United States Patent

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[54] **INDIUM ALLOY SEAL AND CATHODE-RAY TUBE ENVELOPE EMPLOYING SUCH SEAL**
8 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** .... **220/2.3 A,** 29/472.7, 65/43
[51] **Int. Cl.** **H01k 1/42**
[50] **Field of Search** .... 228/2.1, 2.1 A, 2.3 A; 65/43; 29/472.7

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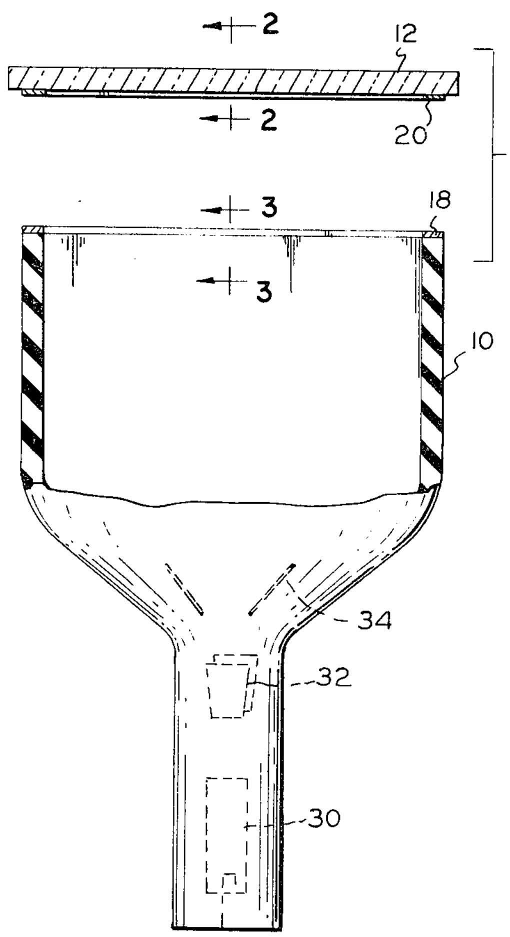
ABSTRACT: A hermetic seal between a crystalline ceramic member and a member of inorganic, nonmetallic material, such as glass, ceramic or semiconductor material, is described which is formed by an alloy of indium and an active metal, such as titanium, zirconium, tantalum and hafnium. In one embodiment, an envelope for a cathode-ray tube is formed by sealing a glass faceplate to a ceramic funnel portion by the indium alloy seal. As a result of the short time required for such sealing, the cathode ray tube envelope may be first evacuated and then sealed during the same heating cycle so that such evacuation can be performed through the large end of the envelope at such faceplate.



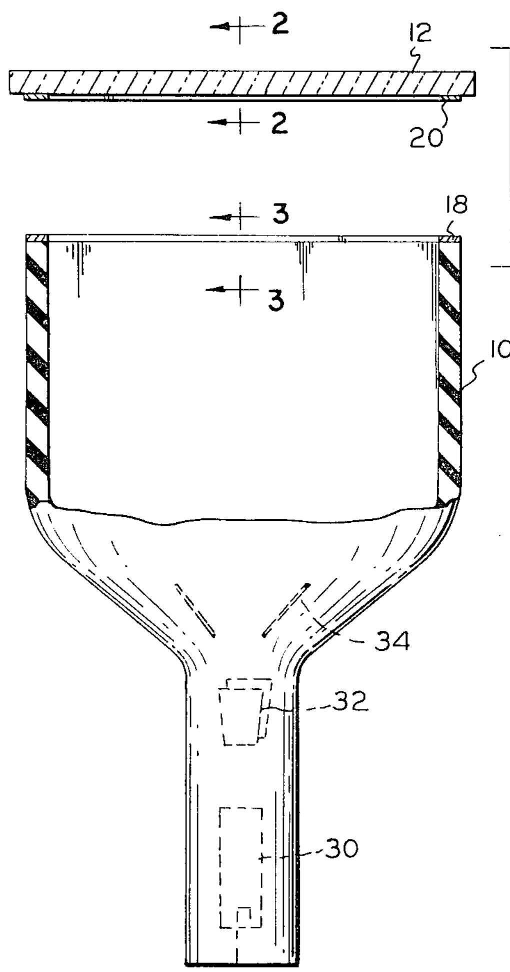


FIG. 1

FIG. 2

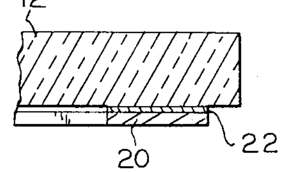
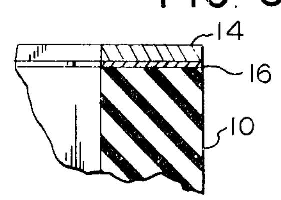


FIG. 3



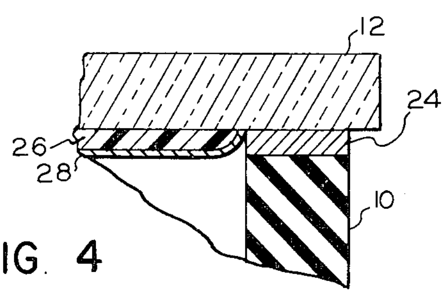


FIG. 4

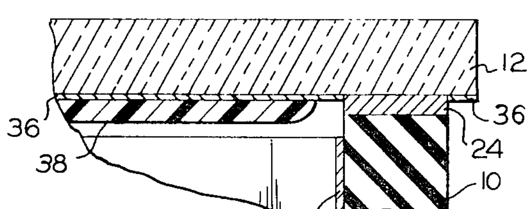


FIG. 5

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INDIUM ALLOY SEAL AND CATHODE-RAY TUBE ENVELOPE EMPLOYING SUCH SEAL

BACKGROUND OF THE INVENTION

The subject matter of the present invention relates generally to the bonding of ceramic members to other members of inorganic, nonmetallic material and, in particular, to such bonding by means of a hermetic seal made of an alloy of indium and an active metal, such as titanium, zirconium, tantalum and hafnium, which readily forms an oxide that bonds to the ceramic.

Ceramic to metal seals employing a sealing material of "active metal" are described in the article by M. E. Knoll in Review of Scientific Instruments, Vol. II, No. 1, Jan., 1961, pages 83 to 85. Previously, it was thought that indium alone would not form a good eutectic alloy with active metal for bonding to ceramic. For this reason, the indium was first alloyed with an equal amount of lead and a small amount of copper before alloying with titanium to seal a ceramic member to a metal member.

Cathode-ray tube envelopes have been previously made by bonding glass faceplates to ceramic funnel portions with seals of devitrified or crystallized glass, as described in U.S. Pat. No. 3,079,936 of W. H. Wilbanks et al., which is assigned to the assignee of the present application. The indium alloy seal of the present invention has the advantage over the devitrified glass seal of this previous envelope that the sealing step can be carried out in a much shorter time so that the sealing of the glass faceplate to the ceramic funnel can take place after evacuation of the envelope during the same heating cycle that is used for such evacuation. In addition, this enables the tube to be evacuated through the large, open end of the funnel which considerably reduces the time required for evacuation pumping. As a result, the manufacturing time and cost are greatly reduced.

Another advantage of the invention is that the use of an indium alloy seal eliminates the need for matching the coefficient of expansion of the sealing material with that of the ceramic and glass since the seal is made of a ductile metal which absorbs any stresses. This also enables the use of a thinner faceplate since such faceplate is not subjected to as much stress.

A further advantage is the lower sealing temperature of the indium alloy seal, which together with the short time required for sealing, prevents any damage to the phosphor layer on the faceplate, or any sagging of the glass faceplate. Also, the sealed envelope can be opened simply by melting the seal to enable easy repair or replacement of defective elements within the tube, after which the envelope is again evacuated and resealed by heating the same sealing material.

In addition to bonding ceramic to glass, the indium alloy seal of the present invention can be employed to bond ceramic members to other ceramic members, or to members made of other inorganic, nonmetallic materials, such as semiconductor material, for example, the silicon chips used for integrated circuits.

It is therefore one object of the present invention to provide an improved seal of a low-temperature metal alloy for bonding a ceramic member to another member of inorganic, nonmetallic material.

Another object of the invention is to provide a hermetic seal of a ductile metal between the glass faceplate and ceramic funnel portion of a cathode-ray tube envelope.

A further object of the invention is to provide an improved method of forming such a seal using an alloy of indium and active metal.

Still another object of the invention is to provide an improved method of manufacture of the cathode-ray tube envelope requiring a short sealing time which enables evacuation of the envelope through the large end of the ceramic funnel before it is sealed to the glass faceplate and thereby reduces the manufacturing cost of such tube.

An additional object of the invention is to provide such a seal of a ductile metal which reduces the thermal stresses on the ceramic member and the glass member and forms a strong, hermetic seal without need to match the thermal expansion of the glass and ceramic.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will be apparent from the following detailed description of certain preferred embodiments thereof and from the attached drawings of which:

FIG. 1 is an elevation view, with parts broken away for clarity, of a cathode-ray tube being manufactured in accordance with the method of the present invention during evacuation and prior to the sealing of the glass faceplate to the ceramic funnel;

FIG. 2 is a vertical section view taken along the line 2—2 of FIG. 1;

FIG. 3 is a vertical section view taken along the line 3—3 of FIG. 1;

FIG. 4 is a partial section view of a completed cathode-ray tube in accordance with one embodiment of the present invention after the sealing step of FIG. 1 has been completed; and

FIG. 5 is a partial section view of another cathode-ray tube, having the seal of the invention, which provides bistable storage of charge images.

DESCRIPTION OF PREFERRED EMBODIMENTS

As shown in FIGS. 1, 2 and 3, the hermetic seal of the present invention may be formed between a crystalline ceramic member, such as the hollow, ceramic funnel portion 10 of a cathode-ray tube envelope, and a glass member, such as the light transparent glass faceplate 12 of the cathode-ray tube. However, it is also possible to seal the ceramic member to a member of inorganic, nonmetallic material other than glass, including semiconductor material, such as silicon, quartz or a ceramic, such as fosterite and alumina. It should be noted that the term "ceramic" as used herein refers to a crystalline material whereas the term "glass" refers to a noncrystalline material.

As shown in FIG. 3, the seal of the present invention may be formed by coating a layer 14 of indium metal on the edge of the large, open end of the ceramic funnel 10, over an intermediate layer 16 of active metal, such as titanium, zirconium, tantalum or hafnium, or hydrides of such metals. The active metal is one which forms an oxide that bonds to the ceramic material of funnel 10 when heated. The ceramic funnel 10 is made of a crystalline ceramic, such as the fosterite or alumina ceramic material of the type discussed in U.S. Pat. No. 3,207,936 of W. H. Wilbanks et al. The active metal layer 16 and the indium layer 14 may be coated on the ceramic funnel in any conventional manner by brushing, spraying, silk screening or extruding a liquid solution of metal powder, organic binder and solvent. The indium and active metal powders are ground to a particle size which will pass through a 325 mesh. The active metal layer may be extremely thin, on the order of a few hundred angstroms, if it is evaporated onto the ceramic member, or it may be thicker, on the order of about 0.0005 inch, when applied as a liquid solution. Any suitable organic binder, such as methyl methacrylate plastic resin, and solvent, such as alpha-terpeneol, can be used in the solution. After drying to remove the solvent, the active metal layer 16 and later the indium layer 14 are adhered to the funnel edge by the binder.

If the indium layer 14 is applied with a thickness of 0.002 inch or more, it may be necessary to add approximately 0.25 of 1 of active metal powder to the indium powder in the liquid solution to improve the wetting of the indium layer on the active metal layer. It is also possible to apply the indium layer 14 as a preformed washer member, in which case the washer is made of an alloy of 99.75 indium and about 0.25 active metal and is then applied over an evaporated active metal layer 16.

As shown in FIG. 1, once the ceramic funnel 10 has been coated with the active metal layer 16 and the indium layer 14, it is heated in an inert atmosphere of argon or in a vacuum having a pressure of at least 10^{-3} torr from room temperature to a temperature of about 650° C. in approximately 15 minutes to form an alloy layer 18 which is bonded to the ceramic. The heating cycle may be more rapid since it is limited only by the resistance of the ceramic funnel to heat shock. The alloy layer 18 includes an alloy of indium and active metal and is believed to be bonded to the ceramic by an oxide of the active metal at the metal to ceramic interface.

As shown in FIG. 2, another metal layer 20 is coated on the glass faceplate 12 prior to sealing such faceplate to the ceramic funnel. The metal layer 20 is formed by a suitable wetting metal, such as gold, copper, silver or nickel, which wets the glass and draws the indium over the surface of the glass during sealing. The wetting metal 20 is vacuum deposited onto the glass faceplate in the annular seal area adjacent to the edge of the faceplate. The faceplate 12 is made of any suitable light transparent glass, such as the soda lime glass sold by Corning Glass Works as Corning No. 0080, or any of the common lead glasses, such as that designated by Corning No. 0120, which are discussed in the above-mentioned U.S. Pat. No. 3,207,936. Before the wetting metal layer 20 is deposited, the surface of the glass plate is thoroughly cleaned. Also, while not absolutely essential, it is good practice to apply an intermediate layer 22 of nickel, chromium or titanium beneath the wetting metal layer to improve its adherence to the glass. This intermediate layer 22 may be applied by vacuum vapor deposition. The thicknesses of these two layers 20, 22 are not critical as long as good bonding to the glass is achieved during the sealing. Similarly, it is possible to seal a ceramic member to a glass faceplate with the wetting layer 20 on the faceplate being a vapor deposited active metal, such as titanium, and the intermediate layer 22 eliminated. In this case, the seal between the two members is made of about 600°to 650° C. The advantage of this latter example is that the seal between the faceplate 12 and the funnel 10 is made in a single firing, that is, the funnel need not be prefired to bond the indium-titanium alloy, since this is accomplished at the time of sealing. However, the faceplate is limited to glasses which will withstand the higher temperature for a short time without degrading. Examples of these glasses are Corning Nos. 0080, 7740 (Pyrex) and 7900 (Vycor). The same limitations applies to the materials subsequently deposited upon the faceplate. In a like manner, when one ceramic member is sealed to another ceramic member, the wetting layer 20 on the other ceramic member should also be made of an active metal, such as titanium, and the intermediate layer 22 eliminated. As above, the seals are obtained in a single firing step, at a temperature of about 650° C.

The sealing step is accomplished by heating the glass faceplate 12 and the ceramic funnel to a temperature above approximately 160° C. to melt the indium alloy layer 18. The rate of heating may be as rapid as possible so long as the thermal shock resistance of the members is not exceeded. If the faceplate 12 and the ceramic funnel 10 are initially spaced from each other as shown in FIG. 1, the heating temperature should not exceed about 210° C. to prevent dewetting of the solder from the faceplate. Once the faceplate is moved into contact with the ceramic funnel, the seal takes only a few seconds to complete. At this point, the temperature is reduced to below the freezing point of the indium solder to produce an indium alloy seal 24 which hermetically seals the faceplate to the ceramic funnel, as shown in FIG. 4. In this regard, it should be noted that this indium alloy seal 24 now contains the wetting metal 20 as well as the active metal 16, so that it is a slightly different freezing temperature from that of the alloy layer 18.

As shown in FIG. 4, a phosphor layer 26 forming the fluorescent screen of the cathode-ray tube may be coated on the glass faceplate 12 prior to the heating step which forms the indium alloy seal 24. In addition, an electron transparent, light reflecting layer 28 of aluminum may be provided over the surface of the phosphor layer to increase the brightness of the light image produced thereby. The aluminum layer 28 may be provided in contact with the seal 24 so that it may be connected to an external ground or other voltage source. The sealing of the faceplate to the funnel can take place in the air if the cathode-ray tube envelope is to be evacuated later in a conventional manner through an exhaust opening in the base of the envelope. However, it is preferable to perform the evacuation of the envelope through the large, open end of the ceramic funnel 10 prior to the sealing of the faceplate using the same heating step for evacuation bake out and sealing. This is possible because of the greatly reduced time required for sealing. If this procedure is adopted, the sealing step takes place within a vacuum furnace and the vacuum is maintained until the seal 24 is formed since the envelope is evacuated during heating and such seal acts to hermetically seal the evacuated envelope.

During evacuation, the temperature may be increased above the sealing temperature to speed the release of any gases absorbed on the internal surfaces of the funnel 10, faceplate 12 and the metal parts in the tube, including the electron gun 30, as well as the vertical deflection plates 32 and the horizontal deflection plates 34. When the out gasing is complete, the temperature may be lowered back to the sealing temperature below 210° C. and then the faceplate is lowered into contact with the funnel. It should be noted that it is possible to initially position the faceplate in contact with the funnel during the out gasing and sealing, but this results in longer evacuation time. The faceplate and the edge of the ceramic funnel, on which the indium alloy layer 18 is provided, must be held in level horizontal positions to prevent the metal coating thereon from flowing off of the seal areas. This is prevented to some extent if the faceplate and the funnel are initially placed in contact.

In addition to the conventional cathode-ray tube of FIGS. 1 and 4, the seal of the present invention may also be employed in a direct viewing bistable storage tube of the type shown in U.S. Pat. No. 3,293,473 of R. H. Anderson. As shown in FIG. 5, the faceplate 12 of such a storage tube is coated with a thin, light transparent conductive layer 36 of tin oxide or other suitable material beneath a phosphor layer 38 of tin oxide or other suitable material beneath a phosphor layer 38 which serves as the storage dielectric of such tube. The phosphor layer 38 may be an integral or undivided layer which is sufficiently porous to enable secondary electrons emitted from its rear surface to pass through the phosphor layer and be collected by the transparent conductive coating 36. Thus, the indium alloy seal 24 penetrates through the thin, conductive layer 36 during bonding to the glass faceplate 12.

The storage tube of FIG. 5 is provided with the same electron gun structure and deflection plates of the tube of FIG. 1, and in addition includes at least one flood gun source of low-velocity electrons (not shown) which uniformly bombards the phosphor layer to cause bistable storage of a charge image written thereon by the main electron gun 30. A collimating electrode 40 of aluminum or other suitable metal is coated on the inner surface of the ceramic funnel 10 in order to collimate these low-velocity electrons so that they strike the phosphor storage dielectric 38 at approximately right angles thereto in order to prevent image spreading of the stored charge image.

It will be obvious to those having ordinary skill in the art that many changes may be made in the details of the preferred embodiment of the invention. For example, other inorganic, nonmetallic materials may be employed, including the crystallized glass ceramic "Pyroceram" sold by Corning Glass Works. Also, the cylindrical neck portion of the envelope may be made of glass and sealed to the ceramic funnel by another indium alloy seal. Therefore, the scope of the invention should only be determined by the following claims.

I claim:

1. Apparatus including a ceramic to nonmetallic bond formed by a metal seal, comprising:

a pair of members of inorganic, nonmetallic material at least one of which is made of crystalline ceramic; and

a metal seal bonding said pair of members together, said seal being made of a ductile metal alloy, including indium and an active metal material selected from the group consisting of titanium, zirconium, tantalum and hafnium, which forms a bond with said ceramic.

2. An apparatus in accordance with claim 1 in which the alloy includes a wetting metal selected from the group consisting of gold, silver, nickel and copper.

3. An apparatus in accordance with claim 1 in which the other member is also made of crystalline ceramic.

4. An apparatus in accordance with claim 1 in which the other member is made of glass.

5. An apparatus in accordance with claim 1 in which the other member is made of semiconductor material.

6. An apparatus in accordance with claim 1 in which the one member is a ceramic funnel portion and the other member is a light transparent glass faceplate portion of an envelope for a cathode-ray tube, and the seal is an annular, hermetic seal between one end of said funnel portion and said faceplate portion.

7. An apparatus in accordance with claim 6 in which the faceplate is a flat, glass plate having a layer of phosphor material provided on its inner surface.

8. An apparatus in accordance with claim 7 in which a light transparent, conductive film is applied to the faceplate beneath the phosphor layer and extends through the seal to the exterior of the envelope.

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