

[54] **HIGH-EMISSION COLD CATHODE**

[75] Inventor: **Lloyd Mancebo**, Livermore, Calif.

[73] Assignee: **The United States of America as represented by the United States Atomic Energy Commission**, Washington, D.C.

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313/357

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[58] Field of Search **29/25, 18; 313/33, 205, 210,**
313/211, 336, 351, 357; 330/4.3; 331/94.5

[56] **References Cited**

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Primary Examiner—Maynard R. Wilbur

Assistant Examiner—N. Moskowitz

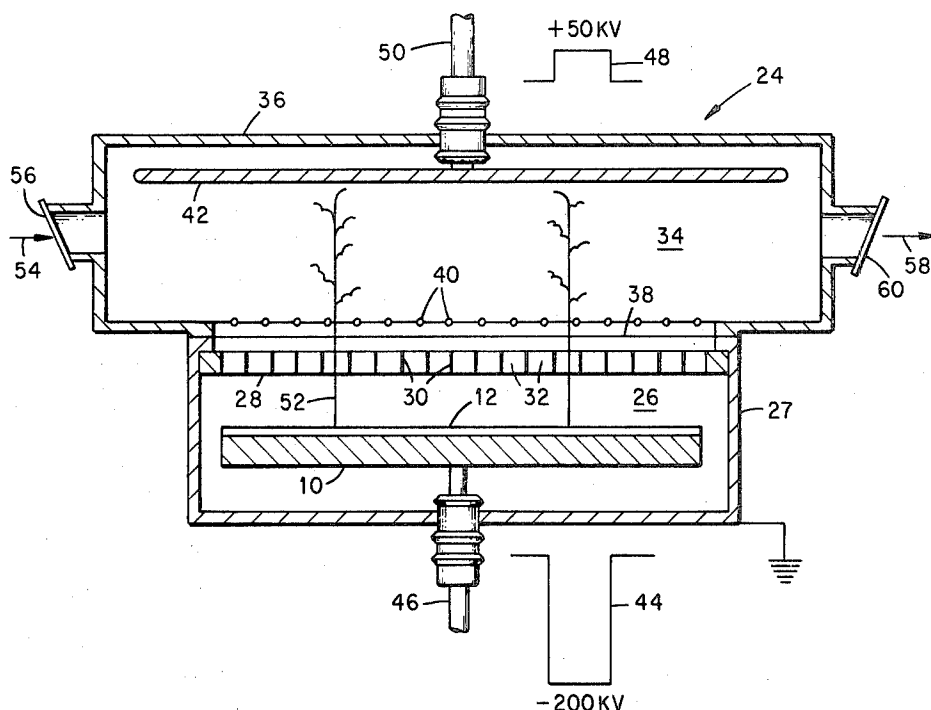
Attorney, Agent, or Firm—John A. Horan; Frederick A. Robertson; Clifton E. Clouse, Jr.

[57] **ABSTRACT**

A field-emission cathode having a multitude of field emission points for emitting a copious stream of electrons when subjected to a high field. The cathode is constructed by compressing a multitude of tungsten

strips alternately arranged with molybdenum strips and copper ribbons or compressing alternately arranged copper plated tungsten and molybdenum strips, heating the arrangement to braze the tungsten and molybdenum strips together with the copper, machining and grinding the exposed strip edges of one side of the brazed arrangement to obtain a precisely planar surface, etching a portion of the molybdenum and copper to leave the edges of the tungsten strips protruding for electron emission, and subjecting the protruding edges of the tungsten strips to a high electric field to degas and roughen the surface to provide a large number of emitting points. The resulting structure is particularly useful as a cathode in a transversely excited gaseous laser where the cathode is mounted in a vacuum chamber for emitting electrons under the influence of a high electric field between the cathode and an extractor grid. The electrons pass through the extractor grid, a thin window in the wall of the laser chamber and into the laser chamber which is filled with a gaseous mixture of helium, nitrogen and carbon dioxide. A second grid is mounted on the gaseous side of the window. The electrons pass into the laser chamber under the influence of a second electric field between the second grid and an anode in the laser chamber to raise selected gas atoms of the gaseous mixture to appropriately excited states so that a subsequent coherent light beam passing through the mixture transversely to the electron stream through windows in opposite ends of the laser chamber stimulates the excited atoms to amplify the beam.

3 Claims, 4 Drawing Figures



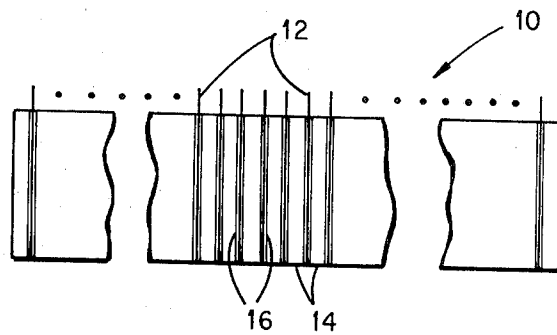


Fig. 1

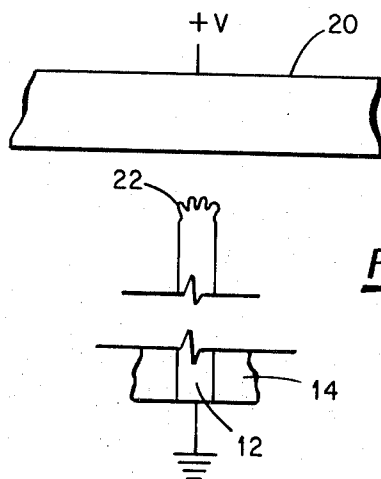


Fig. 3

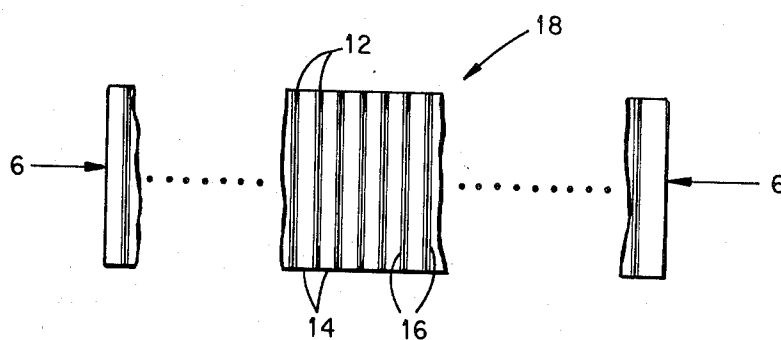


Fig. 2

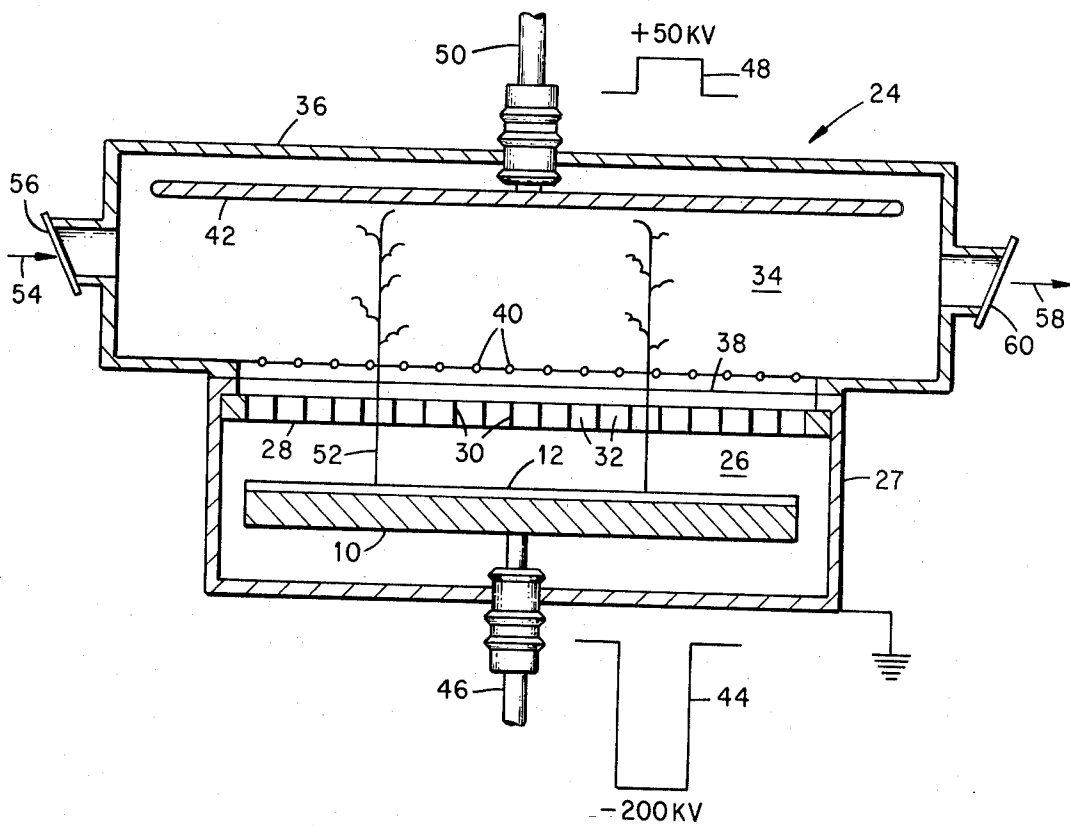


Fig. 4

HIGH-EMISSION COLD CATHODE

BACKGROUND OF THE INVENTION

This invention relates to a high-emission cold cathode and method for making the cathode, and more particularly, the invention relates to a cold cathode comprising a multitude of thin parallel strips that provide a large planar emitting surface for uniform emission of a large electron current.

Cold cathodes are particularly desirable where there is a requirement for a high-current electron stream since the energy, equipment and maintenance required for hot cathodes in a large installation that is to operate over extended periods is a major economic consideration. As a result, various cold cathode arrangements have evolved, for example, cathodes having smooth emitter surfaces, cathodes composed of pin arrays, and plasma cathodes. However, a high current cannot be obtained from a smooth emitter surface before arcing destroys the field; pin arrays are difficult to make coplanar and generally require a resistor for each pin to limit arcing; and the operation of plasma cathodes depends on the presence of gas and other contaminants that cause arcing when long pulses are required. In particular, no prior art cold cathodes are known that fulfill the various requirements of a developing technology such as in the fields of transversely excited gaseous lasers, thyratrons, klystrons, and other devices requiring large electron stream currents. These requirements include providing a cold cathode that can emit electrons in pulses having widths that may be varied over a wide range. Such a cathode is particularly useful in prototype equipment where design parameters have not been completely determined. Other requirements include a high and uniform current density from a large cold-cathode surface area without arcing and without continual degassing. Moreover, a successful high-emission cold cathode, particularly one that is to be widely used over long periods, should be low in original cost, have low operating costs, be simple to construct, rugged and reliable.

SUMMARY OF THE INVENTION

In brief the invention is a high-emission cold cathode constructed by stacking a multitude of first electrically conducting strips of a first material alternately with a multitude of second electrically conducting strips of a second material, brazing the stack of strips together, machining the exposed strip edges of one side of the stack to obtain a precisely planar surface, and etching a portion of the second strips away from the planar surface, leaving the edges of the first strip protruding and coplanar.

It is an object of the invention to produce a high current of uniform density from a cold cathode having a large surface area.

Another object is to emit an electron stream from a cold cathode in pulses that may have widths that vary over a wide range.

Another object is to minimize arcing from a cold cathode when subjected to a very high electric field.

Another object is to provide a high-emission cold cathode that is low in original cost, that has low operating costs, is simple to construct, is rugged, reliable and substantially free of trapped gases.

Other objects and advantageous features of the invention will be apparent in a description of a specific

embodiment thereof, given by way of example only, to enable one skilled in the art to readily practice the invention which is described hereinafter with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side view of a high-emission cold cathode according to the invention.

FIG. 2 is a side view of a stack of emission strips, spacer strips and brazing material during manufacture of the cathode of FIG. 1.

FIG. 3 is an expanded view of the end of a single emitting element of the cathode of FIG. 1 after aging of the element in the presence of a high electric field.

FIG. 4 is a cross-sectional view of a transversely excited gaseous laser and shows use of the cathode of FIG. 1 in the laser.

DESCRIPTION OF AN EMBODIMENT

Referring to the drawing there is shown in FIG. 1 an expanded view of a high-emission cold cathode 10, according to the invention. The cathode 10 includes a multitude of very thin electrically conducting emission strips 12 of a first material that are spaced apart by means of electrically conducting spacer strips 14 of a second material. A joining material 16 is provided between each emission strip and spacer strip to form a joint that makes the strips into an integral cathode unit. The cathode 10 is constructed by alternately arranging a multitude of emission strips 12 with a multitude of spacer strips 14 of equal width into a stack 18 (FIG. 2). The joining material may be either coated onto the strips 12 and 14 or placed therebetween in strip form. Pressure is applied to the stack of strips in the direction of arrows 6-6 to compress the strips 12 and 14 and material 16 together. The strips may be conveniently stacked in a brazing jig and the pressure applied mechanically by the jig. The stack is then heated, such as in a hydrogen furnace, to a temperature at which the material 16 flows into the strips 12 and 14. Pressure is continuously applied to the stack during the heating. After cooling, the surface to be used for electron emission may be easily machined and ground so that the surface is precisely planar. The other surfaces also may easily be machined and polished to the desired shape to minimize field-emission points. Then all surfaces not to be used for electron emission are masked and the stack immersed in an etching solution to remove only the spacer material and joining material to a predetermined depth. The edges of the emission strips 12 are left protruding above the spacer strips 14, such as shown in FIG. 1, with the edges precisely coplanar. The protruding edges are then subjected to a high electric field by means of a voltage applied between the stack and an anode 20 (FIG. 3) until the cathode is degassed and the edges of the strips 12 are roughened. The roughness is caused by the growth of whiskers 22 which constitute enhanced field emission points and result in a substantial increase in emission current.

The particular construction of the cathode 10 leads to a structure that can produce very high density emission currents since the strips 12 can be made very thin and closely spaced so that a multitude of strips are easily provided in a small space. The thinness of each strip edge as well as its roughness results in enhanced field emission and therefore high current. Moreover, the

current density is uniform over the entire emitting surface since the edges of the strips 12 were made precisely coplanar before etching of the cathode so that all field emission points experience substantially the same electric field. Arcing is also minimized since there is no one point more likely to arc from coplanar emitting points to a parallel planar anode. The cathode 10 also is rugged since the emission strips 12 have a long length and are firmly embedded between the spacer strips 14 over their entire length.

A particular use of the cathode 10 is for amplifying laser beams in a transversely excited gaseous laser 24 such as shown in FIG. 4, wherein the cathode 10 is shown mounted in a vacuum chamber 26 defined by a wall 27. The cathode is mounted with the plane of the protruding edges of the spacer strips 12 parallel to an extractor grid 28. The grid 28 is comprised of ribs 30 that are spaced apart to leave wide spaces 32 therebetween for passage therethrough of electrons from the cathode 10 into a chamber 34 of the laser 24. The orientation of the ribs 30 makes them structurally strong to withstand high fields; and they are mounted in a direction that is transverse to the emitter strips 12 to avoid congruency of the ribs and strips so as to maximize the emitting area that is clearly exposed to the chamber 34. The chamber 34 is generally defined by a wall 36 and is filled with a laser gas, such as a carbon dioxide-nitrogen-helium mixture. A thin window 38, typically 0.0005 inch, is suitably mounted in the wall 36 to contain the gas mixture in the chamber 34 and to pass electrons from the vacuum chamber 26 into the gas-filled chamber 34. Next to the gaseous side of the window 38 is a grid 40 for sustaining an electric field that extends to an anode 42. The grids 28 and 40 protect the thin window 38 from damage due to incidental arcing and other electrical stresses.

In operation of the laser 24, the chamber walls 27 and 36, the grids 28 and 40, and the window 38 are all maintained at ground potential. Large negative pulses 44 are applied to the cathode 10 through a connection 46. The pulses 44 are applied synchronously with the application of large positive pulses 48 to the anode 42 through a connection 50. The resulting field between the cathode 10 and grid 28 extracts electrons 52 from the cathode. The electrons pass through the openings 32 in the grid 28, the window 38 and the openings in the grid 40 into the chamber 34. Collisions of the electrons with constituents of the gas mixture in chamber 30 ultimately raise selected gas atoms to appropriately excited states. A laser beam 54 is generated synchronously within the period of the pulses 44 and 48 and directed to pass through a thin window 56, set at an angle in accordance with Brewster's law, and into the chamber 34 in a direction that is transverse to the electric field between the grid 40 and anode 42. The laser beam 54 causes stimulated emission of the excited gas atoms in the direction of the beam 54, thereby increasing the energy of the beam 54 to form an amplified beam 58 which passes from the chamber 34 through a window 60 also set at an angle in accordance with Brewster's law.

In one embodiment of the invention, the cathode 10 was constructed of 50 molybdenum strips, 50 tungsten strips, and 100 copper strips brazed together under pressure at a temperature of 1,100°C in a hydrogen furnace. The emitter surface was machined and ground to be coplanar within 0.001 inch. The molybdenum and copper was etched away with a solution of HNO₃ and H₂SO₄ to a depth of 0.1 cm. The emitter surface was then subjected to an electric field which was raised to 3.2×10^7 KV/cm over a period of 3 hours to age the cathode. During operation of the cathode, the cathode was subjected to three million 60 KV pulses at a rate of 10 pulses per second. The pulses produced an electric field of 3×10^7 V/cm and a current density of 1.0 amps/cm². Arcing occurred over no more than one percent of the operating period and there was no significant deterioration of the cathode at the end of the period.

While an embodiment of the invention has been shown and described, further embodiments or combinations of those described herein will be apparent to those skilled in the art without departing from the spirit of the invention.

What I claim is:

1. A high-emission cold cathode in combination with a transversely excited gaseous laser, including:
a first multitude of electrically conducting strips of a first material;

a second multitude of electrically conducting strips of a second material brazed to said first strips and alternately arranged with said first strips to space them apart, the edges of said first strips protruding from said second strips on one side of said cathode, the edges of said protruding strips being coplanar;

an elongated chamber filled with a laser gas;
an anode electrode mounted within said chamber;
a window in the wall of said chamber opposite said anode, said window being pervious to the passage of electrons therethrough; and

a vacuum chamber mounted adjacent said gas filled chamber at said window, said cathode being mounted within said vacuum chamber for emitting electrons to pass through said window into the gas-filled chamber for exciting the gas to a higher energy level for subsequent amplification of a coherent beam of radiation passing through said gas-filled chamber.

2. The combination of claim 1, further including an extractor grid mounted within said vacuum chamber between said cathode and said window, said grid being mounted precisely parallel to a plane defined by the edges of said protruding strips, and means for sustaining a high electric field between said grid and said cathode.

3. The cathode of claim 1, wherein said first strips are tungsten, said second strips are molybdenum, and said first and second strips are brazed together with copper between the strips.

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