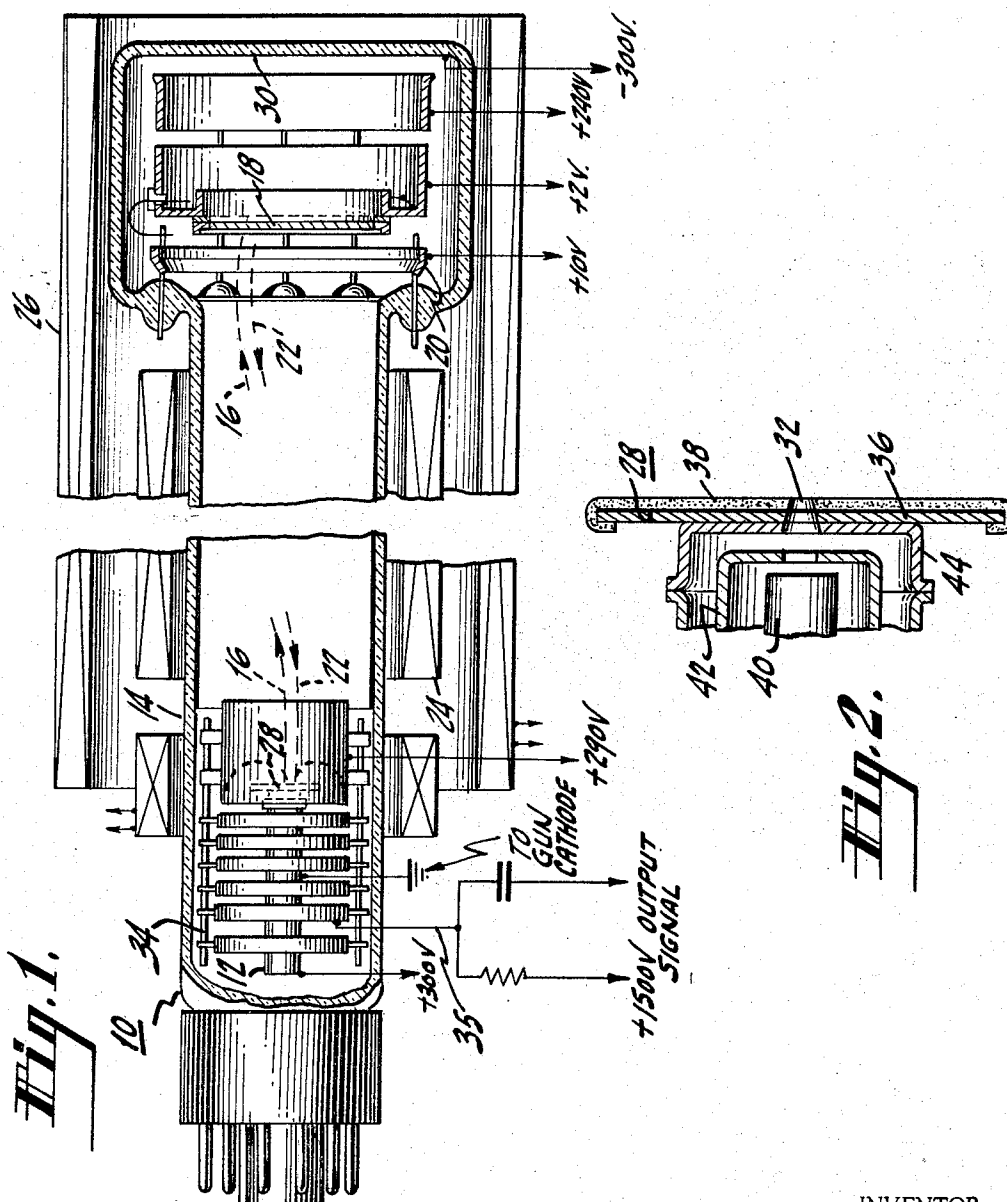


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ELECTRON MULTIPLIER DYNODE HAVING AN APERTURE
OF REDUCED SECONDARY EMISSION
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ELECTRON MULTIPLIER DYNODE HAVING AN APERTURE OF REDUCED SECONDARY EMISSION

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ABSTRACT OF THE DISCLOSURE

A first dynode of an electron multiplier is provided with an aperture for the passage therethrough of an electron beam. In order to reduce secondary emission from the walls of the aperture when beam electrons impinge thereon, the walls are coated with a relatively low secondary emission material such as carbon.

This invention relates to electron multipliers and in particular to an electron multiplier having an improved first dynode for use in a photosensitive pickup type of tube.

A photosensitive type of pickup tube such as the image orthicon includes an electron multiplier having a first dynode in the form of a disc-like structure comprising a metal substrate having thereon a coating of a material of high secondary electron emission such as magnesium oxide. The disc-like structure has a central opening therethrough of about one mil diameter for service as a beam limiting aperture with respect to an electron beam passing therethrough.

One problem associated with the first dynode of the type described concerns a nonuniform secondary emission therefrom. Such nonuniform secondary emission is undesirable because it introduces spurious effects in the output signal.

Accordingly, it is an object of my invention to provide an improved first dynode of an electron multiplier section of an image orthicon tube.

It is a further object to provide a first dynode of an electron multiplier section of an electron tube that is characterized by substantial improvement in respect of uniformity and freedom from spurious signals.

Briefly, according to the present invention, I have discovered that substantial reduction in spurious signals in the output of an image orthicon tube can be effected by increasing the smoothness of the first dynode substrate surface upon which the high secondary emission material such as magnesium oxide is deposited, and by coating the walls defining the beam limiting aperture in the first dynode with a material having a relatively low secondary emission ratio. The substrate referred to is preferably made of nickel and formed by electroplating in which the plating bath is restricted to ingredients that assure freedom from surface irregularities in the plated structure, either as a consequence of the plating operation or those evolved during tube operation. The material of low secondary emission that is coated on the walls defining the beam limiting aperture is preferably pure carbon. This material has such a low order of secondary emission as to be considered an effective suppressor of such emission.

My invention will be more clearly understood by reference to the accompanying single sheet of drawings wherein:

FIG. 1 is a longitudinal section of a pickup tube of the type incorporating the invention; and

FIG. 2 is an enlarged sectional view of the first dynode structure of the tube of FIG. 1.

Although the invention is applicable to all types of tubes wherein an electron multiplier arrangement is used, it is particularly advantageous in photosensitive pickup tubes using an electron multiplier structure. For simplicity

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of illustration, the invention will, therefore, be described with particular reference to a pickup tube of the image orthicon type as an example.

In FIG. 1 there is shown a sectional view of an image orthicon type tube 10. The tube comprises an electron gun 12 in one end of an evacuated envelope 14. The electron gun 12 is of a well-known type and further description thereof is not necessary. The electron gun 12 produces an electron beam 16 which is accelerated by conventional accelerating electrodes to the target electrode 18 with potentials such as those shown in FIG. 1. The target electrode 18 is an electrolytic conductor such as glass or a semiconductor such as magnesium oxide, and is supported in a transverse relation to the path of the electron beam 16. Mounted immediately adjacent to the target electrode 18 is a decelerating electrode mesh screen 20 which serves to bring the velocity of the electron beam 16 to substantially zero in front of the target surface. The electron beam 16 lands on the target 18 and drives the front or scan surface of the target 18 to cathode potential, after which the electron beam is reflected by the target as return electron beam 22. The fields produced by a deflection yoke 24 and focus coil 26, cause the electron beam 16 to scan the target and also cause the return beam 22 to scan a first dynode electrode 28.

At the end of the tube 10 opposite the gun 12 and on the side of target 18 remote from the gun 12, there is formed a photocathode 30 which emits electrons in proportion to the amount of light focused thereon from a scene to be reproduced. The photocathode 30 normally includes an oxidized and cesiated silver alloy, or a film of antimony activated with small amounts of a plurality of alkali metals. Examples of conventional photocathodes may be found in US Patent 2,682,479 to Johnson and the US Patent 2,770,561 to Sommer.

In operation, electrons from the photocathode 30 are accelerated and focused onto the back surface of the target 18, e.g., the surface remote from the electron gun 12, and produce by secondary electron emission, a charge pattern which appears on the side of the target 18 facing the electron gun 12. When the electron beam 16 is scanned across the side surface of the target 18 facing the electron gun 12, the beam is reflected from the areas of the target that have not been charged by the photocathode 30 and therefore are at substantially cathode potential. The beam 16 lands on the areas of the target 18 that are charged by the photocathode until the charge pattern is neutralized by the beam. Once the charge is removed or neutralized, the balance of the beam is reflected toward the electron gun 12. The reflected beam 22 is therefore modulated in proportion to the amount of charge on the target 18.

The reflected electron beam 22 travels toward the electron gun 12 and scans across the first dynode 28 that forms a beam limiting aperture 32 for the primary electron beam 16. The return electron beam 22 is multiplied by secondary electron emission from the first dynode 28 and is directed into an electron multiplier system 34. The electron multiplier system 34 may be of any type such as that disclosed in US Patent 2,433,941 to Weimer. The modulated return electron beam 22 is converted into output video signal voltages which may be taken from a collector electrode or final dynode of the electron multiplier system 34 via lead 35.

It will be seen from the foregoing that the first dynode 28 is an important translating element in the path of the signal modulated beam 22. The fact that the signal modulated beam 22 strikes the first dynode 28 while in a relatively low kinetic energy state prior to amplification by the multiplier system 34, renders the beam particularly susceptible to sources of noise in the first dynode.

I have discovered that two of such sources of noise

comprise the surface of the first dynode 28 upon which the signal modulated beam 22 impinges, and the wall defining the beam limiting aperture 32.

In connection with the surface noise source of the first dynode 28, the surface condition of the metal substrate 36 and the tolerable thickness of the magnesium oxide coating 38 thereon are significant. Where the coating 38 consists of magnesium oxide for enhanced secondary emission, it is desirable to keep it as thin as possible and yet assure a desired secondary emission characteristic. A relatively thick coating is objectionable because of its resistance to the flow of electrons from the metal substrate 36 to the surface portion of the coating undergoing electron depletion by virtue of a secondary emission ratio of the material of the coating in excess of one. It is found that when the magnesium oxide coating 38 has a thickness of about 100 Angstroms, it serves well as a secondary emitter. A tolerable thickness range for acceptable results is from 25 Angstroms to 125 Angstroms.

This thickness dimension is so small that it has imposed a requirement for a highly smooth surface of the substrate 36 upon which the coating 38 is deposited. Where the substrate 36 is made of nickel, it has heretofore been made by electroplating to a suitable thickness, such as two mils, from a plating bath consisting of nickelous chloride, nickelous carbonate and boric acid dissolved in de-ionized water. In order to assure a desired surface smoothness of the nickel substrate so made, there is added to the plating bath by prior practices, a "brightener" in the form of an organic material such as gum arabic dissolved in the water of the plating solution. I have found that the presence of sulfide ions in the plating bath and of carbon in the "brightener" solution constitute impurities that adversely affect surface smoothness of the plated nickel. These impurities cause the plated nickel to become brittle and rough upon heating during tube processing and this brittleness results in a grainy background in the video output of an image orthicon in which such plated nickel forms the substrate of the first dynode.

I avoid the source of noise due to contaminants in the plating bath employed in forming the nickel substrate 36, and yet obtain a highly smooth surface on the plated nickel. This is accomplished by using a plating bath consisting of nickel sulfamate, boric acid and nickel chloride in a suitable solvent such as de-ionized water. The surface smoothness obtained by using this bath is such that the relatively thin coating 38 of magnesium oxide covers all portions of the surface and with no irregularity in the substrate surface protruding through the coating. The absence of such protruding irregularity contributes to uniformity in the output of the first dynode.

With respect to my discovery that the walls defining the aperture 32 contribute to noise in the video output as a consequence of secondary electron emission therefrom, I have found that one cause for this condition resides in the accidental deposition of barium or barium compounds upon such walls during processing of a cathode 40. The cathode 40 includes a metal substrate having thereon an electron emitting material. This material in its initial form comprises the carbonates of barium, strontium and calcium. This material is converted from the carbonate form to the oxide form by heating the cathode to a temperature of about 1300° C. During the actual conversion process at this temperature, a portion of the carbonates evaporates, passes through a control grid 42, and deposits on the walls of aperture 32. After the cathode has been processed and during later operation of the tube, a portion of the converted oxides of barium, strontium and calcium evaporates from the cathode and deposits on the carbonate coating on the walls of aperture 32. Such walls are at a temperature of about 300° C. during tube operation, and the cathode temperature is about 1050° C.

The coatings of carbonates and oxides of barium,

strontium and calcium upon the walls of aperture 32 are characterized by a relatively high ratio of secondary emission. I have found that a portion of the beam 16 emitted by the cathode 40 impinges upon the walls of aperture 32 and produces secondary electron emission therefrom. A portion of this emission leaves the aperture 32 from the end thereof remote from the cathode 40, and since it has a relatively low energy, this portion of the emission is deflected back to the multiplier system 34. Such additional secondary electrons enter the multiplier system 34 where they are amplified and superposed upon the output signal as noise.

One attempt to solve the problem of unwanted secondary emission from the walls defining the aperture 32, involved flaring the aperture from the end thereof remote from the cathode 40, as shown in FIG. 2. The purpose of the flare is to cause secondary electrons from the aperture walls to be reflected back into a chamber defined by a first accelerating electrode 44, where they can do no harm. While this helps to a certain extent, it is not completely successful.

I have found that an appreciably greater reduction in noise occurred when I coated the walls of aperture 32 with a material having a relatively small secondary emission characteristic. The material found best for this purpose is an organic material such as a material of the group consisting of colloidal graphite, which is pure carbon, and carbon compounds such as petroleum lubricating oil or grease. I apply this material by means of a suitable brush or by causing the material to flow through the beam limiting aperture 32 as a consequence of establishing a differential in atmospheric pressure at the two faces of the dynode 28. Both of these techniques cause the suppression emission material to coat the walls of the aperture 32 without blocking the aperture. The thickness of the coating applied is at least about 200 Angstroms, which is a relatively small fraction of the one mil diameter of the aperture. During subsequent tube processing the volatile components of the applied material are driven off.

The organic material constituting the aperture wall coating reacts chemically with emitting carbonates and oxides evaporated from the cathode to produce a compound having an appreciably smaller ratio of secondary electron emission than the initial carbonates and oxides.

However, the best reduction in noise is realized when the organic emission suppressing coating is porous, as by sand blasting by sand having a particle size appreciably smaller than the one mil diameter of aperture 32. Such particle size may be two microns or less. The porous character of the sand blasted coating further contributes mechanically to secondary electron suppression in that any secondaries released by one pore wall will strike an opposite pore wall, and because of the relatively low potential of the secondaries, the striking electrons are incapable of releasing further secondaries. The mechanical suppression of secondaries by the porous character of the coating on the walls of aperture 32, coupled with the chemical suppression by the aforementioned composition of the emission suppression coating, results in appreciably eliminating the walls of aperture 32 as a source of noise.

I have found that when the emission suppression coating on the walls of aperture 32 is porous, effective secondary emission suppression is also realized with coating compositions other than those specified in the foregoing. I have found that any coating composition having a secondary emission ratio of one or less and substantially free from oxidation can be employed with satisfactory results when the coating is made porous. Thus, in addition to carbon and carbon compounds, as mentioned in the foregoing, the coating may consist of one of chromium, palladium, gold, etc., which are materials having a secondary emission ratio of less than one.

If the secondary emission suppression coating is made

of a porous inorganic material, the suppression of secondaries is effected primarily in a mechanical manner. When the pores are sufficiently deep to accommodate the carbonates and oxides evaporated from the cathode, below the surface of the coating, the suppression of secondaries is nearly as effective as when the coating comprises a porous organic material.

It is to be noted that the flared structure of the walls defining the aperture 32, as described in the foregoing, is of some advantage even with the mechanical and chemical secondary suppression means described.

It is apparent from the foregoing that I have provided an advantageous first dynode in an electron multiplication system that will find useful application in an image orthicon type of tube as well as in other areas where an electron multiplier is used.

I claim:

1. An electron multiplier tube having:

- (a) a first dynode,
- (b) said first dynode having walls defining an aperture therein,
- (c) a cathode having an electron emissive coating thereon disposed relatively close to and in axial register with said aperture, whereby some of the material of said electron emissive coating is undesirably deposited on said walls during formation of said cathode,
- (d) said walls having thereon a coating of a material comprising a chemical compound of an organic material and a portion of said emissive material deposited on said walls, said compound having a secondary electron emission ratio less than one.

2. An electron multiplier having:

- (a) a first dynode,
- (b) said first dynode having walls defining a sole aperture therein,
- (c) a source of primary electrons adjacent to said first dynode,
- (d) said temperature being outwardly flared, from the end thereof remote from said source,
- (e) said walls comprising a coating constituted of a material having a secondary electron emission ratio less than one.

3. An electron multiplier having:

- (a) a flat first dynode,
- (b) said first dynode having walls defining only a single aperture therein having a diameter of about 1 mil,
- (c) said walls having thereon a porous coating of a material having a secondary electron emission ratio less than one.

4. An electron multiplier having:

- (a) a flat first dynode having a coating thereon of a material having a secondary emission ratio greater than one,
- (b) said first dynode having walls defining an aperture therein,
- (c) said walls having thereon a coating of a material having a secondary electron emission ratio less than one.

5. An electron multiplier having:

- (a) a first dynode having a coating thereon of magnesium oxide,
- (b) said first dynode having walls defining an aperture therein,
- (c) a cathode coated with electron emitting material adjacent to said aperture,
- (d) said walls having thereon a coating made of an organic material chemically compounded with a portion of said electron emitting material deposited on said walls during fabrication of said cathode, and having a secondary electron emission ratio less than one.

6. An electron multiplier having:

- (a) a first dynode,
- (b) said first dynode having walls defining an aperture therethrough,

- (c) said aperture communicating with a chamber,
- (d) said walls having thereon a porous coating of a material comprising a compound of electron emitting material and an organic material, and having a secondary emission ratio not greater than one, and being flared outwardly towards said chamber.

7. An electron multiplier having:

- (a) a flat first dynode having a coating of magnesium oxide on one surface thereof,
- (b) an electron beam source adjacent to a surface of said first dynode opposite to said one surface thereof,
- (c) said first dynode having walls defining an aperture therethrough and flaring outwardly toward said electron beam source,
- (d) said walls having thereon a porous coating of a material having a secondary emission ratio not greater than one.

8. An electron multiplier having:

- (a) a flat first dynode,
- (b) said first dynode having flared walls defining an opening therethrough,
- (c) said flared walls having a coating thereon of a material having chemical and mechanical properties for suppression of secondary electron emission from said walls, and
- (d) a plurality of additional dynodes adjacent to said first dynode,
- (e) said flared walls diverging in the direction of secondary electron travel towards said additional dynodes,
- (f) whereby said additional dynodes are preserved from spurious secondary emission from said walls.

9. An electron multiplier having:

- (a) a flat first dynode having a surface characterized by a relatively high characteristic of secondary emission,
- (b) said first dynode having flared walls defining an opening therethrough,
- (c) said flared walls having a porous coating thereon of an organic material for suppression of secondary electron emission from said walls,
- (d) a plurality of additional dynodes adjacent to said first dynode,
- (e) said flared walls diverging in the direction away from said first dynode surface,
- (f) whereby said additional dynodes are preserved from spurious secondary emission from said walls.

10. An electron discharge device having:

- (a) an elongated envelope,
- (b) an electron multiplier system supported in one end portion of said envelope,
 - (1) said multiplier system comprising a flat first dynode having an aperture therein,
- (c) an electron gun adjacent to one face of said dynode and positioned to direct an electron beam through said aperture, and
- (d) a target positioned in the other end portion of said envelope in the path of said beam and adapted to reflect at least a portion of the electrons in said beam toward the other face of said first dynode, whereby the reflected electrons strike said one face of said first dynode and are directed to other dynodes of said multiplier system,
- (e) said first dynode having walls defining said aperture therein,

- (1) said walls having thereon a coating for suppressing secondary electron emission therefrom, whereby said multiplier system is free from spurious electron emission from said walls.

11. An electron discharge device having:

- (a) an elongated envelope,
- (b) an electron multiplier system supported in one end portion of said envelope,
 - (1) said multiplier system comprising a flat first

- dynode having an aperture therein, and other dynodes,
- (c) an electron gun adjacent to one face of said dynode and positioned to direct an electron beam through said aperture,
- (d) said dynode having another face opposite said one face, said opposite face having thereon a coating of magnesium oxide for a ratio of secondary emission therefrom greater than one, and
- (e) a target positioned in the other end portion of said envelope in the path of said beam and adapted to reflect at least a portion of the electrons in said beam toward the said another face of said first dynode, whereby the reflected electrons strike said one face of said first dynode and secondary electrons from said one face are directed to said other dynodes of said multiplier system,
- (f) said first dynode having walls defining said aperture therein,
- (1) said walls being flared away from said one face of said first dynode and having thereon a coating for suppressing secondary electron emission therefrom, whereby said multiplier system is free from spurious electron emission from said walls.
- 12. An electron multiplier having:**
- (a) a flat first dynode having a relatively smooth surface,
- (1) said surface having thereon a relatively thin coating of magnesium oxide,
- (b) said first dynode having walls defining an opening therethrough and diverging as they extend from said surface,
- (c) said flared walls having a porous coating thereon of a material having a relatively low secondary emission ratio for suppression of secondary electron emission from said walls,
- (d) a plurality of additional dynodes adjacent to said first dynode and in electron transfer relation with respect to said coating,
- (e) whereby said additional dynodes are preserved from non-uniform secondary emission from said

coated surface, and from spurious secondary emission from said walls.

13. An electron discharge device having:

- (a) an elongated envelope,
- (b) an electron multiplier system supported in one end portion of said envelope,
- (1) said multiplier system comprising a flat first dynode having an aperture therein, and other dynodes in electron transfer relation to said first dynode,
- (c) an electron gun adjacent to one face of said first dynode and positioned to direct an electron beam through said aperture, and
- (d) a target positioned in the other end portion of said envelope in the path of said beam and adapted to reflect at least a portion of the electrons in said beam toward the other face of said first dynode,
- (e) said other face of said dynode having thereon a coating of magnesium oxide whereby the reflected electrons strike said coated other face of said first dynode and are directed to said other dynodes of said multiplier system,
- (f) said first dynode having walls defining said aperture therein,
- (1) said walls having thereon a coating of substantially pure carbon for suppressing secondary electron emission therefrom, and being outwardly flared as they extend from said coated surface, whereby said multiplier system is free from spurious electron emission from said walls.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,346,752

October 10, 1967

Donald F. Battson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 2, for "wall" read -- walls --; line 25, after "of" insert -- nickelous sulfate, --; column 5, line 39, for "temperature" read -- aperture --.

Signed and sealed this 22nd day of October 1968.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents