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R. L. SJÖBERG ETAL
STORAGE TUBE WITH COMPOSITE TARGET CONSISTING
OF DISPLAY PHOSPHOR, POROUS DIELECTRIC
AND METALLIC MEMBRANE COLLECTOR

3,368,093

Filed July 20, 1965

2 Sheets-Sheet 1

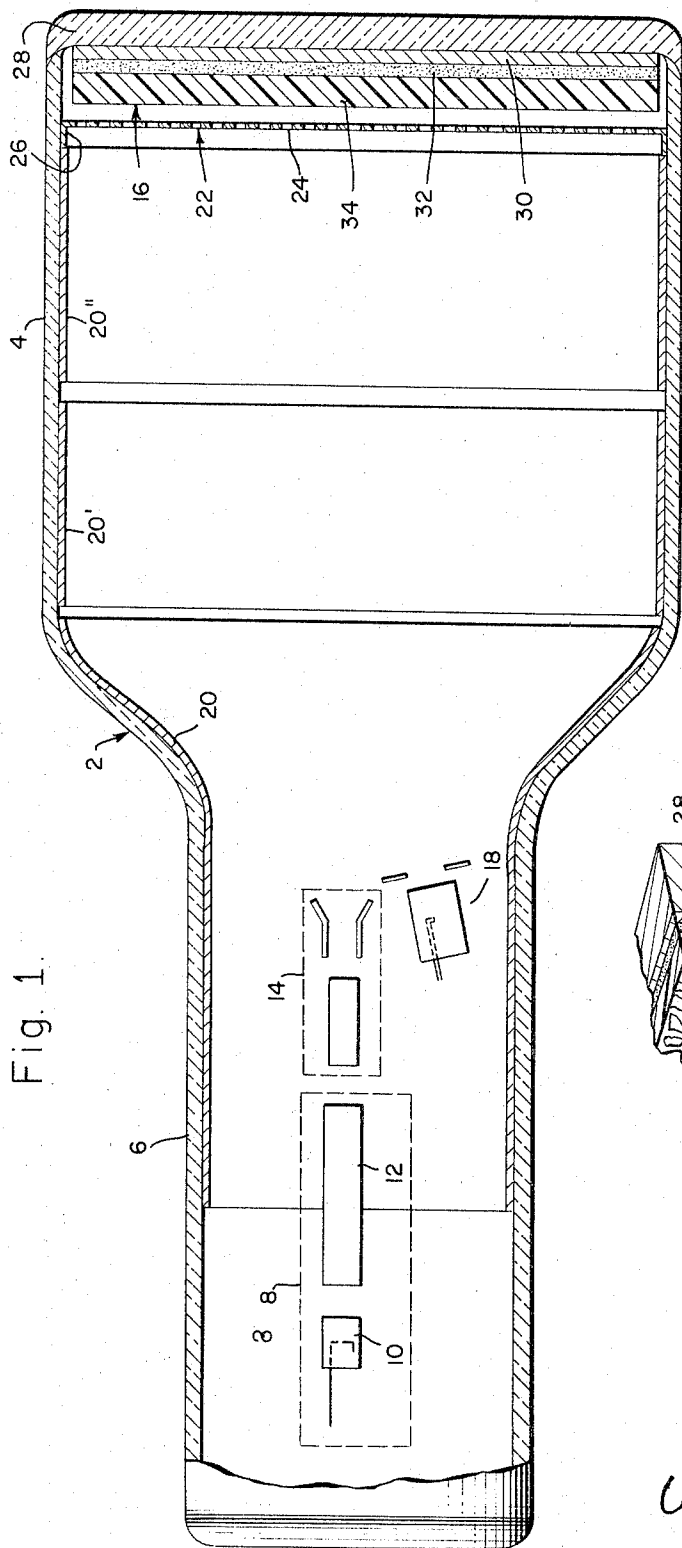


Fig. 1.

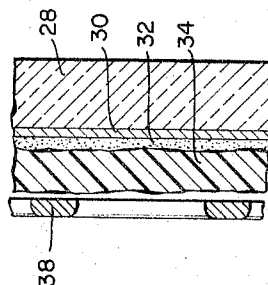


Fig. 2.

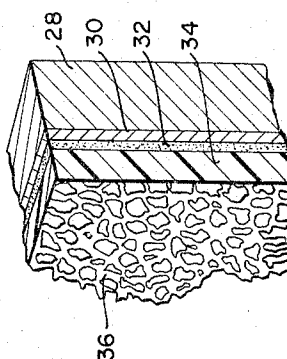


Fig. 3.

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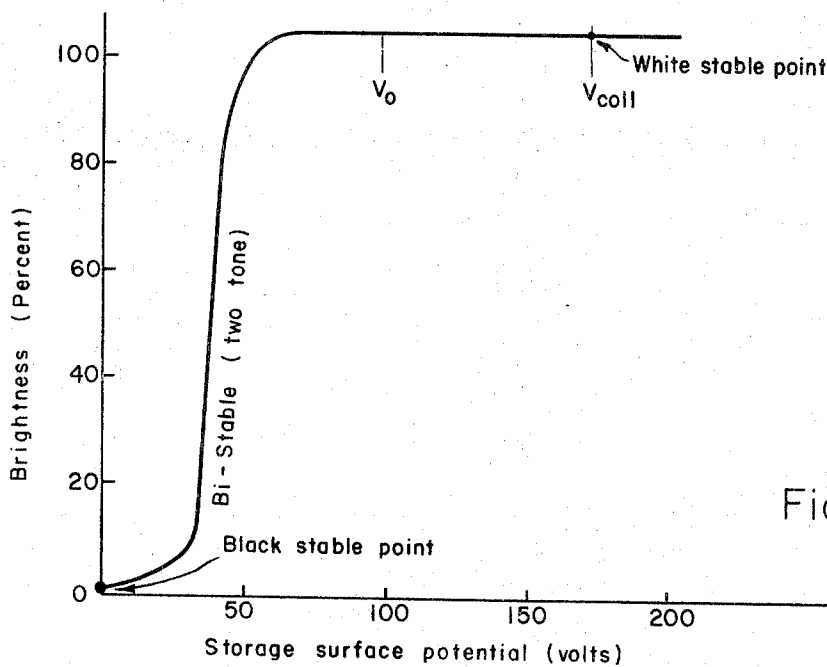


Fig. 4.

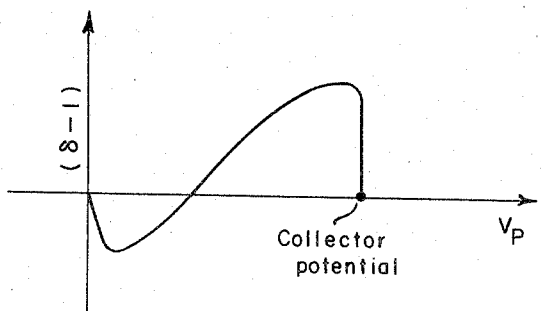


Fig. 5.

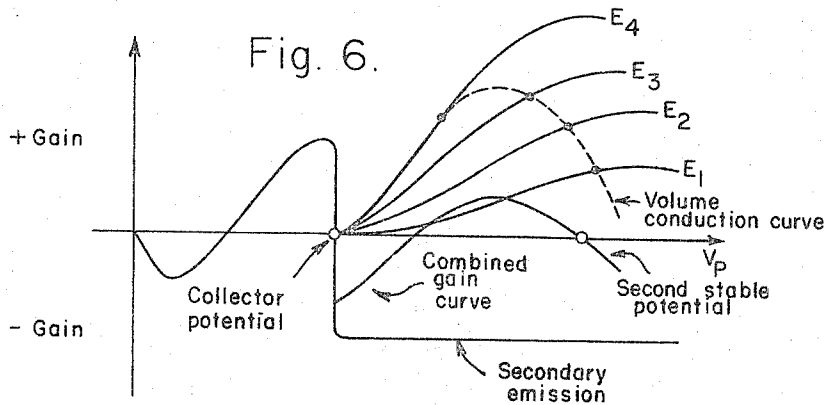


Fig. 6.

3,368,093

STORAGE TUBE WITH COMPOSITE TARGET CONSISTING OF DISPLAY PHOSPHOR, POROUS DIELECTRIC AND METALLIC MEMBRANE COLLECTOR

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ABSTRACT OF THE DISCLOSURE

A direct-viewing storage tube having a porous dielectric layer for storage purposes disposed directly on the phosphor layer constituting the viewing screen.

This invention relates to direct-viewing cathode ray storage tubes, particularly of the bistable type. More particularly, the invention relates to a bistable direct-viewing storage tube not requiring a mesh-type storage target.

A direct-viewing storage tube is a cathode ray tube in which the output is visual and in the form of a bright and persistent display of what is generally nonrecurrent pictorial information. Such tubes are utilized for the persistent display of such types of information as radar or sonar data, processed alpha-numeric information, narrow-band television pictures and transient waveforms (as in oscilloscope applications). There are two principal kinds of direct-viewing storage tubes: the bistable type and the half-tone type. The bistable or two-tone tube presents displays in two shades of grey (black and white) and utilizes regeneration to provide an indefinitely long retention time. The half-tone tube provides a continuous range of grey shades but usually has a limited retention time. The present invention relates to direct-viewing storage tubes of the bistable or two-tone type and prior art tubes of this kind and their operation are described in U.S. Patent No. 2,788,466 to S. Hansen.

In general, such direct-viewing storage tubes comprise four essential elements: a storage target or mesh, an adjacent phosphor viewing screen, a flood electron gun and a writing electron gun. Almost all previously known storage tubes of this type have employed a storage target which is a fine metal screen with several hundred holes per linear inch and having a thin layer of an electrically insulating dielectric material deposited on the side of the screen facing the flood electron gun. The electrons from the flood gun cover or blanket the surface of the storage target in a uniform broad beam of slow electrons. By scanning the storage target with an electron beam of elemental cross-sectional area produced by the writing gun, a charge pattern corresponding to the picture to be displayed is formed on the surface of the dielectric layer by secondary electron emission, for example. Each elemental area of the charge pattern controls the transmission of electrons from the flood gun through the storage target much like the control grid of any triode vacuum tube controls the plate current. In areas of the dielectric layer where the charge pattern is more positive, relative to the flood gun cathode, flood electrons penetrate the storage mesh and impinge upon the phosphor viewing screen. In areas where the pattern is negative relative to the flood gun cathode, the flood electrons are repelled by the storage target and cannot penetrate therethrough to reach the viewing screen. Flood electrons which do pass through the storage target are accelerated so that they strike the phosphor viewing screen at a high energy and produce a light pattern corresponding to the charge pat-

tern on the dielectric storage surface. As long as the charge pattern remains undisturbed, the display persists.

It will be noted, therefore, that such direct-viewing storage display tubes have heretofore required the utilization of a storage target comprising a fine mesh screen support electrode member having a dielectric coating thereon separately disposed intermediate the necessary electron guns and the viewing screen.

It is therefore an object of the instant invention to provide an improved direct-viewing storage tube.

Another object of the invention is to provide an improved direct-viewing storage tube which does not require a separate mesh storage target.

Still another object of the invention is to provide an improved direct-viewing storage tube having a simplified storage target structure.

These and other objects and advantages of the invention are realized by providing a storage display tube with a combination storage and viewing target structure in which a layer of porous (low density) dielectric material is formed directly on the light-producing phosphor layer. A mesh electrode for collecting secondary emitted electrons is also provided in the tube either adjacent to or in contact with the porous dielectric layer. With a dielectric layer of sufficient porosity flood electrons arriving at areas thereof which are positive with respect to the flood gun will penetrate the dielectric layer and strike the viewing screen or phosphor layer, thus causing fluorescence.

The invention will be described in greater detail by reference to the drawings in which:

FIGURE 1 is a partly schematic, partly cross-sectional elevational view of a direct-viewing storage tube incorporating a storage target structure according to the present invention;

FIGURE 2 is a cross-sectional view in perspective of one embodiment of a portion of a storage-viewing target structure according to the invention;

FIGURE 3 is a cross-sectional view of another embodiment of a portion of a storage-viewing target structure according to the invention; and

FIGURES 4, 5 and 6 are explanatory diagrams to illustrate the functioning of the storage-viewing target structure of the invention.

Before proceeding with a detailed description of the invention, it may be helpful at this point to explain the operation of a bistable direct-viewing storage tube. With reference to FIGURE 4, a typical bistable-storage-characteristic curve is shown where display brightness is plotted against the storage-surface potential. Some of the electrons from the flood gun provide the display and others are responsible for regenerative action (by which is meant restoring or maintaining the stored potentials). It will be understood that there are two equilibrium dielectric potentials: (a) the potential of the flood gun cathode, or "black," and (b) the potential of the collector mesh, or "white." At those portions of the storage target surface which are at the potential of the flood gun cathode, no flood electrons can penetrate the storage target for display purposes. At those portions of the storage target surface which are at the potential of the collector-mesh, flood electrons can penetrate the storage target for display purposes. In the absence of a writing electron beam, the "black" and the "white" areas of the storage dielectric are maintained at their respective equilibrium potentials by the low energy flood electrons. Thus, in the "white" areas, where the dielectric surface is charged to the collector or positive potential, the flood electrons strike at a velocity sufficient to produce a secondary emission ratio greater than unity; hence, more than one secondary electron is released for every incident flood electron and, as

long as the collector electrode remains more positive than the dielectric surface, it will attract and collect the secondary electrons so that a net positive charging current will exist. Any tendency of the surface to fall below the collector potential is thus compensated for by the positive charging action of secondary emission. In the "black" areas, near zero-volt potential, the flood electrons strike the dielectric surface with almost zero velocity and produce virtually no secondary electrons. Hence, any tendency of the surface potential to rise above zero volts is compensated for by the negative charging action of the extremely low energy flood electrons. Surface areas with a potential having any value between zero and that of the collector potential will be driven in either the negative or the positive direction until they reach one or the other of the two stable points.

As will be seen in FIGURE 4, a point, V_0 , represents the critical potential which divides the two regions of negative and positive regeneration. Thus, in order to write a "black" surface to "white," the writing beam must raise the storage-surface potential to a value just beyond this critical potential so that positive regeneration will carry the surface the rest of the way to the collector potential. This is accomplished by the writing beam which deposits a positive charge pattern by using the high secondary electron emission ratio of the dielectric at the writing beam energy. A stored pattern can be erased by momentarily decreasing the collector potential in order to eliminate the bistable regeneration. If the collector potential is decreased to a value slightly below the critical potential, V_0 , positive regeneration is eliminated and the potential of the written area on the dielectric will be reduced to zero volts (i.e., to "black").

Referring now to FIGURES 1 and 2, a bistable direct-viewing storage tube is shown which does not require a storage dielectric target separate from the viewing screen. The storage tube comprises an evacuated envelope 2 having a relatively large diameter bulbous portion 4 and a narrow neck portion 6. Disposed within the neck portion 6 is an electron gun 8 for forming a "writing" electron beam of elemental area. This electron gun may be of conventional design and construction and includes a cathode 10, a beam-forming electrode section 12, and a deflection system 14 for causing the beam formed by the electron gun 8 to orthogonally scan the target structure 16 disposed in the large bulbous portion 4 of the tube 2. Also disposed in the neck portion is a flood electron gun 18 of conventional design and construction which is adapted to flood or blanket the target structure 16 with a relatively broad beam of low energy electrons.

The inner surface of the tube 2 may be provided with one or more collimating lenses 20, 20' and 20'' in order to collimate the flood electrons from the flood gun 18 so that these electrons arrive at the target structure 16 at approximately normal incidence. The collimating electrodes may be constituted by conductive coatings of graphite, for example, on the inside of the bulb 4.

In the embodiment of a storage tube according to the invention shown in FIGURE 1, a collector mesh electrode member 22 is disposed adjacent to but spaced from the target structure 16. The collector electrode 22 may comprise an electroformed nickel screen 24 rather tautly stretched across the edge of a ring support member 26 and welded thereto. The collector mesh may typically have a thickness of about 0.0004" to 0.0008" and include about 250 openings per inch so as to be substantially transparent to electrons from the writing and flood beam electron guns 8 and 18.

So far in the description of the present invention the elements and components of a conventional direct-viewing storage tube have been described. However, as noted hereinbefore such conventional tubes have next included two separate and spaced target structures—a storage target member and a viewing target or screen. In the present invention, the functions of these separate structures are

performed by a single target structure with the mesh support structure of the storage target being eliminated. This is achieved by providing the viewing screen structure in a conventional manner on the inner surface of the optically transparent end portion or faceplate 28 of the tube 2. Thus, the viewing portion of the target comprises an optically transparent conductive coating 30 which serves as an accelerating electrode for the flood electrons which penetrate the storage target portion of the target structure 16. The accelerating electrode member 30 may comprise a layer of stannous oxide, for example, over which is disposed a phosphor layer 32 of material capable of being excited into luminescence by the impingement of electrons thereupon. Disposed on the phosphor layer 32 is a storage dielectric layer 34 which may be of any suitable electrically insulating material exhibiting secondary electron emission and which is porous or of very low density. Such a porous dielectric layer 34 may be fabricated by evaporating the dielectric material onto the previously settled phosphor layer 32 under a very high gas pressure in the range of 1000 to 2000 microns of mercury. Alternatively, the porous layer 34 may be formed by loosely depositing dielectric particles by the well-known settling process. Almost any insulator material can be employed for the dielectric layer 34 providing it has a secondary electron emission ratio greater than unity and sufficient electrical resistivity (i.e., at least 10^{13} ohm-cm.). Typical examples of such dielectric materials are talc and magnesium fluoride. With a porous dielectric layer 34, many of the flood electrons arriving at the areas thereof which are the higher or positive potential will enter the dielectric layer and proceed through it and then be accelerated and strike the phosphor layer 32 causing it to luminesce at that point or area.

Because of the electrical resistivity of the porous dielectric layer 34, the surface thereof facing the flood gun 18 can be maintained at or near the potential of the flood gun cathode which is the "black" stable point mentioned previously in describing the operation of storage tubes of the bistable mode of operation. Likewise, because of the resistivity of the dielectric layer 34, the side or surface thereof in contact with the phosphor layer 32 can be held at several hundred or even several thousand volts higher in potential. Hence, areas of the dielectric surface facing the flood gun which are below the first cross-over potential of the surface (i.e., the potential at which the secondary emission ratio is less than unity) are charged in the negative direction by the flood electrons and are maintained thereby at the "black" stable potential near or at the flood gun cathode potential. Areas of the surface of the dielectric layer 34 which are above the first cross-over potential (that is, where the secondary electron emission ratio is greater than unity) are charged in the positive direction by the flood electrons and are maintained thereby at the second or "white" stable potential near or at the potential of the collector electrode 22. The dielectric surface may be switched in point-to-point fashion from the lower or "black" stable potential to the higher or "white" stable potential by the writing beam produced by the writing electron gun 8 while the switch from the higher ("white") potential to the lower ("black") may be accomplished by means of the flood electrons in combination with a lowering of the collector potential to a value below the first cross-over potential.

It will thus be understood that in operation the tube of the present invention functions in a substantially similar manner as the bistable direct-viewing storage tubes of the prior art. One of the main problems encountered in operating a bistable tube according to the present invention, where the storage target portion serves as a viewing screen as well, is obtaining the desired light output since the collector potential in a bistable tube is usually around 150 volts with respect to the storage surface and a 150 volt acceleration is not sufficient to produce useful luminescence. This problem is overcome

by the present invention and the target structure shown by the use of the transparent conductive layer 30 which may have a potential of about one kv. thereon.

The theory of the operation of the combination storage-viewing target of the present invention is as follows: with the collector electrode potential at about 100 volts, the surface of the porous insulator layer 34 is at the collector potential in the unwritten ("dark") state. The secondary emission curve in FIGURE 4 shows this stable operating potential. The porosity of the dielectric layer 34 allows higher beam penetration (x) since the amount thereof is inversely proportional to density according to:

$$x = k\sigma^{-1}V^2$$

where σ =the density, V =the primary beam potential and k =a constant. In contrast with the bulk dielectric storage targets of the bistable storage tubes of the prior art, the density of a porous dielectric layer according to the present invention can be made by one or more of the methods described previously as low as 2% of the normal bulk insulator. The porous insulator layer therefore is charged by volume conduction to the phosphor layer potential by the writing beam (which may be operated at from 2 to 3 kv.) which can penetrate the porous insulator layer 34. Hence, once the writing beam has charged the dielectric surface to the potential of the phosphor layer, flood electrons landing on the dielectric surface will have a beam energy of about 1 kv. Thus the flood electrons can also penetrate the dielectric layer 34 and excite the phosphor layer 32 as well as maintain the higher potential by volume conduction despite the fact that the collector electrode 22 is at the lower potential. This result is obtainable by making the thickness of the porous dielectric layer 34 less than the collector cell dimension. The porous dielectric layer must also have a higher volume conduction ratio than the secondary emission ratio of the dielectric layer. Since porous dielectric layers having a volume conduction gain of greater than 10 are attainable with a secondary emission gain of 2 or 3, these conditions are met.

With reference to FIGURE 5, the two stable operating potentials in terms of the secondary emission curve and the volume conduction curve can be seen. The volume conduction curves shown are for different electric fields, E . As the surface of the dielectric layer charges toward the phosphor potential, the electric gradient across the porous dielectric layer varies so that the dotted curve is the actual gain curve that applies. As can be seen from this figure, the combined volume conduction gain-secondary emission gain curve crosses the unity gain axis to give the second stable operating potential.

While in the embodiment of FIGURE 1 the collector electrode 22 has been shown and described as an electron transparent electrically conductive electrode or mesh disposed adjacent to but spaced from the target assembly 16, this is not necessarily the only arrangement possible according to the invention. In fact, if collimation of the flood beam is not critical, as well might be the case in some applications, then the collector might well be constituted by a ring (such as the collector support ring 26 in FIGURE 1) surrounding the storage surface area. In another embodiment, shown in FIGURE 2, the collector electrode may comprise a layer 36 of electrically con-

ductive material such as aluminum deposited directly on the surface of the dielectric layer 34 in the form of a metallic membrane having many separate voids constituting a large percent (at least 50%) of the surface area of the dielectric layer 34. Thus the porous dielectric layer 34 will be exposed to the writing beam and the flood beam through these voids in the conductive collector layer 36. Alternatively, it is possible to utilize a collector member 38 in the form of a metallic mesh deposited on the dielectric layer 34 as shown in FIGURE 3. Such a contact collector may be formed by evaporating a metal through a mask onto a thin plastic film and then transferring the conductive screen thus formed to the surface of the dielectric layer 34. This transfer may be accomplished by immersing the plastic film in a vat filled with water and causing the film to settle upon the top of the dielectric layer by decanting the water from the vat. Thereafter the assembly is heated in order to evaporate or decompose the plastic film leaving the thin conductive screen 38 in place on the dielectric layer 34.

There thus has been described a bistable direct-viewing storage tube which uses a simplified and meshless storage target structure in combination with a viewing target and hence is easier and more economical to manufacture.

What is claimed is:

1. A bistable direct-viewing storage tube comprising:
 - (A) an evacuated envelope having a viewing faceplate;
 - (B) a first electron gun disposed in said envelope for forming an electron beam of elemental cross-sectional area;
 - (C) a target structure in said envelope comprising:
 - (1) an electrically conductive light transparent film disposed on the inner surface of said faceplate;
 - (2) a layer of phosphor material disposed on said transparent film;
 - (3) and a layer of porous dielectric material selected from the group consisting of talc and magnesium fluoride disposed on said phosphor layer;
 - (D) a second electron gun disposed in said envelope for flooding said porous dielectric layer with a broad beam of electrons;
 - (E) and an electron transparent electrically conductive electrode member in the form of a metallic membrane having separate voids therein constituting at least fifty percent of the surface area of said layer of porous dielectric material disposed on the surface of said porous dielectric layer for collecting secondary electrons emitted therefrom.

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