United States Patent

Stowe

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[54] HYDROGEN-FILLED GAS DETECTOR HAVING CATHODE HELIX SUPPORTED BY ENVELOPE WALL

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[52] **U.S. Cl.** .....**313/217,** 250/83.6 R, 313/223, 313/93

[51] **Int. Cl.**.....**H01j 17/06,** H01j 17/20, H01j 39/28

[58] **Field of Search**.....250/83.6 R; 313/217, 93

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[57] **ABSTRACT**

An ultraviolet detector in which the electrode configuration is non-symmetrical in that one electrode operates permanently as the emitter and the other as the collector, at least one of the electrodes supported by the inner surface of the tube envelope and offering an expansive wide angle field of view for incoming ultraviolet radiation. The electrodes are DC biased to provide a high voltage difference therebetween, i.e., between cathode, or emitter, and anode or collector, the former responsive to each photon of ultraviolet energy incident from within the wide angle.

1 Claims, 5 Drawing Figures

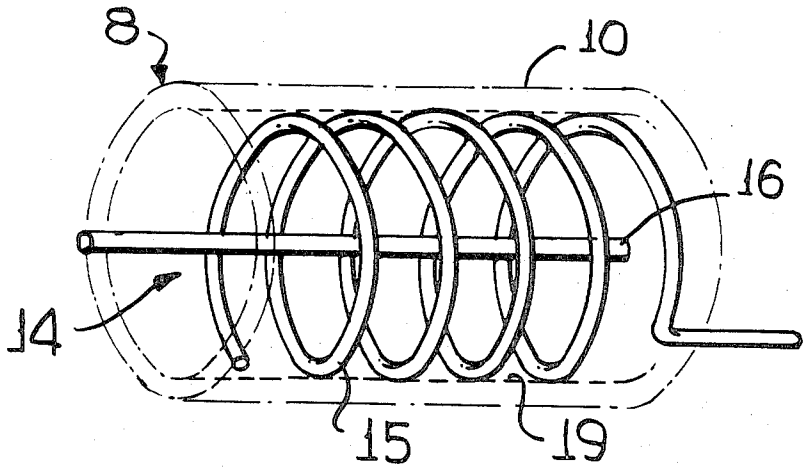


FIG.1

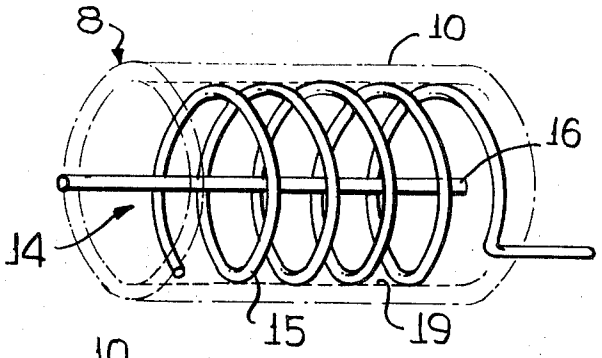


FIG.2

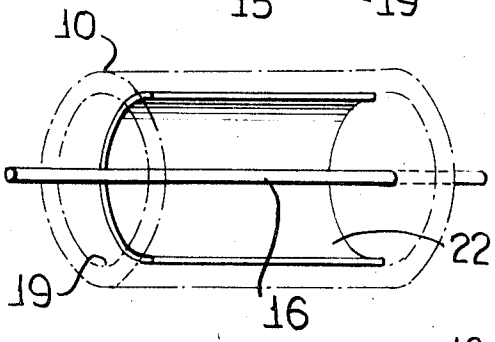


FIG.3

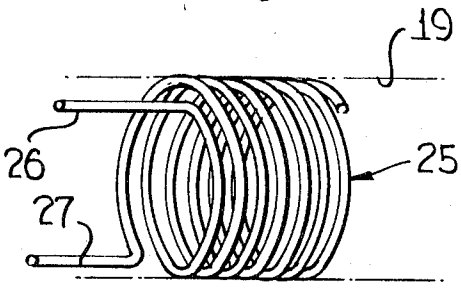


FIG.4

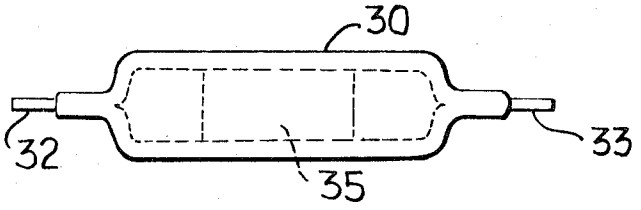
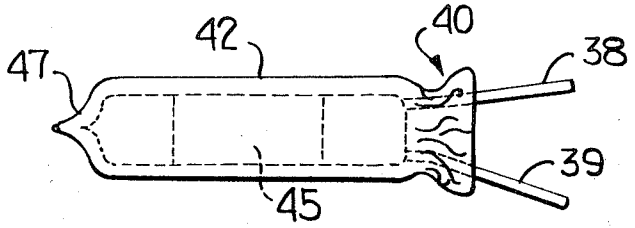


FIG.5



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HYDROGEN-FILLED GAS DETECTOR HAVING CATHODE HELIX SUPPORTED BY ENVELOPE WALL

BACKGROUND OF THE INVENTION

The present invention relates generally to radiation detectors and more particularly to ultraviolet detectors especially suitable for flame detection.

Photoemissive surfaces are widely used for radiation detection in the region above 1,500 angstroms, and photomultipliers of several designs are available for use in the 2,000- to 3,000-angstrom region. A major difficulty experienced with the prior art photoemissive detectors has been their prohibitive cost, complexity and generally low sensitivity.

A typical prior art ultraviolet detector comprises a tube having two symmetrical electrodes within a gas-filled glass envelope. The electrodes, which are generally spaced parallel wires, alternate as cathode and anode as the tube is operated on alternating current (a-c), or rectified a-c, the latter provided by an undulating voltage whose polarity remains positive or negative while approaching zero in each half-cycle. Ultraviolet radiation within the range of capabilities of the tube, both as to spectral and magnitude characteristics, incident on the cathode (negative electrode) during a given half cycle displaces electrons therefrom, and those electrons emitted at maximum or almost maximum voltage between the electrodes produce ionization of the fill gas to create an avalanche current that continues for the portion of the half cycle during which the voltage is sufficiently high. When the voltage drops below a certain limiting value toward the end of the half cycle, the ionization discharge ceases and will begin again only upon emission of electrons during an interval of the following half cycle in which a sufficiently high voltage exists between the electrodes.

Such a detector provides a relatively high average current over a substantial number of half cycles in response to ultraviolet radiation of sufficiently high intensity. In this manner the following circuitry, that is, the circuitry subsequent to the detector, will respond only to average current generated by the detector over several half cycles rather than to a single half cycle call for current initiated by cosmic rays, sunlight, or other sources of ultraviolet radiation.

A typical prior ac supply potential is of the order of 700 volts at 60 cycles, with average current running between approximately 1 and 25 milliamperes, depending upon the intensity of ultraviolet radiation impinging upon the detector.

One significant disadvantage of such prior art ultraviolet radiation detectors is the existence of the so-called "dead time" during each half cycle of operation, in which the tube is incapable of responding to incoming radiation. Moreover, since such detectors are responsive to average current over a significant number of half cycles, it will readily be appreciated that the response to an alarm condition, should the detector be used, for example, as a monitor of flames in a particular area under observation, is relatively slow.

Still further, the prior art ultraviolet detectors of the type described above use a symmetrical, spaced, parallel wire electrode configuration of relatively small receptor surface area. Accordingly, sensitivity to incoming UV radiation is rather poor.

SUMMARY OF THE INVENTION

Briefly, according to the present invention, an ultraviolet radiation detector is provided in which the detector tube contains a mechanically symmetrical or non-symmetrical electrode configuration, the photoemissive electrode of which has a surface area preferably substantially greater than the surface area of the collector electrode, and in which the emitter at least is supported by the inner surface of the tube envelope. In this manner, the surface area of the photoemissive electrode is substantially increased over prior art designs, resulting in enhanced response over these prior art designs. Also, since the electrode configuration is electrically non-symmetrical, that

is, only one of the electrodes is an emitter, a reduction in size of the over-all tube or detector is permitted, while maintaining a relatively large surface area of the emitter electrode. Despite the reduction in size of the over-all tube, there is no sacrifice of ruggedness, since the mass of envelope material (e.g., glass) is increased in relation to the over-all volume of the detector. Moreover, since the cathode, or emitter, at least is supported by the interior of the tube envelope, the detector is better equipped to resist shock and and is much more rugged, than the prior art detector configurations.

It is to be noted in addition that sensitivity of prior art tubes to cosmic radiation and other extraneous sources of ultraviolet radiation, that is to say, sources other than that which is to be monitored, such as flame, produces operation in the Geiger mode (i.e., avalanche breakdown) as a result of the unwanted radiation, this effect being largely a function of the volume of the detector tube. In detector tubes according to the present invention the reduced cross-section of the envelope and of the gas filling the envelope to the incoming radiation flux is effective to reduce the sensitivity of the detector to these extraneous sources of ultraviolet radiation.

Accordingly, it is a principal object of the present invention to provide an ultraviolet detector having increased ruggedness, increased sensitivity to radiation to be detected as a result of larger emitter area, and reduced sensitivity to unwanted radiation such as cosmic radiation.

It is another object of the present invention to provide an ultraviolet detector of non-symmetrical electrode configuration and large emitter area to provide a substantial number of ionization breakdowns per unit of flux so as to provide a greater number of pulses per second for unit flux, whereby to provide faster sensing.

It is a feature of the present invention that the electrodes are biased by a high-voltage d-c supply, such that there is no dead time as is encountered in a-c operated, quenched types of tubes of the prior art type.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of certain preferred embodiments thereof, especially when taken in conjunction with the accompanying drawings, in which:

FIGS. 1 and 2 are perspective views of two preferred embodiments of detector tubes having non-symmetrical electrode configuration in accordance with the invention;

FIG. 3 is a perspective view of a symmetrical electrode configuration which may be employed in detector tubes of the present invention; and

FIGS. 4 and 5 are side views of envelope packages suitable for maintaining the electrode configurations shown in the preceding figures.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A major problem encountered in photoemissive type detectors is the achievement of proper spectral response characteristics, and this in turn is linked to the provision of a clean surface of metal for the electrodes so as to exhibit a sharp cut-off at the desired wavelength. Tungsten, for example, has a photoelectric work function which is of such value to exhibit photoemissivity to ultraviolet radiation shorter than approximately 2,700 angstroms. Similarly, for palladium, having a photoelectric work function of approximately 4.96, the sharp cut-off of response is observed at a wavelength of approximately 2,500 angstroms. To achieve this sharp cut-off, the metal surface of the electrode must be extremely clean since any impurities tend to lower the work function and therefore to raise the cut-off wavelength. The result of impure electrode surfaces is a spectral response which decreases near the desired cut-off wavelength but wherein some increased response may be observed above that wavelength.

Other factors also tend to influence the sharpness of the long wavelength cut-off, factors such as the orientation of the individual grains within the electrodes and the variation of work function with orientation, but these effects may be neglected in relation to other more gross effects.

Referring now to FIG. 1, the ultraviolet detector 8 includes a glass envelope 10 shown in phantom to more clearly reveal the electrode configuration 14. Since the detector need only have a window transparent to ultraviolet radiation, it is also suitable to provide a detector envelope whose base and, at least partially, side area comprises a ceramic material with a window of glass or crystal material having suitable transmission characteristics. Silica glasses are employed extensively for ultraviolet detector windows, but their low thermal expansion makes them difficult to seal into an assembly. The low strength of glasses also detracts somewhat from their desirability. Sapphire (Al_2O_3) crystal windows, while moderately expensive, possess most of the attributes desired in window material. For one thing, sapphire is transparent to ultraviolet below 1,500 angstroms, and is much stronger than glass, as well as having a moderate thermal expansion, and is a material which can be metallized for brazing into an assembly.

The electrodes 15, 16 may be fastened to a ceramic header (not shown) using electrical feedthroughs of conventional design, as well as employing well known ceramic-to-metal sealing techniques. For example, the metal leads may be brazed into an integral assembly with the ceramic header. Matching coefficients of expansion are readily achieved with a number of commercially available alumina ceramics and low-cost alloys.

In the electrode arrangement 14 shown in FIG. 1 the central electrode 16 is substantially coincident with the axis of the envelope, is preferably composed of tungsten, and is the collector or anode of the detector tube. The outer electrode 15 is a helically wound metal wire operating as the cathode, or emitter, and is also preferably composed of tungsten, and is supported by the interior surface 19 of the detector envelope. As will be observed from the packaging arrangements to be described presently, each electrode may exit from the tube at the same end or at different ends. It will be noted, in either event, that the cathode, or emitter 15, has a substantially greater surface area than is available with the spaced parallel wire detectors of the prior type described earlier. Moreover, the particular configuration of the cathode or photoemitter electrode acts to provide a 360° field of view for incoming radiation to the detector, provided, of course, that the envelope is composed of a material acting as a window throughout 360° about the axis of the tube.

A typical method of assembly of the ultraviolet detector tube involves initially attaching the electro-polished electrodes to pins in the ceramic header by spot welding, then brazing the header and window into a detector body. This is followed by evacuation, i.e., outgassing, of the envelope and electrode cleaning. The final step is to flush the interior of the tube with hydrogen, followed by further evacuating and filling to approximately 200 millimeters pressure with ultra pure hydrogen. Particular care must be exercised in the brazing and cleaning operations to assure that the detector chamber is leak-tight and scrupulously clean. Hydrogen may diffuse through even minute leaks with resultant degradation in performance.

If desired, external lenses (not shown) may be employed to improve the range of intensities of ultraviolet radiation over which the tube is responsive, or to modify the angular coverage of the detector. This may be accomplished, for example, by use of silica glass lenses readily available in a number of aperture and focal length sizes. Typical angular coverage is from about 2° to about 5°, readily achieved with a simple lens. For line coverage, a cylindrical lens may be employed to provide a fan-shaped spatial sensitivity. The detector alone provides almost isotropic coverage of a 180° solid angle, and use of any lens will restrict this angle with some resultant improvement in sensitivity.

In operation of the ultraviolet detector of FIG. 1, the ultraviolet energy incident on the cathode in the region of the spectrum ranging from approximately 1,500 angstroms to about 2,800 angstroms produces photoelectric emission from the cathode. In this respect, it will be observed that each photon or quantum of incident ultraviolet radiation is sufficient to release an electron from the emitter electrode by raising the energy level of that electron to a value exceeding the work function of the emitter material. The liberated electrons are accelerated by the field between the electrodes, produced by a d-c bias thereon, and initiate an ionization avalanche in the gas with which the tube is filled. This produces a comparatively large current which flows through a load circuit (not shown) to which the electrodes are coupled. Passage of the current through an external resistor, for example, to raise the potential drop thereacross and decrease the bias voltage across the electrodes, whereby to extinguish the tube avalanche current, is effective to cause generation of a pulse from the tube.

Referring now to FIG. 2, another embodiment of the invention is provided by a concentric arrangement in which the anode or collector electrode 16 is again aligned along the axis of the tube. In this arrangement, however, the cathode or emitter is a foil electrode 22 of semi-cylindrical or half-cylindrical configuration, bonded or otherwise secured to the inner surface 19 of the tube envelope 10 as shown in the Figure.

Alternatively, the cathode may be coated on the interior surface of the glass tube by conventional deposition techniques.

The embodiment of concentric electrodes as shown in FIG. 2 has the advantage that the half-cylindrical cathode or emitter electrode 22 may be formed from sheet material which is fastened to and supported by the inner surface 19 of the glass envelope. In the alternative event that the electrode is deposited directly on the interior surface of the tube, it is important to note that the electrode layer need not be uniform and may even be spotty, but that it must be substantially pure metal. It is also possible to provide a sufficiently thin electrode layer to be partially transparent to ultraviolet radiation so that the interior surface of the detector tube operates partially as a window to radiation and partially as a cathode. In the latter situation, it would be necessary that the layer, if coated around the entire internal periphery of the glass tube, be substantially uniform in thickness. It will be observed that a half-cylindrical cathode provides a substantially 180° solid angle field of view for the detector.

Referring now to FIG. 3, the double helix electrode configuration 25 there shown is not of the non-symmetrical type as are those of FIGS. 1 and 2, but the arrangement of electrodes permits the support of both by the internal surface 19 of the tube. In essence, the configuration is of the parallel type, both cathode 27 and anode 28 being helical in form with coils of each alternately positioned relative to the other, but the electrode arrangement has many of the advantages of the non-symmetrical arrangements which have been discussed earlier, in that the surface area of the electrode is substantially increased over prior art types, a wide angle field of view is presented to incoming radiation, and electrode support is provided by the interior surface of the tube to ruggedize the electrode structure. I have found that for the electrode configuration of FIG. 3, it is desirable to provide an internal spacer or support member (not shown) to insure the maintenance of uniform spacing between the two electrodes, and for this purpose, the electrodes may be wound in helical fashion on a ceramic or glass mandrel.

It should be observed that in all of the designs described above, a substantially increased emitter area is provided over that available in the prior art detector tubes, and that this provides the advantage of a greater number of breakdowns in the fill-gas per unit of flux incident on the detector tube itself. This photo-emissive "gas-gain" detection provides a substantial number of advantages over prior art UV detection tubes in respect to stability, sensitivity to desired radiation, discrimina-

tion against undesired radiation, and speed of response. In effect, detector tubes according to the present invention operate as digital generators, in part because of their response to individual photons of ultraviolet radiation incident on the tube and in further part because of the d-c bias between the electrodes. This corresponds to some extent to a Geiger mode of operation, but with the advantages discussed above. It should also be noted that the present invention provides detector tubes which are relatively insensitive to ultraviolet radiation from sources other than the source to be monitored. Sensitivity to extraneous radiation is largely a function of detector tube volume and volume of gas contained in the tube, and it will be observed that there is here produced a reduced cross-section of gas to particle flux as a result of electrode configurations which are well suited to subminiature tube packaging.

Materials suitable for the electrodes include tungsten, platinum, rhodium, platinum-rhodium alloy, nickel, gold, iridium and palladium. Tungsten has a work function of about 4.52 electron volts and a threshold of about 2,750 angstroms. It has excellent mechanical properties at high temperatures, such as those required during bake-out. The Tungsten wire, however, is difficult to purify, requiring techniques such as zone refinement, by drawing through diamond or sapphire dies, or the like. The metal can only be purified to approximately five decimal places, but is relatively gas-free. Tungsten wire can also be electro-polished rather easily, and if desired, the metal may be plated or evaporated directly on the tube surface with no mechanical or chemical difficulties, using a suitable base or substrate material, such as glass or ceramic. Vapor plating, however, does not usually provide the purity obtained by zone refinement, typically being about 4 decimal places pure, and is generally performed by reduction of halogen compounds or by thermal decomposition of compounds such as tungsten hexacarbonze. Tungsten has a low coefficient of thermal expansion, and must have a hot-pressed seal or graded seal when employed in a feed-through arrangement with glasses or glass envelopes.

Platinum has a work function of approximately 6.3 and therefore a threshold for ultraviolet radiation of about 2,000 angstroms. Commercially available, substantially pure metal is an advantage, but the mechanical properties of platinum at high temperatures are not so good as those of tungsten. Platinum is not desirable in wire form, but is useful as a coating. In any event, its work function is relatively high and thus renders it suitable for specialized types of detectors.

Rhodium has a good work function, for present purposes, approximately 4.58 electron volts, and a threshold therefore, of approximately 2,600 angstroms. A platinum-rhodium alloy is desirable from the standpoint of east of polishing, temperature characteristics, and strength in either the wire or foil forms.

Gold is probably the most desirable metal to be employed as a coating, having good temperature stability of its work function. For example, the work function at 20° C. is 4.82 electron volts, indicative of threshold of 2,550 angstroms, and at 740° C. is 4.73 ev, leading to a threshold of 2,640 angstroms. Accordingly, gold offers the advantage of a temperature-stable emitter. While it is available in extremely pure forms, it is quite soft and malleable mechanically and hence is not as desirable in the bulk form as in the coating form. It is readily vacuum-evaporated, and ion plating on glass seems feasible, as does chemical vapor plating.

Referring now to FIG. 4, any of the previously described exemplary embodiments of electrode configurations may be packaged in a subminiature tube glass envelope having an axial lead 32, 33 extending from either end thereof, each lead attached to a respective one of the internal electrodes. The active area 35, i.e., the electrode configuration is preferably centrally located longitudinally of the tube as shown in FIG. 4, and the leads emanating from the tube are secured by hot pressed seals which act as a hermetic seal against leakage of the fill-gass.

The packaging arrangement of FIG. 5 is similar to that of FIG. 4, except that both leads 38 and 39, for a two-electrode detector tube, project from a single end 40 of the detector tube 42. Again the active area 45 is located substantially centrally along the longitudinal axis of the detector tube, and the glass envelope is closed over the leads by means of a hot-pressed seal or a graded glass seal. The envelope is evacuated and gas filled from the other end 47, after which the latter end is pinched off to provide the hermetic seal.

I claim:

1. An optical radiation detector tube comprising

a hermetically sealed elongated cylindrical envelope transparent to ultraviolet radiation over its entire cylindrical surface, said envelope having a longitudinal axis and being closed by end headers,

a pair of spaced electro-polished tungsten electrodes housed by said envelope, each of uniform diameter throughout, one of said electrodes constituting a cathode composed of metal having a work function selected for photo-emission of electrons in response to incidence of only preselected wave lengths of ultraviolet radiation thereon with cut off within the range of about 1,500 A to 2,800 A, the other of said electrodes constituting the anode, both of said electrodes having a common longitudinal axis coincident with the longitudinal axis of said envelope, said cathode being a helix having spaced apart turns and contacting throughout its length, the interior surface of said envelope and being wholly supported thereby, at least a portion of the cylindrical surface of said envelope being unobstructed by said electrodes to permit passage of optical radiation incident on the exterior of said tube to the interior of said tube via said unobstructed surface, said anode extending axially only and supported solely by said headers,

an ionizable gas in said envelope, and

respective leads constituted of extensions of said electrodes made of the same metal as said electrodes and continuous therewith without connections or splices of any kind extending from said envelope for application of a d-c potential difference between said electrodes to provide an electric field for accelerating electrons liberated by said cathode toward said anode,

said gas being ionizable in response to emission of electrons from said cathode sufficiently that incidence of individual photons of ultraviolet radiation on said cylindrical surface is effective to produce emission of electrons from said cathode and consequent triggering of ionization avalanche discharge between said electrodes when voltage is applied between said anode and cathode.

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