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[54] ELECTRON BEAM BOLOMETER

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[56] References Cited

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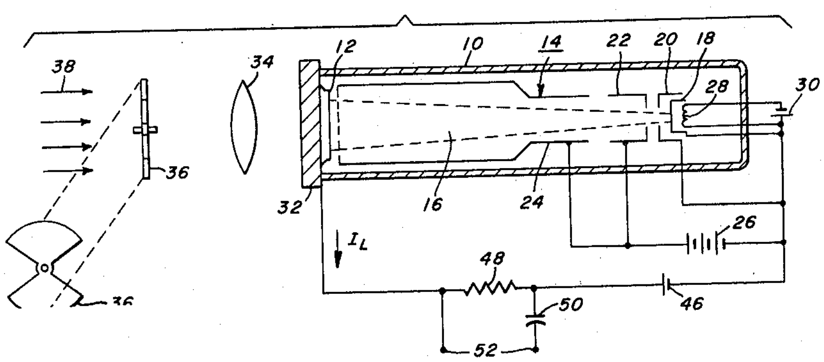
[57] ABSTRACT

A bolometer which operates at room temperature and which can be made sensitive to all blackbody radiation in the visible spectrum and extending into the infrared, depending upon the nature of a faceplate used. The bolometer is constructed by sandwiching a suitable semiconductor in smoke form between gold black as one electrode and a flooding electron beam as the other, the sensing layer being mounted in a vacuum tube.

6 Claims, 3 Drawing Figures



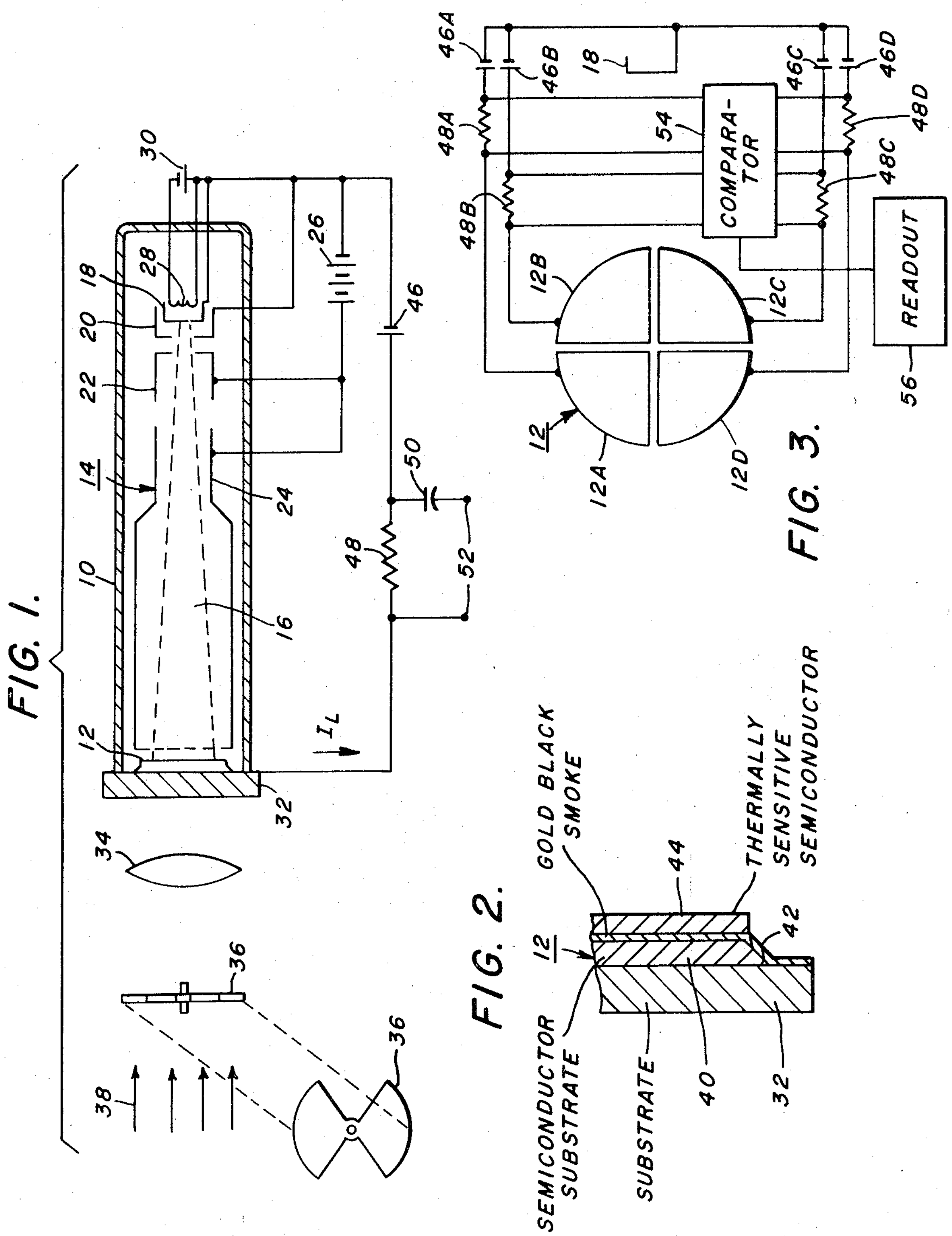


FIG. 1.

FIG. 2.

FIG. 3.

ELECTRON BEAM BOLOMETER

BACKGROUND OF THE INVENTION

As is known, semiconductor-type bolometers have been constructed according to prior art teachings from a very thin film of semiconductive smoke material sandwiched between gold smoke layers. Incident radiation on one of the gold smoke layers, comprising a black body, will generate heat which, when transmitted to the semiconductive film, will change its conductivity as a function of the intensity of the radiation. By applying a direct current potential across the semiconductive film by means of contacts connected to the gold smoke layers, the current through the semiconductive film and a load resistor in series therewith will theoretically be an indication of applied radiation and its intensity.

The semiconductor smoke and gold smoke films used in a bolometer of the type described above must, of necessity, be very thin and be produced by evaporation techniques. A typical thickness of the semiconductive film might be 10 microns and that of the gold smoke layers only 1 micron. It is, of course, difficult to control the thickness of the semiconductor smoke film over its entire surface; and because it is extremely thin, the gold smoke layers on opposite sides of the semiconductive smoke film may be extremely close, giving rise to capacitive coupling or possible arcing and resultant false outputs. As a result, the fabrication of bolometers of this type requires the maintenance of extremely high tolerances, possible malfunctioning in service and a high manufacturing rejection rate.

Another type of bolometer constructed in accordance with prior art teachings utilizes only one gold black smoke layer on one side of a semiconductive smoke film, the other side of the film being scanned with an electron beam in much the same manner as the photosensitive surface of a vidicon is scanned such that a space distribution conductivity image will be converted into a video signal as the electron beam scans back and forth. However, since the surface of the semiconductive smoke film must of necessity be a coarse, flocculent structure, the coarseness of the layer contributes to noise in the output video signal, results in a very low signal to noise ratio and drastically limits sensitivity. Furthermore, scanning techniques of this sort limit the semiconductive materials which can be used to those having a resitance-capacitance time constant of at least 0.03 second. This eliminates the possibility of using other semiconductor materials having shorter time constants.

SUMMARY OF THE INVENTION

In accordance with the present invention, a thin semiconductive smoke film is coated on one side only with gold black smoke to form a blackbody which absorbs radiation and heats the semiconductive film to change its conductivity. This gold black smoke film also acts as one electrode adapted for connection to a source of direct current biasing potential.

Instead of coating the other side of the semiconductive film with a second gold smoke film to form an electrode, or instead of scanning the other side with an electron beam, the semiconductive film with a gold black smoke film applied to one side only is disposed within an evacuated envelope and the electrode on the other side provided by a flooding electron beam electrically connected to the other terminal of a direct current biasing source. In this manner, the problems encountered due to conductive films on opposite sides of a thin film of semiconductive smoke material are eliminated; the sensitivity of the device is increased; and manufacturing tolerances need not be as stringent. At the same time, since a flooding electron beam is used which floods the entire surface of the semiconductive film with electrons rather than a scanning pencil-type beam, the pattern noise is held constant and reduced essentially to zero.

The device of the invention is essentially a point detector rather than an image detector. The location of the point source, however, can be determined by dividing the radiation-sensitive semiconductive layer and gold smoke layer into segments, such as quadrants, whereby the location of the point source can be determined by observing the relative conductivities of the respective quadrants.

In one embodiment of the invention shown herein, a thermal insulator comprising a semiconductor in smoke form is first applied to a substrate, which in the usual bolometer constitutes a heat sink. Upon this thermal insulator is applied the gold black smoke radiation absorber; and upon this, and in intimate contact with it, is applied the semiconductor smoke. Thus, the sensing materials are thermally isolated from the substrate heat sink, with a resultant increase in sensitivity.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification, and in which:

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic diagram of one embodiment of the invention;

FIG. 2 is an enlarged cross-sectional view of the semiconductive and gold black smoke layers of the sensing element of the invention shown in FIG. 1; and

FIG. 3 is an illustration of an alternative embodiment of the sensing element of the invention divided into sectors so as to facilitate determination of the location of a point source of radiation.

With reference now to the drawings, and particularly to FIG. 1, the embodiment of the invention shown includes an evacuated vacuum-tight enclosure **10** of a suitable material, such as glass, which is utilized to enclose a thermally sensitive target structure **12** and associated apparatus, generally indicated by the reference numeral **14**, for producing a flooding electron beam **16** which impinges upon substantially the entire surface of the thermally sensitive target **12**. By "flooding electron beam" it is meant that the beam is defocused such that the electrons emitted by a cathode **18** do not travel in a straight line but rather diverge and spread out in all directions to cover substantially the entire surface of the target **12**.

The flooding electron beam generating apparatus includes a first grid **20**, a second grid **22** and a third grid **24** which serve to accelerate the electrons emitted by the cathode **18** toward the target **12** without focusing them into a pencil beam as is done, for example, in a vidicon. The two grids **22** and **24** are connected back to the cathode **18** through battery **26** which biases these grids positive with respect to the cathode. The grid **20**, on the other hand, is connected directly to the cathode which is provided with a heater **28** connected to a power supply, such as battery **30**.

The envelope **10** has an input window **32** at one end thereof which may in some cases comprise glass but which is preferably a wide band transmitting material such as silver chloride, barium fluoride, calcium fluoride, or possibly quartz such that it permits the transmission of both visible and infrared radiation. Positioned in front of the input window **32** is an optical system, schematically illustrated by the lens **34**, and a chopper **36** which serves to chop the input radiation such that movement of a target will be readily detected in output signal from the device. Incident radiation, identified by the arrows **38**, this passes through the copper **36** and then the optical system **34** to the thermally sensitive target **12**.

The thermally sensitive target **12**, which is mounted on the input window **32**, is shown in detail in FIG. 2. The input window **32**, in addition to transmitting a wide band of input frequencies, also acts as a substrate for the formation of the thermally sensitive target **12**. The target is formed by initially depositing a layer of semiconductive porous or smoke material **40** on the surface of the substrate **32** by vapor-deposition techniques. This substrate may typically have a thickness in the range of about 5 to 15 microns. Deposited on the surface of the film **40** is a gold black smoke film **42**; and deposited on the gold black smoke film **42**, also by vapor-deposition techniques, is a thermally sensitive semiconductive smoke film 44 typically having a thickness of about 10 microns. The thickness of the gold black smoke film 42, however, is only about 1 micron.

The film 40 typically comprises Sb_2S_3 but may be formed from any suitable semiconductive material which will transmit a wide band of frequencies from the visible to the infrared. It constitutes a thermal insulator which isolates the films 42 and 44 from the substrate 32 which would otherwise act as a heat sink. In this manner, the sensing layers 42 and 44 are effectively isolated from the substrate, with a resultant increase in sensitivity.

The gold black film 42 is deposited by evaporating gold in an inert atmosphere, such as nitrogen, at a pressure of about 2 millimeters of mercury, with care to exclude oxygen. The resulting deposit is a black, very porous structure comprising finely divided gold particles wherein each particle touches adjacent neighbors, resulting in good electrical conductivity resembling a thin metal film. At the same time, by virtue of the fact that the film 42 is black, it is a good absorber of radiation, the absorbed radiation generating heat which is transferred to the thermally sensitive semiconductive film 44.

The film 44 may be formed from any semiconductive material whose conductivity will change in response to heat. However, the preferred materials include AS_2Se_3, Sb_2S_3, Sb_2Se_3, and In_2Te_3. As was mentioned above, the resistance-capacitance time constant is not particularly important as compared with a storage image tube, which means the Sb_2Se_3 and In_2Te_3 which have low time constants can be used. The semiconductive layer 44, like the gold black smoke layer 42, is evaporated in a vacuum chamber under an inert gas pressure of 1 millimeter of mercury in helium and condensed upon the substrate in smoke form to a thickness of about 10 microns.

With reference again to FIG. 1, a source of biasing potential 46 and a load resistor 48 are connected in series between the gold black smoke layer 42 and the cathode 18. In this manner, the flooding electron beam acts as cathode on one side of the thermally sensitive semiconductor film 44; while the gold black smoke is the positive electrode. Incident radiation, such as infrared radiation, upon the substrate or faceplate 32 will pass through the faceplate and the semiconductive layer 40 onto the gold black smoke film 42 where heat will be generated. This heat, when transmitted to film 44, varies the conductivity of the film 44 such that the number of electrons from the flooding electron beam which pass through the film 44 to the film 42 will be a function of the conductivity of the film 44 and, hence, the intensity of the applied radiation. This variation in electron flow, reflected as a variation in current through load resistor 48, can be applied through coupling capacitor 50 to terminals 52 connected to an indicating device, not shown, such as an oscilloscope.

Typical circuit values, with reference to FIG. 1, are as follows:

1. Current, I_L, through load resistor 48—7×10^{-8} amps
2. Resistance, R_B, of flooding electron beam 16—10^7 ohms
3. Resistance R_C, of thermally sensitive semiconductive layer 44—10^{-9} ohms
4. Resistance, R_L, of the load resistor 48—10^8 ohms
5. Voltage, E, of battery 46—30 volts
6. Voltage of battery 26—300 volts
7. Heater supply voltage—4 to 7 volts

With the arrangement shown, the coarse flocculent structure of the semiconductive smoke layer 44 will not give rise to noise due to a scanning electron beam since the beam does not scan but rather floods the surface of the film 44. At the same time, the problems mentioned above which are encountered due to gold black smoke layers on opposite sides of the layer

44 are entirely eliminated since the electron beam, rather than a vapor-deposited layer, acts as one of the two electrodes for the layer 44.

In the system shown in FIG. 1, an output signal across load resistor 48 will indicate the existence of an irradiating body in front of the faceplate 32; but will not indicate the location of the body with respect to the axis of the tube. A system for indicating the position of the blackbody is shown in FIG. 3 wherein the target 12 is divided into four sectors 12A, 12B, 12C and 12D which are electrically insulated from each other. The four sectors 12A–12D, or more accurately the black gold smoke layers thereon, are connected through four load resistors 48A, 48B, 48C and 48D and four batteries 46A, 46B, 46C and 46D back to the cathode 18. The load resistors 48A–48D, in turn, are connected to a comparator 54 which compares their magnitudes and produces an indication to a readout device 46 which indicates the position of an irradiating object and the intensity of the radiation. For example, if the magnitude of the signal across load resistor 48B is greater than that detected across all other load resistors, and if that detected across load resistor 48C is greater than that across the remaining two load resistors, it is known that the target is to the upper right of the axis of the tube. As will be understood, the target may be further subdivided to provide greater accuracy in pinpointing the location of an irradiating object.

Although the invention has been shown in connection with certain specific embodiments, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

We claim as our invention:

1. In a radiation pickup device, an evacuated envelope, means including a cathode at one end of said envelope for generating a flooding electron beam, a target electrode at the other end of said envelope and in the path of said flooding electron beam, said target electrode including a film of semiconductive material whose electrical conductivity characteristics change in response to heat and having a first side flooded by said electron beam, a layer of gold black smoke deposited on the other side of said film of semiconductive material, and means including a source of potential and a load impedance connected in series between said cathode and said layer of gold black smoke, the arrangement being such that upon exposure of the gold black smoke to incident radiation heat will be generated to heat the semiconductive film and change its conductivity characteristics whereby current flowing through the semiconductive film will be varied with the flooding electron beam acting as one electrode for the semiconduc,ive film and the gold black smoke layer acting as the other electrode.

2. The radiation pickup device of claim 1 wherein said film of semiconductive material has a thickness of about 10 microns and said layer of gold black smoke has a thickness of about 1 micron.

3. The radiation pickup device of claim 1 wherein said gold black smoke layer is deposited on a second film of semiconductive material which, in turn, is deposited on a substrate heat sink.

4. The radiation pickup device of claim 1 wherein said film of semiconductive material is selected from the group consisting of As_2Se_3, In_2Te_3, Sb_2S_3 and Sb_2Se_3.

5. The radiation pickup device of claim 3 wherein said second film of semiconductive material comprises Sb_2S_3.

6. The radiation pickup device of claim 1 wherein said film of semiconductive material is in smoke form.

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