

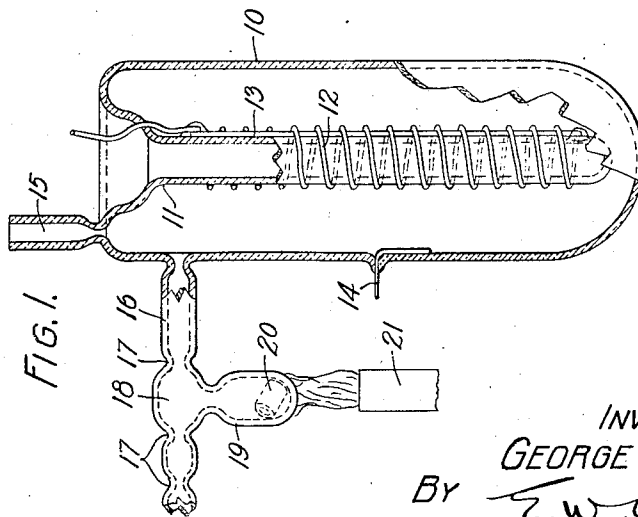
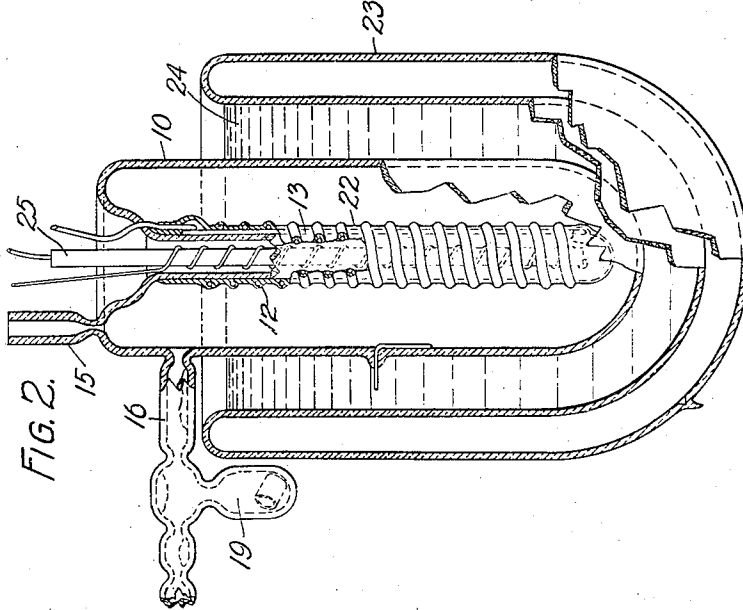
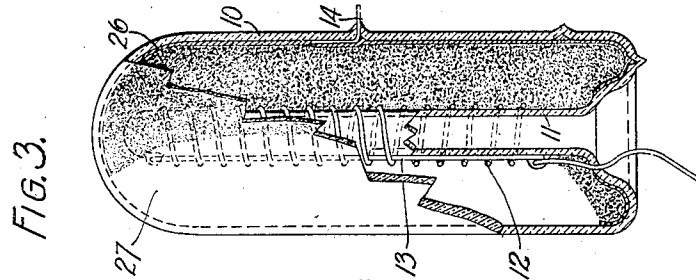
Jan. 9, 1934.

G. R. STILWELL

1,942,501

LIGHT SENSITIVE TUBE

Filed April 6, 1927



INVENTOR:
GEORGE R. STILWELL
By *E. W. Adams*
ATTORNEY

UNITED STATES PATENT OFFICE

1,942,501

LIGHT-SENSITIVE TUBE

George R. Stilwell, Bayonne, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application April 6, 1927. Serial No. 181,552

12 Claims. (Cl. 250—27.5)

This invention relates to light-sensitive devices, and more particularly to large photoelectric tubes for television systems.

In the manufacture of commercial photoelectric tubes it is customary to form a layer of light-sensitive material by distillation on the inner surface of the wall of the tube to act as the cathode and to arrange an anode centrally within the tube. Such tubes have heretofore been of comparatively small size, usually not more than 1½ inches in diameter. For a disclosure of this type of tube the reader is referred to an article entitled, "The alkali metal photoelectric cell" by Herbert E. Ives in the Bell System Technical Journal, Volume V, April, 1926.

When an attempt was made by the present inventor to increase the size of light-sensitive tubes of the type just mentioned for the purpose of increasing their sensitivity, it was found impossible to obtain a continuous opaque coating by distillation such as had been obtained in the small tubes.

The present invention is the outgrowth of a research into the causes of this failure and the practicability of obtaining large light-sensitive tubes. It pertains both to the method of obtaining a coating of light-sensitive material and to the structure of light-sensitive tubes, and although particularly applicable to tubes of large size, is applicable also to tubes of small size.

In accordance with the invention the deposit of light-sensitive material is obtained by providing a specially or critically positioned auxiliary member or surface within the tube and first obtaining a deposit thereupon, which deposit is later revaporized and redeposited upon the inner surface of the outer walls of the tube. The preferred form of tube is cylindrical in shape, a foot or more in length and at least several inches in diameter. The auxiliary member takes the form of a reentrant tubular stem extending along the major axis of the cylinder, closed at the end projecting within the tube and open at the other end to receive either a heating element or a cooling medium. The anode is in the form of a wire helix surrounding the reentrant stem and held firmly in place thereby, so as to prevent it from vibrating either as a whole or in segments. The reentrant stem is transparent and of small diameter so as to offer little obstruction to incident light when the tube is in use. The tube window, which preferably extends the full length of, and half way around the tube, is produced by applying a moderate amount of heat to one side of the outer wall by "flaming" it with a point flame so

as to cause the light-sensitive coating to flow back upon itself without being vaporized.

The following is a detailed description of the preferred form of the invention, prefaced by a brief description of the method heretofore used.

Fig. 1 of the drawing illustrates the arrangement for the preliminary step in the formation of the light-sensitive coating in the tube according to the invention.

Fig. 2 shows the arrangement of apparatus for the final step of transferring the coating to the inside surface of the outer wall of the tube.

Fig. 3 illustrates a light-sensitive tube made in accordance with the invention with a portion broken away to show the detailed construction.

Heretofore it has been the practice to obtain the coating of light-sensitive material in the tube by connecting the bulb, which is to form the tube, to a vacuum pump and also to a container of vapor of the light-sensitive substance. The vapor is produced in this container, which contains a supply of the light-sensitive material, by the application of heat thereto. Meanwhile the walls of the tube are maintained at room temperature, which is below the solidifying temperature of the vapor. The pressure is maintained so low that the mean free path of the molecules is large compared with the size of the tube, so that the vapor entering the tube continues to move in the direction in which it enters until it strikes the wall opposite the entrance, where a large part of it is deposited by being condensed and solidified. The vapor entrance is then closed and a heating medium is substituted for the cooling medium upon the portion of the tube wall which carries the deposit, the other portion of the tube wall upon which it is desired to have a coating being meanwhile kept cold. The heating is ordinarily accomplished with a flame which is applied upon and around the spot where the deposit is formed until the latter has been revaporized and redeposited where desired. If a deposit occurs elsewhere in the tube where it is not wanted the flame is applied to that portion in the same manner.

The tubes heretofore made have been small, as stated above. It was desired to increase the sensitivity of such tubes by making them many times larger, with the idea of thus bringing practical television one step nearer. Consideration was then given to the form a large tube should take. It was decided that cylindrical tubes several inches in diameter and with a length several times the diameter would not only be well suited for use in television systems but would be prac-

tical from the points of view of cost, ability to withstand atmospheric pressure, and ruggedness. However, when it was attempted to deposit a coating of light-sensitive material upon the inner surface of the wall of such a tube by the usual process it was found impossible to obtain a continuous opaque coating such as had been obtained in the small tubes. This failure seemed to be due to the size of the container or its tubular shape or both. It was subsequently discovered that when a specially positioned auxiliary member or surface is provided within the tube a deposit can readily be made upon it, which deposit can be revaporized and recondensed on the inner surface of the outer wall, and that the most suitable location for this auxiliary body or surface is along a major axis of the tube.

The invention also utilizes the auxiliary member as a support for the anode when the member is so positioned that this can be done.

The invention goes further than this in using a centrally located tubular member, preferably of transparent material, as a support for the anode whether or not such member is also used for the purpose set forth above. It has been discovered that such an arrangement is a marked improvement over light-sensitive tubes heretofore manufactured. It does away with vibrations which have caused much trouble in the development of television and does this without undue light obstruction.

Referring to Fig. 1, the photoelectric tube comprises a cylindrical enclosing vessel 10 of vitreous material having a hollow reentrant stem 11 extending centrally within the vessel substantially the full length thereof. The enclosing vessel and hollow stem are preferably made of pyrex glass because it is highly resistant to corrosion by potassium during the distillation stages. An electrode or anode 12 in the form of a wire helix surrounds the central stem 11, the adjacent turns of the helix being short-circuited by the wire 13 intersecting the turns. One end of the helix 12 is sealed through the enclosing vessel adjacent the hollow stem to form the leading-in wire for the anode 12. A leading-in wire 14 is sealed into the cylindrical wall of the vessel 10, the inner end of which is bent to lie along the inner surface of the vessel. A continuous coating of a light-sensitive material is formed on the inner surface of the vessel, by a method to be hereinafter described, and forms the light-sensitive electrode or cathode of the photoelectric tube. This arrangement forms a light-sensitive tube of rigid construction in which distortion due to vibration of the central electrode is eliminated and the helical anode causes very little obstruction to incoming light rays. Furthermore, the capacitance of the tube is kept at a minimum.

Preparatory to the formation of the light-sensitive coating, the assembled tube structure is connected to a pumping system by the tubulation 15. A glass tube 16, preferably of pyrex glass, is connected to one side of the enclosing vessel 10 as shown in Fig. 1. This tube is provided with a plurality of constricted portions 17 to form a series of bulbs between a gas chamber (not shown) and the interior of the vessel 10. A larger bulb 18 intermediate the ends of the tube 16 is connected to a receptacle 19 in which is placed a portion of glass tube 20 containing a light-sensitive material, such as potassium, or other alkali metal. The potassium is previously purified and sealed in long glass tubes and a portion of the tube containing the potas-

sium is introduced into the receptacle 19 and sealed therein. The potassium is heated in the receptacle 19 by any suitable means, as for instance, by a burner 21, to distill it into the bulb 18. The potassium deposited in the bulb 18 is then redistilled into the series of bulbs formed by the constricted portions 17 in the glass tube 16, to eliminate impurities, in the usual manner. The potassium is then redistilled into the vessel 10 in sufficient quantity to subsequently form a continuous opaque coating on the inner surface of the vessel. The vessel 10 during this stage is maintained at room temperature, and a flame may be played upon the walls where deposition is greatest. However, the "flaming" may be postponed until after the vapor has been condensed. As the result of the condensing and flaming, a deposit is formed on various portions of the tube wall and the central stem and electrode 12, the greater amount being formed in a pool at the lower end of the tube. This completes the preliminary step in distilling the potassium into the tube 10.

A suitable cooling fluid, preferably liquid air, is poured into the hollow stem 11 and the cylindrical surface of the tube 10 is heated by suitable means, as by "flaming", to vaporize the potassium on the inner surface of the tube. The potassium vapor is condensed on the cooled surface of the stem 11 and the electrode 12. This heating and cooling is continued until all the potassium is deposited on the central stem and electrode. The cooling medium is then removed from the central stem 11 and the vessel and central stem are allowed to return to room temperature. Fig. 2 shows the potassium coating 22 on the stem and electrode 12. After the tube has cooled to room temperature, a double walled receptacle 23 is placed around the vessel 10 and filled with a cooling liquid 24, such as liquid air. A heater element 25 is inserted in the hollow stem 11, to vaporize the coating 22 on the stem 11 and electrode 12. The vapor then condenses on the cooled inner wall of the vessel 10 and this heating and cooling is continued until all the potassium is redistilled from the stem 11 and electrode 12 and deposited on the inner wall of the vessel. The heater element 25 is then removed from the hollow stem 11, and the vessel 23 containing the cooling medium is removed from the outside of the vessel 10.

The next step is the removal of a portion of the light-sensitive coating to form a window. In the manufacture of small tubes this has been accomplished by "flaming" the surface of the vessel where it is desired to remove the coating, the heat being sufficient to vaporize all the coating which it is desired to remove. This vapor forms an additional coating on the remainder of the inner surface of the tube by condensation. This method is not suited, however, to the case in hand when a reentrant stem or auxiliary tubular member of transparent material upon which an open-work anode is mounted, is employed. This is for the reason that light from the window passes through the transparent reentrant stem or tubular member thus preventing a shadow being cast and the sensitivity of the tube lowered. If the window were produced by vaporizing the light-sensitive material, an opaque coating would be formed on the walls of the stem, unless this element were maintained hot while the window is being formed, which is inconvenient. Moreover, when the area of the window is large compared to the total area

of the tube wall it is difficult to maintain all of the window area at the desired high temperature and the remainder of the wall at the desired low temperature. The window must, of course, be made after the tube has been removed from the liquid air bath.

To overcome these difficulties the following method has been evolved. The tube, which is in a vertical position on the pump to permit easy application of the liquid air bath, is changed into a horizontal position by softening the neck of the supporting glass tube 15 and twisting the tube into the desired position. A point flame is then played upon the tube wall along a horizontal line near the top of the tube, this flame being allowed to remain in one place only long enough to melt the potassium without vaporizing it. The melted potassium flows downward a short distance adhering to the tube wall and then solidifies. The point flame is then played back and forth with a steady downward progression until the window is of the desired size. The potassium which has been melted during the process ultimately forms a ridge or a coating of greater thickness along the bottom of the window. The window preferably extends nearly the full length of the tube and half way around it.

The tube is then completed in a well known manner by subjecting the potassium coating to a glow discharge in an atmosphere of hydrogen, then replacing the hydrogen by an inert gas, such as argon, neon or helium, and subsequently sealing off the tubulation 15 and distillation tube 16. The tube is then in the completed form as shown in Fig. 3.

By this method it is possible to construct photoelectric tubes having a light-sensitive opaque continuous coating over the full length of the tube and of relatively large size compared with the usual spherical type of photoelectric tube having a diameter of approximately one and one-half inches. A typical tube made in accordance with this invention comprises a cylindrical enclosing vessel having a diameter of three and one-half inches and a length of fifteen inches with a hollow tubular member three-eighths of an inch in diameter and approximately fourteen inches in length. The effective light-sensitive area of the tube is approximately 100 times that of the usual one and one-half inch tube.

While the novel methods and structure of this invention are particularly well adapted to photoelectric tubes of large size they are also obviously applicable to tubes of small size. Moreover the tube may take a variety of shapes and be otherwise modified without departing from the spirit of the invention. The cylindrical form is preferred but a spherical or a toroidal shape would be suitable. These shapes are mentioned, however, merely by way of example and the shape of the container may depart widely from any of the forms mentioned without departing from the spirit of the invention.

What is claimed is:

1. A light-sensitive device comprising an enclosing vessel having a tubular member therein, a wire helix surrounding said member, means conductively connecting adjacent turns of said helix, and a light-sensitive material on the inner side of the outer wall of said vessel.

2. In the manufacture of light-sensitive devices the method of obtaining a coating of light-sensitive material upon the inner surface of the outer wall of the containing vessel, which method comprises depositing substantially all of the material

to be used by distillation upon an auxiliary member, positioned in the vicinity of a major axis of the vessel and well within the vessel, heating said member by energy supplied from without said vessel and thereby revaporizing said deposit, and condensing the vapor upon the inner wall of the vessel.

3. The method of obtaining a window in a light-sensitive device of transparent material, the inner surface of the outer wall of which is coated with a layer of light-sensitive material, which method comprises heating a small area of the wall to a temperature just above the melting point of the coating material and meanwhile holding the device in such a position that the melted material will flow back upon the coating underneath.

4. The method of obtaining a window in a light-sensitive device of transparent material, the inner surface of the outer wall of which is coated with a layer of light-sensitive material which method comprises heating a small area of the wall to a temperature just above the melting point of the coating material, meanwhile holding the device in such a position that the melted material will flow back upon the coating underneath, and repeating this step for other small areas lying along a line forming the upper boundary of the window and subsequently repeating the process, progressing downwardly, until an area of the desired size has been cleared.

5. A light-sensitive device comprising a vessel of transparent material having a hollow reentrant tubular portion out of contact with said vessel at its inner end, an anode around said portion throughout most of its length and rigidly supported thereby, and a cathode comprising light-sensitive material lying along a portion only of the wall of said vessel, the remaining portion comprising a window for the admission of light to activate said cathode.

6. A light-sensitive device comprising a cylindrical vessel having a diameter of several inches and a length of at least three times the diameter, a cathode within said vessel in the form of a layer of light-sensitive material upon approximately half of the inner surface of the outer wall, the remaining portion constituting a window for admitting light to activate said cathode, a tubular member nearly as long as said vessel extending along the major axis thereof and rigidly connected thereto at one end only, and a wire anode wound around said tubular member and rigidly supported thereby.

7. A light-sensitive device comprising a cylindrical vessel of transparent material having a diameter of at least several inches and a length much greater than the diameter, a cathode within said vessel in the form of a layer of light-sensitive material upon approximately half of the inner surface of the outer wall, the remaining portion constituting a window for admitting light to activate said cathode, a tubular member of transparent material within said vessel extending along its major axis, one end only of said member being supported by said vessel, and an open-work anode rigidly supported at many spaced points thereof by said tubular member.

8. In the manufacture of light-sensitive devices the method of obtaining a coating of light-sensitive material upon the inner surface of the outer wall of the enclosing vessel for said device which comprises removing gas from the vessel, causing vapor of said material to enter said vessel in the form of a stream, causing a portion of said vapor to condense upon the inner surface of the

- outer wall of said vessel, heating the outer wall of said vessel and simultaneously cooling a surface lying along the major axis of said vessel and well within the vessel, whereby substantially all of said material is caused to deposit upon said surface, applying heating energy from without the vessel to revaporize the deposit on said surface, and condensing the vapor upon the inner surface of the outer wall of the vessel.
9. The method of obtaining a coating of light-sensitive material within a light-sensitive device of the type having a centrally located electrode, which comprises the steps of depositing light-sensitive material upon a surface within the device spaced from said electrode, artificially cooling said electrode well below room temperature, and simultaneously heating said deposit to cause a redeposition of light-sensitive material on said electrode.
10. A light sensitive device comprising a tubular shaped vessel of transparent material, a cathode therein in the form of a layer of light sensitive material lying along the curved surface of a large portion of the wall of said vessel and substantially the full length thereof, a window opposite said layer of light sensitive material and of about the same dimensions as said layer to admit light to activate said cathode, a long hollow tubular member of transparent material, within and coaxial with said vessel and secured thereto at one end and extending near to but out of contact therewith at the opposite end of said vessel, and an open-work anode rigidly supported by said tubular member, whereby said anode is substantially uniformly spaced throughout its length from said cathode, is rigidly supported to avoid vi-

bration and, together with the support, offers little obstruction to the passage of light from said window to said cathode.

11. A light sensitive device comprising a tubular shaped vessel of transparent material having a diameter at least of the order of several inches and a length at least three times the diameter, a cathode therein in the form of a layer of light sensitive material lying along the curved surface of a large portion of the wall of said vessel and substantially the full length thereof, a window opposite said layer of said light sensitive material and of about the same dimensions as said layer to admit light to activate said cathode, a long hollow tubular member of transparent material within and coaxial with said vessel and secured thereto at one end and extending near to but out of contact therewith at the opposite end of said vessel, said member being open at the end which is secured to the vessel and closed at its other end, and an open-work anode rigidly supported by said tubular member, whereby said anode is substantially uniformly spaced throughout its length from said cathode, is rigidly supported to avoid vibration and, together with the support, offers little obstruction to the passage of light from said window to said cathode.

12. A light sensitive device comprising a vessel and a hollow rigid anode structure of general cylindrical form and of length many times its diameter extending within said vessel and supported at one end only thereby, and a cooperating cathode within said vessel about equally spaced throughout from said anode structure.

GEORGE R. STILWELL.