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SEMICONDUCTOR-TYPE PHOTOCATHODE FOR AN INFRARED DEVICE

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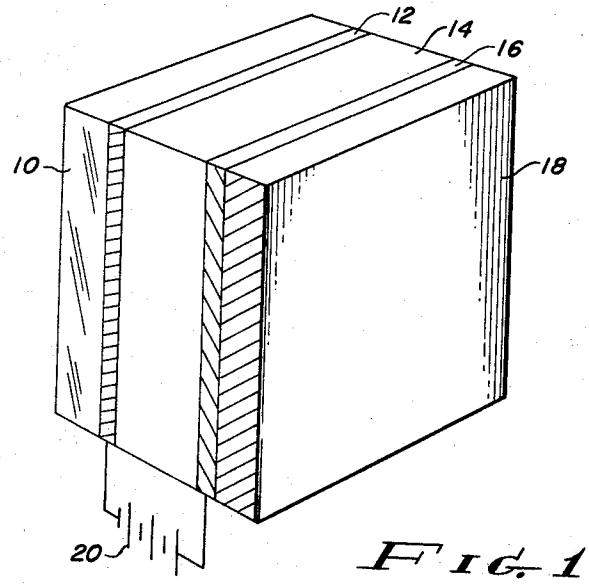


FIG. 1

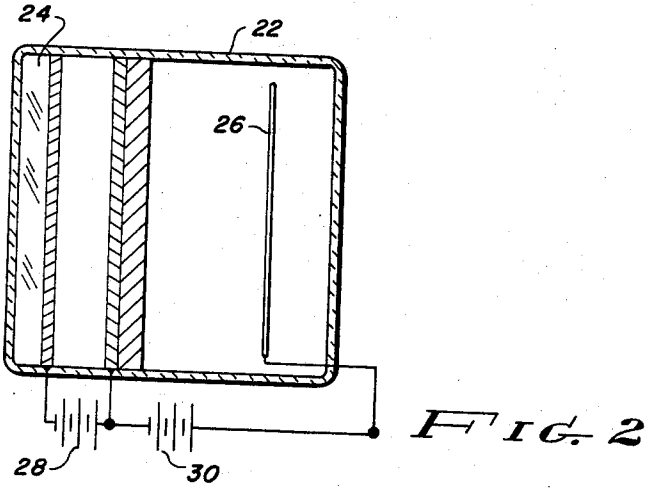


FIG. 2

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SEMICONDUCTOR-TYPE PHOTOCATHODE FOR AN INFRARED DEVICE

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ABSTRACT OF THE DISCLOSURE

A photocathode made of a film of semiconductor material having a film of a large band gap semiconductor material deposited over one surface thereon. On the opposite surface of said large band gap semiconductor film there is deposited a high work function metal film. On the opposite surface of the high work function metal film there is deposited a low work function material.

This invention relates to an improvement in the construction of a cold cathode suitable for use in an infrared detecting device.

An object of this invention is the provision of a novel photocathode for an infrared image transducer.

Yet another object of this invention is the provision of an improved photocathode for an infrared transducer which provides a high conversion efficiency for wavelengths greater than one micron.

Still another object of the present invention is the provision of an efficient photocathode which does not require refrigeration.

Yet another object of the present invention is the provision of a novel and useful photocathode for an infrared transducer.

These and other objects of the invention may be achieved by the provision of a novel cathode in a device for converting infrared photon flux into a visible image. This device comprises an evacuated envelope having an infrared sensitive photocathode in accordance with this invention at one end, and a target which may present a visible image in response to bombardment by electrons. An improved photocathode in accordance with this invention comprises a substrate upon which there is deposited a semiconductor layer, such as P type germanium. Over the germanium layer is deposited a layer of a large band gap semiconductor material. Over the large band gap semiconductor material there are deposited surface layers comprising two films, one being a metal film in contact with the semiconductor layer and having a high work function and the other film on the vacuum side of this layer having a low work function. The metal surface layer is biased positively with respect to the germanium layer.

In response to incident photon excitation hole-electron pairs are created in the P type germanium layer. The electrons, under the influence of the field established by the bias, migrate to and through the semiconductor layer into the surface layers. There, the electrons are liberated into the vacuum from the low work function film. They are accelerated by a second field which is established by suitable biasing between the cathode and the display anode. The electrons then bombard the anode to produce a visible image.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood

from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is an enlarged representation of a cathode in accordance with this invention; and

FIGURE 2 is an illustration of an infrared transducer which employs a cathode in accordance with this invention.

Referring now to the drawings, FIGURE 1 is an isometric representation of a photon-excited cathode in accordance with this invention. The substrate **10** which is made transparent to the infrared rays has deposited thereon a semiconductor layer **12** such as P type germanium. The germanium film, which by way of example may be on the order of three microns thick, absorbs about 90% of incident radiation which creates hole-electron pairs with high quantum efficiency. An ohmic contact for holes is provided around the periphery of the germanium deposit. Adjacent to the germanium layer there is provided a layer **14** of a large band gap semiconductor material. Adjacent to the semiconductor material layer there is placed a very thin layer **16** of a high work function metal. The high work function metal layer is covered by another thin layer **18** of a low work function material. A bias is applied by means of a battery **20** between the germanium layer and the metal layer in such a manner that the metal is positive with respect to the germanium layer.

A suitable material for the large band gap semiconductor layer may be gallium phosphide (GaP); zinc sulfide may also be employed but the gallium phosphide is preferred. The large band gap semiconductor has to make an ohmic contact with the germanium layer. The metal surface layer **16** comprises platinum, tungsten, or tantalum and the low work function layer **18** may be barium oxide or Ag-O-Cs (silver-oxygen-cesium).

In operation, the incident infrared radiation which falls upon the germanium generates hole-electron pairs in the germanium. The electrons diffuse into the large band gap semiconductor, thereafter into the surface films, and then into the vacuum. The bias applied across the cathode establishes the field for controlling the diffusion and drift of the electrons from the germanium to the metal surface layer, and also serves to forward bias the surface barrier formed by the juncture of the large band gap semiconductor and the surface film so that the electrons are injected into the surface films at an energy level above the vacuum level, thus making it possible for the electrons to escape into the vacuum.

In the fabrication of the cathode, while the germanium layer can be evaporated or vapor deposited onto a hot substrate, it is preferable to use a single crystal of germanium of uniformly doped material. This can be bonded to a suitable infrared window, such as quartz, and ground down, polished and etched to the desired thickness. The thickness of the GaP or ZnS is not critical. It is preferred that the thickness of the high work function metal should not exceed 100 angstrom units and the low work function layer should be somewhat thinner.

It should be noted that the cathode is not susceptible to destructive break down because of the field required to be applied thereacross for vacuum emission. This field is on the order of 10^5 volts per centimeter or less, which is one or two orders lower than that for tunnel cathodes. This is because the operation of this device is not dependent upon accelerating the electrons to a high energy level. The carrier transport process is that of diffusion. The applied bias **20** reduces the barrier into the surface film and with the application of the low work function material an effective "window" into the following vacuum of one or two electron volts in extent is provided.

FIGURE 2 illustrates the appearance of an infrared transducer which would employ the photocathode described in FIGURE 1. An evacuated envelope **22** is provided having the photocathode **24** at one end and a suitable target electrode **26** at the other end. The bias **28** for the photocathode is connected between the germanium and metal layer. A bias **30** is applied between the metal layer and the target **26** for accelerating the electrons which are emitted into the vacuum from the photocathode.

There has been accordingly described and shown herein a novel, useful and unique photocathode for an infrared detecting device. It is believed that the photocathode can extend the spectral response of existing image tubes to at least 1.6 microns. The photocathode has a high efficiency and does not require refrigeration in order to be operative.

What is claimed is:

1. A photocathode for an infrared device consisting of a film of P-type semiconductor material, a large band gap semiconductor material deposited on one surface of said P-type semiconductor film, a high work function metal film deposited on the surface of said large band gap semiconductor material which is not in contact with said P-type semiconductor film, a low work function material deposited over the surface of said high work function metal film which is not in contact with said large band gap semiconductor material.

2. A photocathode as recited in claim **1** wherein said large band gap semiconductor material is made of gallium phosphide, said high work function metal film is platinum, and said low work function material is barium oxide.

3. A photocathode as recited in claim **2** wherein said P-type semiconductor film is P-type germanium.

4. The photocathode as recited in claim **1** wherein said large band gap semiconductor material comprises zinc sulfide, said high work function metal film comprises platinum and said low work function material comprises barium oxide.

5. The photocathode as recited in claim **4** wherein said film of P-type semiconductor material is P-type germanium.

6. The photocathode as recited in claim **1** wherein said film of P-type semiconductor material is a P-type germanium, said large band gap semiconductor material is a gallium phosphide, said high work function metal film is tantalum, and said low work function material is barium oxide.

7. A photocathode as recited in claim **1** wherein said film of P-type semiconductor material is P-type germanium, said large band gap semiconductor material is gallium phosphide, said high work function metal film is tungsten and said low work function material is barium oxide.

8. A photocathode as recited in claim **1** wherein large band gap P-type semiconductor material is gallium phosphide, said high work function metal film is tungsten and said low work function material is silver-oxygen-cesium.

9. A photocathode as recited in claim **8** wherein said P-type semiconductor film is P-type germanium.

References Cited

UNITED STATES PATENTS

3,056,073	9/1962	Mead	317—234
3,105,166	9/1963	Choyke et al.	313—346 X
3,150,282	9/1964	Geppert	313—346
3,246,200	4/1966	Kanter	313—94 X
3,321,659	5/1967	Brody	313—94

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