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ELECTRON DISCHARGE DEVICE WITH STORAGE TARGET ELECTRODE

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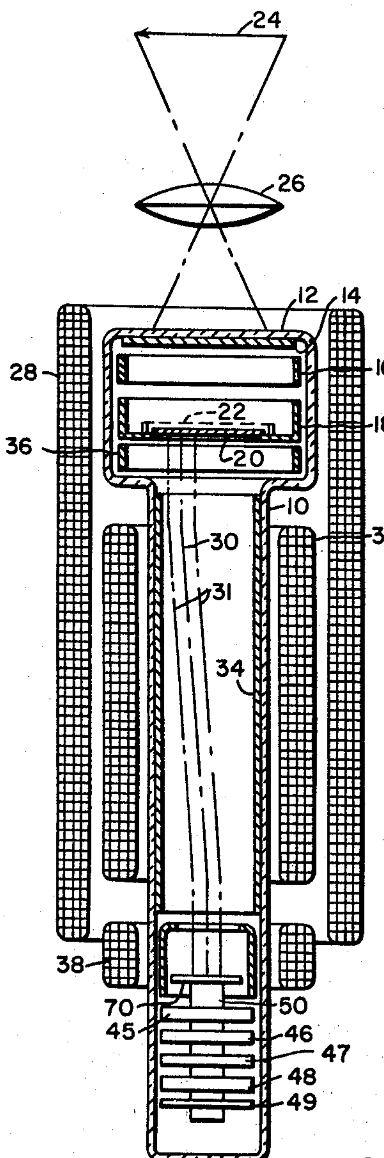

Fig. 1.

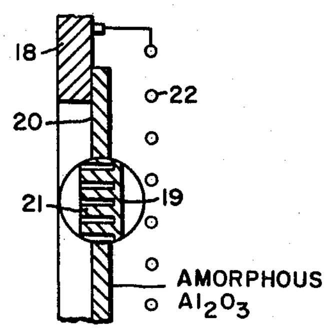

Fig. 2.

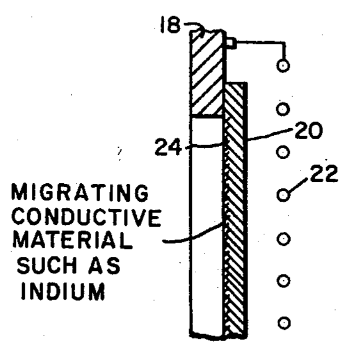

Fig. 3.

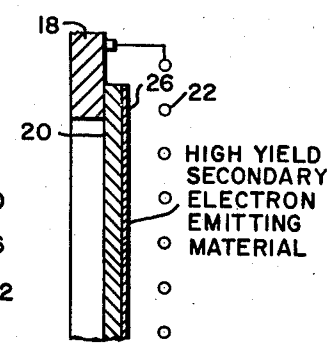

Fig. 4.

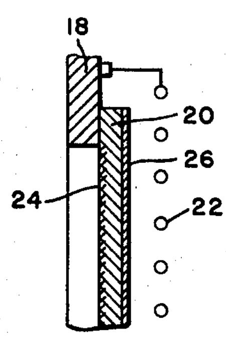

Fig. 5.

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ELECTRON DISCHARGE DEVICE WITH STORAGE TARGET ELECTRODE

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This invention relates generally to electron discharge devices, such as pickup tubes, having storage target electrodes. The invention is particularly applicable to image orthicons.

In camera tubes of the image orthicon type an electron image containing scene information is impressed upon one side of a storage target electrode forming a charge image and the other side is scanned by a uniform electron beam which discharges the charge image. Electrons of the uniform beam not needed to neutralize the charge on the target are captured to provide the output signal from the device.

In conventional image orthicons the target is made of glass having a conductance such that the electrons deposited on the target by the scanning beam leak through and neutralize the positive charge on the opposite side in the $\frac{1}{30}$ of a second that elapses between scans. Such targets exhibit what is known as a "burn" effect whereby after a certain period of useful life electrons from the scanning beam are unable to be conducted through the target within the necessary time and hence the charge thereon is not neutralized. The generally accepted explanation of this phenomenon is that conduction through the glass target is by migrating ions, usually of sodium. The part of the target near the surface on which the electron image is deposited becomes deficient in the ions with age. Thus the life of present image orthicons is limited to about 500 hours.

It is also the case that conventional glass targets for image orthicons have uniform conductivity in all directions which means that lateral conductivity through the target occurs with the same facility as that traverse to the target, reliance being made on having a very thin target so that the lateral conductivity does not cause destruction of fine detail during the scanning time. It has been found necessary to make glass targets with a thickness of approximately 100,000 angstroms in order to have sufficient mechanical strength and so further improvement in this direction is not readily made. Of course, the limitation on glass targets due to lateral conduction prevents any substantial increase of the scanning time (slower scanning) in order to obtain an integrated charge image.

Certain proposals have been made calling for the use of polycrystalline magnesium oxide as a target material. While advantages over the glass targets are thereby obtained, the rigid requirements of modern image orthicon systems require that every possible improvement contributing to long life and mechanical ruggedness be made as well as those providing improved electrical characteristics. For example, television camera systems are being designed to be sent aloft by balloon or orbiting satellites in order to make day and night cloud cover observations, observe low magnitude stars and also for use in industrial and military closed circuit systems requiring long life and a mechanically secure target structure as well as good operating characteristics at low light levels.

It is, therefore, an object of the present invention to provide an improved storage target electrode.

Another object of the invention is to provide an image orthicon device having an improved target which may be readily made and has a high degree of mechanical

strength thereby permitting an image orthicon having long life.

Other objects are to provide an image orthicon having high sensitivity, high resolution and the capability of operating at long storage times as a result of an improved target whose electrical properties do not deteriorate, which exhibits anisotropic conductivity which is greater transverse to its major surfaces and which may be fabricated with mechanical strength in a very thin member.

According to the present invention a device of the image orthicon type is provided having a storage target electrode comprising a layer of amorphous aluminum oxide. The amorphous aluminum oxide of the target electrode may be either porous or non-porous but is preferably made having pores extending transversely almost entirely through it so as to further reduce lateral conduction and provide a higher degree of mechanical flexibility.

In a preferred form of the invention, the storage target electrode has on the surface thereof facing the scanning electron gun of the device a thin layer of a conductive material, such as indium, which has the property of migrating or diffusing into the amorphous aluminum oxide so as to improve transverse conductivity. According to a further modification of the invention, the storage target electrode may have on the surface thereof facing the photocathode a layer of an insulating material having a secondary electron emitting characteristic which is higher than that of the amorphous aluminum oxide so as to produce a more pronounced charge image. In all of the various forms of the invention, the aluminum oxide layer need only be supported at its periphery.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention together with the above-mentioned and further objects and advantages thereof may best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a cross sectional view of a device of the image orthicon type embodying the present invention;

FIGURE 2 is an enlarged partial cross sectional view of the storage target electrode assembly of the device of FIGURE 1;

FIGURE 3 is an enlarged partial cross sectional view of an alternative form of the storage target electrode assembly;

FIGURE 4 is an enlarged partial cross sectional view of a further alternative of the storage target electrode assembly; and

FIGURE 5 is an enlarged partial cross sectional view of a storage target electrode wherein features of the embodiments of FIGS. 3 and 4 are combined.

Referring now to FIG. 1, there is shown a television camera tube of the image orthicon type. The camera tube comprises an envelope 10 of a suitable material such as glass having at one end thereof a light transmissive face plate 12. On the other surface of the face plate 12 is disposed a layer of photoemissive material 14. The photocathode 14 may be of any suitable material well known in the art such as cesium antimonide. Positioned adjacent the photocathode 14 is an accelerating electrode 16 and axially spaced therefrom is an annular electrode 18 for supporting a target electrode 20. The target electrode comprises a layer of amorphous aluminum oxide as will be more fully described hereinafter. Between the target electrode 20 and the photocathode 14 is a very fine conductive mesh 22 closely spaced from the surface of the target 20. The screen mesh 22 is conductively supported by the annular electrode 18.

An object 24 which is to be televised in focused by an appropriate optical system, represented at 26 in FIG. 1, as an optional image on the photocathode 14. An electron image is emitted from the photocathode **14** in accordance with the optional image imposed thereon. By reason of an accelerating field provided between the photocathode **14** and the target **20**, and due to the effect of a focusing coil **28** surrounding the envelope **10** of the tube, a uniform focusing field focuses and accelerates electrons from the photocathode **14** to the target **20**. The electrons strike the target **20** at a relatively high velocity causing a secondary emission greater than unity from the surface of the target **20**. The fine mesh screen **22** acts as a collector electrode of secondaries emitted from the target surface.

The emission of secondary electrons from the surface of the target **20** leaves areas of the target positively charged to an extent related to the density of electrons impingent thereon. In this manner, a positive electrostatic charge image is formed on the target **20**.

The opposite side of the target **20** is scanned during tube operation by a low velocity electron beam **30** emitted from an electron gun structure **50** mounted at the opposite end of the tube envelope **10**. The tube is also provided with an alignment coil **32**, an inner surface conductive coating **34**, a decelerating electrode **36** and deflection coil **38** which are well known in the art. The variout electrodes are provided at suitable potentials as is well known.

The deflection coil **38** causes the electron beam **30** to scan the surface of the target **20**. Electrons from the beam **30** land on the target **20** to maintain the surface thereof at cathode potential. The remainder of the beam approaching the target at close to zero velocity is repelled by the target surface to form a return beam **31** which passes back along substantially the same path as the incident beam **30** and strikes a large dynode surface forming the first stage **70** of multiplier unit which comprises one or more additional dynodes **45**, **46**, **47**, **48**, **49** at successively higher positive potentials from which is derived the tube output signal.

Referring to FIG. 2 there is shown the storage target electrode assembly of the device of FIG. 1 including the annular electrode or support **18** which has suspended thereacross and solely supported therby the target electrode **20** of amorphous aluminum oxide. In front of the storage target electrode **20**, facing the photocathode of the device is the mesh **22** which may be supported by the same annular electrode **18**, as shown, or may be independently supported if desired.

The amorphous aluminum oxide target electrode may be made by beginning with a 99% pure aluminum foil formed by mechanical rolling or vacuum deposition and anodizing it in a suitable electrolyte to produce an aluminum oxide film of a desired thickness, as determined by bath concentration, time, temperature and current density of anodic formation, on both sides of the aluminum foil. The anodized foils is then treated, for example with concentrated sodium hydroxide, so that the layer of aluminum oxide is removed from one surface. Then all of the remaining aluminum is dissolved, for example by hydrochloric acid, leaving a free standing self-supporting film of amorphous aluminum oxide to be used as the target. It is then simply placed across the annular support member where it is held by molecular adhesion of it may be held by a support means which provides clamping.

Depending on the manner in which the aluminum oxide layer is formed it may be either porous or non-porous and either form may be suitably used in the practice of the present invention. The principal difference is that non-porous layer is formed in electrolytes which do not attack or dissolve the aluminum oxide while a porous layer is formed in those which do.

A non-porous aluminum oxide target can be formed by anodization in a 3% tartaric acid bath at an interelectrode voltage of from about 20 volts to about 60 volts, a temperature of about 25° C. and for a time of about 20 minutes. The initial layer is amorphous, as determined by X-ray diffraction, and it remains in the amorphous state

throughout operation since it is never exposed to temperatures greater than about 375° C. and crystalline aluminum oxide is not formed until about 700° C.

For a porous target, which is somewhat preferred over the non-porous form, the anodization process may use an electrolyte of a 5% chromic acid bath at about 10 volts, for a time of about 4.5 minutes, at a temperature of 25° C. This method results in a target having a thickness of from about 350 Angstroms to about 1000 Angstroms. Of course thicker targets may be formed but they are undesirable.

The porous aluminum oxide target **20**, as shown in FIG. 2, has a first portion **19** which is non-porous, presumably formed next to the aluminum foil, and a porous oxide portion **21** thereon. The structure of the target has been determined by electron microscope analysis and the thickness of the target by X-ray attenuation measurements. The X-ray diffraction measurements indicate there is no crystalline structure. The porous target used has approximately 800 pores or openings per square micron spaced approximately 360 angstroms apart. The pores have substantially round openings and are perpendicular to the surface of the oxide. They extend from one surface to the thin non-porous barrier layer **19** which has a thickness of about 100 angstroms or less.

It is desirable to use the porous target electrode because the necessity of removing surface non-uniformities of the original aluminum foil is thereby avoided while in the preparation of a non-porous target it is necessary to have substantial uniformity of the starting foil. The pores also aid in reducing lateral conductivity and in promoting transverse conductivity. The presence of the pores makes the effective target thickness much thinner than the total oxide layer in that it substantially approaches the thickness of only the non-porous portion **19** since conductivity through the pores is much higher than through the aluminum oxide per se. It would not otherwise be possible to fabricate a target of any material which has such a small thickness (about 100 angstroms or less) and yet is mechanically stable and self-supporting. The target **20** is mounted in the device so that the pores face the electron gun **50**, however, no critical orientation in the direction of mounting has yet been observed.

Targets as shown in FIG. 2 have been successfully used and increased tube life has been obtained since the target exhibits electronic conduction which does not deteriorate with age. Also improved resolution and sensitivity have been obtained since the target is so thin and the time necessary for transverse conduction is very short. The advantages of the target of FIG. 2 are especially evident at low light levels, such as about 10^{-3} foot candles and less. Low light level capability is, of course, desirable in any pickup device.

The target of FIG. 2 does exhibit a somewht undesirable property at high light levels in that a saturation effect occurs. The nature of the effect is that a certain stickiness of the image is noted resulting from failure of the target from being discharged during a single scanning period. The cause of the effect is presumably because the number of conductivity electrons in the aluminum oxide is not so large as to readily effect discharge. However, this high light level saturation effect disappears upon a short period of exposure of the target to a white scene or with a period of about 12 hours of inoperation. Another way of avoiding the effect, and the preferred way, is described immediately following.

Referring now to FIG. 3 there is shown a similar arrangement as that in FIG. 2 comprising the annular support member **18**, the conductive mesh **22**, the aluminum oxide layer **20** and in addition thereto a very thin layer **24** of conductive material on the gun side of the target. The use of a layer of conductive material, which may suitably be and is preferably in indium, is desirable in order to avoid the previously described saturation effect which occurs in aluminum oxide targets under high light level conditions. The indium also improves the transverse conductivity of the target resulting in improved overall sensitivity.

The indium layer is formed by evaporation and has a thickness of less than about 200 angstroms and may be as small as a monatomic layer. The improvement caused by the indium layer cannot be readily explained by information presently known. It is believed that the improvement in transverse conductivity is due to the diffusion of indium into the aluminum oxide layer upon application of heat thereto, as occurs during baking out of the tube. The use of indium is somewhat critical in that not all conductive materials produce the same effect but those which have the property of migrating into the aluminum oxide are believed to do so. The indium is disposed on the gun side of the target and may also improve the beam landing characteristics of the scanning beam. Because of the thinness of the target and the indium layer no increase in lateral conductivity results by the use of the indium layer.

Referring now to FIG. 4 there is shown a storage target electrode assembly including the annular support member **18**, the conductive mesh **22** and the aluminum oxide layer **20** having on the mesh side thereof a layer **26** which is an insulating material having a higher secondary electron emitting characteristic than the aluminum oxide. Examples of such materials are barium fluoride and potassium chloride. The use of a better secondary electron emitting material is not at all necessary with the aluminum oxide target since aluminum oxide provides considerable improvement overconventional glass targets. However the layer **26** may provide somewhat higher gain with some resulting improvement in overall sensitivity. For structural stability, this insulating layer should also be amorphous and may be formed by deposition in a gaseous atmosphere and may have a thickness of from about 100 angstroms to 1000 angstroms. Of course, as shown in FIG. 5, such a layer **26** may also be used in an embodiment which also includes an indium layer **24**.

Successfully operating image orthicons have been fabricated in accordance with this invention. In addition to an indefinite target life, as opposed to a life of about 500 hours for conventional glass targets, increased sensitivity has been obtained. For the standard image orthicon target an illumination of about 10^{-5} foot candles on the photocathode is required for 200 TV lines. With an aluminum oxide target as described herein, the required illumination for the same resolution is about 2.5×10^{-6} foot candles and using the embodiment of FIG. 3 with indium on the gun side, an illumination of about 1.25×10^{-6} foot candles is sufficient.

While the present invention has been shown and described in certain forms only, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

We claim as our invention:

1. A pickup tube for a device of the image orthicon type compising a storage target electrode comprising a first layer of amorphous aluminum oxide and a second layer of an insulating material having a higher secondary

electron emission characteristic than said amorphous aluminum oxide, means for impressing an electron image on the surface of said storage target electrode having said second layer thereon and means for scanning a uniform electron beam on the opposite surface of said storage target electrode.

2. A storage target electrode for a device of the image orthicon type comprising a first layer of amorphous aluminum oxide, a layer of indium disposed on one surface of said first layer and a layer of an amorphous insulating material having a higher secondary electron emission characteristic than said amorphous aluminum oxide on the opposite surface of said first layer.

3. A storage target electrode for a device of the image orthicon type comprising an insulating layer of amorphous aluminum oxide having a thickness of from 350 angstroms to about 1000 angstroms and having pores therein extending from one surface of said layer to within about 100 angstroms of the opposite surface of said layer, a layer of indium having a thickness of less than about 200 angstroms disposed on one surface of said insulating layer and a layer of an amorphous insulating material having a higher secondary electron emission characteristic than said amorphous aluminum oxide on the opposite surface thereof.

4. In a device of the image orthicon type, the combination comprising: a storage target electrode comprising a layer of amorphous aluminum oxide, a layer of indium disposed on one surface and a layer of an amorphous insulating material having a higher secondary electron emission characteristic than said amorphous aluminum oxide on the other surface thereof, a peripheral support member providing the sole means of support for said storage target electrode, means including a photocathode for impressing a positive charge image on the surface of said storage target electrode having said secondary electron emissive material thereon and means including an electron gun for scanning a uniform electron beam on the surface of said storage target electrode having said indium thereon.

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