Aug. 4, 1959 E. J. STERNGLASS ET AL 2,898,499

TRANSMISSION SECONDARY EMISSION DYNODE STRUCTURE

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Fig.1.

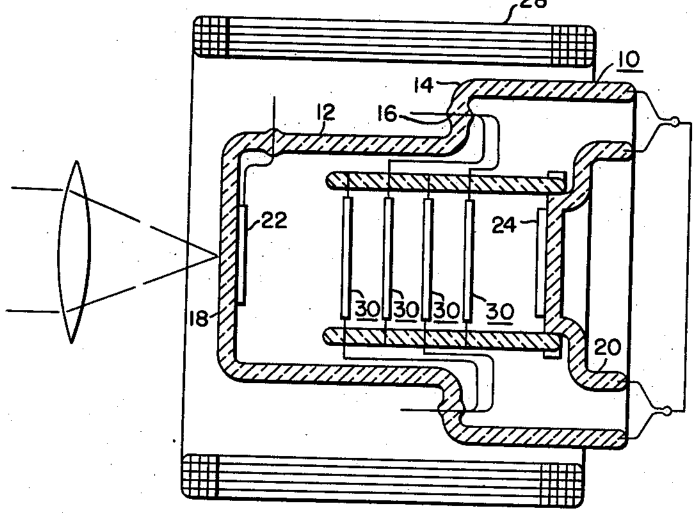


Fig.2.

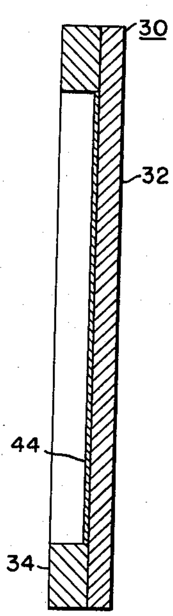


Fig.3.

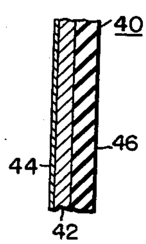


Fig.4.

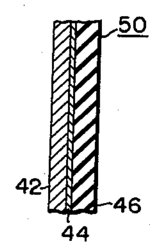


Fig.5.

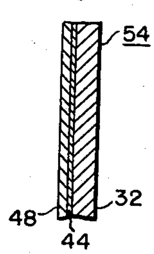
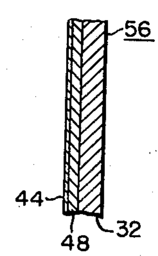


Fig.6.



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TRANSMISSION SECONDARY EMISSION DYNODE STRUCTURE

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Application May 23, 1956, Serial No. 586,826

6 Claims. (Cl. 313—103)

This invention relates to electron discharge devices and, more particularly, to electron multiplying electrodes of the transmissive type adapted to emit secondary electrons on the opposite side of the electrode bombarded by incident electrons.

This invention is an improvement in the electron multiplying electrode structure described in copending application Serial No. 434,467, filed June 4, 1954, entitled "Electronic Discharge Device" by E. J. Sternglass and assigned to the same assignee.

It is an object of this invention to provide an improved electron multiplying electrode.

It is another object of this invention to obtain greater electron multiplication within each stage of electron multiplier electrode.

It is another object to provide an improved electron multiplier electrode of high resolution.

It is another object to provide an improved electron multiplier electrode in which the electron back scattering from an electron multiplier electrode is reduced.

These and other objects are effected by our invention as will be apparent from the following description taken in accordance with the accompanying drawings, throughout which like reference characters indicate like parts, and in which:

Figure 1 is a diagrammatic view of an electron multiplier tube embodying our invention;

Fig. 2 is an enlarged sectional view of the dynode structure utilized in Fig. 1; and

Figs. 3, 4, 5 and 6 are modified secondary emissive dynode structures which may be utilized in Fig. 1.

Referring in detail to Figs. 1 and 2, an electron discharge tube is shown which embodies an electron multiplying assembly. The tube is comprised of an envelope **10** having a tubular portion **12** and an enlarged tubular portion **14** with a connecting flange portion **16**. A substantially planar end wall **18** is provided to close off the portion **12**, while a reentrant end wall **20** closes off the enlarged tubular portion **14** of the envelope **10**. A planar cathode or electron emissive surface **22** is positioned near to or on the interior surface of the end plate **18** and an anode or target element **24** is positioned at the opposite end of the envelope near to or on the end plate **20**. A plurality of secondary electron emissive electrodes or dynodes **30** are interspaced between the cathode **22** and the target **24**.

The planar electron emissive surface **22** positioned on the end plate **18** may be of any suitable type such as thermionic or photoemissive. In our specific embodiment a photoemissive planar surface is utilized as a source of electrons for the discharge device. The photoemissive surface may be of any suitable material such as cesium antimony capable of emission of electrons upon light impingement. The end plate **18** is of a transparent material such as glass to permit passage of radiations of an object to be intensified by the electron multiplier assembly. The photoemissive surface **22** may be mounted on a suitable supporting transparent conductive surface or may be deposited on the interior surface of the end plate **18** as shown. It is desirable with most photoemissive materials to also provide a transparent conductive coating on the end plate **18** prior to the deposition of the photoemissive material layer **22** to provide a conductive electrode for the photoemissive surface **22**. A suitable transparent conductive coating may be of a material such as stannic oxide or a thin, transparent layer of evaporated metal, such as nickel.

The target electrode **24** is positioned at the opposite end of the envelope near or on the end plate **20** and may be of any electron sensitive material to develop a signal representative of the electron bombardment. In our specific embodiment a fluorescent screen **24** is utilized as a target electrode and is of a material that emits light in response to electron bombardment. In order to provide high resolution, evaporated or chemical phosphors may be used instead of conventional powdered phosphors. A suitable fluorescent material might be a phosphor material such as zinc sulphide. It is desirable that a light transparent conductive layer also be deposited on the end plate **20** prior to the deposition of the phosphor to provide an electrode for the phosphor screen. A conductive coating of a material such as aluminum could also be deposited on the exposed surface of the phosphor to provide the electrode for the phosphor screen **24**. The aluminum layer not only serves as an electrode but also to prevent light feedback to the cathode and prevent direct light from passing through to the output.

Positioned between the cathode **22** and the target **24** are the secondary electron emissive electrodes or dynodes **30**. In the specific embodiment shown in Fig. 1, four dynodes **30** are illustrated. The number of dynodes **30** within the envelope is dependent on the amount of amplification desired from the device. Lead-in members for the dynodes **30** are brought out through the flange **16** and spaced to provide exterior terminals. Magnetic focussing is provided by means of coil **28**. Although for applications that do not require high resolution, the magnetic focussing may be omitted.

Referring to Fig. 2, a detailed structure of a dynode **30** is shown. The dynode **30** is comprised of a self-supporting insulating support film **32** of a thickness of the order of 300 to 500 Angstroms made of a material such as Al_2O_3. It may in addition carry a suitable secondary emissive material of higher yield such as KCl, MgF_2 or MgO as will be described below. The thin layer of aluminum oxide Al_2O_3 may be prepared in the following manner. A thin sheet of aluminum foil approximately 99.7% pure and .0007 inch thickness may be utilized. The sheet of foil of the desired dimensions, which may be of the order of 2 to 3 inches in diameter, is checked to insure that there are no pinholes. The foil is pressed and cleaned and placed in an aqueous solution of ammonium citrate 3% by weight and anodized to the desired thickness of aluminum oxide by the adjustment of voltage. A piece of lead may be used for the cathode. By this procedure an aluminum oxide coating of desired thickness is formed on both surfaces of the sheet simultaneously. The anodized aluminum foil is removed from the electrolyte and washed in distilled water and then pure acetone. Next the anodized layer on one side of the aluminum is removed by treatment with a suitable caustic reagent such as sodium hydroxide. After the sodium-hydroxide has had an opportunity to act on the aluminum oxide film the aluminum may be washed in distilled water and the aluminum oxide film on one surface removed. The aluminum sheet without aluminum oxide or one surface may now be immersed in a suitable acid solution such as hydrochloric and the aluminum layer may be etched away leaving only a thin membrane of the aluminum oxide layer. The thus completed aluminum oxide layer may be washed, dried and then mounted to a suitable frame member of a material such as nickel, glass, Invar, or stainless steel.

The thus prepared aluminum oxide film 32, which may be of the thickness of 300 to 500 Angstroms, is mounted to the frame 34 shown in Fig. 2. The frame 34 may have a circular opening of a diameter of 2 inches or greater. The aluminum oxide film 32 may be held to the nickel frame 34 by means of surface adhesion or a binder. The next step in preparing the dynode shown in Fig. 2 is to deposit a thin layer 44 of a material having a high average atomic number about 25 or greater, such as gold, onto the side of the aluminum oxide layer 32 on which the electrons from the photocathode or previous dynode will impinge. The term average atomic number as used herein refers to the atomic number of a single element or the average of the atomic numbers of the elements in a compound. One possible method of depositing a suitable scattering layer 44 is by evaporation. The thickness of the electron scattering layer of a material such as gold should be of the order of 100 Angstroms or less.

In Fig. 3 a modified dynode structure 40 is shown in which an aluminum oxide film 42 is utilized solely as the support layer of the dynode and an electron scattering layer 44 is deposited on one surface of the film 42 with a layer 46 of a high secondary emissive material such as potassium chloride, sodium chloride, magnesium oxide or magnesium fluoride deposited on the other side. The thickness of this insulating layer 46 may be of the order of 200 to 300 Angstroms. The secondary emissive layer 46 should provide a long mean free path for secondary electron. A material having a large energy gap between the filled valence band and the conductive band has this characteristic. This will result in a large yield of secondary electrons from the surface of the insulator 46 since the secondary electrons can diffuse easily through a substantial thickness of material without loss of energy. The secondary emissive layer 46 may be deposited on by evaporation techniques. In this application it is also desirable that the aluminum oxide film 42 which acts as a support layer should be of as minimum a thickness as possible, of the order of 200 to 300 Angstroms. It should also be noted that the electron scatterer may also be evaporated on so as to be between the aluminum oxide support layer 42 and the secondary emissive layer 46, as shown in the dynode 50 in Fig. 4.

It has also been found that the thickness of the electron scattering layer 44, which may be as low as 20 Angstroms in thickness, does not serve as a good electrical conductor, but yet to attempt to increase the thickness of this scattering layer would result in the necessity of higher accelerating voltages provided between each dynode stage. To overcome this difficulty, a thin conducting layer 48 of a metal of low atomic number, such as aluminum or beryllium or a conducting compound such as stannic oxide may be deposited on the entrance side of the dynode 54 as shown in Fig. 5. This low atomic number conductive layer 48 may precede layer 44 of scattering material as shown in Fig. 5 or follow the layer 44 as shown on dynode 56 in Fig. 6. The layer 48 may be deposited by evaporation in vacuum in the same operation as the evaporation of the scattering layer 44. The thickness of this conducting layer 48 may be of the order of 100 Angstroms, which is thin enough to have a small effect on the penetration of the incident electrons from the preceding stage while at the same time materially increasing the electrical conductivity across the face of the dynode structure. The conducting layer 48 may also be added to a type of composite film shown and described in Figs. 3 and 4. It is desirable also to deposit the conducting layer 48 in the form of a black deposit such as may be obtained by evaporation through an atmosphere of an inert gas. This reduces light reflection to the cathode, and greatly minimizes the background glow.

Other metals such as alloys of aluminum magnesium and tantalum may be used in place of aluminum to form oxide layers by anodization. In the case of the tantalum oxide, the tantalum may serve not only as the support layer but also as the electron scattering layer.

In the operation of the structure shown in Fig. 1 a radiation image is projected onto the photocathode 22. The photocathode 22 in response to the radiation image projected thereon will generate an electron image corresponding to the light image projected thereon. Under the influence of the accelerating potential, which may be of the order of 2000 volts applied to the first dynode 30, the electron image emitted from the photocathode 22 will be accelerated to a sufficient velocity such that the incident electrons velocity will be substantially reduced to zero by the time they have passed through the entire dynode structure. The incident electrons on striking the scattering layer 44 will be deflected from the incident angle of the electron and thus the electron entering the secondary emissive layer 32 or 46 will pass a longer distance than if the incident electron were not deflected. The longer path of the electron in the secondary emissive layer 32 or 46 results in a greater number of secondary electrons being generated, and thus the yield or amplification of the dynode is increased by a substantial amount.

It is found that the secondary yield from a gold film alone is slightly less than two for one incident electron, while the electron emission from a potassium chloride film alone is also less than two. When a 50 Angstrom layer of gold was placed on the bombarded side of a 600 Angstrom layer of potassium chloride, the secondary yield from the resulting dynode was greater than six for a single incident electron of similar energy striking the gold or potassium chloride alone. The secondary electrons emitted from the secondary emissive surface are emitted with an average energy of about 2 electron volts and, as previously explained, the incident electrons are substantially absorbed within the dynode. The low energy secondary electrons, emitted by the dynode are again accelerated by the potential applied to the following dynode and so on through the electron multiplying assembly. The secondary electrons emitted from the final dynode 30 are then accelerated by a high potential of the order of 4 to 10,000 volts into incidence with the target 24 and generate an intensified light image corresponding to the image projected onto the photocathode 22.

It is thus seen by the utilization of the continuous layer of aluminum oxide support film 32 or 42 that the metallic grid support member described in the above-mentioned application is not required. The continuous film support increases the gain per stage in that the grid type support resulted in a considerable number of incident electrons being absorbed or reflected back by the metallic grid. It is also obvious that the resolution of the device is now not limited due to the mesh structure of the grid support. The removal of the metallic grid support member also prevents back scattering of electrons from the metallic grid which, in turn, resulted in halations in the final intensified image. It has also been found in the evaporated type of insulating film support structure described in the above-mentioned application that there was a lack of flatness in the surface and also wrinkles which affected the resolution of the image. It should also be noted that the aluminum oxides and also magnesium oxides that may be utilized for the support member and also as a secondary emissive layer 32 have high stability under electron bombardment and this is particularly important in high current amplification.

It is also possible in order to obtain greater heat dissipation from the dynode while obtaining additional mechanical strength and electrical conductivity to utilize a wire or mesh support since the aluminum oxide layer is the primary support. This mesh might be of a woven type permitting open areas as large as 90%.

Although we have shown the electron multiplier dynodes incorporated within an image intensified type structure, it is obvious that these dynodes may be utilized in any type structure or combination in which the desirable features previously set forth are advantageous. While we have shown our invention in several forms, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit and scope thereof.

We claim as our invention:

1. In a transmissive type secondary electron emissive dynode structure in which electrons bombarded one surface of said dynode and secondary electrons are emitted from the opposite surface of said dynode, said dynode comprising a continuous support layer of a coherent oxide prepared by anodization transmissive to electrons, a thin continuous film of electrical conductive material of low atomic number disposed on the surface of said support member opposite from that surface on which the bombarding electrons strike said dynode and transmissive to electrons and a thin layer of insulating material exhibiting the property of transmissive type secondary emission in which electrons bombard one surface and secondary electrons are emitted from the opposite surface disposed on the exposed surface of said electrical conductive layer.

2. In a transmissive type secondary emission dynode structure having the property of emitting secondary electrons from a first surface in response to electron bombardment of a second surface, a peripheral support ring of relatively massive size, a relatively thin continuous electron scattering layer of a solid material of an atomic number greater than 25 and transmissive to electrons, a superposed continuous support film transmissive to electrons of a coherent oxide prepared by anodization disposed in contact with one surface of said scattering layer and supported on said support ring and a thin continuous layer of insulating material exhibiting the property of transmissive secondary emission in which electrons bombard one surface and secondary electrons are emitted from the other surface disposed on the other surface of said scattering layer.

3. In a transmissive type secondary emission dynode structure having the property of emitting secondary electrons from a first surface in response to electron bombardment of a second surface, a peripheral support ring, a continuous support film of a thickness of about 200 to 500 Angstroms of a coherent oxide of an element of the group consisting of aluminum and magnesium disposed and supported on said peripheral support ring, said support film being transmissive to electrons, and an electron scattering continuous layer of a thickness of about 20 Angstroms and of a material of an atomic number greater than 25 disposed on one surface of said support film, said support film and said scattering layer positioned between said first surface and said second surface.

4. A transmissive type secondary emissive dynode structure having the property of emitting secondary

electrons from a first surface in response to electron bombardment of a secondary surface comprising a peripheral support ring, a continuous support film of a thickness of about 200 to 500 Angstroms of a coherent oxide of an element of the group consisting of aluminum and magnesium and disposed and supported on said support ring, said support film transmissive to electrons, an electron scattering layer of a thickness of the order of 20 Angstroms and of a solid material having an atomic number greater than 25 disposed on one surface of said support film for scattering electrons directed through said layer and a thin layer of the order of about 300 to 500 Angstroms of an insulating material exhibiting the property of transmissive secondary emission in which electrons bombard one surface of said layer and secondary electrons of a greater number than incident electrons are emitted from the opposite surface, the exposed surface of said insulating layer forming the emissive surface of said dynode structure.

5. In a transmissive type secondary emissive dynode structure having the property of emitting secondary electrons from a first surface in response to electron bombardment of a second surface, a peripheral support ring, a continuous support film of the thickness of about 200 to 500 Angstroms of a coherent oxide of an element of the group consisting of aluminum and magnesium disposed and supported on said support ring, an electron scattering layer of a thickness of the order of 20 Angstroms of a solid material having an average atomic number greater than 25 disposed on one surface of said support film, and a thin layer of about 300 to 500 Angstroms of an insulating material exhibiting the property of transmission secondary emission in which the number of secondary electrons emitted from one surface is greater than the number of electrons bombarding the other surface, said insulating layer disposed on the free surface of said support film.

6. In a transmissive type secondary emissive dynode structure having the property of emitting secondary electrons from a first surface in response to electron bombardment of a second surface, a peripheral support ring of a conductive material, a continuous support film of a thickness of the order of 200 to 500 Angstroms of a coherent oxide of an element of the group consisting of aluminum and magnesium and disposed and supported on said support ring, a continuous electron scattering layer of a thickness of about 20 Angstroms of a solid material having an average atomic number greater than 25 disposed on the surface of said support film and a thin continuous layer of insulating material about 300 to 500 Angstroms exhibiting the property of transmissive type secondary emission in which secondary electrons are emitted from one surface in response to bombardment of the other surface, said insulating layer disposed on said electron scattering layer.

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