

[54] **HIGH VACUUM, FIELD EFFECT ELECTRON TUBE**

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[51] Int. Cl. **H01j 1/16, H01j 19/10**

[58] Field of Search. **313/309, 336, 351**

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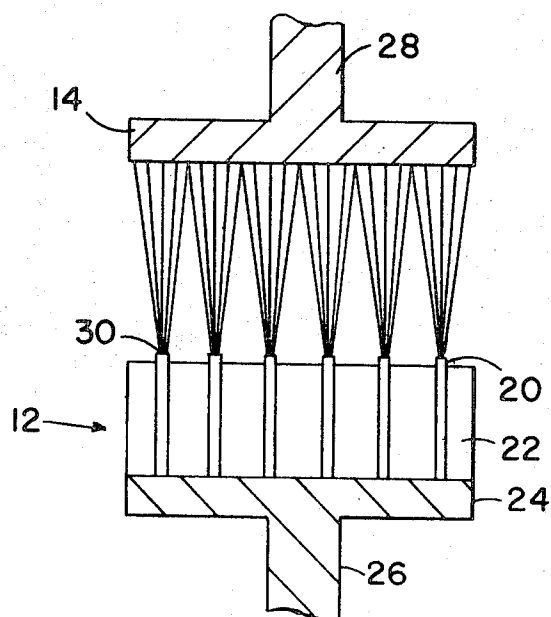
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[57] **ABSTRACT**

An improved electron tube is provided which eliminates the need for a heated electron source and affords simplified construction. The tube, a high vacuum tube, is capable of operating over an extended range of electrical potentials. The electron tube operates on the principle of electric field effect emission for the electron source, requiring neither gas, vapor nor a heated electrode in its envelope. Two active elements, an emitter and a collector, are enclosed in an evacuated chamber with outside connections to each element. The collector is a metal plate and the emitter is an oxide-metal composite which contains a very large number of metal filaments embedded in an insulating oxide matrix. The number of filaments normally exceed one million per square centimeter of exposed surface, having ends connected on the back side to a conducting plate for external connection.

3 Claims, 6 Drawing Figures



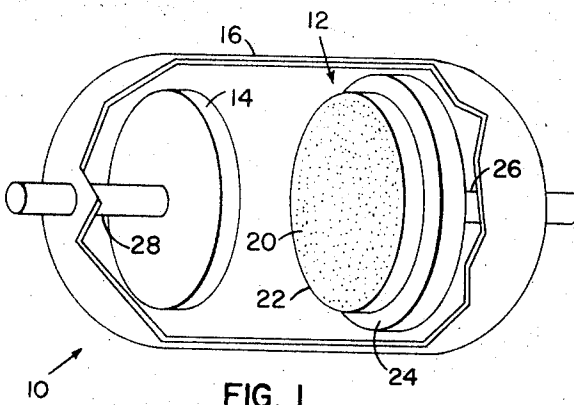


FIG. 1

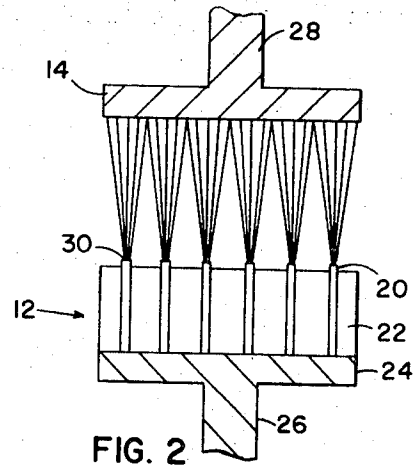


FIG. 2

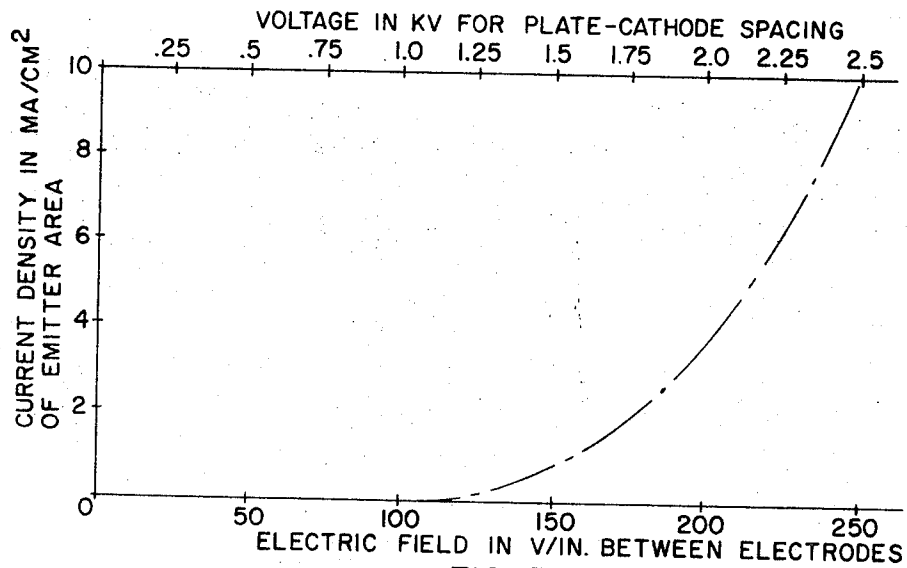


FIG. 3

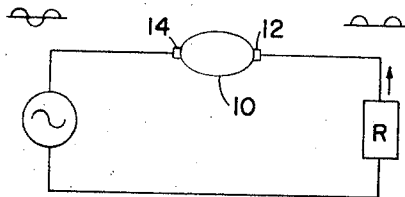


FIG. 4

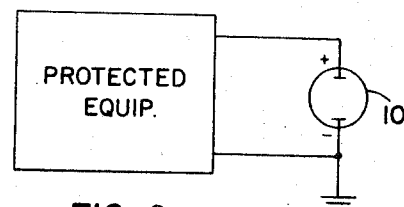


FIG. 6

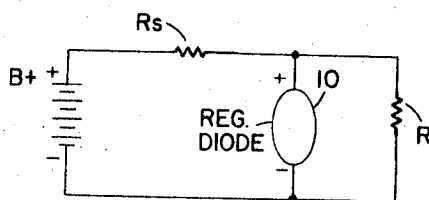


FIG. 5

HIGH VACUUM, FIELD EFFECT ELECTRON TUBE

BACKGROUND OF THE INVENTION

Prior art diode tubes include the high vacuum and the gas or vapor filled tube. The gas filled tube is capable of drawing large currents but is usually limited to low voltages because of arcing and ultimate tube damage at high voltages. The gas filled tube usually operates with a cold emitter and is capable of regulating voltages of the order of only a few hundred volts. The high vacuum tube, often used for high voltage rectification is expensive and fragile. Heater-emitter isolation is difficult to achieve and a warm-up time is required before operation of the tube can begin. Special designs are required to contain the heat at the thermionic emitter and to reduce damage caused by the transfer of heat from the thermionic emitter to other tube components. Cooling devices are required on high power tubes to dissipate the heat that leaks from the thermionic emitter.

SUMMARY OF THE INVENTION

The present invention is a field effect, diode electron tube capable of operating over an extended range of potentials. The high vacuum, field effect tube requires no gas in the envelope, no heated (thermionic) emitter, and can be designed for operation over an extremely wide range of potentials and power requirements. This field effect electron tube utilizes field emission as a means for obtaining electrons from the emitter or cathode. Operation over an extended voltage range is achieved by varying the spacing between the two elements, emitter and collector, to obtain the desired electric field for the required current at the specified operating potential. Due to the fact that current is a function of the electric field only, for a given emitter, the electron tube is capable of operating over a greater voltage range than conventional electron tubes used in similar functions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a preferred embodiment of the field effect, diode vacuum tube.

FIG. 2 is a diagrammatic, enlarged view of the electrodes and the electric field therebetween.

FIG. 3 is a typical voltage current curve for the field effect diode tube.

FIG. 4 is a typical rectified circuit employing the field effect diode tube.

FIG. 5 is a typical voltage regulation circuit utilizing the present invention as a voltage regulator.

FIG. 6 shows a field effect, diode tube in a typical over voltage protection configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, wherein like numerals represent like parts in each figure, FIG. 1 discloses a preferred embodiment of the present invention. A high vacuum, cold cathode diode 10 comprises two active elements, an emitter 12 and a collector 14. An envelope 16 forms an evacuated (vacuum) chamber housing the active elements. Envelope 16 may be constructed of glass, ceramic or metal with insulating feed-throughs for external circuit connections. Collector 14 is a metal plate which may be constructed of molybdenum, tungsten or other metal suitable as an anode or

electron collector. Emitter 12 is an oxide-metal composite which contains metal rods 20 (filaments) embedded in an insulating oxide matrix 22. The rods may also be of molybdenum, tungsten or other suitable metal. Oxide 22 can be formed of any suitable oxide, such as uranium oxide which will insulate adjacent filaments.

Metal rods 20 are less than 1 micron in diameter and the quantity exceeds one million in each square centimeter of material. Rods 20 extend through the matrix and are attached to a metal backing plate 24 by brazing or soldering such that both thermal and electrical contact is made between the metal rods in the emitter and the backing plate. The emitter backing plate 24 and collector 14 are connected to metal rods 26 and 28 respectively which feed through the insulated envelope 16 for providing external electrical connectors.

As an electrical potential is applied across the terminals of field effect tube 10, an electric field is generated in the region between collector (anode) 14 and the oxide-metal matrix emitter (cathode) 12. As depicted in the enlarged view of FIG. 2, the electric field concentrates on the ends of metal rods 20. A high electric field is concentrated at these end points or surfaces 30. The electric field causes emission of electrons from surfaces 30, with the electrons being drawn to collector 14, causing current to flow. The amount of current flow depends on the field, the filament diameter and the number of filaments in the matrix. A small filament diameter enhances electron emission from the end thereof. These parameters are adjustable in conjunction with the emitter size for various applications ranging from low voltages to extremely high voltages. The theory of electric field emission from point sources is well established and is applicable to the emitter filaments. When a potential is applied to the tube, the non-uniform electric field is concentrated between collector 14 and the ends of each filament 20.

The field effect diode affords circuit over-voltage protection and is capable of satisfactory operation over a large range of potentials. No energy source is needed for over-voltage protection and the response time is limited only to the time required for the electrons to cross the small gap between the two conductors.

A voltage-current curve is shown in FIG. 3 for a typical tube 10. From this curve it is apparent that no current is drawn for lower voltages, but once a voltage is reached that is sufficient for electron flow, the increase in current is exponential as the voltage increases. The voltage at which the field-effect tube begins to draw current can be varied by fabricating the tube with electrode spacing which allows current flow to begin at the desired voltage. Maximum allowable currents are determined by emitter size.

FIG. 4 discloses tube 10 connected between an alternating current generator and a load R for providing typical rectification of the generated signal. When an ac voltage is applied to anode 14, current will flow through tube 10 and load R with an electric potential being developed across R when the anode is at a higher potential than emitter 12, or for one-half cycle. During the other half-cycle, no current flows through the tube. Suitable capacitors, chokes and resistors can be added for filtering, and two devices can be used for full wave rectification as done in conventional rectifiers.

In FIG. 5 field effect tube 10 is shown functioning as an extended range, voltage regulator similar in opera-

tion to operation of other voltage regulating devices. Tube 10 is typically connected in parallel with a load R across a battery B+ and in series with a resistance Rs. During operation, a steady current is maintained through tube 10 as long as the source voltage B+ is constant. However, variation of the B+ level changes the current through diode 10. Hence, when the potential of the source increases, the current through the regulating diode 10 increases in an exponential manner, dropping more voltage across Rs and regulating the potential supplied to load R.

In FIG. 6, field effect tube 10 is shown functioning as an over-voltage protection unit. Tube 10 is typically connected in parallel across the device or equipment to be protected and is designed such that no current flows through the tube under normal conditions. However, when the voltage on the equipment to be protected begins to increase, due to static charges, lightning, surges, or other reason, current will flow through field effect tube 10 which in turn removes the charge from the device or equipment to be protected. Although not limited thereto, applications of the field effect diode include protecting delicate electronic equipment from line surges, extinguishing arcs in switches and draining off lightning strikes on missiles and other aircraft.

This field effect diode provides a multitude of advantages over prior art devices. Since the emitter operates at ambient temperature, no power is required to heat the emitter, which results in an inherently more efficient device. The current flow in the tube, for a given emitter, is a function of the electric field, thus allowing the emitter to be used for numerous functions over a wide range of potentials by varying the spacing between the emitter and the collector to achieve the required electric field for the specific application. The design of the emitter is simplified since it is not necessary to contain the heat at the emitter as in designs that use thermionic emitters. The curve of voltage versus current for a diode using a field effect emitter, as shown in FIG. 3, is different from curves obtained from gas filled diodes and diodes with thermionic emitters. The curve obtained from the diode using the field effect emitter is continuous and the same basic equation holds for current values over several orders of magnitude. No breaks are apparent such as in the curve for thermionic emitters in the region where emitter saturation begins to occur. No electrons flow at zero potential as in a diode with closely spaced elements using a thermionic emitter. Unlike the gas filled tube which requires an activation voltage greater than the operating

voltage, the diode containing a field effect emitter begins to draw current at lower voltages, thus providing better over-voltage protection for equipment than the gas filled tube.

Although a particular embodiment and form of the invention has been described, it will be obvious to those skilled in the art that modifications may be made without departing from the scope and spirit of the invention. Accordingly, it is understood that the invention is limited only by the claims appended hereto.

We claim:

1. A high vacuum electron tube having an extended range of operation and comprising: first and second electrodes in spaced apart, coaxial relationship; a vacuum housing assembly for encompassing said electrodes; first and second conductors connected respectively to said first and second electrodes and extending external of said housing for applying an electric potential thereto whereby an electric field and current flow is provided between said electrodes, and said first electrode having a plurality of parallel surfaces for emitting electrons at prevailing ambient temperatures toward said second electrode; said first electrode is an emitter assembly having a plurality of equally spaced parallel rods and said second electrode is a collector, said emitter having a plurality of uniformly spaced elongated rods having a minimum density of one million rods per square centimeter and extending toward said collector for providing current flow between the collector and emitter; said rods being of equal length, and having one end thereof in common; and said common ends being coupled to said first conductor; a backing plate electrically connected between one end of said rods and said conductor, and an insulating filler between said rods; said second electrode is a planar collector having the collecting surface normal to the coaxially aligned electrodes; and said rods having the other ends thereof terminated in a plane parallel with said collecting surface for providing an electric field between each of said rods and said collecting surface and current flow therebetween when a potential difference is developed across said electrodes; and wherein said filler is an oxide-metal matrix.

2. An electron tube as set forth in claim 1 wherein said rods are less than 1 micron in diameter.

3. An electron tube as set forth in claim 1 wherein said first electrode is an emitter requiring no heat for operation, current flow through the tube being a function of the field between the electrodes.

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