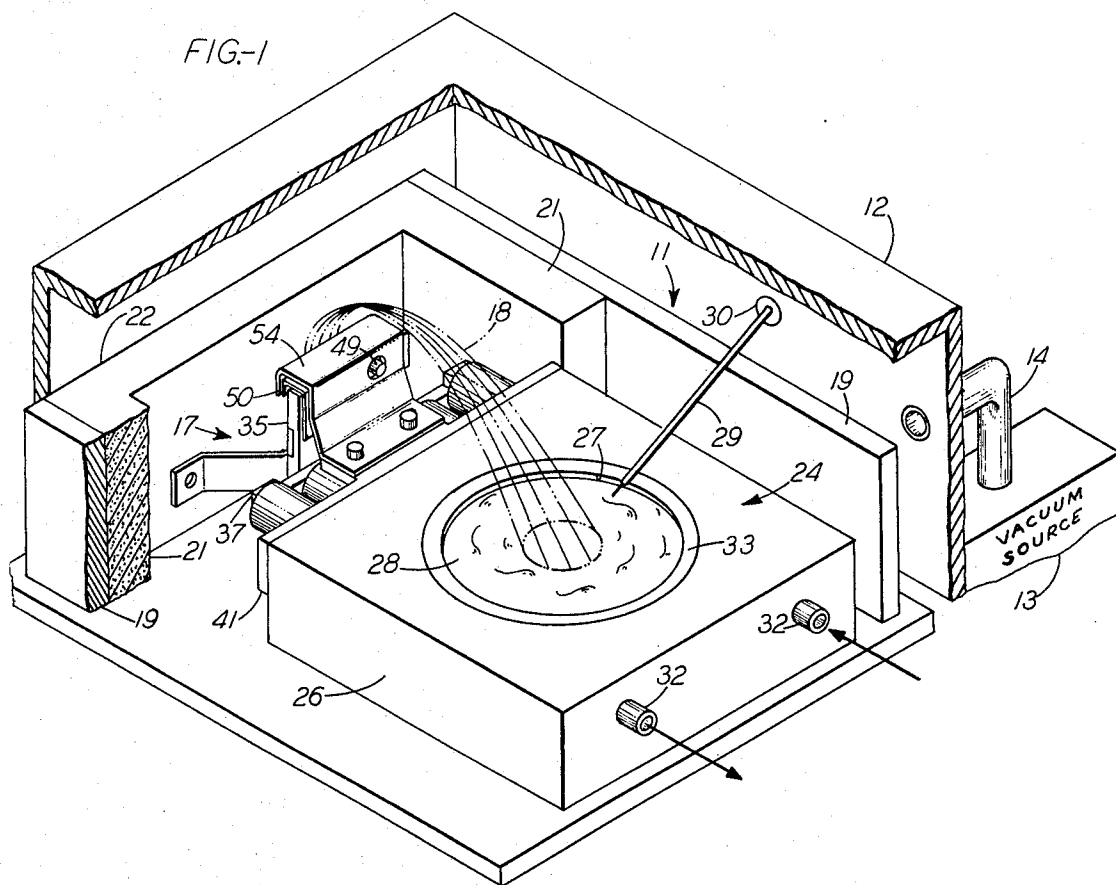
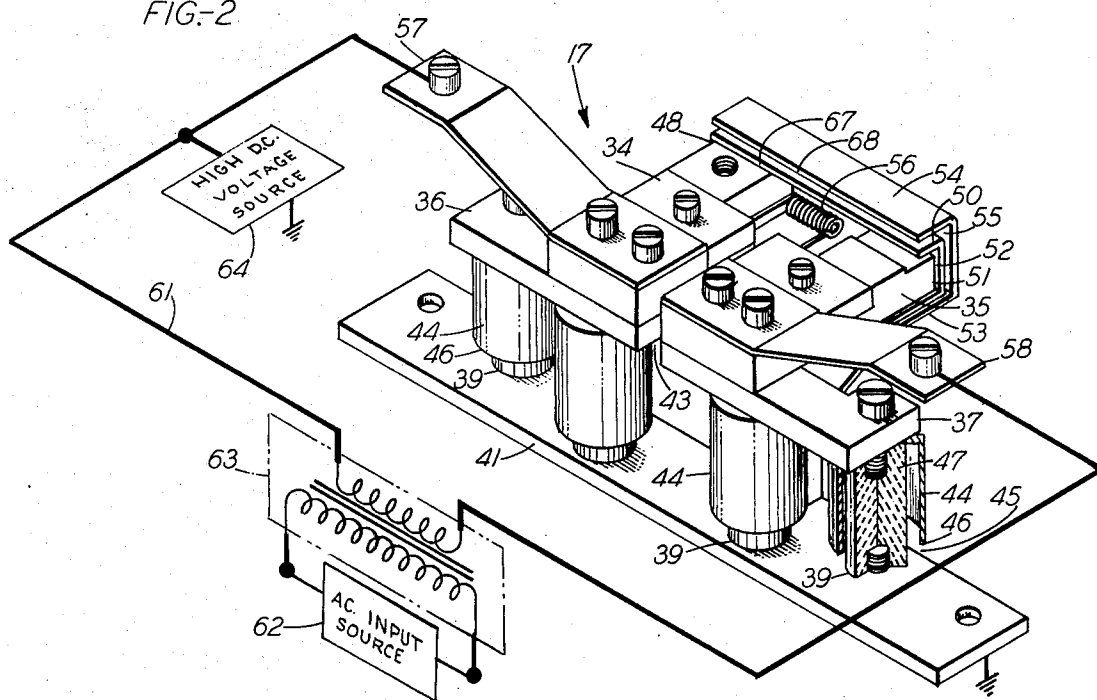


FIG.-2



## EMITTER BLOCK ASSEMBLY

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates to electron beam furnaces, and more particularly, to improvements in emitter block assemblies of such furnaces.

#### 2. Discussion of the Prior Art

An electron beam furnace generally includes a vacuum enclosure, facilities for generating an electron beam, and other facilities for directing the generated beam toward a target material to impinge upon and heat the material. An emitter block assembly of an electron beam furnace is part of the facilities for generating an electron beam.

These furnaces are capable of heating relatively small amounts of material to extremely high temperatures. As a result, electron beam furnaces often form a part of a vapor deposition apparatus for depositing thin coatings of material on workpieces. The vapor deposition apparatus is advantageously used in the manufacture of microcircuits for depositing conductive layers of material on substrates.

In depositing conductive layers the vapor deposition apparatus is housed in an enclosure capable of retaining a vacuum. Among other things, this enclosure usually contains a plurality of electron beam furnaces. The presence of more than one electron beam furnace within the enclosure permits a corresponding number of different materials or metals to be sequentially evaporated onto substrates at various work stations within the enclosure.

In operating the vapor deposition apparatus, substrates are loaded into or unloaded from the apparatus sequentially through a vacuum lock. The vacuum lock permits the continuous operation of the apparatus without excessive pressure variations within the vacuum enclosure of the apparatus each time substrates are loaded or unloaded.

However, to obtain access to assemblies within the enclosure, as for instance, to service such assemblies, air has to be admitted to the enclosure before the enclosure can be opened. For example, to service the electron beam furnaces a complete shutdown of the apparatus becomes necessary.

It is, therefore, desirable to provide assemblies within the enclosure which do not require frequent maintenance. Extended maintenance intervals of the vapor deposition apparatus decreases its downtime and raises its efficiency, thus lowering the cost of devices processed by such apparatus.

The emitter block assembly of the electron beam furnace includes a filament mounted between two spaced electrodes. An alternating current passing through the filament heats it and raises the energy level of the electrons therein to boil them from the filament.

By maintaining the filament and an associated cathode cap at a high negative potential in proximity of a ground or neutral potential, an electrostatic field is generated at the filament. In this field the electrons emitted from the filament are accelerated in the direction of the field to form an electron beam away from the filament.

A prior art emitter block assembly includes a base which is held at ground potential. Spaced therefrom

through ceramic insulators is a single cathode bracket at a high negative potential.

A first block is mounted directly to the bracket and a second block is mounted spaced from the first and separated from the bracket by ceramic insulators to permit a low alternating potential to be sustained between the two blocks. A filament is mounted between the blocks by attaching an end of the filament to each of the blocks. The aforementioned cathode cap is attached to the first block and extends parallel to the filament toward the second block. However, the cap is spaced from the second block by a ceramic insulator. An anode cap extends from the base toward and parallel to the cathode cap. The cathode and anode caps provide an electrostatic field to accelerate electrons once they have formed as an electron cloud at the filament.

An alternating current at a low potential is applied through the filament by coupling each of the cathode blocks to one of the terminals of a secondary coil of a stepdown transformer. The secondary coil of the transformer is insulated from its primary coil by high voltage insulation. The insulation permits the secondary circuit to be subjected to or float on the high negative potential applied to the bracket while the alternating potential in the primary coil of the transformer remains referenced to ground.

In the operation of an electron beam furnace containing the described emitter block assembly, ion bombardment is directed against the assembly. Apparently, electron bombardment of the material to be heated generates positively charged ions. The positive ions follow substantially the same path of the electrons but in the opposite direction and impact on the emitter block assembly. Upon striking the emitter block assembly, ions neutralize and again become a metal.

In bombarding the emitter block assembly, some of the ions strike the insulators separating the second cathode block from the bracket. It has been discovered that as a coating of metal accumulates on the insulators, the insulators become increasingly conductive to partially short out the alternating potential between the first and the second blocks. Consequently, the filament sees less and less current and becomes less and less heated. As a direct result of the decreased heating of the filament, the electron beam decreases rapidly.

Frequent failures of the emitter block assemblies in vapor deposition apparatus have been attributed directly to the partially shorted insulators for mounting the secondary cathode block to the bracket. Since every one of the emitter block assemblies in the deposition apparatus experiences similar failures, the described apparatus has to be shut down frequently to permit the emitter block assemblies in the enclosure to be replaced.

To economize on the operation of such an apparatus, it is desirable to minimize the failures occurring in the emitter block assemblies.

### SUMMARY OF THE INVENTION

According to the invention, a novel emitter block assembly includes a base, and at least one insulator mounted to the base. First and second cathode blocks are mounted to the insulator with a gap between each of the blocks. A filament is attached with one end to each of the blocks. Provisions are made for applying a first potential between each of the blocks and the base,

and for applying a second potential between the first and the second blocks to cause a current to flow through and heat the filament. Provisions for applying an electrostatic field adjacent the filament permit a stream of electrons to be drawn from the heated filament.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The advantages of such a novel emitter block assembly will become more apparent when read in conjunction with the following detailed description and the accompanying drawings wherein:

FIG. 1 is an isometric view, partially in section, of an electron beam furnace; and

FIG. 2 is an isometric view of an emitter block assembly of FIG. 1 and of a schematic diagram showing electrical connections made to the emitter block assembly.

#### DETAILED DESCRIPTION

The present invention is best described in reference to the environment in which it operates and in reference to major associated apparatus elements. FIG. 1 shows an electron beam furnace partially in section, which is designated generally by the numeral 11. The furnace 11 is housed in an enclosure 12 of which only a portion is shown. The enclosure 12 is part of a major piece of apparatus, such as, for example, a vapor deposition apparatus used in the production of microcircuits.

A vacuum pumping system 13 coupled to the enclosure 12 by appropriate piping 14 maintains a high vacuum within the enclosure while the apparatus is operating. The vacuum within the enclosure 12 is typically in the order of  $100^{-6}$  Torr.

The furnace 11 includes an emitter block assembly, designated generally by the numeral 17. This assembly 17 generates free electrons and accelerates the electrons so generated to form a beam 18 of electrons.

The electrons are accelerated toward a magnetic field extending between two poles 19 of a magnet 21, one pole of which has been omitted in FIG. 1 to more clearly portray other elements of the apparatus. The field of the magnet 21 is controllable by electrical inputs to coils mounted in a base 22 of the magnet 19. The field of controlled strength deflects the electrons at right angles to the direction of the field and to their undeflected paths to direct the electron beam 18 in a curved path toward a target, designated generally by the numeral 24.

The target 24 is basically a crucible 26 which is preferably made of copper. An open cavity 27 in the center of the crucible 26 retains a target material 28 which is to be vaporized. When the magnetic field is properly adjusted, the electron beam 18 strikes the material 28 in the center of the cavity 27 to vaporize the material.

As the material 28 in the cavity 27 becomes vaporized, it is continually replenished by a supply wire 29 fed into the enclosure 12 through a vacuum port 30.

To prevent the crucible 26 from overheating and from melting, the crucible is preferably liquid-cooled. Tubular passages 32 through the crucible 26 are externally connected to a source of recirculating liquid coolant (not shown). The temperature of the coolant is controllable to prevent heat damage to the crucible 26. In addition, when a heat-conductive material as, for in-

stance, gold or aluminum is to be evaporated, a liner 33 of an insulating material such as carbon prevents an excessive amount of energy to pass into the crucible 26.

As the beam 18 strikes the material 28 in the crucible 26, the material 28 becomes heated and vaporized. Portions of the vaporized material 28 becomes ionized. The ions, being charged with a polarity opposite to that of the negative electrons react to the electrostatic and magnetic fields of the furnace 11 and travel along substantially the same path in a direction opposite to the direction of travel of the electrons. Having larger masses than the electrons, the ions follow a path with a larger radius and strike portions of the emitter block assembly 17.

FIG. 2 shows an enlarged view of the emitter block assembly 17 of FIG. 1. The assembly 17 of FIG. 1 has been oriented in FIG. 2 to portray more clearly particular elements of interest of the assembly 17. Particular attention is directed to cathodes or cathode blocks 34 and 35. These blocks 34 and 35 have been isolated from each other to prevent the ion bombardment of the assembly 17 from electrically shorting the block 34 to the block 35.

The blocks 34 and 35 are mounted to separate supporting brackets 36 and 37, respectively. A pair of cylindrical insulators 39 spaces each of the blocks 34 and 35 and their related brackets 36 and 37 from a common base 41. A gap 43 separates the bracket 36 from the bracket 37 as well as it separates the block 34 from the block 35.

The insulator 39 for mounting the cathode blocks 34 and 35 and their associated brackets 36 and 37 are pair-wise removed from the center of the emitter block assembly 17. The center region of the assembly 17, located on either side of the gap 43, is particularly subjected to such ion bombardment.

In addition to being removed from the center of the assembly 17, the insulators 39 are also shielded from ion bombardment by cylindrical metal cups 44. One of these cups 44 is placed coaxially over each of the insulators 39. The cups 44 extend from the brackets 36 and 37 toward the common base 41. A gap 45 between rims 46 of the cups 44 and the base 41 maintains electrical isolation between the brackets 36 and 37 and the base 41. Ions which would otherwise strike the insulators 39, and form a bridging conductive coating on their surfaces, are instead stopped in their path by the metal cups 44.

The insulators 39 are commercially available. They are of solid ceramic material and are axially tapped at each end to be easily attached to one of the brackets 36 and 37 and to the base 41.

The cathode blocks 34 and 35 are cantilevers, extending from their mountings at the brackets 36 and 37 toward the top (as oriented in FIG. 1) of the assembly 17. The block 34 is longer than the block 35. At an end 48 the block 34 has a provision 49 for mounting a cathode plate or cathode cap 50.

The cap 50 extends from the block 34 toward and across an end 51 of the block 35. Because of the difference in length between the blocks 34 and 35, the cathode cap 50 remains spaced from the block 35 by a gap 52.

Mounted to the base 41 is an anode plate or anode cap 53. An upper end 54 of the anode cap 53 is formed to extend spaced from, but parallel to the cathode cap

50, such that a gap 55 exists between the cathode cap 50 and the anode cap 53.

Except for the insulators 39 spacing the cathode blocks 34 and 35 from their common base 41, and as further described, the blocks 34 and 35 are not physically connected to each other. However, a filament 56 is mounted between the blocks 34 and 35 to provide electrical continuity between the two blocks. Terminals 57 and 58 are connected to the blocks 34 and 35, respectively, to provide a means for coupling the block assembly 17 to electrical circuitry.

In FIG. 2 a schematic diagram of control circuit 61 for the emitter block assembly 17 is shown. The circuit 61 includes an A.C. power source 62 coupled to a step-down transformer 63. The transformer 63 is insulated to sustain a high voltage in excess of 10,000 volts between its primary and secondary coils. A secondary output of the transformer 63 is coupled to the terminals 57 and 58 respectively. The transformer 63 is typically operated with a controlled A.C. input voltage from the source 62 which is variable between 0 and 115 volts. A resulting secondary output voltage typically ranges between 0 and 12 volts A.C., respectively. The secondary output voltage is applied between the terminals 57 and 58. This voltage is sustained between the blocks 34 and 35 and applied to the ends of the filament 56.

As a result of the voltage applied to the filament 56 it becomes heated. The energy level of electrons moving through the filament 56 is raised and the electrons start to boil off the filament. A D.C. high voltage source 64 is coupled to the secondary circuit of the transformer 62 and to ground. The base 41 is also coupled to ground to establish a high voltage potential between the blocks 34 and 35 and the base 41. The high voltage source 64 has its negative terminal connected to ground. In a typical operation, the voltage applied to the cathode is in the order of negative 10,000 volts.

The high voltage source 64 having its output coupled to the secondary circuit of the transformer 62 causes the secondary circuit including the cathode blocks 34 and 35 and the filament 56 to be referenced to or float on the output voltage of the source 64. Since the voltage source 64 puts out a steady state voltage, the inductance of the transformer 62 is not seen by such a voltage. Consequently, the negative high voltage is applied to both terminals 57 and 58 regardless of whether the connection from the high voltage source 64 is made directly to terminal 57 or terminal 58 or to both.

Applying the output voltage to the cathode block 34 subjects the cathode cap 50 to the same potential. The anode cap 53, on the other hand, is mounted to the base which is coupled to ground. Because of the narrow gap 55 between the cathode cap 50 and the anode cap 53 and the high potential applied between the caps 50 and 53, a strong electric field exists between the surfaces of the caps 50 and 53.

The filament 56 is located adjacent an edge 67 of the cathode cap and in proximity to an edge 68 of the anode cap 53 which extends parallel to the edge 67 and the filament 56. In a region near the edges 67 and 68, the field between the anode and cathode caps 50 and 53 experiences a fringing toward the filament 56. Electrons boiling off the filament enter the field. The field accelerates the electrons boiled off the filament 56 and propels them through the magnetic field of the magnet 21.

Because of complete physical separation between the two blocks 34 and 35, ion bombardment near the center of the assembly along the gap 43 is not capable of forming a bridging coating on insulators between the two blocks 34 and 35. In the absence of such bridging coating the resistance of the two blocks 34 and 35 is determined by the resistance of the filament. Consequently, the current flowing through the filament 56 is controllable (typically in the order of 20-50 amps), by varying the voltage of the AC power source 62. The amount of current through the filament 56 in turn controls the rate at which electrons are boiled off the filament 56 to form the beam 18.

The described improvement of the emitter block assembly 17 increases the life of the assembly 17 and reduces the operating costs of the electron beam furnace 11 and its associated apparatus.

While a specific embodiment of the invention has been referred to, it must be understood that modifications to the embodiment can be made without departing from the spirit and scope of the disclosed invention.

What is claimed is:

1. An emitter block assembly comprising:
  - a base;
  - first and second cathode blocks;
  - at least two insulators, of which at least one is mounted to each of the two blocks and to the base, such insulator spacing the respective block from the base and from the other of the two blocks with a gap between the blocks, each insulator being located away from the gap;
  - a filament, coupled between the blocks, the filament being the only element bridging the gap between the two blocks; and
  - means for applying a first potential between the blocks and the base and a second potential between the first and the second blocks.
2. An emitter block assembly according to claim 1, comprising two pairs of insulators, each pair of insulators being mounted to the base and each pair having one of the blocks mounted thereto.
3. An emitter block assembly according to claim 2, wherein each cathode block comprises a mounting bracket and a cathode, each mounting bracket being mounted to one of the pairs of insulators, and each of the cathodes being mounted to its respective mounting bracket.
4. An emitter block assembly according to claim 3, further comprising shields extending from the mounting brackets about each of the insulators toward the base, the shields being spaced from the insulators and from the base to sustain an electrical potential of the magnitude of the first potential across a gap between the shields and the base.
5. An emitter block assembly according to claim 1, wherein the means for applying the potentials comprises a high voltage source of negative polarity with respect to a neutral ground, an alternating low voltage source, and electrical circuitry including a terminal on each of the blocks to apply the high voltage to each of the blocks and the ground to the base and an alternating low voltage across the two blocks to cause an alternating current to flow through the filament and heat the filament.
6. An improved emitter block assembly for generating an electron beam in an evacuated enclosure, in-

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cluding a pair of cathode blocks mounted with a gap therebetween to support an alternating potential between the blocks, an electron emitting filament mounted electrically between the blocks, and a base spaced from the blocks and the filament for supporting a high voltage difference between the blocks and the base, wherein the improvement comprises:

a pair of supporting brackets, each bracket being attached to one of the blocks to support the blocks, and each bracket located one side of the gap and its extension toward the base; and means, for mounting the brackets to the base, and for

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electrically insulating the brackets from the base, the mounting and insulating means being located on both sides of and away from the gap and its extension toward the base, such that no element other than the filament bridges the gap between the blocks.

7. An emitter block assembly according to claim 5, further comprising means for applying an electrostatic field adjacent the filament to permit a stream of electrons to be drawn from the heated filament.

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