May 21, 1957 J. J. LAMB 2,793,331

SEMI-CONDUCTIVE DEVICES

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FIG. 1

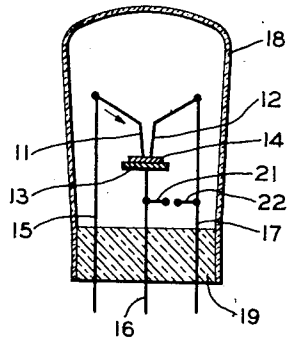


FIG. 2

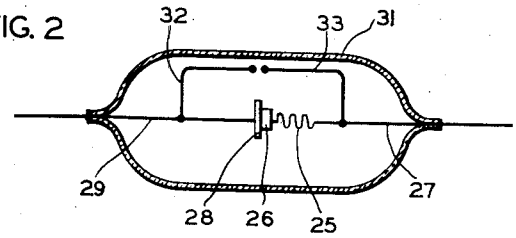
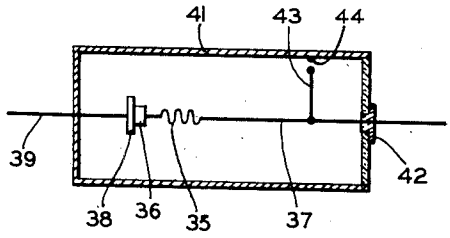


FIG. 3



INVENTOR
JAMES J. LAMB

BY J. L. Stirling

ATTORNEY

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SEMI-CONDUCTIVE DEVICES

James J. Lamb, South Norwalk, Conn., assignor to Sperry Rand Corporation, a corporation of Delaware

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This invention relates to electronic devices utilizing semi-conductive material in association with a plurality of electrodes, such as what are now more commonly referred to as crystal diodes, transistors, or the like.

More particularly, the invention relates to improvements in devices of this type whereby protective means are incorporated therewith for preventing damage or irreversible changes in the operating characteristics of the device as a result of subjecting the device to a voltage overload or to operating conditions tending to cause overheating in the junction or electrode contact areas.

It is, of course, well-known that devices of this type possess limitations with respect to the amount of voltage they are able to adequately sustain and beyond which limitation permanent impairment of the device will occur. Although, in order to overcome this possibility of damage from excess voltage, the circuit in which the semi-conductive device is employed is commonly provided with voltage limiting means to keep the voltage across the device within a safe prescribed range, any failure of said limiting means or any abnormal voltage rise beyond which such limiting means is not able to withstand will still result in the practical destruction of the semi-conductive device. It is also well-known that in certain types of circuits with which said devices may be employed, such as pulsing circuits, the spot temperature at the point of electrode contact with the semi-conductor, which has relatively high instantaneous values, may build up to a point so as to cause irreversible changes in the operating characteristics of the device as a result of excessive contact or junction heating.

The features constituting the improvements in accordance with the present invention including the provision of an envelope in which the semi-conductive device is sealed, the envelope being filled with a gas of the noble group, a relatively inert gas such as hydrogen, or mixture thereof. Also contained within the envelope are means arranged to provide a protective or discharge gap between the leads for the two electrodes across which the excessive voltage could occur. By proper coordination of the type of gas employed and pressure thereof with the width of the protective gap and the nature of the coating on the gap electrodes, various break-down potentials, corresponding to the safe operating limit of the device, at which a glow discharge across the protective gap will occur may be readily established thereby protecting the semi-conductive material and/or the electrodes in contact therewith from any adverse effects resulting from such excess potential. When the device is to be employed in circuits wherein electrode heating may be a critical factor, the gas sealed in the envelop may be one such as hydrogen whereby the electrode heat will be better dissipated through the molecular conduction cooling properties thereof.

It is, therefore, an object of the invention to positively protect semi-conductive devices from damage resulting from excess potentials.

It is a further object of the invention to better protect

semi-conductive devices from damage resulting from overheating.

It is a still further object of the invention to provide a semi-conductive device with means integral therewith for preventing permanent impairment to the semi-conductive element thereof as a result of excessive potentials or overheating.

Further objects of the invention, together with features contributing thereto and advantages accruing therefrom, will be apparent from the following description when read in conjunction with the drawing, wherein

Figure 1 is a sectional view of an embodiment of the invention as adapted for a transistor;

Fig. 2 is a sectional view of an embodiment of the invention as adapted for a crystal diode; and

Fig. 3 is a sectional view of another embodiment of the invention as adapted for a crystal diode.

Fig. 1 illustrates the invention as adapted for a transistor of the point-contact type and comprising the usual emitter electrode **11**, collector electrode **12** and base electrode **13** each maintained in suitable contacting relationship to a body of semi-conductive material **14**, such as germanium or the like. Each of the electrodes **11**, **12**, and **13** are joined to respective leads **15**, **16**, and **17**, which means also serve to support the transistor elements within the confines of a hermetically sealed envelope consisting of a shell **18** and a base portion **19**, the leads being suitably encased and sealed within the base portion of the envelope and extending therethrough, so as to provide means for connecting the device within the circuit with which it is to be used. The shell **18** may be of any suitable shape or design and fabricated of any suitable material such as glass, metal or the like, it being understood that the shell **18**, when affixed to the base portion **19**, effects a sealed-in area in which the transistor elements, as above described, are disposed.

The envelope provides means for containing an ionizable gas in association with a protective discharge gap formed by electrodes **21** and **22** connected to the base and collector leads **16** and **17**, respectively. The gas employed to fill the envelope may be a gas of the noble group or a relatively inert gas such as hydrogen or mixture thereof, and, in the present instance, a mixture consisting of 98% neon and 2% argon is employed at a pressure ranging from 20 to 60 mm. of mercury. The discharge electrodes **21** and **22**, in the present instance, constitute nickel rods which are welded to their respective leads and disposed so as to provide a gap approximately $\frac{1}{32}$ of an inch, the electrode connected to the more negative lead, which, in the present instance would be the electrode **22** since the transistor shown in Fig. 1 is of the N type, preferably being coated at the tip with a barium-strontium compound, so as to provide a glow discharge break-down potential of the order of 60 to 90 volts as determined specifically by electrode spacing or gas pressure, or both. In the event a lower break-down potential were desired, of approximately 45 volts, for example, the tip of the more negatively connected electrode may, instead, be coated with a cesium compound. It will, of course, be understood that although Fig. 1 shows a point-contact transistor of the N type, the invention is not limited to use with only this type of transistor, but is equally well adapted for use with transistors of the P type, the invention being adaptable also to transistors having a different form of electrode contacts, such as junction transistors whether of the N–P–N type or P–N–P type.

Fig. 2 shows the invention in an embodiment incorporating a crystal diode of the point-contact type and comprising the usual cat-whisker cathode **25** disposed to make rectifying contact with a body of semi-conductive material **26**, such as germanium or silicon, and connected

to a negative lead 27, together with an anode 28 disposed for making low-resistance contact with the semi-conductive material and connected to a positive lead 29. In this instance, the envelope 31 is shown as being of glass, having sealed off tabulation at each end through which the respective positive and negative leads pass, although it should be understood that the envelope may be of other designs or shapes and constructed of other materials with equally advantageous results. The protective discharge electrodes consist of rods 32, 33, which may be of nickel or the like, welded to a respective one of the leads 27, 29 so as to project at substantially right angles therefrom, said rods being bent as to dispose the tips thereof at a gap of approximately 1/32 of an inch. As in the case of the Fig. 1 embodiment, the envelope is filled with a gas of the noble group or mixture thereof, and preferably a mixture consisting of 98% neon and 2% argon at a pressure of between 20 and 60 mm. of mercury. The breakdown potential at which glow discharge will occur may be determined by the nature of the coating applied to the tip of the more negative electrode 33, a coating of a barium-strontium compound giving a glow discharge break-down of about 60 to 90 volts, a coating with a cesium compound providing a glow discharge break-down of approximately 45 volts. If it should be desired to provide for glow discharge break-down at higher potentials or if the device is to be employed in circuits tending to make the heating of the electrode contacts a critical factor, the envelope may be filled with hydrogen gas at the same pressure of from 20 to 60 mm. of mercury, thereby providing a glow discharge break-down potential of about 115 volts. The use of a gas such as hydrogen, in addition to increasing the glow discharge break-down potential, has the added advantage of improving contact cooling since it is well-known that the spot temperature at the point of contact in semi-conductive devices of this type may be of quite high instantaneous values under certain operating conditions, so that the molecular conduction and convection cooling accomplished by a gas such as hydrogen is beneficial in preventing irreversible changes because of contact heating.

Fig. 3 illustrates another embodiment of the invention incorporating a crystal diode comprised of a cat-whisker cathode 35 disposed for point contact with a body of semi-conductive material 36 and connected to a negative lead 37, together with an anode 38 disposed for low resistance contact with the semi-conducting material and connected with a positive lead 39. In this embodiment, the semi-conductive device is contained within an envelope 41 hermetically sealed and of any suitable shape but fabricated of material such as metal or the like having good electrical conducting properties. In this form, the positive lead wire 39 is connected to the envelope and the negative lead wire 37 in passing through the end of the envelope is insulated therefrom by a hermetically sealed plug 42 of glass or the like. In this embodiment, the protective discharge gap is formed by a discharge electrode 43, which may be a rod of nickel or the like, welded to the negative lead 37, the tip of said electrode being disposed so as to form a discharge gap between it and the wall of the envelope 41 which, as above mentioned, is an electrical conductor and connected to the positive lead 39 so as to thereby provide a shunt circuit around the diode elements. Preferably, a spot of nickel or the like is placed on the wall of the envelope 41 adjacent the electrode 43 so as to provide an electrode tip 44 of opposite polarity for the discharge gap. In this embodiment also, the envelope is filled with inert gases of the same mixture and at the same pressure as above described, or hydrogen gas if higher break-down potential or a better cooling effect is desired, and in a similar manner the more negative electrode tip 43 may be coated with various compounds depending upon the particular glow discharge breakdown potential desired. Although the invention is disclosed in Figs. 2 and 3 in conjunction with crystal diodes of the point contact type, it will be apparent that the invention is also equally well adaptable for crystal diodes of the junction type.

From the foregoing, it will be seen that through the improvements constituting the present invention, in any of its embodiments, a potential in excess of the break-down voltage of the particular gas used will cause glow discharge across the protective discharge gap thus preventing application of potential in excess of the break-down value to the solid semi-conductor element of the device associated therewith. Since it is well-known that electrical currents under voltages of even less than rupture values may cause a formation of junction variants at the electrode contacts to the semi-conductor element which change its characteristics materially from those desired and intended, the improvements according to the instant invention above described will also result in minimizing the effects of such junction variants. Since it is also known that even under non-operating conditions there may occur junction changes as a result of incidental corrosive action on the electrodes, the features of the invention residing in the sealing in of the semi-conductive device with an inert gas effectively prevents the breathing of water vapor or the inhalation of other undesirable impurities, thereby preventing detrimental effects from this source while at the same time providing the desired ionization discharge characteristics for overlead damage or rupture prevention.

While there has been herein described what are considered to be highly desirable embodiments of the invention, it is obvious that many changes in form could be made without departing from the spirit thereof, and it is, therefore, not intended to be limited to the exact forms herein shown and described nor to anything less than the whole of the invention as hereinbefore set forth and as hereinafter claimed.

What is claimed as new, and desired to be secured by Letters Patent, is:

1. The combination with an electronic control device utilizing a body of semi-conductive material disposed in contact with electrodes connectable to sources of different potentials, of enveloping means hermetically sealing said device, and circuit establishing means disposed within said envelope and connected to said electrodes for shunting the current applied to said electrodes around said semi-conductive material when the potential difference between said electrodes reaches a predetermined value.

2. A combination with an electronic control device utilizing semi-conductive material disposed in contact with electrodes connectable to the sources of different potentials, of enveloping means hermetically sealing said device, and circuit establishing means including an ionizable gas disposed within said enveloping means, said circuit establishing means including elements electrically connected to said electrodes for shunting the current applied to said electrodes around said semi-conductive material when the potential difference between said electrodes reaches a magnitude sufficient to ionize said gas.

3. The combination with an electronic control device utilizing semi-conductive material disposed in contact with electrodes connectable to sources of different potentials, of enveloping means hermetically ensealing said device, and circuit establishing means disposed within said enveloping means, said circuit establishing means including an ionizable gas and discharge electrodes electrically connected to respective leads for said semi-conductive device, said latter electrodes being disposed to provide a circuit including a discharge gap and effective in cooperation with said gas for shunting current around said control device when the potential difference across said device reaches a magnitude sufficient to ionize said gas.

4. The combination as set forth in claim 3, wherein the control device comprises a transistor, the discharge electrodes being connected to the respective leads to the base and collector electrodes thereof.

5. The combination as set forth in claim 3, wherein the control device comprises a crystal diode, the discharge electrodes being connected to the respective leads to the anode and cathode electrodes thereof.

6. The combination as set forth in claim 3, wherein said enveloping means includes a casing having electrical conducting properties and electrically connected to one of the leads for said control device, said casing being disposed so as to constitute one of the discharge electrodes in the shunt circuit around said control device.

7. The combination as set forth in claim 2, wherein the ionizable gas consists of one or more gases of the noble group.

8. The combination as set forth in claim 2, wherein the ionizable gas comprises hydrogen gas.

9. The combination as set forth in claim 3, wherein the more negative discharge electrode is coated with a substance having a lower work function than that of other discharge electrode.

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