



# PATENT SPECIFICATION

DRAWINGS ATTACHED

**L090.585**

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Date of Application and filing Complete Specification: Jan. 7, 1966.

No. 878/66.

Application made in United States of America (No. 445944) on April 6, 1965.

Complete Specification Published: Nov. 8, 1967.

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Index at acceptance:—H1 K(1D3A, 4F8, 5A); C1 M(19E1A, 19E2C, 19E3C5, 19E4D, D15, S10, S20)

Int. Cl.:—H 0111/02

## COMPLETE SPECIFICATION

### Improvements in or relating to Photosensitive Devices

We FAIRCHILD CAMERA & INSTRUMENT CORPORATION, of 300 Robbins Lane, Syosset, Long Island, New York, United States of America, a Corporation of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a protective enclosure for a photosensitive device and a process for forming such a device. In particular, this invention relates to a protective enclosure adapted for efficient space utilization and having an optically flat transparent window, and to the process for forming such an enclosure.

It is well known in the semiconductor art that photosensitive semiconductor devices, such as silicon and germanium photodiodes and phototransistors, require protection from hostile environments in order to provide stable and reliable operation. The design of such an enclosure where space and economics are important considerations poses a difficult problem. For example, where photodiodes are employed in a punched card reader it is necessary that the size of the enclosure be limited. In the case of photodiodes and similar devices this size limitation conflicts with the principle that the response of such devices is proportional to their light sensing area. Thus, it is desirable to make the device within the enclosure as large as practical and to make the enclosure as small as possible.

The problem of producing a low cost, economical device is accentuated by the optical requirements of its enclosure. It is necessary when enclosing such a device that the enclosure should include a window located adjacent the device. The window should have a minimum of influence on the direction and intensity of the incident radiation. This pro-

vides an efficient device and affords the system designer a maximum of use flexibility.

In the prior art, two general classes of protective enclosures for semiconductor photosensitive devices have been developed. In one class of device a glass window has been installed in the cap of a standard transistor enclosure. Such devices are shown in U.S. Patent 2,898,474 issued on August 4, 1959 to R. F. Rutz and U. S. Patent 2,749,488 issued on June 5, 1956 to S. E. Mayer. This arrangement suffers from two disadvantages—inefficient use of space and unsatisfactory optical properties. In general, such enclosures are too bulky for many applications and the window is of poor quality and varies from unit to unit in manufacture. In order to provide flat uniform windows, the cost of the enclosures would be increased by at least an order of magnitude. In addition to these disadvantages, the seal around about the window in such arrangements may be imperfect and the mechanical soundness of the package may leave much to be desired.

The second class of prior art enclosures has employed small diameter glass tubings which are flame sealed on one end to provide a window. At the other end of the enclosure a head assembly with fine lead wires is inserted and provided with a pinch-off seal. This enclosure, which is generally referred to as the "match stick" package, suffers from the disadvantages of extreme fragility of the leads and seal and relatively uncontrolled optical properties of the window. Such a package does have the advantage of permitting high density packing of the device for data processing applications. A prior art patent disclosing an enclosure similar to the "match stick" package is U. S. Patent 3,134,058 issued to A. M. Walkow on May 19, 1964.

The object of the present invention is to

[Price 4s. 6d.]

devices



provide a device in which the disadvantages of the devices of the prior art are avoided.

According to the invention, an enclosed photosensitive device adapted for effective utilization of space and efficient transmission of light to the photosensitive device, comprises a conductive supporting and connecting pin, a photosensitive device connected to said pin, a tube around and separated from said pin, sealing glass substantially filling the separation between said tube and said pin and sealing attached to said pin and tube and a rim joined to said tube adjacent said photosensitive device and substantially filled with sealing glass having optically flat surfaces, whereby the photosensitive device is exposed to light through said optical surfaces and is protectively enclosed by said tube and rim sealed with glass.

The process for forming the enclosed photosensitive device according to the invention comprises the steps of sealing a rim with glass and welding said rim to a tube sealed at one end and having a photosensitive device mounted at the other end, said rim welded to said end adjacent said photosensitive device, whereby an enclosed photosensitive device is formed having an optically flat window adjacent said photosensitive device.

Preferably the welding step is a resistance welding step and the sealing of the rim includes the steps of outgassing and oxidizing said rim, filling the rim with a sealing glass having a coefficient of expansion matching that of the metal so that the sealing glass is exposed at one surface of the rim, and then firing the rim and sealing glass to form an intimate bond and seal between the rim and sealing glass.

The use of two parts, the rim and the tube, enables a photosensitive device mounted at one end of the tube to be easily reached prior to joining the two parts. This enables one of the leads of the photosensitive device to be readily attached to the inside diameter of the tube. The resistance welding of the two parts is accomplished without affecting the tube seals or creating contamination within the enclosures. This welding may be facilitated by gold plating the two tubes and forming an angular edge of one of the two parts being joined.

The invention will be readily understood by reference to the detailed specification which follows and the drawings wherein:

Fig. 1 is a sectional view of the enclosed photosensitive device; and

Figs. 2-7 shows the device at various stages of manufacture.

Referring to Fig. 1, the enclosure comprises a tube 10 joined to a rim 12 by a resistance weld 14. The Kovar tube 10 (Registered Trade Mark) is filled with a sealing glass compound 16, such as Corning (Registered Trade Mark) 7052 Kovar sealing

glass, which surrounds a pin 18 located along the axis of cylindrical tube 10. Glass 16 functions as a support for pin 18. Preferably rim 12 and pin 18 are made from a conductive metal which has a coefficient expansion matching the sealing glass to be used, such as Kovar or Fernico which contain approximately 54% Fe, 28% Ni and 18% Co by weight. Pin 18 has a photosensitive device 22, such as a phototransistor or photodiode, attached to its flat end 24 with one lead 26 from the photosensitive device connected to tube 10.

The sealing glass 16 forms an intimate seal around pin 18 and the inside diameter of tube 10 for a substantial portion of their length. The sealing glass around pin 18 seals one end 20 of the enclosure. In addition to forming a seal, the sealing glass 16 adds strength and rigidity to tube 10, thereby providing a mechanically sound package. The fragility of the lead connection to the package is minimized by the use of a pin surrounded and supported by glass.

The rim 12 at the top of the enclosure has an inside diameter smaller than that of tube 10, resulting in the wall of rim 12 being thicker than tube 10. Although this is not critical, a thicker outer rim reduces heat shock on the glass-to-metal seal during the final welding operation. The thickness of rim 12 enables a resistance weld to be employed to connect tube 10 and rim 12; this thickness prevents the inside diameter of rim 12 from reaching a temperature that might alter the inside seal. The resistance weld 14 forms a continuous, reliable, air tight joint that may be formed without contaminating the enclosure.

The rim 12 is entirely filled with sealing glass 30 having an exposed surface 32 substantially flush with the top surface 34 of rim 12. Both surfaces are finished by mechanical polishing or fire polishing to form an optically flat transparent window. Thus, the rim 12 and sealing glass 30 located adjacent photosensitive device 22 forms a window that is adapted to evenly distribute light incident thereto over the surface of device 22. In addition, when rim 12 is attached to tube 10, the device 22 is enclosed by a hermetic seal in a mechanically rigid enclosure. The use of a tube-like structure enables photosensitive devices to be employed in high density arrangements. Tubes and rims having an outside diameter of .080 inches have been employed. It should be noted that the inside diameter of tube 10 and rim 12 need not be much greater than the exterior dimension of device 22.

The process for forming the device shown in FIG 1 is illustrated in FIGS 2-7. A tube 40 is prepared for sealing by first outgassing and then oxidizing its inside diameter (FIG 2). The outgassing removes any carbon

minimized

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that exists on the inside diameter, thereby preventing the formation of gas bubbles when the inside diameter of tube 10 is later sealed with glass. The oxidation of the inside diameter is necessary for the glass to form a seal with the tube. Both the outgassing and oxidizing are well known procedures in the glass-to-metal sealing art.

The tube 40 is next filled with sealing glass that may take the form of a cane of sealing glass 32 with a diameter slightly smaller (about 1 mil) than the inside diameter of tube 40. The sealing glass 32 and tube 40 are fired in an inert atmosphere at a temperature between about 950° and 1150°C, preferably about 1100°C whereupon a seal is effected around the inside diameter of tube 40 (FIG 3).

A plurality of glass filled and sealed tubes 40 are joined to form an integral composite bundle 42 typically having a diameter of one inch (FIG 4). This joining may be readily accomplished by employing an epoxy fixture having a plurality of holes with a length about as long as tubes 40. The glass filled tubes 40 are dipped in epoxy which secures the tubes in the holes of the fixture. This produces composite member 42 which includes a plurality of glass filled tubes.

The composite member 42 is then sliced into a plurality of wafers 44 that typically have a thickness of 2-4 mils greater than the thickness of the finished rim 12 (FIG 5). Slicing may be accomplished on a diamond saw such as the ones commonly used in the semiconductor art. After slicing, the wafers are lapped and polished to a final thickness and finished by well known techniques. The polishing may be accomplished either by mechanically polishing wafers 44 or by fire polishing individual rims 12 in an inert atmosphere and temperature adapted to prevent undesired flow of the sealing glass. The use of fire polishing has the advantage of resealing any leaks or cracks in the glass-to-metal seal which may be caused by mechanical shock during the sawing operation or other processing and handling operations. Fire polishing is also somewhat more economical than mechanical polishing. However, for extremely high quality windows, a mechanical polish produces a more nearly perfect finish than the fire polishing technique.

Regardless of the polishing technique employed, the individual rims 12 must eventually be separated from wafer 44. This may be readily accomplished by placing the wafers into a container 46 and submerging it in a solvent 48 contained in tank 50 (FIG 6). The solvent is selected to be one which will dissolve the epoxy or other material which holds the individual rims together. Thus a plurality of individual rims will remain at the bottom of container 46 when it is removed from solvent 48. The individual

glass filled rims 12 may then be prepared for welding.

The rims 12 are joined to tubes 10 sealed with glass 16 and having a photosensitive device mounted therein. The glass filled tubes 10 are formed by outgassing, oxidizing and firing in a manner substantially identical with that employed to form tubes 40 (FIGS 2 and 3). The main differences between forming glass filled tube 40 and glass filled tube 10 is that a Kovar pin 18 is placed within tubular sealing glass 16 of tube 10, but not, of course, in tube 40. The sealing glass 16 and pin 18 are placed within tube 10 and fired simultaneously to seal one end of tube 10. The sealing glass 16 does not entirely fill the tube 10 as there is no glass above the surface 52 of pin 18. This removes the glass seal a sufficient distance from weld 14 (FIG 1) so that it is not substantially affected by the heat generated during welding. In addition, a portion of the inside diameter of tube 10 remains available for use as an electrical connection to photosensitive device 22 via lead 26. The bottom of the photosensitive device 22 is also electrically connected to pin 18.

The completed rim 12 and tube 10 are joined by an appropriate welding procedure. Preferably, tube 10 is resistance welded to rim 12. This is facilitated by first forming an angled edge at the end of tube 10 adjacent the surface of rim 12 where the weld is formed. This edge is preferably an acute angle of 60° or less, making a V-configuration which provides high contact pressures between rim 12 and tube 10 with a low total applied force. The use of a low total force avoids column buckling of the thin tube while electrical contact around the entire periphery of the joint is achieved. The use of the thin tube enables the weld area to be positioned a sufficient distance from the glass-metal seal of rim 12 to avoid cracking of the seal during the welding cycle. It has been found that a particularly excellent weld results when tube 10 and rim 12 are gold plated with a sufficient thickness of gold to provide good electrical contact between the welding electrodes 54 and 56. A gold plated thickness of approximately 200 microinches has proven satisfactory for this purpose. With tube 10 and rim 12 positioned as shown in FIG 10, electrodes 54 and 56 contact tube 10 and rim 12, respectively, and form the resistance weld 14. Thus, the enclosure of the photosensitive device shown in FIG 1 is completed.

The above process enables enclosures for photosensitive devices to be economically and reliably manufactured. The resulting devices are uniform and provide a window of excellent optical properties. The enclosure is hermetically sealed by a sealing glass which has a substantial seal length and which also pro-

vides a mechanically secure arrangement. The joining of tube 10 and rib 12 is accomplished without contamination of the enclosed region which houses the photosensitive device and without substantially affecting the metal-glass seal.

#### WHAT WE CLAIM IS:—

1. An enclosed photosensitive device adapted for effective utilization of space and efficient transmission of light to the photosensitive device, comprising:

a conductive supporting and connecting pin;  
a photosensitive device connected to said pin;

- 15 a tube around and separated from said pin;

sealing glass substantially filling the separation between said tube and said pin and sealingly attached to said pin and tube;

- 20 a rim joined to said tube adjacent said photosensitive device and substantially filled with sealing glass having optically flat surfaces, whereby the photosensitive device is exposed to light through said optical surfaces and is protectively enclosed by said tube and rim sealed with glass.

2. The enclosed photosensitive device of claim 1 further characterized by said pin being metal, said photosensitive device being a semiconductor device, and said tube being the same metal as and encircling said pin, said sealing glass having a coefficient of expansion matching said metal, and said rim being of the same metal as said pin.

- 35 3. The enclosed photosensitive device of claim 2 further characterized by said rim being joined to said tube by a resistance weld at the end of said tube adjacent said photosensitive device.

- 40 4. The enclosed photosensitive device of claim 1 further characterized by said rim having substantially the same outside diameter as said tube.

5. The structure defined in claim 4 where-

in said tube has a diameter less than 0.100 inches and said glass-sealing compound filling the separation between said tube and said lead has a length that is greater than half the length of said tube.

6. The structure defined by claim 5 wherein the tube and rim are a nickel-iron-cobalt alloy and the glass sealing compound matching the coefficient of expansion of said alloy is substantially within said tube and rim.

7. The structure defined in claim 6 wherein said optically flat surfaces are fire polished.

8. A process for forming the enclosed photosensitive device of claims 1—7 comprising the steps of:

sealing a rim with glass; and

- welding said rim to a tube sealed at one end and having a photosensitive device mounted at the other end, said rim welded to said end adjacent said photosensitive device, whereby an enclosed photosensitive device is formed having an optically flat window adjacent said photosensitive device.

9. The process of claim 8 further characterized by said welding step being a resistance welding step.

10. The process of forming an enclosed photosensitive device of claim 8 further characterized by the additional first step of outgassing and oxidizing said rim, and then filling the rim with a sealing glass having a coefficient of expansion matching the metal so that the sealing glass is exposed at one surface of the rim, and then firing the rim and sealing glass to form an intimate bond and seal between the rim and sealing glass.

11. An enclosed photosensitive device substantially as described with reference to the accompanying drawings.

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