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ELECTRODE ASSEMBLY FOR VERY HIGH-FREQUENCY
ELECTRON DISCHARGE DEVICES
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Fig. 1.

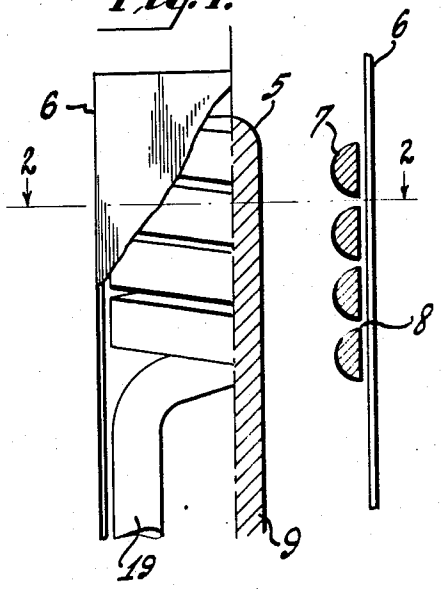
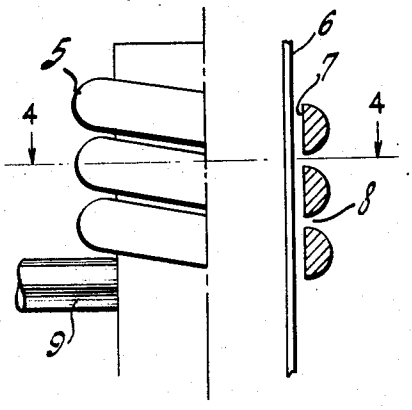


Fig. 3.



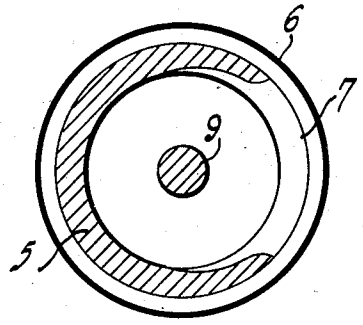


Fig. 2.

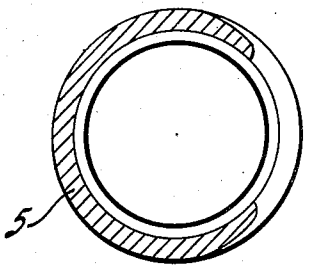


Fig. 4.

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ELECTRODE ASSEMBLY FOR VERY HIGH-FREQUENCY ELECTRON DISCHARGE DEVICES

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5 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices and more particularly to vacuum tubes operating at very high frequencies.

An object of this invention is to improve the electrode structure of vacuum tubes and thereby increase the efficiency at very high frequencies.

Another object of the invention is to reduce the transit time of the electrons in vacuum tubes intended for ultra high frequency operation.

A particular advantage of the invention is that the electrode structure permits a high electron current density at substantially reduced transit time.

Another advantage of the invention is that directly heated thoriated tungsten cathodes of high electron density may be employed with comparatively low heating current.

Other objects and advantages will be apparent from the following description of the invention, pointed out in particularity in the appended claims and taken in connection with the accompanying drawing in which Fig. 1 is an elevational view partly in axial section of a cathode structure and a cooperating electrode constructed in accordance with the invention; Fig. 2 is a cross-section in the plane along the lines 2—2 of Fig. 1; Fig. 3 is an elevational view partly in axial section of a modification of the structure shown in Fig. 1; Fig. 4 is a cross-section in the plane along the line 4—4 of Fig. 3.

In vacuum tubes intended for use at very high frequencies the electron transit time is an important factor. These tubes may have a number of electrodes or they may be simple two-element devices. In any case, the electron transit time from the cathode to the next cooperating electrode is the most important factor from a structural point of view. The transit time from the cooperating electrode, which is usually in the form of a grid, to other electrodes can more easily be controlled and can be made less than the transit time between cathode and grid by adjusting the anode voltage or screen grid voltage.

The invention herein disclosed is particularly concerned with the transit time between the electron emitting cathode and the next cooperating electrode which may be an anode or a grid, depending upon the particular function for which the tube is designed. The structure of the cathode and the placement of the cooperating electrode are the salient features with respect to the improvements which this invention offers. Consequently, for the purpose of a clear understanding, only the cathode and the next cooperating

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electrode will be illustrated and described. It is to be understood that a vacuum tube incorporating the basic features of the invention may have a number of other electrodes besides the cathode and the next cooperating electrode.

Considering a two-element tube, the transit time T of the electrons from a plane cathode to a plane anode is given by the well known formula:

$$T=6.6\times10^{-10}(d/i)^{1/3} \text{ seconds}$$

in which d is the anode-cathode distance measured in cms. and i the density of space charge limited current flowing to the anode in amperes per square cms. Accordingly, for a given current and given d, T decreases as the current density increases. The maximum current density practically obtainable depends on the nature of the cathode. For an oxide coated cathode it is about 150 ma./cm.^{2}; but for a thoriated tungsten cathode it may be as great as 2000 ma./cm.^{2} If, therefore, it is important to have the smallest possible transit time, thoriated tungsten cathodes are preferable to oxide coated cathodes.

But in order that the transit time should be small, d must be small. Thus, in certain vacuum tubes d is sometimes as small as 0.01 cm., and is much less than the radius of curvature of the cathode. (This is the justification for discussing only the case of plane cathode and anode.) It is necessary then that the cathode surface should be smooth on the scale of d. Thus, if the cathode were a wire helix, the gaps or depressions between the turns would cause variations in the effective value of d over the cathode which are known to be undesirable. Smooth oxide coated cathodes of large diameter are easily obtainable in the form of indirectly heated cylinders; but, so far as it is known, thoriated tungsten cathodes have always been directly heated wires. However, a wire 1 mm. in diameter would require an impracticably large current to heat it. If, therefore, the theoretical advantage of thoriated tungsten in respect of transit time is to be utilized, some method must be found of making cathodes of thoriated tungsten that have a diameter at least of the order of 1 mm., are substantially smooth on a scale of 0.1 mm., and yet can be heated by practicable currents.

According to the invention, this problem is solved by winding a helix of thoriated tungsten wire, nearly close-wound, grinding the surface of the helix until it becomes substantially a smooth cylinder and presenting the ground surface to the adjacent cooperating electrode. If, as has been more usual in the past, the cathode

is inside the anode, the outer surface of the helix must be ground. But if, as is now known to be advantageous in vacuum tubes of the type specified, the cathode is outside the anode, then the inner surface of the helix must be ground.

If the helix were really close wound and consecutive turns touched each other, the current required to heat the cathode would be as great as if the helix were a continuous cylinder. There is no difficulty in winding the helix so that there are gaps between the turns large enough to electrically insulate adjacent turns yet not large compared with the distance between the ground surface and the adjacent electrode; then the gaps will not detract substantially from the effective smoothness of the ground surface.

Two embodiments of the invention will now be described by way of example, with reference to the accompanying drawing.

In each figure, 5 is a cathode in the form of a helix of thoriated tungsten wire which in practice may be 0.4 mm. in diameter; 6 is a cylindrical cooperating electrode; 7 is the ground surface of the helical wire presented to the electrode 6; 8 indicates the gaps between the turns of the helix whose width is approximately equal to the distance between the surface 7 and the electrode 6.

In Fig. 1 one lead 9 to the helix is returned inside the helix; in Fig. 3 it projects outwardly from the helix. The other lead 10 (not shown in Fig. 3) is parallel to the axis of the helix.

The embodiment shown in Fig. 3 differs only in that the helical cathode 5 is wound around the cooperating electrode 6. In this case the cooperating electrode 6 which, as previously explained, may be an anode or a grid, is inside the cathode 5. In order to obtain the advantages in this structure, the inside surface of the cathode 5 is smoothly ground to present an even surface to the outer periphery of the electrode 6. The distance between the two cooperating surfaces is preferably not greater than the distance between adjacent turns of the helically wound wire. This distance is referred to as the gap and is indicated by reference character 8.

The cross-sections illustrated in Figs. 2 and 4 show the uniform cylindrical spacing of the electrodes and the arrangement of the lead wires.

The uniform surface presented by the ground side of the cathode 5 is practically equivalent to a cathode of solid cylinder yet the heating current is not more than required by the length of wire of which the cathode is wound. In this manner thoriated tungsten as well as other high electron density materials may be used for a directly heated cathode of high emitting strength.

What I claim is:

1. An electron discharge device having two electrodes, one of said electrodes comprising a cathode for supplying electrons, said cathode comprising a helix having a plurality of relatively closely wound turns of wire, adjacent ones of said turns being spaced from each other a distance less than a diameter of said wire, said wire having a flat side, said flat side forming a wall of said helix having a substantially smooth surface, the other of said electrodes having a uniformly smooth surface, the flat side of said wire being adjacent said smooth surface of said other of said electrodes and spaced therefrom by a distance less than a diameter of said wire.

2. An electron discharge device having a plurality of electrodes, including a cathode, said cathode comprising a tungsten wire wound in the form of a helix, said wire having a flat active surface on one side of said helix, adjacent turns of said helix being relatively closely spaced to cause said active surface to form substantially continuous tubular surface along the entire of said one side of said helix, another of said electrodes comprising a tubular member disposed adjacent said cathode, with said flat active surface facing said tubular electrode and spaced therefrom by a distance less than the diameter of said wire for reducing the transit time of electrons from said active surface whereby said device is adapted for operation at very high frequencies.

3. An electrode assembly including a cathode and an additional electrode adjacent said cathode, said cathode comprising a helix of a plurality of wound turns of wire, the distance between adjacent ones of said turns being substantially equal to the spacing between said cathode and additional electrode, said spacing being less than a diameter of said wire, a portion of said wire having a flat side, said portion comprising one side of said helix, said side of said helix facing said additional electrode and comprising a substantially smooth active surface.

4. An electron discharge device having a plurality of electrodes including a cathode, said cathode comprising a helix formed by a plurality of turns of wire, said wire having a flat surface on the outer side of said helix, adjacent turns of said helix being spaced by a distance less than the diameter of said wire for providing a substantially continuous and smooth tubular surface on said outer side of said helix, and a tubular electrode surrounding said cathode and having a uniformly smooth inner surface facing said flat surface of said helix and spaced from said flat surface by a distance less than a diameter of said wire for good operation of said device at very high frequencies.

5. A directly heated cathode comprising a helix of thoriated tungsten wire, said helix having inner and outer walls, said wire being semicircular in cross section whereby one side of said wire is flat and the opposite side is rounded, the turns of said helix being disposed with said flat side of said wire parallel to the axis of said helix and forming one of said walls, adjacent ones of said turns being spaced to provide insulation therebetween, the spacing between said turns being smaller than a diameter of said wire, whereby said flat side of said wire forms a substantially smooth and continuous tubular surface for increased current density thereon.

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