July 16, 1957 B. SCHWARTZ ET AL 2,799,814

GERMANIUM PHOTODIODE

Filed Sept. 1, 1953

Fig. 1

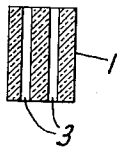



Fig. 2

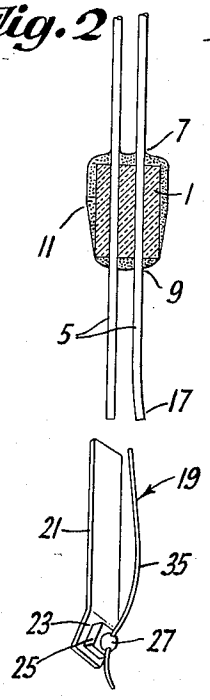



Fig. 3

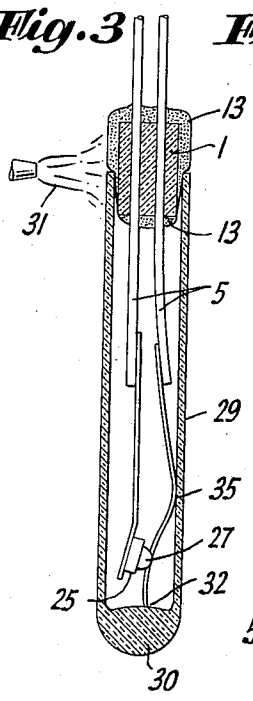



Fig. 4

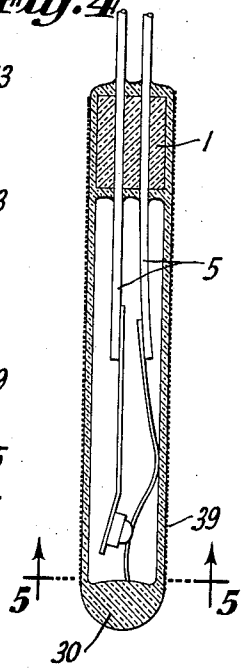



Fig. 6

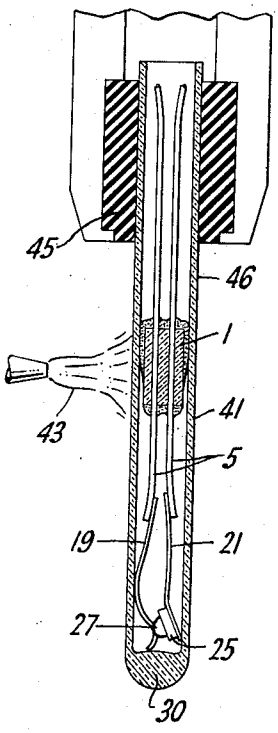



Fig. 7

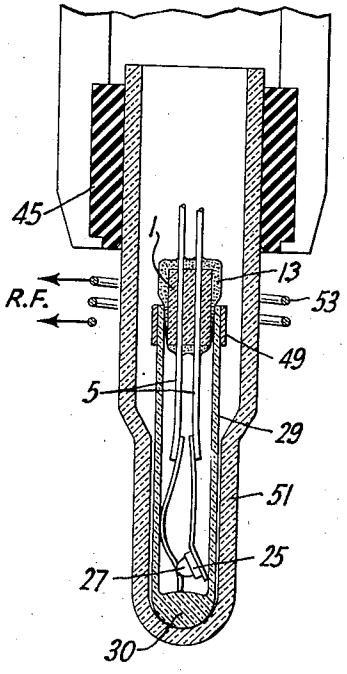
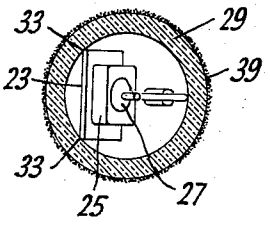



Fig. 5

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# GERMANIUM PHOTODIODE

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8 Claims. (Cl. 317—234)

This invention relates to the structure and methods of manufacture of electrical devices having a hermetically sealed envelope. One aspect relates to means and methods for obtaining rigid mounting of the parts within an envelope and to hermetically sealing the parts therewithin.

It is an object of the invention to mount within an envelope the assembled components of such electrical devices as contact rectifiers, photodiodes and the like in such manner that they will be able to withstand severe shock and vibration.

It is a further object to seal heat sensitive electrical devices in an envelope with minimum hazard of injury to the devices from the heat.

A still further object is to form a fused glass seal in an envelope enclosing a semiconductor.

An additional object is to evacuate the envelopes of electrical devices, especially miniature devices, and seal such envelopes, while so evacuated, in an effective manner.

Sometimes electrical devices are made exceedingly small so that, as in the case of manufacture of the crystal photodiodes here exemplified as embodiments of our invention, the envelope may be less than ⅝ of an inch long and less than ⅛ of an inch in diameter. In such cases, where the envelope is of glass, or the like, the leads from the electrodes exit from the envelope through a very thin insulating wall, and the wall is very apt to crack or chip away due to any intended or accidental bending of the exterior portion of the lead-in wires of the tube. It is therefore another object of this invention to provide for a construction which shall avoid this possibility of breakage while yet providing for a good hermetic seal between the leads and the envelope.

It is desirable to seal these devices against admission of water vapor and other deleterious gases; and it is further desirable to evacuate their envelopes. Because of the exceedingly small size of the tube there is great difficulty in exhausting the same. Where parts are so small, to provide the envelope with a discrete exhaust tubulation for the exhaust port of a conventional vacuum tube exhausting and sealing machine involves practical difficulties. It is therefore still another object of this invention to provide a new and effective means and method for exhausting exceedingly small envelopes, and to heat-seal such evacuated envelopes despite the sensitivity of the enclosed components to heat.

Furthermore, the ordinary methods of sealing the glass with gas flames having pencil point sharp tips while efficacious in sealing the portions of the envelope together yet may give rise to damage to electrodes within tubes of the size here dealt with since heating with gas does not confine the heat to the selected area desired to be heated as much as would be desired. It is therefore yet a further object of the invention to provide for a new mode of effecting sealing of the tubes.



These and other objects will be apparent after reading the following specification and claims when taken in conjunction with the accompanying drawing in which

Fig. 1 is a cross sectional view through a cylindrical ceramic plug utilized in the construction of an illustrative germanium photodiode embodying features of this invention.

Fig. 2 is an enlarged view partly in section showing the plug with leads threaded therethrough and sealed thereto, with a semiconductor junction photodiode ready to be joined to the leads.

Fig. 3 is an enlarged view showing the photodiode in assembled relationship with the envelope in the process of being sealed to the plug.

Fig. 4 illustrates the completed photodiode.

Fig. 5 is a still greater enlarged sectional view of a completed photodiode along the line 5—5 of Fig. 4, and

Figs. 6 and 7 illustrate alternative means and methods of sealing the envelope in fabricating the device of Fig. 4.

It should be understood that although the invention has been illustrated specifically as applied to a photodiode, it will be apparent, after reading the specification, that portions of the invention are applicable to many forms of electronic tubes and are not necessarily restricted to photodiode construction.

Referring to the drawings more in detail, there is disclosed a cylindrical plug **1** made of a suitable ceramic material as steatite in which are formed a number of bores **3**. In the case of the photodiode chosen for illustrative purposes, there are two bores. Inserted through these bores are conventional leads **5** such as dumet, these leads being sealed to the ceramic by fusing low melting glass frit or suitable glaze around the leads where they enter or leave the plug, as indicated at **7** and **9**. In the case of the form of invention disclosed in Figs. 1 to 4, the glass at the top of the plug not only embraces the leads **5** but extends down about the periphery of the ceramic plug as indicated at **11**. The lower ends of one of the leads **5** is slightly curved away from the other lead, as at **17** and suitably secured to this curved end, by welding or otherwise, is a fine nickel wire **19** as an extension of its lead **5**. Likewise, mounted on the other lead, is a nickel strip **21** as an extension of its lead **5**, the lower end of which is bent backwardly, as at **23**. Mounted on the lower face of the bent portion is an N-type germanium die **25**, surmounted by a germanium-indium alloy button **27**. The nickel wire is joined to the button. In use, the junction between the indium and the germanium die is exposed to a source of light, as will be subsequently explained more in detail. The fabrication of such junction photodiode involving meticulous heat-treatment, etching and other treatments, is well known and need not be elaborated here; but the junction is readily damaged by excessive heating, and it is desirable for stability and long life that the unit be enclosed in a sealed envelope.

After the electrode parts have been thus assembled, the bulb **29** is slipped over the unit, into telescopic relation to the ceramic plug **1**, until the end of the bulb **30** is engaged by end **32** of wire **19** and the bulb is fused to the plug by means of the low-melting glass **13** through suitable application of heat, as from a flame **31**.

The bent back portion **23**, in the completed tube, see Fig. 5, has its rectangular corners **33** resting against the inner wall of the bulb **29** while the nickel wire **19** has an outwardly bowed portion **35** thrusting against the opposite wall of the bulb. Thus the junction and its leads are restrained against lateral movement through three point contact of the electrodes with the lateral walls of the bulb. Further by reason of the mounting of the

electrodes on the lead-in wires 5, there is provided a mount for the electrodes which resists any displacement of parts endwise of the bulb due to shock or vibration.

The bulb 29 is provided with a thickened lens portion 30 for focusing light onto the junction of the indium alloy button and the germanium. The rest of the bulb is advantageously coated with some opaque substance 39, as a black paint, to prevent stray light from hitting the sensitive portion of the diode. Apart from its photosensitivity, the junction is an excellent rectifier; and where so used, the coating can be extended over the end of bulb 29, to guard against stray effects due to light changes.

By virtue of the inherently tough ceramic plug, the leads may be deformed without special danger of cracking, as would be entailed in an all-glass end. Also, the leads can be placed very close to each other without danger of their drifting together during the head-sealing of the envelope, as would frequently occur were the sealed end formed of soft glass.

The structure of Fig. 4 may be both evacuated and sealed as indicated in Fig. 6. The glazed ceramic plug of Fig. 3 is controlled carefully so as to be slightly smaller in diameter than the inner diameter of bulb 41, that is purposely much longer than bulb 29. The entire plug carrying the leads and the rectifying junction is dropped into the bulb and the plug is fused throughout its length to the glass bulb that is heated externally as by flame 43. This is effected while the free end of the bulb is held in a rotating chuck 45. Prior to the sealing operation just described, the envelope is evacuated by suitable vacuum pumps, similar to the techniques employed to evacuate radio tubes during their manufacture. Subsequent to the sealing operation, the skirt 46 of the bulb 41 may be cut off immediately above the ceramic plug. The cut-off edge may be flame polished if desired.

In Fig. 7 there is illustrated another mode of joining the plug and envelope. Instead of utilizing a gas flame at the locus of fusion of the ceramic parts, with possibility of heat spreading beyond the desired region and thereby damaging the semiconductor junction, the heat of fusion is obtained by electric induction. About the area to be heated, there is painted a ring or stripe of electrically conductive material 49, as silver paint, or silver oxide reduced to metallic silver by firing, in a preliminary treatment in a reducing-atmosphere furnace. The assembly of parts, as in Fig. 3, is inserted in a furnace whose wall 51 is an insulator, as quartz. To effect fusion of the glass, the painted portion of the envelope is inductively coupled to high-frequency energized coil 53, whereupon the metallic ring or stripe 49 acts as a shorted secondary and heats up sufficiently to soften and fuse the adjacent glass frit or glaze on the ceramic. Thus a sealing of parts is accomplished. The lower portion of quartz wall 51 is of reduced diameter to hold bulb 29 upright and keep band 49 spaced from wall 51 during heating operations. As in Fig. 6, the bulb is evacuated before sealing is effected, by suitable vacuum pumps; also suitable getters in the vacuum line may be used. The imperfect fit of glazed plug 1 within bulb 29, before the heating and softening of the low-melting glass 13 is started, provides a passage for evacuation of the bulb. Because this passage is constricted, the period of evacuation may be somewhat longer than would be the case where a separate exhaust tubulation is formed on the envelope. But the added bulb-heating involved in tipping off such tubulation and the added size of the resulting unit make such exhaust tubulation undesirable, since the units as shown may be packed one against the other in a row or in a rectangular matrix for sensing punch cards.

Having thus described our invention, what we claim as new is:

1. An electrical device comprising an envelope, multiple leads in said envelope braced against the walls thereof, one of said leads carrying a rectifying junction, said rectifying junction being in contact with a second of said of leads and engaging said second lead at one point, only, intermediate the length thereof.



2. An electrode tube comprising an envelope, a pair of electrodes in said envelope with their upper ends in spaced apart relation, one of said electrodes carrying a rectifying junction, said rectifying junction lying in contact with the other of said electrodes toward the lower ends of the electrodes, each of said electrodes having portions bearing against the walls of the envelope while in said contacting relation to inhibit separating movement of the electrodes.

3. An electrical device comprising an envelope having a cylindrical wall, a pair of leads within said envelope having their lower ends in spaced apart relation, one of said leads having an end bent toward the cylindrical wall, with corners of the so bent end bearing against the cylindrical wall at two points, a rectifying junction carried by said bent end and engaged by the other one of said leads, said other lead being bowed outwardly intermediate of its ends into bearing engagement with the cylindrical wall of the envelope.

4. An electrical device comprising an envelope having elongated walls, a pair of lead-ins rigidly sealed in one end of said envelope, a contact rectifying device carried by at least one of said lead-ins in said envelope at the opposite end thereof, each of said lead-ins having portions bearing against the elongated walls of the envelope.

5. An electrical device comprising an envelope and lead-ins therein, an insulating plug at the otherwise open end of said envelope through which said lead-ins extend, a conductive device in said envelope and connected to said lead-ins, a glass seal about an end face of said plug and extending about the sides of the plug, and said envelope comprising a portion sealed to said extending glass.

6. An electrical device comprising an envelope and lead-ins therein, a plug at the bottom of said envelope through which said lead-ins extend, a conducting device in said envelope and connected to said lead-ins, a glass seal about the bottom and top of the plug, said glass seal extending about the entire periphery of the plug and said envelope comprising a portion fused to the glass about the plug to form a sealed envelope.

7. An electrical device comprising an evacuated envelope and lead-in wires extending through an end thereof, a ceramic plug at the bottom of said envelope through which said lead-in wires extend, a rectifying device within said envelope remote from said plug and carried by said lead-in wires, a low-melting glass seal extending over about the inside end of said plug and extending about the sides of the plug, and said envelope having a portion telescoped over the plug, said portion being fused to the envelope by the low-melting glass seal.

8. The method of fabricating a hermetically sealed and evacuated rectifying device, including the steps of forming a glass tube with one end closed and with the opposite end open, applying an encircling conductive film to the exterior of the tube adjacent its open end, forming a subassembly including a rectifying junction on leads sealed in and extending through a ceramic plug and spaced from said junction sufficiently to afford thermal isolation, coating the ends of said plug and the sides thereof contiguous with one end with a low-melting glass, inserting said rectifying junction into the tube to a position adjacent the closed end thereof with the plug extending into said open end adjacent said encircling conductive film, inserting the tube and the inserted subassembly into a chamber having insulating walls about and spaced from said encircling film, evacuating the chamber and said tube, and inductively heating said film from the exterior of the chamber to heat-seal said plug to the open end of said tube.

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