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[54] GAS-DETECTING DEVICE
6 Claims, 4 Drawing Figs.

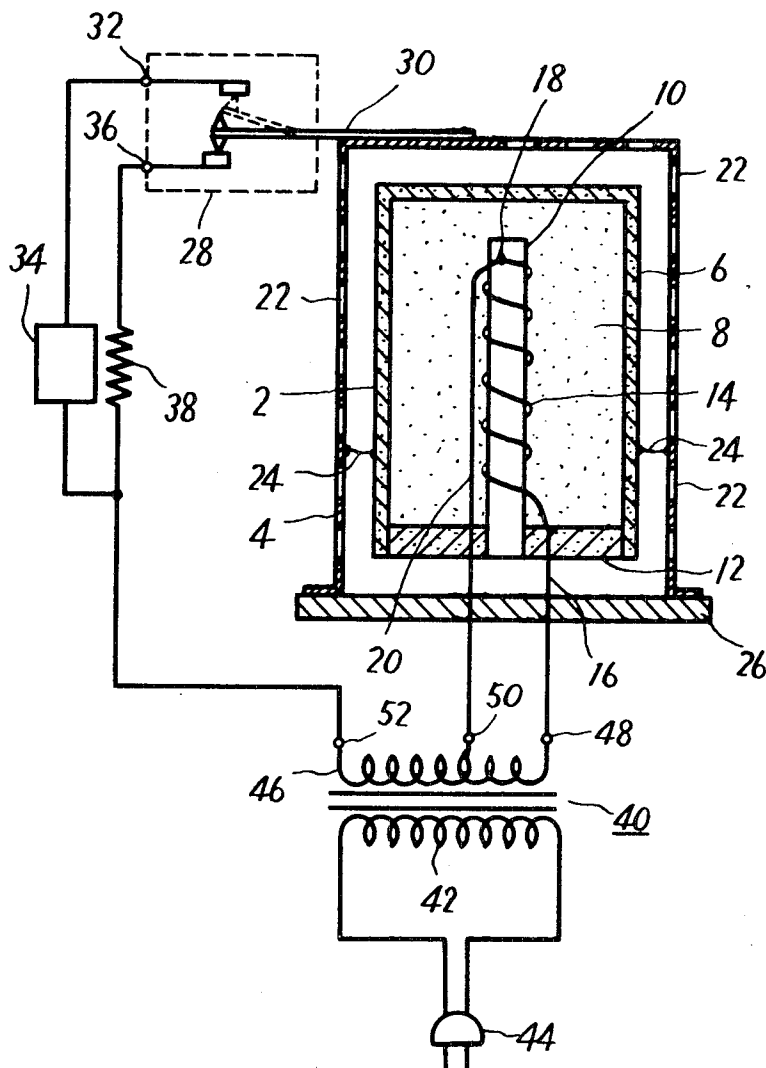
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23/254 R, 254 E, 232 R, 232 E; 73/23, 25-27

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ABSTRACT: A gas-detecting device having a gas responsive semiconductor, a pair of electrodes in contact with the semiconductor, means for heating the semiconductor to stabilize its resistance at a predetermined value, time delay switching means and an alarm circuit and an impedance circuit interconnected with said electrodes and said switching means so that the impedance circuit will be connected with the semiconductor electrodes during the heating period and upon stabilization of the semiconductor the switching means will automatically and effectively disconnect the impedance circuit and substitute the alarm circuit.



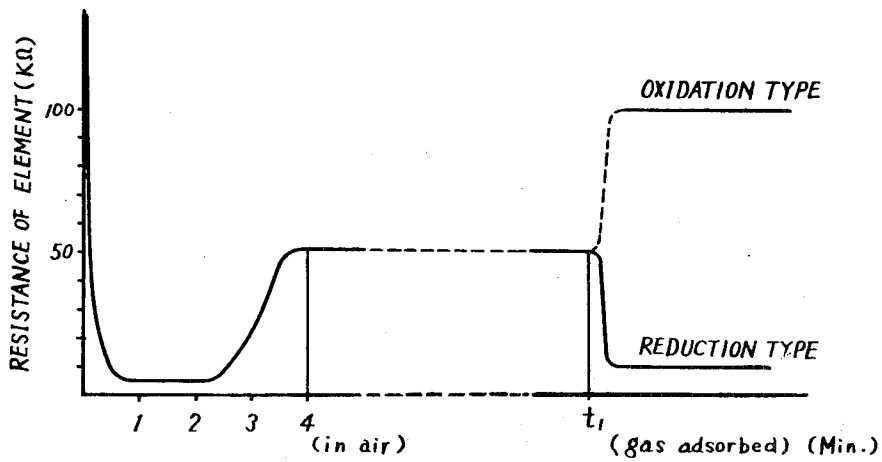


Fig. 1

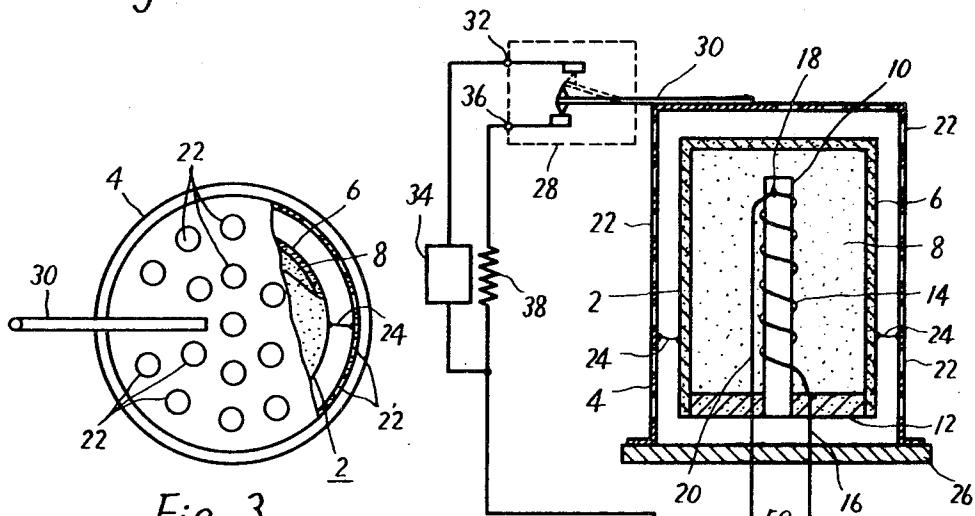


Fig. 3

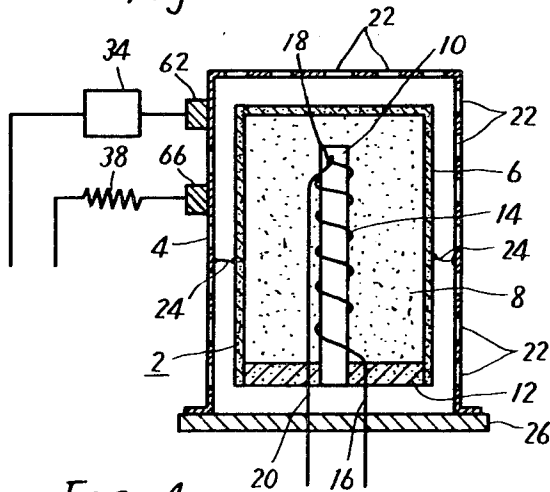


Fig. 4

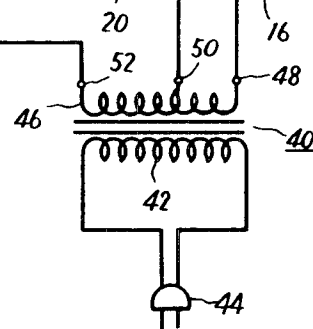


Fig. 2

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GAS-DETECTING DEVICE

This invention relates to a detector for gas, smoke and other air-contaminating vapors and more specifically to a detecting device utilizing a metal oxide semiconductor element which varies in impedance when exposed to reducing gases such as hydrogen, carbon monoxide, alcohol vapor, gasoline vapor or smoke and embodies means for preventing the production of an erroneous alarm during initial periods of operation when the resistance of the metal oxide semiconductor is unstable.

Detecting devices for gas, smoke, and other similar air contaminants utilizing metal oxide semiconductor elements must be heated to a predetermined temperature in order to increase their sensitivity. While the desired operating temperature depends on various characteristics of the semiconductor element such as its geometry, and the desired detecting sensitivity, it has been determined that a temperature in the range of 170° to 230° C. is generally preferable.

Assuming that the metal oxide semiconductor element of the detector has a geometry such that the interelectrode resistance is of the order to 50,000 ohms when heated to a temperature in the range of 170° to 230° C. and when the ambient air does not contain any contaminant such as gas or smoke, such semiconductor will vary in resistance from an exceedingly high value of the order of hundreds of thousands of ohms to values as low as 5,000 ohms during a period of approximately four minutes required to bring the semiconductor up to its stable operating temperature. Under these conditions the semiconductor detector will produce an alarm during the initial heating period even though smoke or gas does not contaminate the ambient air.

This invention overcomes the aforementioned disadvantages and utilizes switching means associated with the alarm circuit to prevent the generation of an alarm until after the semiconductor has attained a predetermined temperature. Semiconductor elements do not reach a stable state until after it has been heated to a temperature that will permit a predetermined current to flow between the electrodes. In prior gas-detecting devices thermistors have been inserted with the alarm circuit to delay initiation of the alarm circuit. While this procedure has certain advantages, it does not provide the desired reliability and dependability for an alarm device.

Accordingly one object of the invention resides in the provision of a novel and improved circuit for gas detectors having metal oxide semiconductor elements which will provide stable operation throughout the entire temperature range. This may be obtained in accordance with the invention by utilizing an auxiliary circuit having an impedance substantially equivalent to the capacitance of the alarm circuit and means for interconnecting the auxiliary circuit with the semiconductor element until the latter reaches a predetermined temperature and operation is stabilized. After the semiconductor element has become stabilized, the alarm circuit is automatically substituted for the auxiliary circuit to place the detector in an operational condition.

The gas detector in accordance with the invention includes a metal oxide semiconductor element having a resistance which varies materially when exposed to a reducing gas or smoke and a pair of electrodes in contact with the semiconductor element to provide for the flow of current through the semiconductor. The device further includes a heater for heating the semiconductor, an alarm circuit, an auxiliary impedance circuit having substantially the same impedance as the alarm circuit and a delayed switching means for connecting the auxiliary circuit to one of the electrodes for a predetermined time period after energizing the heating element and at the conclusion of the time period at which the semiconductor element reaches a predetermined temperature or its so-called steady state, disconnecting the auxiliary circuit and substituting the alarm circuit therefor.

The above and other objects and advantages of the invention will become more apparent from the following description and accompanying drawings forming a part of the application.

In the drawings:

FIG. 1 is a graph showing the change in resistance of a metal oxide semiconductor element during the heating period;

FIG. 2 is a cross-sectional view of one embodiment of a gas-detecting device in accordance with the invention together with a schematic circuit diagram;

FIG. 3 is a plan view in partial section of a gas-detecting device of FIG. 2; and

FIG. 4 is a cross-sectional view of a modified embodiment of the detector and circuit shown in FIG. 2.

The gas-detecting device in accordance with the invention utilizes a metal oxide semiconductor element that is heated to the temperature of the order of 170° to 230° C. to stabilize its detecting sensitivity. It has been found that this temperature range affords a smooth and continuous change of resistance of the semiconductor element in response to changes in concentration of gases and smoke in the ambient air and thus is suitable for practical applications. Assuming that the metal oxide semiconductor element has a geometry such that its interelectrode resistance is of the order of 50,000 ohms when heated to a temperature of the order of 170° to 230° C. Such a semiconductor element will overcome resistance variations during the warmup period as illustrated in FIG. 1. The initial resistance of the semiconductor prior to heating is of the order of hundreds of thousands of ohms and may be deemed to be an insulator at normal temperatures. When the semiconductor is heated, the resistance initially drops to as low as 5,000 ohms after the first thirty seconds, and this condition continues for approximately 2½ minutes. Thereafter the resistance gradually increases until it reaches the inherent value of the material, namely, approximately 50,000 ohms after a period of 4 minutes.

The change in resistance of the semiconductor element during the initial heating period as illustrated in FIG. 1 is believed to result from the fact that the semiconductor absorbs water and gases while it is cold and then during the heating step, the water and gas react with the semiconductor material to reduce its resistance. After a predetermined period of heating, the water and gas are expelled from the element and the resistance then approaches the inherent resistance of the material which in the present case is of the order of 50,000 ohms.

When a reducing gas or smoke contacts a heated semiconductor element, its resistance will vary materially. With semiconductors of the reduction type, the resistance drops from approximately 50,000 ohms to approximately 10,000 ohms as shown in FIG. 1 after the time t_1 . With semiconductors of the oxidation type, the resistance increases to approximately 100,000 ohms as shown in FIG. 1.

Reduction-type metal oxide semiconductors will generate an alarm when the resistance falls below 50,000 ohms, and accordingly, during the heating time period of 30 seconds to 3 minutes, the semiconductor resistance will drop sufficiently to create erroneous alarms. In the case of an oxidation-type semiconductor material, the erroneous alarm would be generated within the first 30 seconds of the heating period.

One embodiment of a structure in accordance with the invention is illustrated in FIGS. 2 and 3. This structure includes a gas-detecting element generally denoted by the numeral 2 and a surrounding metal cap generally denoted by the numeral 4. The gas-detecting element 2 includes a cup-shaped electrode 6 open at the bottom end and having a number of openings therein to provide for the flow of air. A metal oxide semiconductor material 8 fills the cup-shaped electrode 6 which in the case of a reduction type semiconductor would be SnO_2 . A second electrode 10 which is in the form of a flat or cylindrical rod is embedded in the semiconductor material 8 and extends downwardly into an insulating plate 12 which is secured and closes the bottom end of the electrode 6. The electrode 10 may be formed of a nickel-chromium alloy and further includes a heating wire 14 which is wound about and insulated from the electrode 10. One end of the heating wire 14 is connected to a conductor 16 which extends downwardly through the insulating plate 12. The other end of the heating wire is connected to a conductor 20 which also extends

downwardly through the insulating plate 12. The junction 18 of the heating wire 14 and the conductor 20 is also electrically connected to the electrode 10 so that the conductor 20 also serves as a connection to one of the electrodes of the gas-detecting element.

The cap 4 has a plurality of holes 22 extending therethrough to permit smoke to enter the cap. The cap 4 is also electrically connected to the electrode 6 by conductors 24 and is fixed to an insulating plate 26.

A bimetallic switch 28 includes a bimetallic element 30 which is electrically and mechanically coupled to the top of the cap 4. The switch 28 has one contact 32 connected through an alarm device 34 and then to the terminal 52 of a secondary winding 46 of the transformer 40. The primary winding 42 is connected by means of a plug 44 to a suitable source of alternating current. A second contact 36 is connected through a resistor 38 having an impedance substantially equivalent to the alarm circuit 34 and thence to the terminal 52 of winding 46. The conductor 16 of the heater winding 14 is connected to the terminal 48 of the secondary winding 46 while the conductor 20 is connected to the terminal 50 of the winding 46.

With the aforementioned structure that portion of the secondary winding between the terminals 48 and 50 may provide approximately 1.5 volts for supplying energy to the heater 14. The portion of the secondary winding 46 between the terminals 50 and 52 provides approximately 100 volts for producing a current flow through either the resistor 38 or the alarm circuit 34 as the case may be and thence through the semiconductor 8.

When the metal oxide semiconductor element 8 is not heated, the contact carried by the bimetallic element 30 will be engaged with the contact 36. When energy is supplied to the transformer 40, the bimetallic switch 28 will be in the position as illustrated in solid lines placing the resistor 38 in circuit with the semiconductor 8. Under these conditions an erroneous alarm cannot occur. After a period of time which permits the semiconductor 8 to attain a predetermined temperature and thus maintain a stable resistance, the bimetallic switch 30 will be operated and moved to the dotted line position shown in FIG. 2 to disconnect the resistor 38 and connect the alarm circuit 34 with the electrodes 6 and 10. In the case of a reduction type semiconductor 8 the bimetallic switch will prevent an erroneous alarm even though the semiconductor resistance may drop to as low as 5,000 ohms. It will be observed that the temperature of the outer cap 4 is spaced from the electrode 6 and thus its temperature will increase very slowly as it is not in intimate contact with the gas-detecting element 2 and also has a fairly large thermal capacity. Thus the bimetallic switch will operate only after the semiconductor element 8 reaches a stable value of the order of 50,000 ohms. Therefore, by selecting a heater 14 of appropriate heating capacity and utilizing a cap 4 of predetermined size, a delay of approximately 4 minutes can be obtained before the bimetallic switch 28 functions to switch the system from the resistor 38 to the alarm system 34 at which time the semiconductor 8 will be sufficiently stabilized.

When gas or smoke is not present in the ambient air or the concentration is below a specific value, the interelectrode resistance of the semiconductor 8 when at its stable operating temperature will be about 50,000 ohms and the current flowing through the alarm circuit 34 will be too small to activate the alarm. However, if the air becomes contaminated with a gas such as hydrogen, carbon monoxide, or a vapor of an organic fuel such as alcohol or gasoline or if the air becomes contaminated with smoke at a specific concentration, then such gas, vapor or smoke will pass through the porous electrode 6 and penetrate the metal oxide semiconductor 8. This will cause the resistance in the case of a reduction type semiconductor to abruptly decrease as shown by the curve in FIG. 1 following the time t_1 . The decrease in resistance will increase the current flowing through the alarm 34 and thus activate it. When the concentration of gas, vapor or smoke in the

ambient air falls below a specific concentration, the resistance of the semiconductor will return to its normal or original value within a time of several seconds to several minutes.

Should the resistance of the metal oxide semiconductor 8 require more than 4 minutes to become stabilized then a bimetallic switch having a greater time delay would be utilized or in the alternative the size of the cap 4 may be increased to introduce additional delay. In the alternative should the semiconductor element become stabilized in less than 4 minutes, a more sensitive bimetallic switch may be employed. In addition to the utilization of SnO_2 as the semiconductor 8, such materials as ZnO , Fe_2O_3 , TiO_2 , V_2O_5 , MnO_2 , WO_3 , ThO_2 , MoO_3 , CdO , and PbCrO_4 may also be utilized.

A modified embodiment of the invention is illustrated in FIG. 4, and this embodiment of the invention utilizes a semiconductor element in place of the bimetallic switch 28 of the embodiment shown in FIG. 2. Since the detecting element of FIG. 2 is identical to the detecting element of FIG. 4, only the switch operation will be discussed.

In the embodiment of FIG. 4, a temperature-responsive resistor 62 is affixed to the cap 4 and has a resistance characteristic which decreases with an increase in temperature. A second temperature responsive resistor 66 is also fixed to the cap 4, and its resistance increases with an increase in temperature. For example, a thermistor or a criteistor may be utilized as the resistor having a negative temperature characteristic while a posistor or semistor may be utilized as the resistor having positive temperature characteristics.

When the heater 14 is first energized and the cap 4 has not become heated, the resistance of the resistor 66 will be very much below that of the resistor 62. Accordingly, during the initial heating period when the resistance of the semiconductor 8 is unstable, current will flow through the resistor 66 and the resistor 38 as in the case of the embodiment illustrated in FIG. 2. At the same time insufficient current will flow through the alarm 34 to activate it. Thus an erroneous alarm cannot be produced during the initial heating period. When the resistance of the semiconductor 8 is stabilized and the temperature of the cap 4 is raised to a predetermined level after a specific time period, the resistor 66 will greatly increase in value while the resistor 62 will materially decrease in value. This action affectively connects the alarm circuit 34 to the detecting device and disconnects the resistor 38. Under this condition the device is operable to detect contamination in the ambient air.

The embodiments of the invention as described above afford a number of advantages. For instance through the utilization of an impedance circuit having the same impedance as the alarm circuit and by interconnecting the impedance circuit with the semiconductor during the heating period, stabilization of the semiconductor 8 is accomplished under normal operating conditions so that the substitution of the semiconductor 8 is accomplished under normal operating conditions so that the substitution of the alarm circuit for the impedance circuit will not adversely affect the detector. Furthermore, a smooth and rapid transfer from an unstable state during the initial heating period to the normal operating state is accomplished without any chance of the production of an erroneous alarm. Moreover, since the entire operation is automatic, human errors that may occur in preparing the detector for operation will be eliminated.

While the time delay switch in each embodiment of the invention has been described as a thermal switch, it is evident that a timing switch which functions after a predetermined time period corresponding to the time required for stabilization of the semiconductor element 8 may also be utilized.

While only certain embodiments of the invention have been illustrated and described, it is apparent that alterations, modifications and changes may be made without departing from the true scope and spirit thereof as defined by the appended claims.

What is claimed is:

1. A gas-detecting device comprising a metal oxide semiconductor element having a resistance characteristic which changes in the presence of a contaminating gas in the ambient air, a pair of electrodes in contact with said semiconductor including means for producing a current flow through said semiconductor, means for heating said semiconductor to a predetermined temperature, an alarm circuit having a predetermined impedance, an impedance circuit having the same impedance as the alarm circuit and time delayed switching means interconnected with said alarm circuit, said impedance circuit and said electrodes, said switching means normally connecting said impedance circuit with said electrodes and maintaining the last said connection for a predetermined time after energizing said heating means and then automatically disconnecting said impedance circuit and substituting said alarm circuit whereby said alarm circuit will be activated upon a predetermined resistance change of said semiconductor.

2. A gas-detecting device according to claim 1 wherein said time delay switching means includes a temperature-sensing element responsive to the temperature of said semiconductor

element and a double throw switch actuated by said temperature changing element and connections between the last said switch and said impedance circuit and said alarm circuit.

3. A gas-detecting device according to claim 2 wherein said time delayed switching means includes a bimetallic element.

4. A gas-detecting device according to claim 2 wherein said semiconductor element is enclosed within a perforated metal cap and said temperature-sensing element is thermally coupled to said cap.

5. A gas-detecting device according to claim 1 wherein said time delay switching means includes a first resistor having a positive temperature characteristic, a second resistor having a negative temperature characteristic, means thermally coupling said resistors to said semiconductor element and connections between said first resistor and said impedance circuit and between said second resistor and said alarm circuit.

6. A gas-detecting element according to claim 5 wherein said thermal coupling means comprises a metal cap enclosing said semiconductor element.

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