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INFRA-RED SENSITIVE DEVICES

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Fig_1

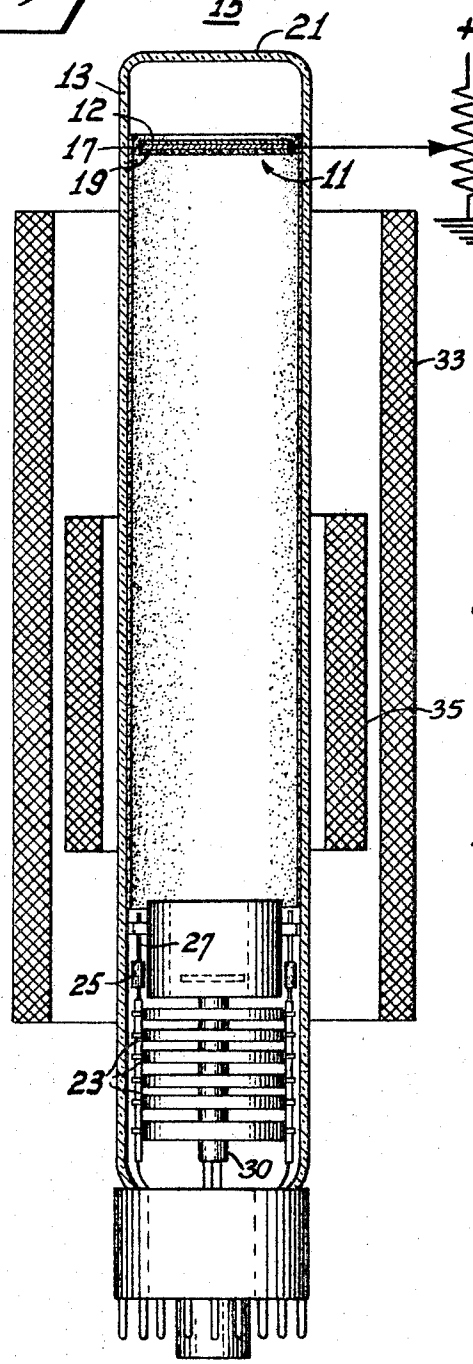
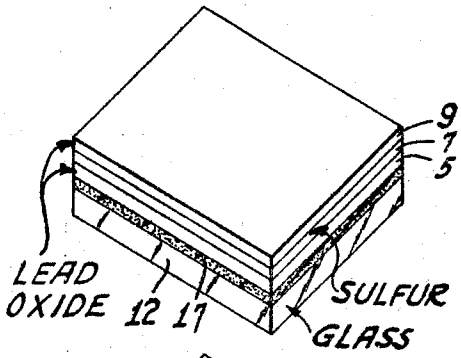


Fig_2



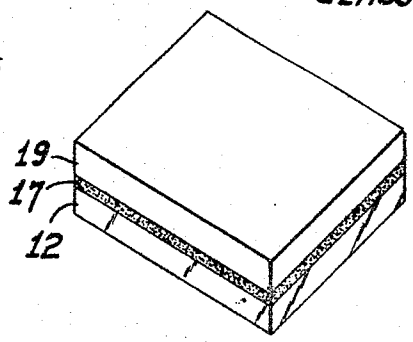


Fig_3

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INFRA-RED SENSITIVE DEVICES

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This invention pertains to devices sensitive to infra-red rays and particularly to an infra-red sensitive target for use in such devices.

There are many applications of electronic devices which are used to convert radiant energy into electrical signals. Such devices employ suitably sensitive targets to receive the radiant energy, which may be light rays, infra-red rays or energy of other wavelengths. The targets react to the radiant energy in a characteristic manner, for example by becoming charged or by emitting electrons, and then they are suitably operated, as by an electron beam if they become charged or by some collector device if they emit electrons, to produce the desired electrical signal. Such an electrical signal is representative of the received radiant energy.

Some typical examples of such electronic devices which convert radiant energy into electrical signals are pickup tubes (image dissector, iconoscope, image orthicon, vidicon, and the like), phototubes, photoconductive cells, and the like. The targets used in these devices for receiving the radiant energy comprise photoelectric targets which may be designed to operate according to any of the three well-known photoelectric effects. These effects are the photovoltaic effect, which is the generation of an electromotive force between two electrodes when either of them or the intervening medium is illuminated; the photoconductive effect, which is the reduction of the electrical resistance of materials by illumination; and the photoemissive effect, which is the emission of electrons from illuminated surfaces.

This invention pertains to the detection of objects by infra-red radiation from such objects. A television-type camera tube such as the image orthicon is suitable for such purposes, if provided with a suitable infra-red sensitive target.

With respect to the type of target employed in this device, up to the present time, infra-red detection devices have been used which employ photoemissive targets generally composed of silver, oxygen, and caesium. Such targets are limited in spectral response to a maximum value of approximately 1.2μ. On the other hand, targets of the photoconductive type, such as those made of lead sulfide, have a satisfactory response above 1.2μ in the intermediate infra-red region of the spectrum. However, these targets have limited applicability for infra-red detection because of their electrical characteristics, such as low resistivity. However, successful infra-red sensitive targets should have a satisfactory response to radiation of a wavelength substantially greater than 1.2μ, to a value on the order of 2μ. Such a target must also have a resistivity, on the order of 10^{10} ohm centimeters, such that, under normal operating conditions, the dark current is approximately 0.1 microampere.

Resistivity has reference to that quality of photoconductive material which enables it to store an electrical charge in a given spot without leakage from front to back surface as long as there is no light on the target. Dependent upon the resistivity of the target material is its dark current which is the current flowing through the material between energized electrodes when there is no light on the target.

Accordingly the principal object of this invention is to

provide an improved infra-red responsive device having a novel and improved target.

Another object is to provide a novel infra-red sensitive target.

Another object is to provide a novel method of making an infra-red sensitive target.

A further object is to provide a photoconductive target having high resistivity and a good response to infra-red radiation in the range of .5μ to 2μ.

In general, the objects of this invention are accomplished by depositing layers of lead oxide and sulfur on a conducting member comprising an insulating base member coated with a transparent conductive material such as tin chloride. The deposited layers are heat treated to achieve a uniform, chemically complex structure having the desired characteristics of spectral response and resistivity.

The invention is described in detail with reference to the single sheet of drawings wherein:

FIG. 1 is a longitudinal section of a pickup tube having a target made according to my invention mounted therein; and,

FIG. 2 is a perspective showing details of a target made according to my invention but not yet thermally activated; and,

FIG. 3 is a perspective view of the completed target made according to my invention.

This invention contemplates the use of a camera-type pickup tube envelope, electron gun, beam focusing and accelerating electrodes, and signal producing means to house the infra-red sensitive target. One such suitable tube is the image orthicon, however other tubes may be used. Image orthicons are shown and described in U.S. patents to Weimer, 2,452,620; and to Forgue, 2,441,315 and 2,460,381. The orthicon employed in this invention includes an electron gun 30, an electron multiplier 23, focusing means 33 and deflecting means 35.

A target 11 made according to the method of the invention to be described in detail below is mounted in an envelope 13 of an orthicon tube 15. The target 11 comprises a non-conductive, transparent base plate 12 made of glass or some similar suitable material. A coating 17 of a transparent conductive material is provided on the base plate 12. The coating 17 is transparent to infra-red rays and may be a layer of a material such as tin chloride or a thin film of platinum, manganese, palladium or the like. On the conductive coating is prepared a composite layer 19 of a complex chemical reaction product.

According to one target design made according to the principles of this invention, the target was arranged in the form of a volume two centimeters square and 10^{-4} centimeters thick. However, targets of other sizes may be readily made according to the principles of the invention by simple mathematical scaling.

To make a target of this size the following procedure may be employed.

Referring to FIG. 2, the glass plate 12 which forms the foundation for the target is coated with the layer 17 of one of the conductive transparent materials named above.

Next approximately 100 milligrams of lead oxide are evaporated as a layer 5 on the conductive coating 17 from a platinum boat or other suitable device placed approximately 6.5 centimeters away from the target. This evaporation takes place in an atmosphere of oxygen at a pressure of 10 to 20 microns of mercury. Air may be used instead of oxygen but the results are not as satisfactory or as easily controlled or as predictable because of the variable humidity of the air and its inate contamination. This evaporation takes place in a temperature range of from 65° C. to 75° C. which is critical for

this first evaporation. The evaporation is accomplished in a time of two to five minutes which is not critical.

Next, approximately 60 micrograms of sulfur are evaporated from a glass cup, or other suitable device, held in contact with the target so that substantially all of the sulfur is deposited thereon as a coating 7. The same vacuum and oxygen atmosphere are used in this step as in the first. The temperature range at which this evaporation takes place is 100° C. to 175° C. and is not critical. After deposition of the sulfur, another layer 9 is formed from approximately 50 milligrams of lead oxide evaporated from a platinum boat or other suitable device. This evaporation also is effected at the same vacuum and in the same atmosphere as the other evaporations and the temperature range is again 100° C. to 175° C. and not critical.

The next step in the process is a thermal activation by which the desired infra-red response and resistivity of the target are obtained. The first step of the thermal activation comprises baking the target at a temperature in the range of 100° C. to 150° C. for ten to twenty minutes in an atmosphere of oxygen and at a vacuum of approximately 5 millimeters of mercury. Next, the temperature is raised to a value in the range of 125° C. to 175° C. and the target is further baked for one-half to one hour in air at atmospheric pressure.

As stated above, the degree of thermal activation determines the infra-red response and resistivity of the target and the exact procedure selected is intended to provide the best infra-red response for a satisfactory value of resistivity. The theory of the effect of the thermal activation on the layers of chemicals deposited on the glass support is not completely understood. However, it is believed that on activation, the target becomes a composite, crystalline complex of lead oxide, lead sulfide and lead oxide:lead sulfate. It is believed that the crystalline complex is uniformly distributed through the target.

After the target has been produced, the following procedure is followed to mount it in the tube envelope 13 and process the assembly to its final operating condition. The procedure requires careful evacuation and heat treatment of the tube without disturbing the condition of the target which has already been treated to achieve the best infra-red response and resistivity.

The tube without the target is preliminarily processed according to conventional procedures, including evacuation and baking at a temperature on the order of 450° C. for approximately three hours. The tube is then opened at the gun end so that the heat of later resealing will not affect the target. The target is mounted in the tube in any suitable manner with the glass support 12 of the target 11 adjacent to the end of the tube and the layer of chemical constituents 19 facing the electron gun. Thereupon the tube is resealed and processed further by evacuating and baking for approximately one-half hour at a temperature in the range of 100° C. to 140° C. It is often convenient to activate the thermionic cathode at the same time. Finally, the exhaust tubulation by which the tube is exhausted is sealed and the getters 25 are flashed. In practice it has been found that more than the usual number of getters are required because the final baking out has taken place at a lower than usual temperature in order to preserve the characteristics of the target. In this embodiment, eight getters are used and they are mounted around the tube on the support rods 27.

Operation of the completed pickup tube is the same as for any orthicon except for the target and it has been found that for the particular target produced as described above and for one suitable method of operation, a potential of approximately plus 10 volts applied to the conductive coating is sufficient to cause the electron beam from the electron gun to strike the target at the desired velocity for proper reflection of the unused portion of the beam to the electron multiplier 23 of the tube. Other potentials may be used for other methods of operation of the tube.

What is claimed is:

1. A device for receiving infra-red images comprising an evacuated chamber, an electron gun mounted at one end of said chamber for producing a beam of electrons, means for focusing and deflecting the output beam from said electron gun, and an infra-red sensitive target positioned at the other end of said tube, said target comprising an insulating support, a conductive coating mounted on said support and an infra-red sensitive photoelectric layer deposited on said conductive layer, said infra-red sensitive photoelectric layer comprising complex reaction products of lead oxide, sulfur and oxygen.

2. A device for receiving infra-red images comprising an evacuated chamber, an electron gun mounted at one end of said chamber for producing a beam of electrons, means for focusing and deflecting the output beam from said electron gun, and an infra-red sensitive target positioned at the other end of said tube, said target comprising an insulating support, a conductive coating mounted on said support and an infra-red sensitive photoelectric layer deposited on said conductive layer, said infra-red sensitive photoelectric layer comprising complex reaction products of lead oxide, sulfur and oxygen, said photoelectric layer having a resistivity on the order of 10^{10} and 10^{12} ohm centimeters and a time constant on the order of one-tenth second.

3. A photosensitive device comprising a non-conductive base plate, a conductive coating deposited on said plate, and a composite layer on said conductive coating of complex reaction products of lead oxide, sulfur and oxygen.

4. A photosensitive device comprising a non-conductive base plate, a conductive coating deposited on said plate, and a composite layer of photoelectric material deposited on said conductive coating and comprising crystalline complexes of lead oxide, lead sulfide and lead oxide:lead sulfate.

5. A target for a radiant energy detection device comprising a non-conductive base plate, a conductive coating deposited on said plate, and a composite layer on said conductive coating of complex reaction products of lead oxide, sulfur and oxygen, said composite layer having a resistivity on the order of 10^{10} to 10^{12} ohm centimeters and a time constant of the order of one-tenth second.

6. A target for a radiant energy detection device comprising a non-conductive base plate, a conductive coating deposited on said plate, and a composite layer on said conductive coating of complex reaction products of lead oxide, sulfur and oxygen, said composite layer having an infra-red response of approximately .5μ to 2μ and a time constant of the order of one-tenth second.

7. The method of making an infra-red sensitive element comprising the steps of applying a conductive coating to a glass support, depositing a layer of lead oxide on said conductive coating at a temperature in the range of 65° to 75° C., applying a layer of sulfur on said layer of said oxide, depositing a second layer of lead oxide on said sulfur and thermally activating said layers of chemicals to produce a desired infra-red response and resistivity.

8. The method of making an infra-red responsive element comprising the steps of applying a conductive coating to a glass support; applying a layer of lead oxide on said conductive coating by evaporating in an atmosphere of oxygen at a pressure of 10 to 20 microns of mercury and at a temperature in the range of 65° to 75° C.; applying a layer of sulfur on said lead oxide layer by evaporation in an atmosphere of oxygen at a pressure of 10 to 20 microns of mercury at a temperature in the range of 100° to 175° C.; depositing another layer of lead oxide on said sulfur layer by evaporation in an atmosphere of oxygen at a pressure of 10 to 20

microns of mercury at a temperature in the range of 100° to 175° C. and thermally activating said layers of chemicals to achieve the desired infra-red response and resistivity.

9. The method of making an infra-red responsive element comprising the steps of applying a conductive coating to a glass support; applying a layer of lead oxide on said conductive coating by evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury and at a temperature in the range of 65° C. to 75° C.; applying a layer of sulfur on said lead oxide layer by evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury at a temperature in the range of 100° C. to 175° C.; depositing another layer of lead oxide on said sulfur layer by evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury at a temperature in the range of 100° C. to 175° C. and thermally activating said layers of chemicals to achieve the desired infra-red response and resistivity.

10. The method of making an infra-red responsive element comprising the steps of applying a conductive coating to a glass support; applying a layer of lead oxide on said conductive coating by evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury and at a temperature in the range of 65° C. to 75° C.; applying a layer of sulfur on said lead oxide layer by

evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury at a temperature in the range of 100° C. to 175° C.; depositing another layer of lead oxide on said sulfur layer by evaporation in an atmosphere of air at a pressure of 10 to 20 microns of mercury at a temperature in the range of 100° C. to 175° C. and thermally activating said layers of chemicals to achieve the desired infra-red response and resistivity, said thermal activation comprising baking said target for ten to twenty minutes at a temperature in the range of 100° C. to 150° C. in oxygen at 5 millimeters pressure and baking said target for one-half hour to one hour at a temperature in the range of 125° C. to 175° C. at atmospheric pressure.

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