Jan. 13, 1959 J. E. BEGGS 2,868,610

METHOD AND APPARATUS FOR MAKING VACUUM ENCLOSURES

Filed Oct. 22, 1954

Fig. 1.

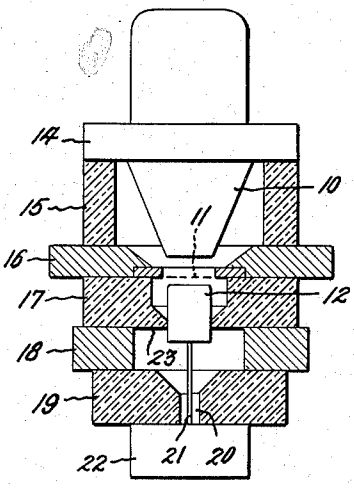


Fig. 3.

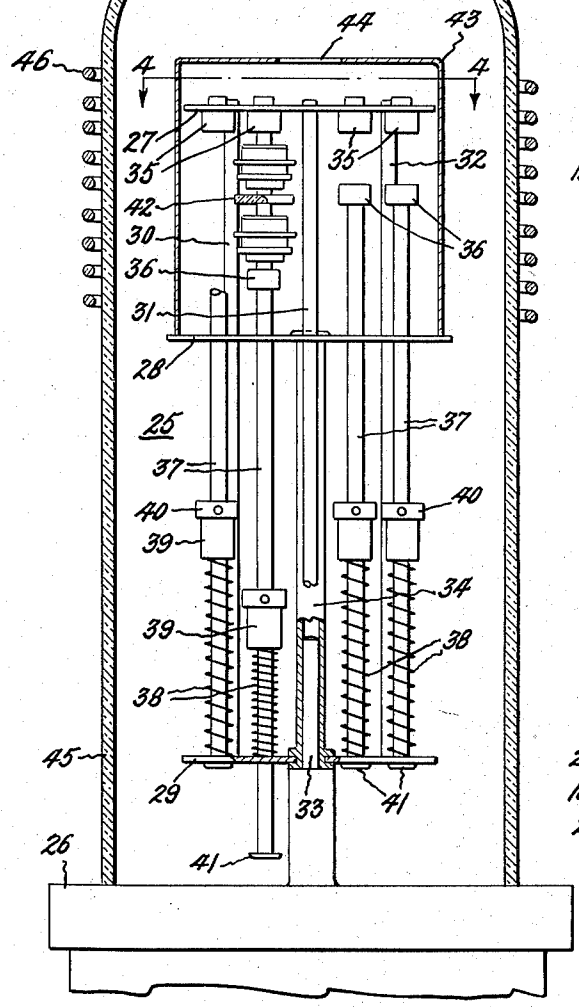


Fig. 2.

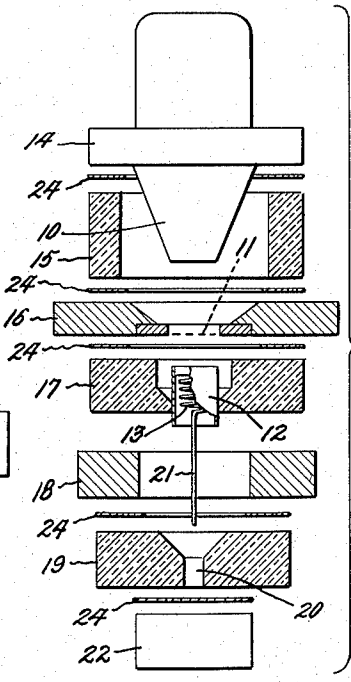
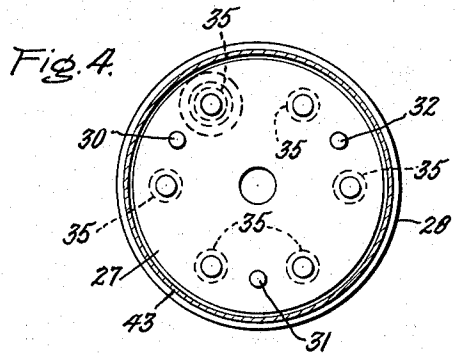


Fig. 4.



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METHOD AND APPARATUS FOR MAKING VACUUM ENCLOSURES

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Application October 22, 1954, Serial No. 464,126

8 Claims. (Cl. 316—19)

The present invention relates to an improved method and apparatus for making vacuum enclosures. While this invention is subject to a wide variety of modifications and applications, it is particularly suited for use in the construction of electric discharge devices, such as electron tubes, and will be described in that connection.

In the operation of electric discharge devices at high frequencies, it is necessary to keep the interelectrode capacitances at a low value. This may be accomplished by utilizing smaller electrode surfaces; however, in order to obtain any appreciable output, it is necessary to obtain more emission from a limited cathode area which generally results in higher operating temperatures. The use of refractory materials such as ceramic insulators for the envelopes of electric discharge devices have permitted higher operating temperatures and have come into widespread use, and in accordance with this invention, there is provided an improved method of assembling electric discharge devices employing ceramic insulators as part of the tube envelope.

In these electric discharge devices, metal members are employed which provide terminals for the various electrodes of the discharge device. These metal members are bonded readily to the ceramic members to form the electric discharge device envelope and may be heated to a temperature high enough to activate the cathode without producing objectionable vapor pressure from the tube parts thereby avoiding contamination of the interior of the electric discharge device and the necessity for a separate operation of filament lighting. The metal members may be formed of metal which absorbs gases from the device during manufacture and use.

It is, accordingly, an important object of this invention to provide an improved apparatus and method for making electric discharge devices in which degassing of the parts, exhausting the envelope, formation of internal electrical connections, activation of the cathode and sealing of the envelope are all accomplished in a single operation by heating the device as a whole.

A further object of this invention is to provide an improved apparatus and method for making vacuum enclosures.

It is also an object of this invention to provide an apparatus and method for simultaneously making a plurality of vacuum enclosures.

It is another object of this invention to provide an improved method and apparatus for making electric discharge devices which results in better evacuation of the devices and eliminates contamination of the interior of the devices.

It is still another object to provide a method of fabricating the tube envelope which eliminates the necessity for any sealing off operation apart from the fabrication of the envelope itself.

According to an aspect of this invention a vacuum enclosure, such as an electric discharge device, is formed by stacking members of metal and a refractory material

such as ceramic with metal shims interposed between the members. The metal shims are of such material that they alloy with the metal members to form a bond between the members. One or more enclosures are placed in a chamber while being held in an apparatus that urges the members together. The enclosure is evacuated while the members are heated to a temperature below the melting point of an alloy of the shims and metal members to degas the members. The enclosure is then heated to a temperature above the melting point of the alloy to hermetically seal the enclosure by bonding the members together.

Further objects and advantages of this invention will become apparent as the following description proceeds, reference being had to the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Figure 1 illustrates an elevational view, in section, of an electron tube made in accordance with this invention; Figure 2 is an exploded elevational view, in section, which shows the parts prior to the fabrication of the tube envelope. Figure 3 is an elevational view of apparatus embodying this invention, and Figure 4 is a sectional view taken along the line 4—4 of Figure 3.

Figures 1 and 2 of the drawing illustrate an electric discharge device of the triode type which includes an anode 10, a control electrode 11, a cathode 12 and a heater element 13. The envelope of the device is made up of conductive and insulating members, the conductive members being connected to the various electrodes. The anode includes a circular flange 14 which is sealed to the upper end of a ceramic cylinder 15. Electrode 11 is supported by a circular metallic terminal 16 which is bonded between the lower end of cylinder 15 and a ceramic cylinder 17 which also supports cathode 12. The cathode terminal is provided by a metal ring 18 which is sealed between ceramic cylinder 17 and ceramic cylinder 19 having a central opening 20 through which the heater lead 21 extends. This opening is closed by a metal disk 22 which provides the heater terminal and completes the envelope of the device. The cathode 12 is connected with terminal 18 by a metal coating 23 formed on the lower surface of ceramic cylinder 17.

In accordance with an aspect of the present invention, the insulating parts 15, 17 and 19 are formed of a ceramic material which holds its shape during the temperatures encountered in the manufacture of the device. At least part of the conductive metal parts, such as the parts 10, 16, 18 and 22, are formed of a metal or metals selected for the ability to absorb or getter gases and further selected to form alloys with other metals at a melting point below the melting point of any of the component metals of the alloy. Such metals include the titanium group metals which include titanium, zirconium, hafnium and thorium. Alloys of these metals form excellent bonds with ceramics used in electric discharge device manufacture and, in view of the ready availability and easy working characteristics of titanium and zirconium, this description, by way of example, makes specific reference to these metals.

As indicated in the elevational view of Figure 2, metal shims 24 are interposed between adjacent metal and ceramic members. The shims are of nickel although it is possible to use other metals such as platinum, molybdenum, chromium, iron, cobalt, copper or various alloys thereof. Nickel is desirable since it forms an alloy with titanium tube parts and has a low vapor pressure at the eutectic melting point. The parts are arranged in the relationship shown in Figure 2 and loaded into a spring loaded fixture for exhaust, activation of the cathode, and completion of the envelope in accordance with this invention.

As illustrated in Figure 3, the apparatus for supporting electric discharge devices during manufacture may include a fixture 25 supported from a table or plate 26. The fixture includes three separate metal disks 27, 28 and 29 secured together by longitudinally extending rods 30, 31 and 32. The fixture is supported from the table 26 by a pin 33 received within a tube 34 which extends between and is secured to the disks 28 and 29.

The fixture is designed to support the electric discharge device assembly between a plurality of ceramic buttons 35 supported from the upper disk 27 and a similar group of ceramic buttons 36 carried on the upper ends of spring-biased rods 37 which extend through the disks 28 and 29 and are biased upwardly by springs 38 interposed between the upper side of the disk 29 and a shoulder provided by sleeves 39 fixed to the rods 37 by washers 40 which are pinned to the rods. The lower ends of the rods 37 are flanged over at 41 to retain them against the bias of the springs 38.

In Figure 3, two electric discharge devices are shown positioned between one of the buttons 35 and the button 36 carried by one of the rods 37. The devices are separated by a ceramic spacer 42. The upper end of the fixture is enclosed by a cylindrical oven 43 of, for example, tantalum or titanium group metal, but preferably formed of titanium to aid in gettering gases resulting from the fabrication, and having an opening 44 at the top thereof to permit evacuation of the devices mounted within the oven. Disk 28 is larger than the disk 27 and provides support for the open end of the oven. It will be observed that fixture 25 is capable of holding 12 tubes of the size illustrated and that any number of vacuum enclosures can be simultaneously fabricated by increasing the spacing between plates 27 and 28.

Where it is desired to simultaneously manufacture a large number of vacuum enclosures, in the order of 10 to 20 or more, the enclosures may be stacked with ceramic spacers between each and held in intimate contact by a simple jig. The stack is then placed in a glass tube, evacuated and appropriately heated to complete sealing of the enclosure and bonding of the parts. The glass tube is then broken and the jig and completed enclosures removed. This process is carried out on a conventional electron tube vacuum exhaust apparatus so that vacuum enclosures can be fabricated at a very rapid rate.

In carrying out the exhaust of the devices, activation of the cathodes, and sealing of the envelopes, the fixture 25 is closed within a bell jar or other enclosure 45 which is connected to be evacuated by vacuum apparatus (not illustrated). A high frequency coil 46 surrounds the bell jar, in the region of the oven 43, to provide for heating of the oven by high frequency induction and subsequent heating of the discharge devices within the oven.

As a specific example of the utilization of the apparatus and method of this invention, a number of electric discharge devices are formed by stacking the titanium tube parts and ceramic members with interposed nickel shims, as illustrated in Figure 2. The lower surface of the ceramic cylinder 17 is coated with a nitrocellulose compound so that metallic conducting film 23 is formed between terminal 18 and cathode 12 during the bonding and sealing operation. This method and other methods of forming conducting films is more completely described and is claimed in my copending application Serial No. 464,080 filed herewith and assigned to the same assignee as this application. The assembled unsealed discharge devices are inserted in fixture 25.

The vacuum apparatus (not shown) is then put into operation and the discharge devices are heated to a temperature below the melting point of a titanium nickel alloy, of the order of 900° C., to degas the parts, and form and activate the cathode. During this time, gases are withdrawn from the envelope through the small spaces that are available between the adjacent parts of the assembly. If more opening is desired, some of the shims are made discontinuous or corrugated or are provided with thickened portions to increase the openings for the passage of gases from within the device.

As the temperature is raised to a still higher level, the metal of the discharge device parts, in contact with the shims, and the shims melt and alloy. In the case of titanium parts and nickel shims the alloying occurs at a temperature in the order of 1000° C. which is the approximate melting temperature of a eutectic alloy of these materials. The oven and tube are held at this temperature until the shims are completely alloyed with the metal members of the discharge device. A portion of the nickel-titanium alloy flows over the nitrocellulose compound, that has been converted to a carbonaceous residue by the heat, to form a conducting film between the cathode and cathode electrode. The other electrical connections within the electric discharge device are effected by the titanium-nickel alloy formed between the titanium and ceramic parts and which flows over portions of these parts. The titanium-nickel alloy wets the ceramic and forms a hermetic bond between the parts to complete the fabrication and seal the interior of the discharge device. The formation of hermetic bonds including titanium is more completely described in my copending application, Serial No. 409,159, filed February 9, 1954.

The presence of titanium in the discharge device envelope acts not only during the manufacture of the device but also during its life to remove the gases from the interior of the device. It also makes possible the completion of the bonding and sealing of the envelope by an alloy including metal from the envelope parts.

In accordance with this invention, advantage is taken of the relatively low vapor pressure at high temperatures of the discharge device materials to permit the step of activating the cathode without any heating of the cathode apart from the heating of the tube parts as a whole. In this way, the tube is degassed, the cathode is activated and the tube envelope fabricated all in a single operation without any movement of the parts other than the maintenance of intimate contact between the parts accomplished by the spring loaded fixture 25 and without the necessity of making of any external electrical connections to the tube parts such as is necessary where a separate filament lighting operation is required. Since no filament lighting is required, group handling of a large number of electric discharge devices is facilitated.

The completed electric discharge devices may be operated in air at temperatures in the order of 800° C. without unreasonable oxidation of the titanium parts. The internal parts having been degassed at a higher temperature evolve essentially no gases and the internal titanium parts act as a getter to absorb many gases. Therefore, electric discharge devices, made in accordance with this invention display uniformly stable emission throughout the life thereof.

In the foregoing description, there is mentioned specifically, titanium tube parts with nickel shims as the alloying metal. It is considered to be within the scope of this invention to use any of the combinations of materials disclosed in the aforementioned U. S. patent application, Serial No. 409,159, and it will be apparent that the other materials mentioned in the specification and combinations or alloys thereof may be used and that they may be reversed; that is, in a specific example, nickel parts or copper parts may form part of the tube envelope and titanium or zirconium or alloys thereof may be provided in the form of shims which alloy with the tube parts in the bonding operation. Discharge devices of titanium and utilizing copper shims are heated to a temperature in the order of 850° C. to degas and activate the cathode and then heated to a temperature in the order of 900° C. to bond the members and seal the device.

As is well understood by those skilled in the art, the particular ceramic utilized is chosen from those classes

of ceramics which maintain satisfactory electrical and mechanical characteristics throughout the range of operating temperatures of electric discharge devices and also for thermal expansion characteristics which approximately match the thermal expansion characteristics of the metal or metals with which they are used. These ceramics include the alumina bodies of the general formula Al_2O_3, zircon bodies of the general formula $ZrO_2.SiO_2$, and also those ceramics classed as forsterites, steatites, and beryllias.

It will be readily apparent that the method and apparatus disclosed in connection with the description of this invention are ideally suited for the making of vacuum enclosures other than the disk seal triode electric discharge device herein disclosed by way of a specific example. Therefore, in view of the many modifications that may be made without departing from this invention in its broader aspects, it is intended, in the appended claims, to cover all modifications coming within the true spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of making an electric discharge device having a plurality of electrodes including a coated cathode which method comprises assembling in a stack a plurality of alternately arranged metal members and refractory members to form the device, the metal members forming the terminals of the electrodes of the device, interposing metal shim members between adjacent members, one of said members consisting essentially of a metal selected from the group consisting of titanium, zirconium, hafnium, thorium and alloys of more than one metal of said group and the other of said metal members consisting essentially of a metal selected from a second group consisting of copper, nickel, iron, molybdenum, chromium, platinum, cobalt and all alloys of more than one metal of said second group supporting the stack within a chamber, evacuating the chamber and the device while heating the members to degas the device, activate the cathode, and form an alloy of the metal shims and the metal of the metal members to bond the members together and seal the device, the highest heating temperature being lower than the melting point of any of the individual metal members.

2. The method of making an electric discharge device including a cathode electrode, which method comprises assembling metal members and members of refractory material which form the device, interposing metal shims between adjacent members, heating the assembled members and shims to a temperature below the melting point of an alloy of the metal members and shims to degas the members and activate the cathode, subsequently heating the assembled members and shims to a temperature above the melting point of said alloy but below the melting point of the individual members to form a bond between the adjacent metal and refractory material members and seal the device.

3. The method of making a vacuum enclosure which comprises assembling in a stack in alternate relation metal members and members of refractory material to form the enclosure, interposing metal shims between adjacent members shaped to facilitate the passage of gas through the spaces provided in the wall of the enclosure between the members and the shims, controlling the atmosphere within the enclosure by passing gas through said spaces, heating the enclosure to a temperature above the melting point of an alloy of the metals of said metal members and said shim members but below the melting point of either the metal members or metal shim members to form an alloy thereof and wet the members of refractory material and seal the members of the enclosure together.

4. The method of making a vacuum enclosure from members of metal and refractory material and corrugated metal shims, comprising assembling the metal and refractory material members to form the enclosure, interposing the metal shims between adjacent members, evacuating the enclosure through the spaces of the members and shims, heating the members and shims to melt the shims and portions of the members in contact with the shims to seal the enclosure and bond the members together.

5. The method of making an electric discharge device from titanium metal and ceramic members and nickel shims comprising assembling the members to form the envelope of the device, interposing the shims between adjacent members, supporting the members and shims within a chamber, evacuating the chamber and the device, heating the device to a temperature below the melting point of a nickel-titanium alloy to degas the members of the device, and subsequently heating the device to a temperature above the melting point of the alloy to form a nickel-titanium alloy which wets the ceramic and forms an alloy bond between the members to seal the device.

6. The method of making an electric discharge device having a plurality of electrodes including a cathode having an emissive surface from titanium metal and ceramic members and nickel shims comprising assembling the members in a stack to form the device such that the titanium members form the terminals of the electrodes, interposing the shims between adjacent members, supporting the stack within a chamber, evacuating the chamber and the device, heating the device to approximately 900° C. to degas the members and activate the cathode, and subsequently heating the device to approximately 1000° C. to form a nickel-titanium alloy bond between the members to seal the device.

7. The method of making an electric discharge device from titanium metal and ceramic members and copper shims wherein the device has a plurality of electrodes including a cathode having an emissive surface, which comprises assembling the members in a stack to form the device such that the titanium members form the terminals of the electrodes, interposing the shims between adjacent members, supporting the stack within a chamber, evacuating the chamber and the device, heating the device to approximately 850° C. to degas the members and activate the cathode, and subsequently heating the device to approximately 900° C. to form a copper-titanium alloy bond between the members and to seal the device.

8. The method of making an electric discharge device from titanium metal and ceramic members and nickel shims comprising assembling the members in a stack to form the device, interposing the shims between adjacent members, supporting the stack within a chamber, evacuating the chamber and the device, heating the device to approximately 900° C. to degas the parts of the device, and subsequently heating the device to approximately 1000° C. to form a nickel-titanium alloy which selectively flows over the members to complete the electrical connections within the device and to bond the parts together.

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