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PHOTOSENSITIVE CATHODE WITH CLOSELY ADJACENT LIGHT-DIFFUSING LAYER

Filed July 17, 1962

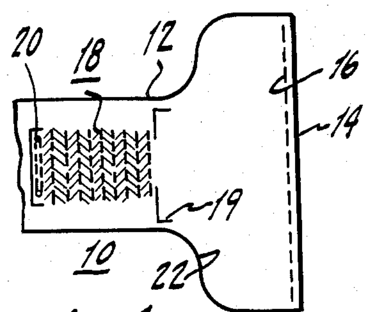

Fig. 1.

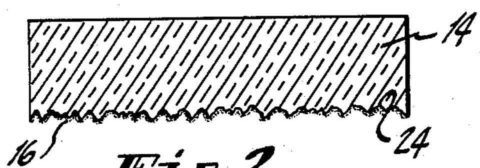

Fig. 2.

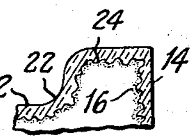

Fig. 1a

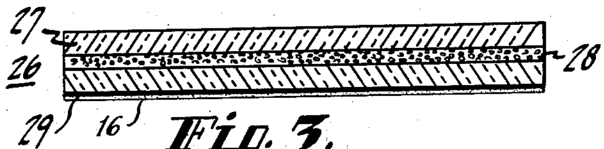

Fig. 3.

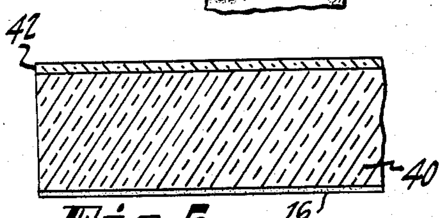

Fig. 5.

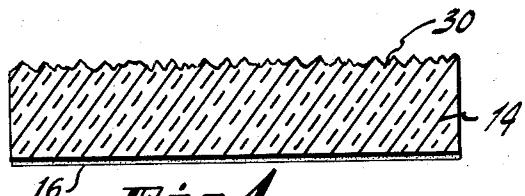

Fig. 4.

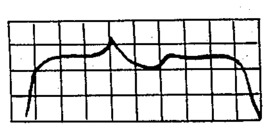

Fig. 6a.

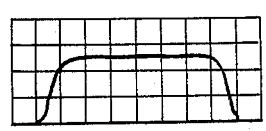

Fig. 6 b.

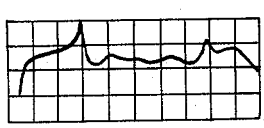

Fig. 7a.

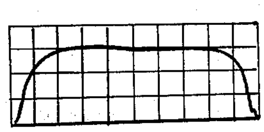

Fig. 7b.

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PHOTOSENSITIVE CATHODE WITH CLOSELY ADJACENT LIGHT-DIFFUSING LAYER

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This invention relates to photosensitive devices. One type of photosensitive device is a photomultiplier tube. Photomultiplier tubes are conventionally used in applications using a parallel beam of light, or an image located at the entrance window of the tube. One application of this type is when the photomultiplier tube is used as a radiation detector. In radiation detecting, the radiations which are to be detected are directed into a phosphor material when the phosphor material is held in contact with the entrance window of the tube. The phosphor material produces light of a wave length to which the photocathode of the photomultiplier tube responds. Certain radiations produce extremely low light level signals, either because of their intensity or their duration, which are difficult to detect.

In the prior art applications of tubes of the type described above, part of the light passes through the photocathode, without producing electrons. One of the reasons for this is that the conventional photocathode is extremely thin. In fact, most photocathodes are described as being semi-transparent. To increase the thickness of the photocathode does not solve the problem since this decreases the efficiency of the photocathode. Any light which passes through the photocathode may be internally reflected.

Part of this internally reflected light is lost by absorption within the tube. Still another part of this reflected light is lost by passage out of the tube envelope by a variety of possible paths one of which is transmission back through the photocathode. For light paths in which the light is internally reflected back to the photocathode, the sensitivity of the tube is enhanced. However, the light is normally reflected back to an area other than the area of origin, which leads to non-uniformity of response which is undesirable. Thus, when used for radiation detection, a short duration pulse of a single radiation may produce light which produces a first output signal and then is internally reflected back to the photocathode to produce a second output signal. The two signals, one of which is unwanted, will usually appear as one large signal which is obviously undesirable.

Still further, when used for radiation detection, radiations may strike one area of the photocathode producing an output signal of a first magnitude. If the same radiation were to strike another area of the photocathode, an output signal of a different magnitude may be produced which would indicate the presence of a different type of radiation. As is obvious such non-uniformities are not desirable.

It is therefore an object of this invention to provide a novel photomultiplier tube having improved uniformity of response across the light sensitive photosurface.

It is a further object of this invention to provide a novel photosensitive device.

These and other objects are accomplished in accordance with this invention by providing an optical diffuser positioned in close proximity to the photocathode. By means of the optical diffuser, internal reflections within the tube are randomized, and the uniformity of sensitivity of the tube is greatly enhanced. Furthermore, the use of the optical diffuser enhances the overall tube sensitivity.

The invention will be more clearly understood by reference to the accompanying single sheet of drawings wherein:

FIG. 1 is a sectional view of a photomultiplier tube made in accordance with this invention;

FIG. 1*a* is a fragmentary view in section of a portion of the tube shown in FIG. 1, and shows a light diffusing surface on the faceplate as well as on the shoulder portion of the tube envelope;

FIGS. 2 through 5 are enlarged fragmentary sectional views of different embodiments of this invention; and

FIGS. 6 (*a* and *b*) and 7 (*a* and *b*) are graphs of the output signal of tubes of the prior art type as compared to output signals from tubes made in accordance with this invention.

Referring now to FIG. 1 there is shown a sectional view of a photomultiplier tube **10**. It should be clearly understood that the invention is applicable to other photosensitive tubes and the photomultiplier tube is shown merely to illustrate a type of tube in which this invention is particularly applicable. The photomultiplier tube **10** generally comprises an evacuated envelope **12** having an input window or face plate **14** on end end thereof. Although the face plate **14** is shown as being flat, it should be understood that it can be of any other configuration such as plano-concave. The face plate **14** supports a photocathode **16** on the internal surface thereof. Positioned in the other end of the envelope **12** is an electron multiplier structure **18**. Between the photocathode **16** and the multiplier structure **18** is an accelerating electrode **19**.

The electron multiplier structure **18** is of any conventional type, and is shown as a "Venetian blind type" electron multiplier. Other types of electron multiplier structures, such as the straight through type or the circular cage type, may also be used. The electron multiplier may be made of any known materials, examples of which are silver magnesium and copper beryllium, which have a high secondary emission ratio and which will multiply the photoelectrons originating from the photocathode **16**. Also, the electron multiplier structure **18** may include any desired number of dynodes. The electron multiplier structure **18** also includes a collector electrode **20** from which output signals are taken in the usual manner.

The photocathode **16** may be supported on a separate support member or on the inner surface of the face plate **14** as shown. The photocathode **16** may comprise any known photoemissive materials such as the conventional S–11 photosurface described in U.S. Patent Number 2,676,282 to Polkosky, issued April 20, 1954, or the conventional multi-alkali surface described in U.S. Patent Number 2,770,561 to Sommer, issued November 13, 1956. Other photocathode materials may be used, and may be selected for response to a particular wave length, e.g., infrared or ultra violet, of radiant energy.

It should be noted that the end of the envelope **12** which includes the electron multiplier section **18** is of a substantially smaller diameter than the face plate or input window **14**. Thus, there are shoulders **22** in the envelope which will tend to reflect radiations which may pass through the photocathode **16**.

As was previously stated, this invention comprises the provision of a light diffuser in close proximity to the photocathode **16**. In general, the light diffuser may be provided as (1) a surface effect on the face plate **14**; (2) by using a special light diffusing glass for the face plate **14**; (3) by providing a translucent material adjacent to the face plate **14**; or, (4) by providing a diffuser within the face plate **14**.

By surface effect is meant the effect obtained when a glass face plate **14** is sand blasted, hydroblasted, or etched. For example, a face plate of .0080 lime glass having a thickness of approximately 0.125 to 0.250 inch may be sand blasted as follows: The sand blasting gun may be positioned 2½ to 3 inches from the face plate while using an air pressure of approximately 50 to 70 pounds. A sand may be used having a grit size of 220. The same glass may be etched by exposing the glass to a 50 percent hydrofluoric and 50 percent sulfuric acid mixture for a period of time of one minute.

Another method of providing the light diffuser is to make the face plate **14** out of a special light diffusing glass such as opal glass. Opal glass of a proper translucent quality may be obtained from many vendors. An example is Foto Opal Glass, Corning Glass Company number 6992.

A third method of providing the light diffuser is to utilize a translucent material adjacent to the face plate **14**. The translucent materials may be approximately 0.005 inch thick and may be made of materials such as opal glass, polytetrafluoroethylene, polyethylene or other light diffusing translucent material which may be positioned adjacent to the face plate **14**. Also, the translucent material may be a coating of material, e.g. enamel, painted on the face plate **14**.

A diffuser may also be sandwiched within the face plate **14**. Thus, the diffuser may be provided by utilizing a face plate **14** which includes small glass spheres, having an index of reflection different from the remainder of the face plate **14**, between two layers of glass.

Referring now to FIG. 2, there is shown an embodiment of this invention wherein a light diffuser **24** is provided on the internal surface of the face plate **14**. Thus, the internal surface may have a light diffuser provided by surface effects. In this embodiment the photocathode **16** is positioned directly on the light diffuser **24**.

A specific example of how the embodiment shown in FIG. 2 may be manufactured is to utilize an input end window or face plate **14** made of .0080 lime glass which has a thickness of approximately 0.125 to 0.250 inch. The internal surface of the end window **14** may be sandblasted with aluminum oxide of a standard nomenclature grit size of 220 for a period of time of approximately 0.5 to 2 minutes. Another example is by etching the same glass material with acid of a concentration of approximately 50 percent hydrofluoric and 50 percent sulfuric for approximately one minute.

When the diffuser **24** has been provided on the internal surface of the envelope face plate **14**, the face plate is sealed to the envelope **12** and the balance of the tube assembly steps are accomplished by any of the methods which are well known in the art. It should be understood that the face plate can be sealed to the body portion of the envelope prior to the time when the diffuser **24** is provided thereon.

An alternative to providing the diffuser only on the face plate **14** is to provide the diffuser also on the internal surfaces of the envelope **12**, i.e., the areas including the face plate **14** and the shoulders **22** as shown in FIG. 1*a*. Thus, in this alternative, the entire envelope from the face plate **14** to the region of the electron multiplier structure **18** is provided with a light diffusing surface. In this latter embodiment any light which may pass through the photocathode **16** will not be reflected from the shoulders **22** but will be randomly diffused throughout the envelope.

Referring now to FIG. 3 there is shown an embodiment of this invention in which a face plate **26** is provided which includes a diffuser within the face plate **26**. Thus, the face plate **26** comprises a first sheet of glass **27** and a second sheet of glass **29** having a diffuser **28** sandwiched therebetween. The diffuser **28** may be a light diffusing translucent layer comprising small glass spheres having an index of refraction different from that of the glass sheets **27** and **29**.

It should be noted that in both the embodiments illustrated in FIGS. 2 and 3 the outer surface of the envelope

face plate may be an optically polished, flat face plate. Thus, for radiation detecting measurements, a flat phosphor body may be positioned in firm optical contact, i.e. with a minimum change of index of refraction between the two bodies, with the outer surface of the face plate.

Referring now to FIG. 4 there is shown an embodiment of this invention wherein a diffuser **30** is provided on the external surface of the face plate **14**. The diffuser **30** may be provided by any of the methods set forth above such as sandblasting, hydroblasting, etching or a molded glass surface.

Referring now to FIG. 5 there is shown an embodiment of this invention in which a face plate **40** is provided having a separate diffuser **42** thereon. The diffuser may be an extremely thin layer, 0.005 inch, of translucent material, e.g. opal glass or a fluorcarbon film. Also the diffuser may be a coating of material, such as enamel, which may be sprayed or painted thereon. By means of this invention, internal reflections are in a large degree randomized and the uniformity of the sensitivity of the tube is greatly enhanced. The improvement is illustrated in FIGS. 6 and 7 which are graphs of the output signal obtained from a tube while using this invention, FIGS. 6*b* and 7*b*, and a like tube without the diffuser illustrated in FIGS. 6*a* and 7*a*. The method of obtaining these characteristics was to scan a single light spot from one edge of the face plate completely across the face plate in a straight line to the opposite edge. The results obtained without the benefit of this invention are quite nonuniform as compared with the results obtained using the same tube type but with a light diffuser in accordance with this invention.

Also, it should be noted that the sensitivity is enhanced. This enhancement has been measured to be as high as 15 percent of the overall sensitivity. The reason that the sensitivity is enhanced is believed to follow from the fact that the diffuser causes a significant fraction of the input light to be directed at low angles to the photocathode, resulting in a greater chance of absorption of this light during its longer passage through the photocathode.

It is preferable that the diffuser used in accordance with this invention absorb the minimum possible amount of light. It is also preferred to select a diffuser which scatters a minimum amount of light in the backward direction. Still further the diffuser is preferably selected so as to maximize lateral scattering of the light.

In any of the embodiments of this invention, the diffuser should be positioned closely adjacent to the photocathode.

When a separate diffuser is used, the index of refraction of the diffuser is preferably selected so as to provide optimum coupling between the medium through which the light is passing, just prior to reaching the diffuser, and the material of the tube face plate.

Thus, this invention provides a novel inexpensive means for improving the uniformity of the sensitivity of photomultiplier tubes. Coupled with this uniformity improvement is an improvement in the overall sensitivity of the tube.

What is claimed is:

1. A photomultiplier tube comprising an evacuated envelope, a photoemissive cathode in said envelope, an electron multiplier means in said envelope and positioned to receive electrons directly from said photoemissive cathode, and a support having a light diffusing translucent region positioned closely adjacent to said photoemissive cathode.

2. A photomultiplier tube comprising an evacuated envelope, said envelope including a wall portion supporting a face plate portion through which light is adapted to pass, a photoemissive cathode within said envelope and positioned to receive light passing through said face plate portion, and an electron multiplier structure within said envelope and positioned to receive photoelectrons from

said photoemissive cathode, said face plate portion of said envelope including a light diffuser, said light diffuser comprising a layer of light diffusing translucent non-conductive material selected from the group consisting of opal glass and fluorcarbon film.

3. A photomultiplier tube comprising an evacuated envelope, said envelope including a wall portion supporting a face plate portion through which light is adapted to pass, a photoemissive cathode within said envelope and positioned to receive light passing through said face plate portion, and electron multiplier structure within said envelope and positioned to receive photoelectrons from said photoemissive cathode, said face plate portion of said envelope including a light diffuser, said light diffuser comprising a layer of a first light diffusing glass sandwiched between two layers of glass, said first glass having a different index of refraction than said second glass.

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