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Wolfgang

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[54] **ELECTRON TUBE WITH BONDED EXTERNAL SEMICONDUCTOR ELECTRODE**

[72] Inventor: **Lozure G. Wolfgang,** Fort Wayne, Ind.

[73] Assignee: **International Telephone and Telegraph Corporation,** Nutley, N.J.

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[52] **U.S. Cl.** ....**313/65 AB,** 313/95, 315/3

[51] **Int. Cl.**.............................**H01j 31/26,** H01j 39/14

[58] **Field of Search**..313/94, 95, 65 R, 65 A, 65 AB, 313/65 T; 315/3

[56] **References Cited**

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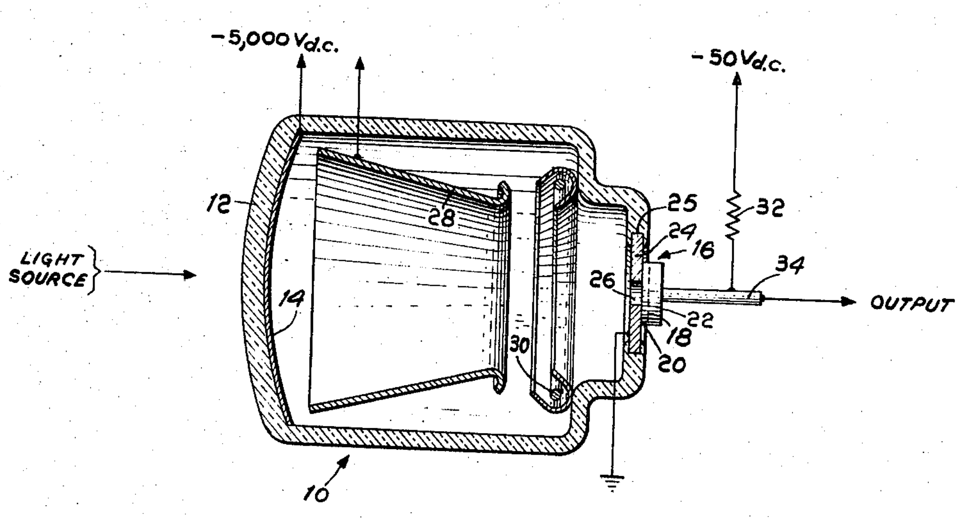
Primary Examiner—Stanley D. Miller, Jr.

Attorney—C. Cornell Remsen, Jr., Walter J. Baum, Paul W. H. Emminger, Charles L. Johnson, Jr., Philip M. Bolton, Isidore Togut, Edward Goldberg and Menotti J. Lombardi, Jr.

[57] **ABSTRACT**

A semiconductor element is hermetically sealed to an evacuated electron tube envelope to provide a target electrode which collects electrons within the tube while the junction area and output electrode are external to the vacuum environment. This minimizes interaction of contaminating materials between electrodes such as a photocathode and the semiconductor.

12 Claims, 1 Drawing Figure



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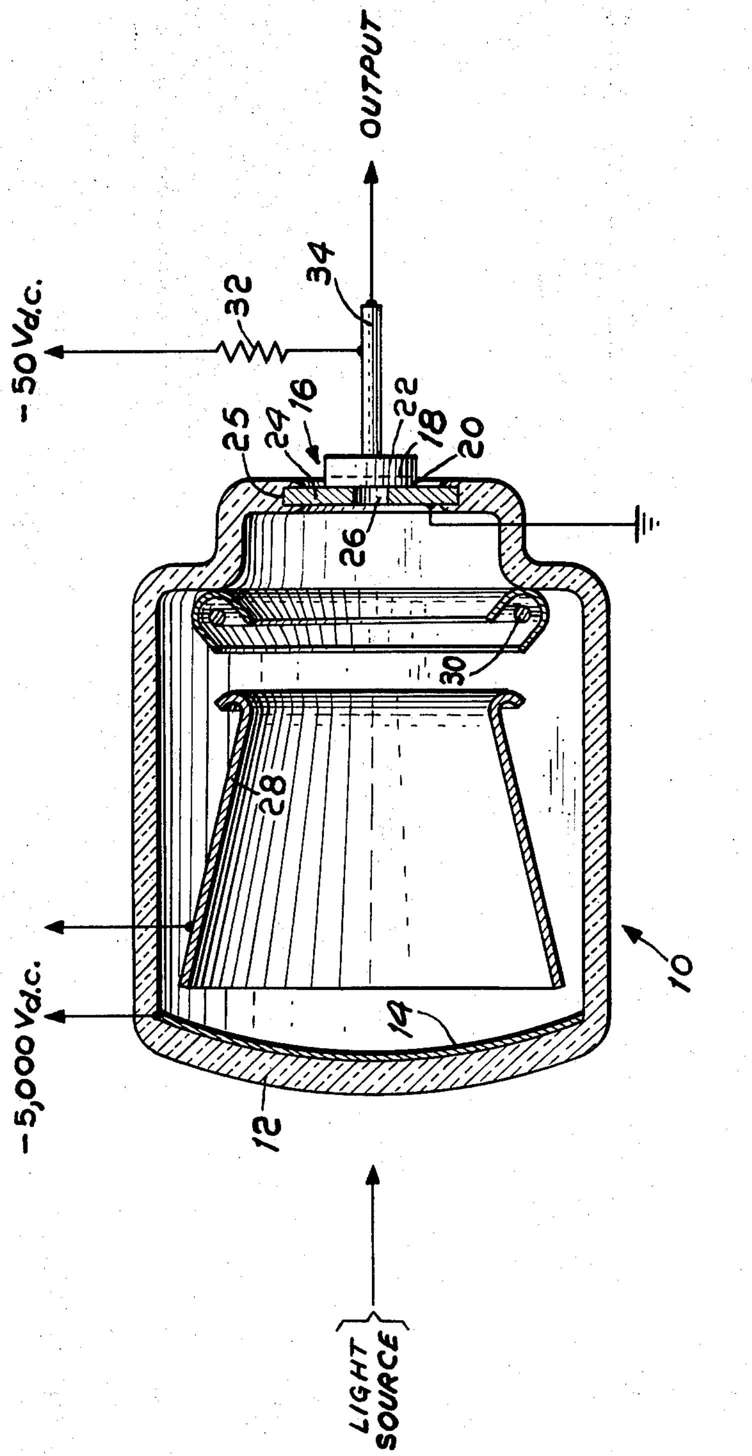

INVENTOR
LOZURE G. WOLFGANG
BY Edward Goldberg
ATTORNEY

ELECTRON TUBE WITH BONDED EXTERNAL SEMICONDUCTOR ELECTRODE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to semiconductor devices used in conjunction with electron tubes and particularly to a semiconductor output device sealed to an electron tube in a manner that avoids exposure of the sensitive semiconductor electrode to the internal deleterious materials.

2. Description of the Prior Art

Semiconductor devices have been used within electron beam tubes to provide amplified output signals, electron multiplication and as switching devices responsive to signals on the electron beam. Examples of such devices are shown in U.S. Pat. No. 2,749,471 issued June 5, 1956 and U.S. Pat. No. 2,886,739 issued May 12, 1959. One of the difficulties in combining such hybrid vacuum-solid state devices is the destructive effect of cathode processing upon the semiconductor material. For example, cesium and other alkali metals, utilized in cathodes processed at elevated temperatures within the completed tube assembly, may rapidly destroy the semiconductor properties. In addition, long term interaction may result in more gradual degradation of the semiconductor element or cathode. In such a case, photocathode materials used in light sensitive tubes may migrate onto the semiconductor or the photocathode surface may be poisoned by materials emitted from the semiconductor or passivating substances employed to protect the semiconductor. Sodium and potassium are commonly employed photocathode materials which, when heated, can attack the silicon oxide protecting layers of planar type silicon semiconductor devices. In particular, the junction areas of the different conductivity type materials of the semiconductor are sensitive to such contamination. One approach which has been explored to overcome these problems is the use of in-vacuum photoprocessing and transfer wherein photocathodes may be processed separately and then cooled and assembled within a vacuum environment. This technique, however, is slow and expensive.

SUMMARY OF THE INVENTION

It is therefore the primary object of the present invention to provide a simple, less costly vacuum tube-semiconductor hybrid structure which substantially minimizes interaction of contaminating materials between a cathode and a semiconductor output device. This is accomplished by a novel arrangement wherein a semiconductor device is bonded and hermetically sealed to one end of a vacuum tube envelope so that one electrode surface is exposed through a small aperture to collect electrons within the tube while the sensitive junction area and other electrodes are external to the envelope. A metallic alloy ring or plate such as a composition of nickel, cobalt and iron, known as Kovar, is preferably used to provide a bond between the semiconductor and the glass envelope. The details of the invention will be more fully understood and other objects and advantages will become apparent in the following description and accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

The FIGURE schematically shows a cross-section of a typical photomultiplier tube employing the semiconductor output device sealed at one end in accordance with the invention.

DESCRIPTION OF THE PREFERRED embodiments

A shown in the FIGURE, a photomultiplier tube glass envelope **10** includes a light transparent faceplate **12** at one end, having a photosensitive electron emissive coating **14** on the inner surface which emits electrons in response to the impingement of light thereon from an external source. A semiconductor device **16**, such as an NP diode, having a junction **18** between the two opposite conductivity type electrodes **20, 22**, is disposed at the other end of the tube. One surface of the semiconductor, including an inner first electrode **20**, is bonded conductively to a metallic ring or plate **24** which is sealed at the outer periphery **25** to the glass envelope. The ring is preferably made of a nickel, cobalt and iron composition commonly known as Kovar which is particularly suitable for sealing directly to glass by well known heating and fusion techniques. For sealing N-type electrodes to the Kovar ring, a nickel-nickel-alloy bond is preferably utilized, while for P-type materials a gold-germanium bond may be employed. In aperture **26** in the ring provides an opening for electrode **20** which is exposed to the electron beam to act as a target for the collection of electrons from the photocathode **14** within the tube. A potential source is preferably connected between the photocathode an electrode **20** or ring **24**, and for example, may apply an accelerating voltage of from −5,000 to −10,000 volts d.c. to the cathode **14**, with the ring **24** being connected to ground or 0 volts d.c. In addition, an electrostatic focusing electrode **28** may be utilized for focusing electrons from the photocathode onto electrode **20**. The potential on the focusing electrode is preferably close to that of the cathode. Element **30** represents an emissive coated electrode utilized during the high temperature processing within the tube to direct a supply of photocathode materials onto the faceplate.

The electrons emitted from photocathode **14** normally penetrate the first or input electrode **20**, which may be an N-conductivity type layer, and pass into the depletion region associated with the junction which extends for the most part into the P-type conductivity material of electrode **22**. The electron passage through the depletion region operates in a well known manner to cause an electron multiplication action. A suitable bias potential between electrodes **20, 22** provides proper operation of the semiconductor. For example, a reverse bias of −50 volts d.c. is applied to the P output electrode with respect to the N input electrode. Use of a PN semiconductor element having reversed positions of the two opposite conductivity type electrodes would require opposite polarity potentials thereacross. The output signal, in the form of current or a voltage pulse developed across a load resistor **32**, is extracted from the connection **34** to the output electrode **22**. The output electrode connection may be in the form of a longitudinally extending stud which can connect to a central conductor of a coaxial output cable.

The external portions of the semiconductor including the remaining surface of electrode **20** bonded to the metal ring around the aperture, the underlying junction and the adjacent surface of electrode **22** are preferably hermetically sealed by an expoxy resin coating or other suitable dielectric encapsulant. For planar type semiconductor devices, the concentric junction and outer electrode surfaces have coatings of protective isolating layers which prevent direct electrical contact to the bonded metal ring. The connections to the electrodes and the hermetic sealing have the same configurations as described above. The semiconductor device may also be a transistor which can be bonded and sealed in a similar manner and the tube may be of an image dissector type or other like device utilizing photocathodes and electron multiplier structures. In addition, the semiconductor may be bonded to tantalum, tungsten or other metals which may in turn be bonded to ceramic tube bodies

It may thus be seen that placement of the sensitive junction area and output electrode of the semiconductor external to the tube and use a narrow aperture exposing only the input electrode to the internal tube environment, as in the present invention, provides a simple inexpensive photosensitive tube which minimizes interaction of semiconductor and cathode materials within an electron tube enclosure. While only a single embodiment has been illustrated and described, it is to be understood that many variations may be made in the particular design and configuration without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. An electron tube device comprising:

an evacuated envelope,

an electron emissive cathode at one end of said envelope, and

a semiconductor device providing an output electrode at the other end, said semiconductor device having a junction therein of two electrodes of opposite conductivity type materials, said envelope including a metallic ring having a narrow aperture

at said other end, said semi-conductor device being hermetically sealed onto said ring over said aperture and enclosing said envelope, said semiconductor device having a first electrode surface exposed to the vacuum and to electrons within said envelope, said junction and a second electrode being external to said envelope and vacuum,

and output means connected to said second electrode.

2. The device of claim **1**, wherein said envelope is of glass and said ring is of a metallic alloy sealed between said glass envelope and first electrode.

3. The device of claim **2**, including potential means connected between said cathode and said first electrode.

4. The device of claim **2**, wherein said first electrode is conductively bonded to said ring over said aperture and a peripheral portion of said ring is sealed to said glass envelope.

5. The device of claim **2**, wherein said metallic alloy ring is made of a composition of nickel, cobalt and iron.

6. The device of claim **3**, including bias means connected between said first and second electrodes.

7. The device of claim **4**, wherein said electron emissive cathode includes a photosensitive coating emitting electrons in response to light impingement thereon.

8. The device of claim **5**, including a gold-germanium bond between said first electrode of said semiconductor and said metallic ring.

9. The device of claim **5**, including a nickel-nickel alloy bond between said first electrode of said semiconductor and said metallic ring.

10. The device of claim **6**, including electron optical means focusing said electrons upon said first electrode.

11. The device of claim **7**, including a dielectric coating hermetically sealing said external junction and second electrode to said envelope.

12. The device of claim **11**, wherein said output means includes a longitudinal stud connected to said second electrode providing a conductor adapted for connection to a coaxial connector.

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