April 18, 1961 M. GARBUNY 2,980,813

PHOTOTHERMIONIC APPARATUS

Filed July 12, 1957 2 Sheets-Sheet 1

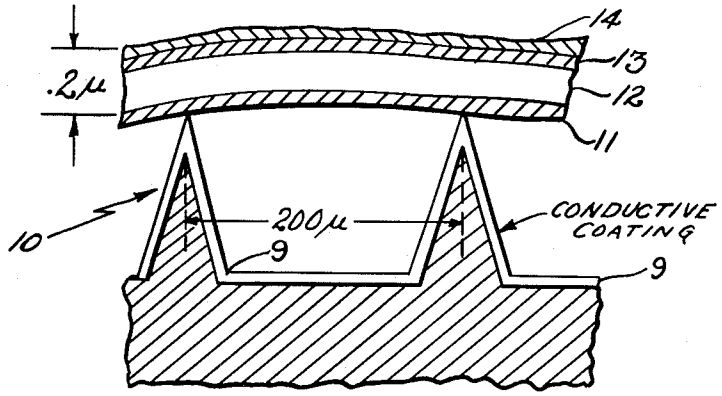


Fig. 1

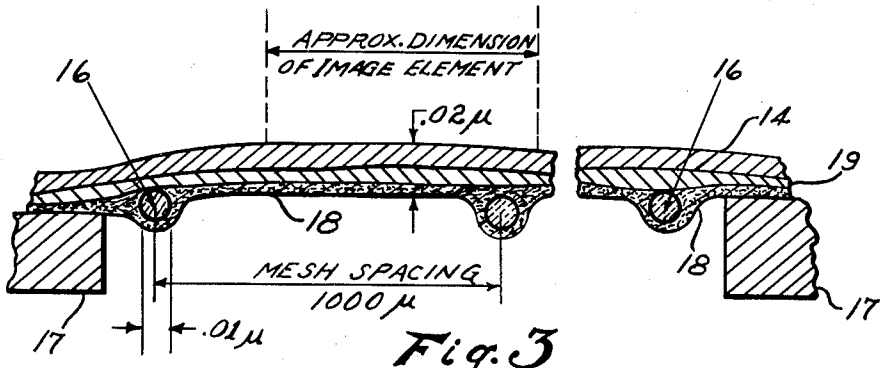


Fig. 3

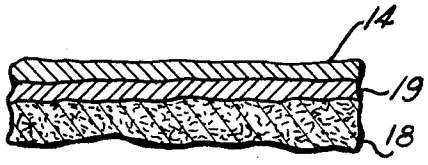


Fig. 2

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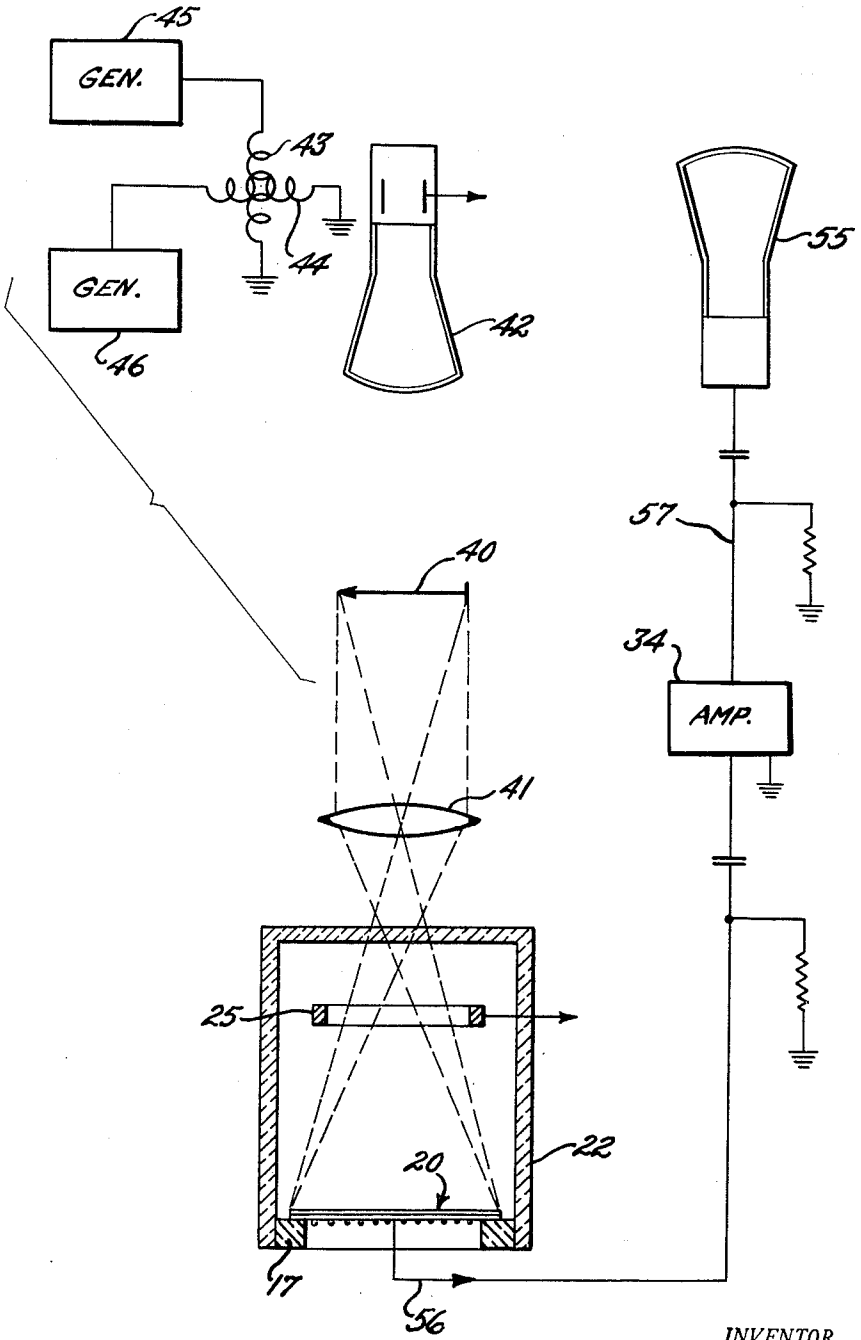


Fig. 4

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2,980,813

PHOTOTHERMIONIC APPARATUS

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Filed July 12, 1957, Ser. No. 671,681

7 Claims. (Cl. 313—65)

This invention relates to photothermionic image conversion, and particularly to structural considerations affecting the efficiency of the image conversion operation.

In thermal radiation detection processes it is customary to provide a photothermionic tube having a thin, freely supported photo-emissive surface onto which there may be projected a thermal image whose infrared radiation activity is to be detected. The impingement of the infrared energy upon the photo surface brings about a temperature distribution throughout said surface, in proportion to the spectral content of the impinging thermal rays. This temperature distribution is scanned with a light spot, and this scanning operation causes the emitted photo-current to be modulated in its intensity to a degree that is controlled by the temperature distribution pattern. The resulting modulated photo-current is then delivered to the electrodes of a television type of cathode ray tube, for display as a visual image upon the screen of such tube.

The heart of the photothermionic tube is the multi-layer assembly commonly referred to as the retina. This retina consists of a laminated structure whose aggregate thickness is ordinarily on the order of 2,500 angstroms, the structure being freely supported on the pinnacles of a regular array of a multitude of photoformed glass points. Such retinas, as heretofore produced, have included alternate layers of silicon monoxide and gold-black, but have had certain shortcomings. The 2500 angstrom thickness delays the thermal penetration time to a greater degree (on the order of $\frac{1}{20}$ sec.) than is desirable; also the thickness factor produces excessive lateral heat dissipation; yet reduction of the overall thickness has not heretofore been feasible because of the necessity for a certain degree of mechanical stability. Another disadvantage is that the upper stratum of silicon monoxide, which lies immediately below the thermal ray-intercepting photo-emissive layer, consists of a multiplicity of discrete sub-microscopic particles, whereas ideally it should be a continuous film in order to prevent direct infiltration of any substantial part of the thermal energy to the underlying gold-black layer. For best results the gold-black layer should have complete strata separation from the upper radiation-intercepting layer. Such complete separation, which has not heretofore been achieved, is attainable by use of the methods of retina construction and preparation, and by the choice of structural relationships, constituting complementary aspects of the present invention.

More specifically, the present invention provides retina assembly methods and retina structural relationships involving inversion of the relative positions heretofore occupied by the first (lower) SiO layer and the gold-black. Since the lower SiO layer in the conventional assembly is known to be continuous, that is, free of the holes and interstices that abound in the upper SiO layer (which lies immediately below the photolayer of the conventional assembly) the inversion of the assembly to bring such continuous SiO layer to the uppermost position, where it will serve to provide strata separation for the photolayer of

the assembly, as proposed in the present invention, results in a virtually complete separation of the photolayer (with its eventual substrate) from the gold-black layer. Consequently, it now becomes possible to employ, as an infravening layer directly below the photolayer, any material suitable to serve as a substrate to the photo surface, for the purpose of facilitating development of ancillary photocurrents in highly temperature-dependent combinations. Heretofore this was not feasible, since the infravening gold-black was not sufficiently shielded from the photolayer, due to the multiplicity of orifices which the discontinuous character of the intervening SiO layer permitted to exist.

Other objects, characteristics, and advantages attributable to the present invention will be indicated upon reference to the following description of the embodiment of the invention illustrated in the accompanying drawings wherein:

Fig. 1 is a vertical sectional view of a retina assembly typical of the prior art;

Fig. 2 is a vertical sectional view of a retina assembled in accordance with the present invention;

Fig. 3 is a vertical sectional view indicating additional details embodying further procedural and structural aspects of the invention; and

Fig. 4 is a diagram partly schematic and partly physical, showing image conversion circuitry utilizing the structure illustrated in Figs. 1, 2 and 3.

Referring first to Fig. 4, there is illustrated therein apparatus and circuitry including a thermionic tube **22** in alignment with an infrared image **40**, a directional lens system **41**, and a cathode ray tube **42** having horizontal and vertical deflecting coils **43** and **44** adapted to be energized by control voltages supplied by generators **45** and **46** respectively, whereby the photosensitive surface of the assembly of Figs. 1, 2 and 3—which assembly is indicated schematically at **20** in Fig. 4—may be activated by the scanning spot which traverses said photosensitive surface in accordance with the deflection pattern established by the deflection coils **43** and **44**; the path of the beam from the cathode ray tube **42** to the photo tube **22** being substantially coexistent with that of the infrared rays focused upon the photosurface under the guidance of the directive lens system **41**. Electrons are collected at the annular electrode **25** from which they are delivered to suitable monitoring or indicating apparatus **55** such as is illustrated and described in applicant's co-pending application Ser. No. 704,843, filed jointly with Robert C. Ohlman on December 23, 1957, which application is entitled "Thermal Image Converter System." The second cathode ray tube **55** receives the amplified output of the photo tube **22** by way of conductors **56** and **57**, amplifier **34** and associated circuitry corresponding to that illustrated, for example, in Fig. 1 of U.S. Patent No. 2,319,195 granted to G. A. Morton on May 11, 1943. By circuitry such as that just described the photo-currents generated in the retina assembly, and representing the thermal energy derived from the infrared image are amplified and made more plainly visible on the surface of the screen of the cathode ray tube **55**, to cause the display at said screen of image corresponding to said infrared image.

Referring first to Fig. 1, the assembly there shown represents the prior art practice. As illustrated in Fig. 1 the assembly includes a first SiO layer **11** resting on the pinnacles of the glass points **10** and serving as a support for the other layers **12**, **13** and **14**, of which layer **14** is the exposed photolayer composed of cesium antimonide or its equivalent, which layer **12** is the radiation-absorbing gold-black layer, and layer **13** is the discontinuous second SiO layer above described. This second SiO layer **13** has the two-fold duty of (*a*) stabilizing the action of the gold-

black layer 12, and (*b*) shielding layer 12 from physical contact with the photolayer 14.

In order to anchor the assembly on the pinnacles of points 10, without risking damage to its delicate structure, it has been customary to apply, as a first step, a conductive organic film 9 such as Zapon. This is, in turn, covered with an evaporated layer of SiO and finally the organic film is removed by heating in the presence of air so that the first SiO layer settles on and makes contact to the glass points. Another function of the second SiO layer may be cited in that it provides occasionally an excellent substrate to the photosurface in that photocurrents may result in such combinations which are highly temperature dependent. Such retinas are presently being produced in routine manner for experimental purposes. There are, however, still certain drawbacks with which this structure is afflicted. One disadvantage is that the retina is still relatively thick leading to a minimum thermal time constant in the order of $\frac{1}{20}$ sec. To make the retina thinner would endanger the mechanical stability of the structure. A certain amount of thermal image degradation is associated with the thickness due to lateral thermal conduction. Another disadvantage associated with this retina is the fact that a top SiO film does not form a continuous layer but consists rather of submicroscopic specks of SiO, thus defeating the purpose of preventing the black from assuming the undesired function of substrate.

The present invention proposes to invert the position of the gold-black with respect to the first SiO layer. Since electron microscope pictures have revealed that the first SiO layer is continuous (free of holes), the strata separation between the photolayer and its eventual substrate, on the one hand, and the black on the other, is virtually complete. Figs. 2 and 3 illustrate this construction, which has the advantage that any desired substrate can now be used under the photolayer; in fact, it may be found advantageous to use the SiO layer itself as a substrate to the photolayer. In prior art practices it has been difficult, if not impossible, to maintain a continuous substrate of the desired nature under the photolayer.

The complete design of the proposed inverted retina is shown in Fig. 3. For firm anchoring of the retina, a web or mesh 16 of extremely fine glass or quartz threads is anchored on a frame 17. The mesh may either be in the form of a cross net or simply in the form of parallel strings. Glass or quartz threads of .1 to .2 mil are preferred because of the low heat conductivity of materials as well as because of the ease with which such thin threads can be manufactured from these materials. The thermal conduction resistance of such a mesh is large enough to establish an exclusive radiation equilibrium between it and its environment so that the temperature distribution of the mesh will be, in equilibrium, that of the retina itself. Therefore, since the thread diameter is much smaller than the linear dimensions of the proposed picture element, the presence of the mesh will not be felt in the temperature distribution of the retina.

Previous results have shown that on close space meshes up to 1 mm. spacings, retinas as thin as 50 Ang. can be produced with great stability. This mesh can be used obviously in this construction to reduce substantially the overall thickness of the retina and thereby reduce its time constant. For instance, using a base of about 60 Ang. thick SiO, 100 Ang. effective thickness of an absorbing black, and about 150 Ang. thick cesium antimonide, the total thickness of the retina amounts only to 300 Ang. which allows a time constant as low as $\frac{1}{200}$ sec. at room temperature and about $\frac{1}{60}$ sec. at a temperature of liquid nitrogen.

The preparation of the retina is as follows: After the web has been formed, it receives on one side a thin Zapon film which is deposited mechanically on it. This is followed by evaporation of silicon monoxide 19 on the far side of the web. This structure is baked at about 300° to 400° C. in air or oxygen, this treatment removing the Zapon film. Gold-black, or equivalent absorption material 18 is evaporated on the near side of the web. However, as previously noted, it may be found advantageous to use the SiO layer 19 itself as a substrate to the photolayer 14, in which event the said photolayer 14 is applied directly upon the surface of layer 19, as illustrated in Figs. 2 and 3. The completed retina structure, consisting of elements 16, 18, 19, and 14 of Fig. 3, is indicated at 20 in Fig. 4. When completed, the structure 20 is placed inside a thermionic tube 22 enclosing an annular cathode frame 17 (see Fig. 4) to achieve the desired radiation equilibrium, with spacing and supporting washers being provided directly below the periphery of annular frame 17, as a convenient means for air escape during exhaustion.

The looped wire directly above retina 20 (Fig. 4) serves as a collector anode, as in E. D. Wilson patent application Ser. No. 293,522, filed June 14, 1952, and which is now abandoned.

Thus the invention proposes novel retina preparation methods and structure such that extremely small thicknesses can be successfully employed thereby reducing materially the time constant. Furthermore, an effective separation of the irregular ("feathery") structure of the absorption black is achieved, with respect to the substrate of the photolayer (or the photolayer itself) thereby making possible any desired continuous substrate for the cesium antimonide.

What I claim is:

1. A photothermionic retina assembly which comprises a continuous layer of silicon oxide and a superimposed layer of incident radiation-absorbing material, said silicon oxide layer being free of discontinuities so that it completely shields the incident radiation-absorbing material from direct thermal energy penetration thereto, and a third layer covering said two layers, said covering layer serving to intercept all radiation directed towards said retina assembly and control its passing to said silicon oxide layer.

2. A photothermionic retina assembly which comprises a mesh of non-conducting thread-like material, and silicon oxide and gold-black films applied to opposite surfaces of said mesh, to form complementary radiation controlling components of said assembly.

3. In a photothermionic retina assembly, the combination with a thermal ray-intercepting photo-emissive layer, of a layer of silicon oxide immediately below said photo-emissive layer, said silicon oxide layer being in the form of a continuous film to achieve complete strata separation along the plane of said silicon oxide layer.

4. In a photothermionic retina assembly, the combination with a thermal ray-intercepting photo-emissive layer, of an incidental radiation absorbing gold-black layer, and a layer of silicon oxide immediately below said photo-emissive layer, said silicon oxide layer being in the form of a continuous film having immediate, intimate surface contact with said gold-black layer, and serving to achieve complete strata separation of said gold-black layer from said ray-intercepting photo-emissive layer.

5. In a photothermionic retina assembly, the combination with a thermal ray-intercepting photo-emissive layer, of an incidental radiation absorbing gold-black layer, said layer including a supporting web of glass threads of small diameter, on the order of 0.2 mil, with mesh spacing on the order of 1 millimeter, and a layer of silicon oxide immediately below said photo-emissive layer, and immediately above said gold-black layer.

6. A photothermionic retina assembly including a mesh of non-conducting thread-like material, and layers of silicon oxide and gold-black, respectively, on opposite surfaces of said mesh.

7. In a photothermionic retina assembly, the combination with a thermal ray-intercepting photo-emissive layer, of an incidental radiation absorbing gold-black layer, said layer including a supporting web of quartz threads of small diameter, on the order of 0.2 mil, with mesh spacing on the order of 1 millimeter, and a layer of silicon oxide immediately below said photo-emissive layer, and immediately above said gold-black layer.

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