Dec. 21, 1948. P. D. WILLIAMS 2,456,761

RUGGED CATHODE

Filed April 19, 1947

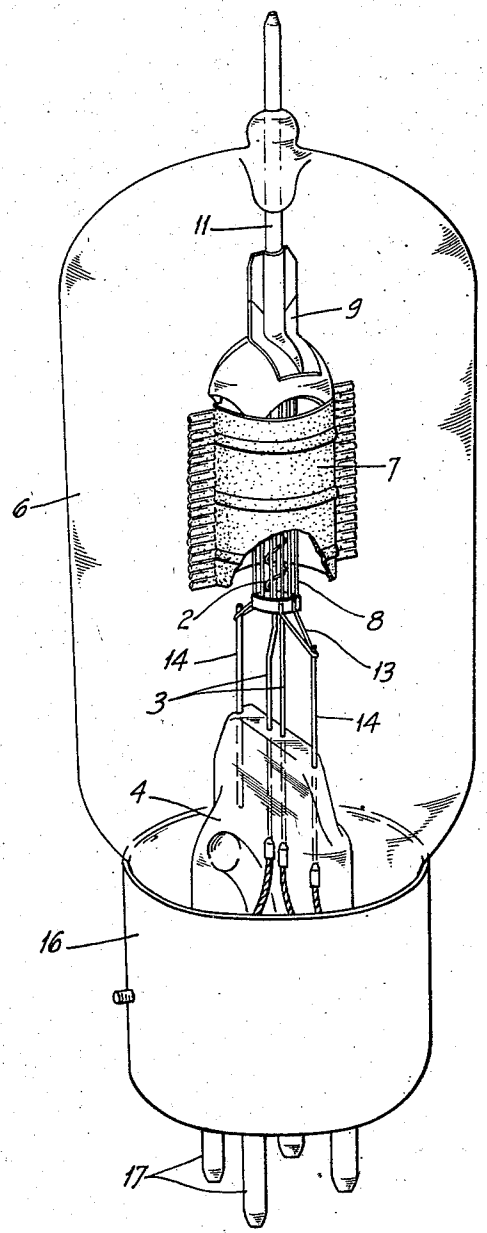


Fig. 1

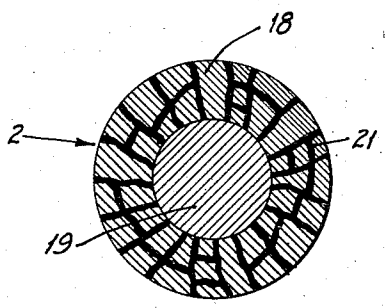


Fig. 2

INVENTOR.
Paul D. Williams
BY Harold E Sarg

ATTORNEY

Patented Dec. 21, 1948 2,456,761

UNITED STATES PATENT OFFICE

2,456,761

RUGGED CATHODE

Paul D. Williams, Palo Alto, Calif., assignor to Eitel-McCullough, Inc., San Bruno, Calif., a corporation of California

Application April 19, 1947, Serial No. 742,489

5 Claims. (Cl. 250—27.5)

1

Filamentary type thermionic cathodes are usually made of thoriated tungsten wire suitably shaped into coils, hairpins or the like depending upon the filament structure used. Thoriated tungsten wire has thorium oxide (thoria) incorporated in the tungsten metal, and is supplied as such to the tube manufacturer. After being fabricated into a filament the wire is carburized (sometimes called carbonized) by a process involving heating the filament in a hydrocarbon atmosphere. In this step carbon is combined in the filament as tungsten carbide, the carbide lying in a layer or ring in the outer regions of the filament wire. The carbon so introduced functions as a reducing agent for gradually reducing the thoria to metallic thorium during the life of the filament, which reduction is required to yield copious electron emission in the operation of a thoriated tungsten filament. In accordance with past practice, the carburized filament is sealed directly into an envelope and the tube then evacuated.

While carburizing the filament is important from the standpoint of electron emission it has the serious disadvantage of making the filament quite brittle and fragile. A filament processed in the usual manner above described constitutes one of the weakest elements in the tube and is responsible for much loss due to breakage, particularly under conditions where the tube is subjected to shock and vibration. Weakness of the filament is due largely to the changes in crystal structure taking place in the outer regions of the filament wire during formation of the tungsten carbide. These changes involve a crystal growth in the carbide layer, producing well defined planes of weakness along the interfaces of the crystals. In addition to the crystal growth the situation is further aggravated by thermal shocks occurring in the carburizing process, causing enlarged crevices or fissures to open up along the cleavage planes. Such cleavage planes frequently extend completely through the carbide layer, which is a substantial portion of the wire diameter, and often a slight shock is all that is necessary to make the filament part at that point.

The broad object of the present invention is to improve the strength of carburized thoriated tungsten filaments.

A further object is to achieve the increased strength without sacrifice of eelctron emission efficiency.

Still another object is to provide a method of ruggedizing a filament of the character described which does not interfere with or obsolete the

2

practices or equipment heretofore used in the fabrication and carburizing of filaments.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention as I may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawing:

Figure 1 is an elevational view of an electron tube embodying the improvements of my invention, portions of the anode being broken away to show the internal structure more clearly; and

Figure 2 is an enlarged sectional view of the filament wire.

In terms of broad inclusion, my method of improving the strength of a thoriated tungsten cathode comprises modifying the crystalline structure of the cathode to reinforce the structure along cleavage planes between the crystals. This is done by introducing a bonding agent between the interfaces of the crystalline structure, the agent used being preferably an element selected from the group consisting of vanadium, boron and rhodium. The final cathode therefore, comprises carburized thoriated tungsten together with the added bonding agent. In my preferred process the cathode or filament is fabricated and carburized in the usual manner, after which the filament is heated in the presence of the bonding agent.

In greater detail, and referring to Figure 1 of the drawing my improved cathode as embodied in a filamentary structure of an electron tube comprises a helical wire 2 welded top and bottom to a pair of leads 3 sealed to stem 4 of envelope 6. Filament wire 2 may be formed into hairpins or other suitable shapes, the helix being shown for simplicity. Other components of the tube illustrated include an anode 7 and a grid 8, it being understood that the improved cathode or filament may be incorporated in a diode or a multigrid tube, either of the internal or external anode type. In the triode shown, anode 7 is supported by a bracket 9 on lead 11 sealed to the upper end of envelope 6. Grid 8 is supported by brackets 13 on rods 14 sealed to stem 4, one of these rods serving as a grid lead. A base 16 cemented to the lower end of the envelope carries prongs 17 connected to the grid and filament leads.

Filament 2 which constitutes the electron emitter is composed of thoriated tungsten wire of the kind ordinarily used in the filaments of

electron tubes. This wire usually contains a small amount of thorium oxide (thoria), say ½% to 1%, incorporated in the tungsten. After being mounted on its stem the filament is carburized by heating in a hydrocarbon atmosphere. Any conventional carburizing procedure may be followed, such as by heating the filament to say 2100° C. in a reduced pressure atmosphere containing a suitable hydrocarbon gas such as benzene. The carbon so introduced is combined with the tungsten as tungsten carbide.

The carbide usually lies in a layer or ring 18 surrounding an uncarburized core portion 19 of te wire (see Figure 2), the depth of the carbide layer being controlled by such factors as time, temperature and the density of the hydrocarbon atmosphere employed during the carburizing process. The amount of carbon introduced is usually measured by the drop in filament current during carburizing, a current drop of about 20% being common practice. In such a filament the thickness of the tungsten carbide layer 18 is equal to about half the wire radius.

From this point on the usual procedure has been to seal the carburized filament in the envelope together with the other electrodes and then evacuate the tube, the various electrodes being heated during evacuation for outgassing purposes. My improvements involve an additional treating step after the carburizing process for reasons hereinafter described.

Thoriated tungsten filaments treated in the conventional manner have quite good electron emission properties but are very weak mechanically. From a study of microphotographs of cross sections of ordinary filament wires both before and after carburizing it became apparent to me that certain changes took place in the crystal structure of the wire during the carburizing procedure which accounted for the mechanical weakness. For example, there was pronuonced crystal growth in layer 18 during formation of the tungsten carbide, some of the larger crystals being coextensive with the thickness of the carbide layer, producing cleavage planes across the layer. It was also observed that these planes of weakness along the interfaces of the crystals actually opened up to produce crevices or fissures through the carbide layer under the thermal shocks occurring during the carburizing process.

In order to obviate this weakness I introduce a bonding agent to cement the crystals together along the interfaces. This is illustrated by the bonding agent lying in veins 21 along the crystal boundaries in Figure 2, which view has been exaggerated to illustrate the structure being described. The bonding agent used preferably comprises an element or combination of elements selected from the group consisting of vanadium, boron and rhodium.

The bonding agent may be included in several ways but I prefer to incorporate it after carburization of the filament. A simple way is to apply the agent as a coating on the filament and then heat the filament to absorb the agent.

When vanadium is used as the bonding agent it may be applied either as a substantially pure metal or as a compound such as vanadium oxide. In the case of the pure metal I prefer to use finely divided vanadium powder. This is mixed with a vehicle such as amyl acetate to a fluid consistency and applied to the filament by spraying. A coating sufficient to completely cover the surface of the wire is satisfactory. The coated filament is then heated in an inert atmosphere, preferably in vacuum, by passing current

through the filament. Heating to about 2200° C. for 10 to 30 seconds is sufficient to cause penetration of the coating material. The penetration appears to occur as soon as the coating melts, indicating that the surface tension and wetting properties of the vanadium are such as promote its travel into the intercrystalline structure of the tungsten carbide. Also, since the vanadium bonds the tungsten carbide crystals tightly together it is apparent that the adhesive energy of vanadium with respect to tungsten carbide is high.

Vanadium being rather hard to get in the pure state I have used the more readily available vanadium pentoxide with good results. The treatment here is the same as that first described except that the coated filament is heated in a reducing atmosphere, preferably an atmosphere of clean dry hydrogen. In this atmosphere the vanadium oxide is at least partially reduced. The inclusion of some oxygen does not appear to be harmful and may actually help in the penetration and cementing properties of the vanadium.

My vanadiumized filaments are much stronger than ordinary filaments. For example, a helical filament about $\frac{1}{10}$ of an inch in diameter and ½ inch long of .0085 inch diameter wire in a tube of the character illustrated was used for comparative testing in a standard high impact machine supplied by the Navy Department. Such tubes with filaments treated in the ordinary manner broke at an average impact of 200 G. Similar tubes having vanadiumized filaments broke at an average impact of 375 G. This constitutes an average improvement of over 85%, which is a decided improvement when it is considered that it almost doubles the strength of the older type filaments.

If boron is used as the bonding agent it may also be applied to the filament either in the pure state or as a compound such as boron carbide. Both boron and boron carbide are handled in a manner similar to vanadium metal, namely, the finely divided boron or boron carbide powder is mixed with a vehicle and coated on the filament, after which the filament is heated in an inert atmosphere to absorb the coating material. Application of the coating may be by spraying or by deposition from a bath by cataphoresis. The boronized filament shows an improved strength approaching that of the vanadiumized filament.

In my process, particularly when boron or boron carbide is used, I prefer to surround the ends of the coated filament with heat shields during the heating step. Small cylinders of molybdenum slightly larger than the filament and temporarily fastened to the filament structure during the heating step work very well. These heat shields are preferably of a length sufficient to extend over the last several convolutions of the filament helix. The shields compensate for the end cooling that normally takes place and provides an evener temperature along the filament length. This insures a more uniform penetration of the coating material.

If rhodium is used as a bonding agent it may be coated on the filament by ordinary electroplating methods. The filament so plated is then heated in vacuum or other inert atmosphere to about 2100° C. brightness temperature as in the preceding treatments.

An important feature of my invention is that the filament is ruggedized without sacrifice of the desirable electron emission properties which

characterize an ordinary carburized thoriated tungsten filament. Many tubes made by my process and life tested for hundreds of hours show that electron emission from the cathode sustains itself with life as well or better than tubes with cathodes treated in the usual manner. Another feature of the invention which will be appreciated by the electron tube industry is that my process merely involves an added step between the usual carburizing and pumping procedure, without interfering with or obsoleting any of the practices or equipment heretofore used in the fabrication and carburizing of filaments.

I am aware of the fact that vanadium has been previously incorporated in some types of cathodes such as disclosed in the patents to Laise 1,569,095 and to Marden et al. 1,787,694; the former describing a cathode in which vanadium and metallic thorium are alloyed with tungsten, and the latter disclosing the substitution of vanadium for thorium as the active material in the cathode. These prior inventors therefore did not solve the problems involved in thoriated tungsten cathodes and do not teach the inclusion of a bonding material such as vanadium in such cathodes.

I claim:

1. A carburized thoriated tungsten cathode having a layer of tungsten carbide and a bonding agent cementing the crystalline structure together in said layer.

2. A carburized thoriated tungsten cathode having a layer of tungsten carbide and a bonding agent cementing the crystalline structure together in said layer, said agent comprising an element selected from the group consisting of vanadium, boron and rhodium.

3. A thoriated tungsten cathode including carbon and vanadium.

4. A thoriated tungsten cathode including carbon and boron.

5. A thoriated tungsten cathode including carbon and rhodium.

PAUL D. WILLIAMS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,695,819	O'Neill	Dec. 18, 1928
1,990,277	Fuessner et al.	Feb. 5, 1935
2,247,755	Hensel et al.	July 1, 1941
2,392,318	Gustin et al.	Jan. 8, 1946