

Oct. 13, 1970

M. BLAMOUTIER ETAL

3,534,207

SECONDARY EMISSION CONDUCTIVITY TARGET COMPRISING FLURAL
LAMINATIONS OF DIFFERENT POROUS MATERIALS

Filed June 5, 1967

2 Sheets-Sheet 1

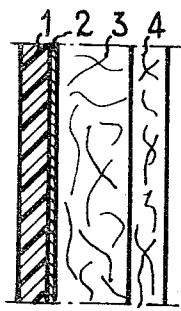
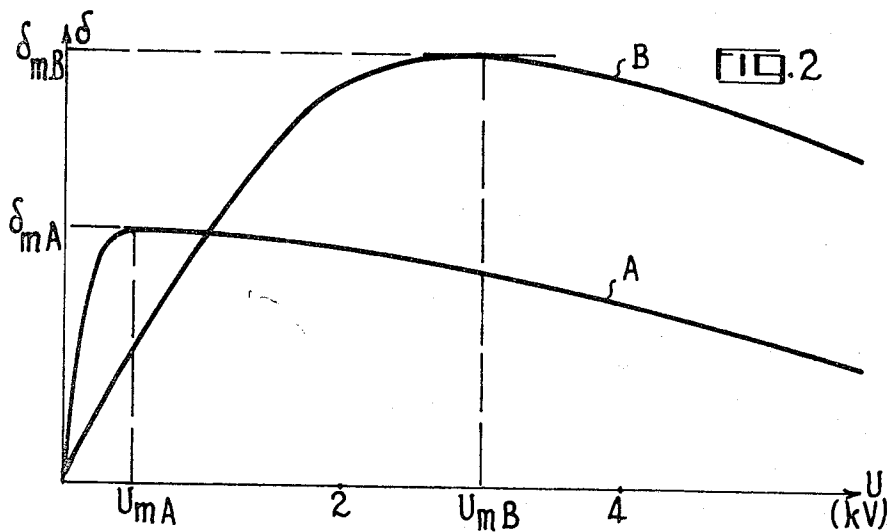
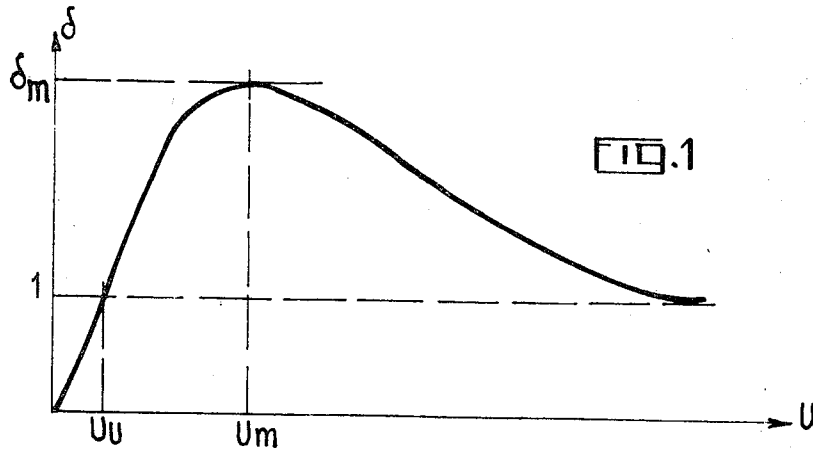


FIG. 3

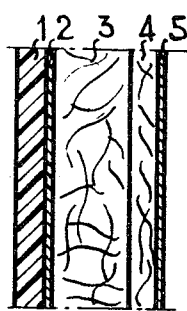


FIG. 4

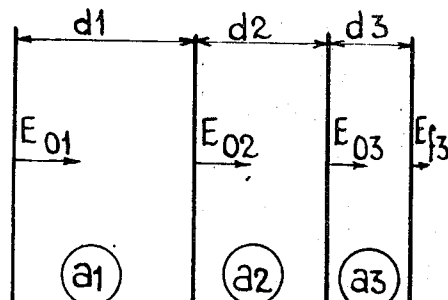


FIG. 6

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Oct. 13, 1970

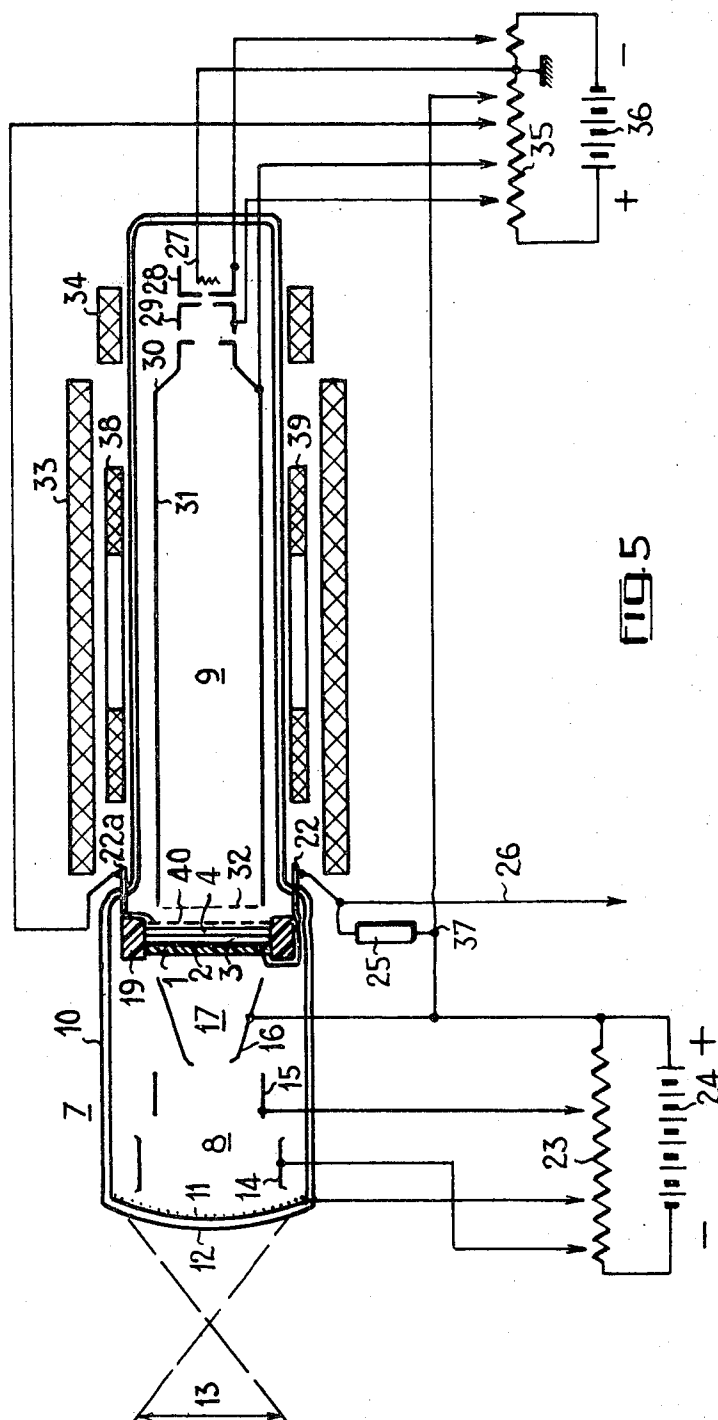
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2 Sheets-Sheet 2



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SECONDARY EMISSION CONDUCTIVITY TARGET COMPRISING PLURAL LAMINATIONS OF DIFFERENT POROUS MATERIALS

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Filed June 5, 1967, Ser. No. 643,456

Claims priority, application France, June 24, 1966, 66,892

Int. Cl. H01j 31/26, 39/04
U.S. Cl. 313—65

9 Claims

ABSTRACT OF THE DISCLOSURE

SEC-type target in which the storage layer bonded to one side of the usual conductive signal plate element comprises a lamination of at least two layers made of porous resistive materials having incrementally decreasing values of the optimal voltage for which the respective materials display maximum secondary emission, said values approximately corresponding to the average residual energies of the incident primary electrons in the respective layers, whereby to improve the over-all secondary emission yield of the target as a whole

This invention relates to target electrodes and dynodes of the so-called secondary-emission conductivity (SEC) type. SEC target electrodes are utilized in various types of electron discharge devices having signal recording and storage properties, including television camera tubes, memory storage tubes and the like. In this disclosure particular reference will be made to camera tubes but it is to be understood that the invention is not limited thereto.

A conventional form of SEC target electrode structure comprises a conductive signal plate element in the form of a very thin metallic foil or film permeable to incident high-energy electrons, and a storage layer bonded to one side of the plate element. The storage layer comprises a highly porous deposit of high-resistance material having good secondary-emission properties, such as potassium chloride, barium fluoride or magnesia. In use, it may be assumed for illustration that a picture beam of primary photoelectrons is emitted from a photocathode positioned on the same side of the target assembly as the signal plate. The photocathode may have a scene optically projected on it or may be otherwise illuminated or irradiated to emit photoelectrons at density rates proportional to the degree of illumination or irradiation of the elementary photocathode surface areas. The photoelectrons are accelerated and focussed on the target assembly so as to strike the signal plate with considerable kinetic energy. These high-energy primary electrons penetrate the signal plate without being appreciably absorbed by it and into the porous storage layer in which they excite secondary emission within the pores. The secondary electrons emitted within the pores and from the surface of the storage layer are removed out of the layer by means of a suitable electric field, and their removal leaves positive charges of holes in the storage layer. The distribution pattern of these positive charges across the surface of the storage layer is an inverted replica of the pattern of incident primary photoelectrons and hence reproduces the brightness distribution pattern across the scene projected on the photocathode.

This charge distribution pattern is read by means of a scanning of low-energy, i.e. slow, read electrons directed from an electron gun at the exposed surface of the storage layer on the side remote from the signal plate element, which beam is deflected in scanning relation across the target surface. The scanning beam is operated at such an energy level that the read electrons just neutralize the

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positive charges in the sequentially scanned areas of the target surface, thereby erasing the charge pattern. Due to this sequential charge neutralizing or erasing action the signal plate will deliver on an output line connected to it a variable-current signal which at any instant of time represents the degree of illumination of the target area being scanned at that instant and constitutes the useful output signal from the device.

An alternative method of utilizing the low-energy scanning or reading electron beam as applied for example in image-orthicon camera tubes, instead of deriving an output signal on a line connected to the signal plate, is to collect the read electrons reflected back from the read surface of the storage layer in an electron multiplier or the like, and use the resulting variable current as the output signal from the device. This invention is to be understood as applicable in conjunction with both reading methods just described, although particular reference will be made in the disclosure to the first method.

Secondary-emission (SEC) target structures, as just defined, are to be distinguished from the so-called electron bombardment-induced conductivity (or EBIC) structures, even though the two types of structure may frequently be used in the same general type of electron discharge tube device. In an EBIC target the requisite transverse conductivity through the structure is achieved, not through the secondary electron emission within the pores of a porous storage layer, but instead through the displacement of charge carriers through the atomic crystal lattice of the storage layer. In an EBIC structure, therefore, it is essential that the storage layer be made at least in part of a suitable high resistance or semi-conductive material in compact form. An outstanding advantage of SEC over EBIC structures lies in the elimination of the difficultly controllable delays or time lags that appear in the operation of the latter structures due to uncontrollable impurities and defects present in the crystal lattice of the constituent materials which act as traps for the carriers and thus reduce their mobility.

It is to be understood that the present invention is directed to SEC structures as distinct from EBIC structures.

The above statements in respect to SEC target electrode structures are equally applicable, mutatis mutandis, to SEC dynode structures, that is, structures made of porous, resistive, secondary emissive material which are adapted to be exposed to primary electrons at one side thereof and emit a greatly amplified beam of output electrons from the opposite side. It is to be understood that while the disclosure will make particular reference to targets, the invention is equally applicable to dynodes.

The invention starts with the recognition that in conventional SEC structure there necessarily is a high proportion of incident primary electrons that do not fully participate in the multiplication process but are absorbed without yielding useful work. The energy of a primary electron decreases gradually as the electron penetrates deeper and deeper into the emissive layer, and there ultimately comes a point at which the electron's residual energy has dropped below the threshold level above which the secondary emission ratio of the material composing the layer exceeds unity. Unless such an incident electron has had the opportunity of expelling secondary electrons before it has reached that point in its travel through the material, it is lost as far as the useful operation of the structure is concerned. More precisely, as will be more clearly understood later, for any type of material there exists a certain optimal value E_m for the energy of a primary electron traversing it, at which the secondary emission ratio is a maximum (δ_m); unless a primary electron knocks out secondary electrons at approximately that point in its travel where its residual energy has that op-

timal value, it produces less than maximum amount of useful work that it could be expected to yield.

According to the invention, the efficiency and gain of an SEC structure can be greatly improved by forming the secondary emissive layer thereof as a lamination of more than one adjacent sub-layers having selected characteristics to be specified below, for ensuring that all or almost all, of the primary electrons produce useful work in exciting secondary emission.

Objects, therefore, of this invention include the provision of improved SEC target and dynode structures in which the secondary emission ratio is maximized at more than one point throughout the depth of the structure; the provision of simple and easily manufactured multilayer SEC electrodes in which the secondary emission yield and consequently the gain of the electrode are substantially improved by suitably predetermining the nature and thickness of each secondary emissive layer composing it. Other objects are to provide electron discharge devices of the class including image converter and brightness amplifier tubes, television camera or pick-up tubes, memory storage tubes and the like, having heightened gain and improved performance due to the improved SEC target electrodes incorporated therein.

In the filed of EBIC targets various structures have been proposed in which more than one different storage layers are provided, for various purposes such as boosting the bombardment-induced conductivity of the target through the use of photoconductivity, cathodoluminescence, and similar effects in addition to secondary emission. In copending application Ser. No. 633,060, filed Apr. 24, 1967, by one of the present co-applicants, there is disclosed a multilayer SEC target structure including a surface layer on the side of the target exposed to the scan or read electron beam, and having characteristics predetermined to prevent or reduce spurious secondary emission that otherwise tends to be excited by the read electrons.

SUBJECT MATTER OF THE PRESENT INVENTION

The present invention is directed to multilayer structures in which the several layers are selected and arranged to achieve improved emission yield and target gain, by forming the target of a lamination of at least two layers of high resistivity, the secondary emissive materials of which are so selected that the optimal voltage values for which the secondary emission ratios thereof are maximal, decrease incrementally from each layer to the next when the layers are traversed in the direction of primary electron travel.

Further, the thicknesses of the layers are so selected with regard to the energy of the incident electrons that the average value of the residual energy of an incident electron within each layer, will approximately equal the said optimal voltage value associated with the material of that layer.

FIG. 1 is a graph showing the variations of secondary emission ratio with primary electron energy for a typical material;

FIG. 2 is a similar graph showing the respective variation curves for two different classes of material as used in the invention;

FIG. 3 is a magnified and stylized sectional view of an EBIC target structure according to the invention;

FIG. 4 similarly shows a modification of the improved structure;

FIG. 5 is a diagrammatic view in axial section illustrating a camera tube embodying the invention; and

FIG. 6 is a diagram of a three-layer structure according to this invention given for purposes of mathematical analysis.

The graph of FIG. 1 illustrates a typical curve showing the variations of the total secondary emission ratio (γ) with accelerating voltage (U) applied to the primary electrons, in an SEC electrode layer. The energy E of

the electrons is given by the formula $E=eU$ in which e is the electronic charge. The curve is representative for practically all known secondary emission substances. The curve is seen to rise rapidly as the accelerating voltage is increased, with the ratio δ exceeding unity at a certain value U_u of the accelerating voltage which may be called the divergence threshold value, and said ratio attaining a maximum δ_m for a certain value U_m , after which the curve drops slowly.

While the general shape of the curve is the same for a wide variety of materials, the individual values differ greatly, especially in the accelerating voltage value U_m for which maximum secondary emission is attained. Thus FIG. 2 shows two curves relating to two different classes of substances in which the values of U_m differ widely. In the class of materials designated "A," the voltage value U_m corresponding to maximum secondary emission ratio δ_m is relatively low say, in a range from 200 to 1,000 volts. For the class of materials with which the curve "B" is associated, the U_m value is considerably higher, say above 2,000 volts. Representatives of class A materials are sodium chloride, lithium fluoride and magnesium oxide. Representative of class B materials are potassium chloride, potassium bromide, sodium bromide, and barium fluoride. Specifically, for KCl, the values U_m and δ_m are respectively about 3 KV and 148, and for NaCl they are about 0.5 KV and 88. The above δ_m values were measured in porous layers 20μ thick.

The improved target assemblies of the secondary emission conductivity (SEC) type according to this invention are characterized in that they comprise composites of A and B class materials, as will now be described.

FIG. 3 shows a SEC target according to one embodiment of this invention as including a laminate of the following layers: Layer 1 is a thin film of alumina, which may be about from 0.05 to 0.1 micron thick, and serves as a mechanical support. Layer 2 is a strip of conductive aluminium foil, e.g. from 0.03 to 0.05 micron thick, which will constitute the signal electrode. Layer 3 is a highly porous coating of "class B" material, e.g. potassium chloride, in highly porous form, and it may be about 20 microns thick. And layer 4 is a coating of "class A" material, e.g. sodium chloride, likewise porous, and its thickness may be about 5 microns. As it will be understood, the values given herein for the thickness of the various layers are mainly illustrative and the actual thicknesses may depart substantially from those indicated. Depending on conditions of use, layer 3 may have a thickness of from about 15 to 50 microns and layer 4 from about 2 to 15 microns. Practical procedure for making a composite target assembly of the kind just described will also be described later.

In the operation of a SEC target screen according to FIG. 3, it may be assumed that a picture beam of photoelectrons emitted from a photocathode positioned to the left of the FIG. 3 assembly and having a scene optically projected thereon, are accelerated and focussed on the target assembly so as to strike its left-hand surface with considerable energy. These electrons penetrate through the insulating and conductive layers 1 and 2, and into the first porous layer 3, comprising potassium chloride, exciting secondary emission therein. Those of the primary electrons that have sufficient energy continue through layer 3 and into layer 4 comprising sodium chloride and excite secondary emission in this layer also.

The secondary electrons from both layers 3 and 4 are removed by means of a suitable electric field, and their removal leaves positive charges or holes in the target assembly. The distribution pattern of these positive charges across the target screen is an inserted replica of the pattern of impinging primary photoelectrons and hence reproduces the brightness distribution pattern in the scene projected on the photocathode. A beam of slow-moving read electrons is directed from an electron gun at the right side of the target assembly so as to scan the

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target surface and sequentially neutralize the positive charges in the sequentially scanned areas of said surface. Due to this sequential charge neutralizing action the signal electrode 1 delivers a variable current signal which at any instant of time represents the degree of illumination of the target area being scanned at that instant and constitutes the useful output signal from the device.

The manner of operation just described is conventional for SEC type targets except for the important differences introduced by the provision of the sequential layers 2 and 3 selected as indicated herein, and these differences in operation will now be described.

The primary photoelectrons striking the left side of the target assembly of FIG. 3 lose a small amount of energy in penetrating through the insulating alumina film 1 and the conductive aluminum signal plate 2, and then progressively lose more and more energy as they travel through the porous secondary emissive layers 3 and 4. At any particular point of its travel through these layers, a primary electron will only be capable of useful action if its residual energy at that point exceeds the threshold value eU_0 at which the secondary emission ratio δ exceeds unity, as shown in FIG. 1. Further, said useful action will be greatest if the average energy of the primary electron in the layer is approximately equal to the value eU_m , corresponding to maximum secondary emission in the layer. Through the use of two laminated layers in which the substance of the first layer has a higher U_m value and the substance of the second layer has a lower U_m value, it is possible to arrange matters so that the average value of the residual energy of the primary electrons travelling through each layer, will have a value corresponding approximately to the particular U_m value in the layer. In this way the efficiency of the primary electron beam in exciting secondary emission in the composite target is substantially maximized. This contrasts with SEC targets of conventional type which include a single secondary emission layer or more than one layer of secondary emission material selected without regard to the teaching of the present invention. In such conventional target assemblies those primary electrons that penetrate to a great depth into the target material and lose most of their energy in the process do not participate to an appreciable degree in the useful work of producing positive charges on the target, and the over-all efficiency is lowered relatively to what is attainable by the use of the present invention.

The above can be clarified by mathematical analysis. The residual energy of an electron that has penetrated a layer of matter is given by the equation

$$E_x = \sqrt{E_0^2 - ax} \quad (1)$$

where E_x is the residual energy of the electron at a depth of x from the surface of the layer, E_0 is the initial energy of the electron on striking the surface of the layer, a is a coefficient depending on the nature and condition of the material comprising the layer.

Considering a layer of depth d , the mean residual energy of a primary electron over the layer is:

$$\bar{E} = \frac{1}{d} \int_0^d E_x dx = \frac{1}{d} \int_0^d \sqrt{E_0^2 - ax} dx \quad (2)$$

integrating:

$$\bar{E} = \frac{2}{3} \frac{1}{ad} [E_0^3 - (E_0^2 - ad)^{3/2}] \quad (3)$$

Now considering a lamination of more than one layer as shown in FIG. 6, and using the same symbols as above followed by the subscript i ($i=1, 2, 3, \dots$) to designate the respective layers, we can see from Equation 3 that the following relation should hold for each layer of

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a laminated target assembly according to this invention, since it is desired that $\bar{E} = \bar{E}_m$ for each layer:

$$\frac{3}{2} a_i d_i E_{mi} = E_{0i}^3 - (E_{0i}^2 - a_i d_i)^{3/2} \quad (4)$$

Referring back to Equation 1, it is evident that the residual energy of a primary electron emerging from a layer of rack i , is

$$E_{fi} = \sqrt{E_{0i}^2 - a_i d_i} \quad (5)$$

Hence, relation (4) can be rewritten:

$$\frac{3}{2} a_i d_i E_{mi} = E_{0i}^3 - E_{fi}^3 \quad (6)$$

Writing Equation 6 for each layer in the lamination, and noting that the initial energy of an electron entering one layer equals the final energy of the electron emerging from the preceding layer (that is $E_{0i} = E_{fi(i-1)}$), we obtain, for a three-layer lamination:

$$\frac{3}{2} a_1 d_1 E_{m1} = E_{01}^3 - E_{f1}^3$$

$$\frac{3}{2} a_2 d_2 E_{m2} = E_{f1}^3 - E_{f2}^3$$

$$\frac{3}{2} a_3 d_3 E_{m3} = E_{f2}^3 - E_{f3}^3$$

Adding these equations, and finally observing that the residual energy E_{f3} of a primary electron emerging from the ultimate layer can be considered negligibly low, we obtain:

$$\sum_{i=1, 2, \dots} a_i d_i E_{mi} = \frac{2}{3} E_0^3 \quad (7)$$

Equation 7 shows that by suitably selecting the materials and thicknesses of the respective layers, it is possible to construct optimal laminated target assemblies for different given values of the initial energy E_0 , i.e. for different given values U_0 of the accelerating voltage at the incidence. The layers can be more than two in number if desired. The optimal values U_m of the accelerating voltage will be incrementally decreasing in the successive layers. The efficiency of a SEC structure can thus be optimized for a broad range of specified conditions. It should be understood that while the above analysis and equations indicate the optimal theoretical conditions that should be satisfied in order to derive full benefit from the inventive concept, in practice it is not essential that the theoretical condition specified by the equations be strictly adhered to SEC assemblies having substantially improved yield or gain over those of the prior art, even though such improvement is not the maximum achievable, can be constructed by providing two (or more) layers in which the U_m values for the respective constituent materials are incrementally decreasing, so that a greater number of primary electrons are made to develop useful work than would otherwise be possible, even if the thicknesses and other parameters of the respective layers depart from the theoretical values given by the above Equation 7. Consequently, the above theoretical analysis should not be interpreted as setting limits to the scope of this invention.

A target assembly according to FIG. 3 can be constructed as follows. The base assembly comprising the alumina foil 1 and aluminum foil 2 is first produced by conventional techniques, such as a process comprising the steps of anodizing an aluminum sheet in order to oxidize it into alumina over a specified depth, removing what remains of the aluminium by etching, and then evaporation-depositing aluminium on alumina film, under a pressure less than 10^{-5} mm. Hg. The alumina film 1 may be from 0.05 to 0.1, e.g. about 0.07 micron thick and the aluminium foil 2 from 0.03 to 0.05, e.g. about 0.04 micron thick. In order to form the "class B" porous emissive layer 3, of potassium chloride, a suitable amount of this

substance may be placed in a "boat" type receptacle made of platinum at a distance of 50 mm. from the base assembly formed as just described, in a vacuum vessel containing nitrogen or other inert gas at a pressure of about 2 mm. mercury. The boat is then heated by Joule effect to about 900° C. to evaporate the KCl and deposit it in the form of a porous or spongy coating 20 microns deep on the aluminum side of the base assembly. The apparent density of the spongy KCl layer deposited under these conditions is about 2% the true density of compact KCl. However, apparent densities as high as 5% the true density are still found suitable.

The second porous emissive layer 4 of "class A" material may be formed in a similar way in the same or a similar vacuum evaporation vessel by placing a charge of sodium chloride in a platinum boat at a distance from the previously prepared assembly and heating the boat to 950° C. to evaporate the NaCl and deposit it as a porous layer over the porous KCl layer. This evaporation-deposition process is continued only long enough to provide a NaCl layer about 5 microns thick. The gas pressure used in this last evaporation-deposition step may be the same as that used in the KCl deposition step, or preferably slightly higher. By controlling the gas pressure during the KCl and NaCl deposition steps it is possible to control the degree of porosity of the respective deposited layers 3 and 4 within certain limits and thereby control the coefficients a_1 and a_2 in the equations previously written herein.

The above referred to copending application Ser. No. 633,060 filed Apr. 24, 1967 discloses a SEC type target assembly including a first or main emissive layer followed by a second emissive layer whose emission-divergence energy threshold is higher than that of the first. By "emission-divergence energy threshold," as will be recalled, is meant the energy of the incident primary electrons above which the secondary emission ratio δ of the layer substance exceeds unity. The object of this higher-threshold layer provided on the side of the assembly directed towards the scanning electron beam, is to prevent or retard the emission of secondary electrons by the incident scanning electrons. Such spurious secondary emission has, in the past, tended to cause a saturation of the useful positive charges in the target and thereby limited the amplitude of the output signal from the device.

It will be readily apparent that the respective teachings of the earlier application and the present invention are independent of one another, and they may be combined into a single structure which will combine the benefits derived from both arrangements. Such structure will now be disclosed with reference to FIG. 4.

The composite SEC target assembly shown in FIG. 4 includes the layers 1, 2, 3 and 4 which may be similar to the correspondingly-numbered layers in FIG. 3. Overlying the class-A layer 4 is an outermost layer 5 directly exposed to the beam of scanning electrons, and comprising a substance having an emission-divergence threshold energy that is substantially higher than that of the adjacent layer 4. Preferably the threshold energy of the outermost layer 5 is higher than about 50 electrons volts. This generally corresponds to an emission ratio α less than about 0.7 for incident electron energies of 15 electrons volts. The outermost layer 5 is preferably somewhat less porous than the underlying layers 3 and 4, and may be composed of any of the substances mentioned as suitable for the surface layer in the co-pending application, such as silicon monoxide, silicon dioxide, calcium fluoride.

In one exemplary procedure the target assembly of FIG. 4 may be produced by placing the structure of FIG. 3 in an evaporation depositing apparatus and evaporating silicon in an argon atmosphere at 0.5 mm. Hg pressure so that it will settle over the exposed surface of the layer 3 and then oxidizing the deposited layer in pure oxygen at atmospheric pressure so as to produce a porous silicon monoxide and/or dioxide layer having an apparent density

about 15% that of the compact substance, to a depth of about from 3 to 8 microns.

FIG. 5 illustrates a camera tube embodying the improved target assembly of this invention. The camera tube generally designated 7 can be considered as comprising an input-output section 8 and a scanning section 9, both arranged in a common evacuated envelope 10. The input-output section 8 includes a photocathode 11 comprising a suitable photoemissive layer deposited on the inwardly concave end face 12 of envelope 10. Thus the photocathode 11 will, in the operation of the tube, emit photoelectrons with a local density from each point thereof corresponding to the local brightness at that point of an image formed on the photocathode by projecting a scene 13 through a suitable optical system not shown. Disposed in the input-output section 8 is a set of coaxial accelerating and focussing electrodes 14, 15 and 16, connected to suitable potentials relative to cathode 11 as later disclosed, so as to accelerate the emitted photoelectrons and focus them upon a SEC target assembly 17 constructed according to this invention, for example as described with reference to FIG. 3. The target assembly 17 is supported in a mounting ring 19, e.g. of ceramic, which in turn is supported in tube envelope 10 by means shown as including the axially extending metal rods 22 and 22a serving as electric connectors as will be presently described.

The power supply means for the input-output section 7 comprises a high-voltage D-C source 24 having a potentiometer resistance 23 connected across it and a plurality of voltage taps along the resistance, connected to the various electrodes as shown. By way of example, photocathode 11 may be connected to a -10,000 volts tap of resistance 23, and the accelerating and focussing electrodes 14, 15, 16 may be connected respectively to -11,000 v., -8,000 v. and the end tap of the resistance which is at a reference potential of +10 volts in this example. The signal output electrode 2 of the target 17 is shown connected by way of connector rod 22 and a load resistor 25 to the reference terminal 37 of the source. Connected to rod 22 between the signal electrode 2 and load resistor 25 is a signal output lead 26.

The scanning section 9 comprises an electron gun positioned in the end of envelope 10 remote from photocathode 11 and comprising a heated cathode 27 followed by a series of coaxial electrodes including Wehnelt electrode 28 and positive electrodes or anodes 29 and 30. The anode 30 has a cylindrical drift tube 31 extending from it towards the target 17 and terminating somewhat short thereof with a fine-mesh field grid 32 supported across the end of tube 31 at a distance of e.g. about 3 mm. from the surface of the outermost layer 5 of target 17. The usual electromagnetic coils are provided around the scanning section of the tube envelope 10, including focussing coil 33 and alignment coil 34, and two pairs of mutually perpendicular deflection yokes one of which is shown as comprising the pair of coils 38 and 39.

The power supply means for the scanning section 9 comprises a relatively low-voltage D-C source 36 having a potentiometer resistance 35 connected across it with a plurality of voltage taps connected to the scanning beam control electrodes as shown. Thus, the cathode 27 is shown connected to the 0 volt (grounded) terminal, while electrodes 28, 29, and 30-32 are shown respectively connected to -60 v., +300 v. and +270 v. The reference terminal 37 of the high voltage source is connected to a +10 v. tap of low voltage resistance 35, as shown.

An auxiliary fine-mesh screen 40 is supported from ceramic ring 19 at an intermediate position between the target assembly 17 and field grid or screen 32. The auxiliary, or stabilizing, screen 40 is connected through post 22a with a potential tap along resistance 35 intermediate between the potentials of scanning gun cathode 27 and field grid 32, e.g. +60 volts.

Reviewing the operation of the camera tube just described, photoelectrons from photocathode 11 on striking the target assembly 17 with high kinetic energies traverse the alumina film 1 and aluminium foil 2 constituting the output signal electrode, being somewhat retarded thereby, and penetrate the porous emissive layers 3 and 4 releasing proportionately very large numbers of secondary electrons in the pores thereof as earlier described. It is noted in this connection that if in the device described the total secondary emission current is measured as the sum of the current collected on conductive plate 1, and the current flowing to the field grid 32, such total secondary emission current will be found to exceed the input current applied by the incident photoelectrons by a multiplying factor which exceeds many times, the secondary emission ratios previously referred to. This is typical of SEC targets and is due to the fact that each incident primary electron sustains a large number of impacts in the porous material, each impact releasing secondary emission.

The secondary electrons released from the emissive coatings of the target assembly 17 are removed by means of an electric field present between the output signal electrode 2 and the scan surface of the target, thereby leaving positive charges behind them at the scan surface. The distribution of these positive charges precisely reproduces the pattern of the primary photoelectrons striking the side of the target directed towards the photocathode and hence the brightness distribution pattern in the image projected on the photocathode, but is greatly increased in intensity as compared to the charge distribution created by the photoelectrons owing to the secondary emission effect, thus providing considerable gain. The positive charge distribution across the target is not instantly dissipated but persists for a very short yet not a negligible time owing to the low electric conductivity in directions parallel to its general plane.

This pattern of positive charge distribution across the target is now read by means of the scanning electron beam in the following manner. The electrons emitted by the electron gun are first axially accelerated and focussed by the combined action of the electrostatic electrodes 28-29-30 and electromagnetic coil 33 so as to be formed into a narrow beam which is scanned across the target screen by the action of the deflecting yokes such as 38-39. The axial acceleration of the electrons in this scanning beam proceeds as far as the field grid 32, after which the electrons are retarded by the reverse field so that on striking the surface of target 17 their residual energy is only that corresponding to the potential difference between the cathode 27 and the target surface. This potential difference is practically null in the absence of a picture beam striking the opposite side of the target from the photocathode, but in the presence of a picture beam the scanning electrons will strike every illuminated area of the target surface with an energy proportional to the positive charge stored in that area and therefore proportional to the degree of illumination thereof as will be understood from the foregoing disclosure. Thus the effect of the scanning beam is to nullify the positive charges on the target, or in other words to equalize the charge distribution pattern formed on the target so that in the steady state the potentials at all points of the target become established at a uniform equilibrium value close to that of the cathode 27. This equalizing process generates a variable current on output line 26 which at any instant of time represents the degree of illumination of the target area being scanned at that instant.

When the target screen 17 is constructed in any of the ways usual prior to the present invention, that is with a single secondary emissive porous layer, or with multiple emissive porous layers the characteristics of which have not been predetermined according to the teachings of the present invention but with some other objective in mind, for instance as disclosed in the co-pending application identified above, the full energy of the picture

beam of photoelectrons is not utilized because the photoelectrons gradually lose energy as they travel deeper and deeper into the layer and many of them will have a residual energy that does not exceed (or only slightly exceeds) the divergence threshold at the time they sustain impacts capable of liberating secondary electrons. Such primary electrons are then absorbed without having produced much useful work or any useful work at all. By providing the two layers 3 and 4 having the characteristics described above, on the other hand, it is ensured that the proportion of primary electrons wasted in this way is greatly diminished.

Experience has confirmed the above theoretical views. It has been determined that a tube constructed and operated as described with reference to FIG. 5 except that the target screen 17 therein was a conventional one using a single potassium chloride layer of otherwise comparable characteristics to the target described with reference to FIG. 3, displayed a target gain of 150 for an output signal current of 50×10^{-9} amperes. When a target according to the embodiment of FIG. 3 described above was substituted, the target gain was found to be increased to 200 or more for the same output current, which is an improvement of at least 33%.

The resulting tube while of increased efficiency still retained another deficiency of prior tubes of the class here envisaged, which is the fact that for proper operation of the tube the stabilizing grid 40 had to be connected to a relatively low potential, about 20 volts, in order to prevent the scanning electrons from gun cathode 27 from exciting spurious secondary emission at the target surface exposed to the scanning beam. For the same reason the stabilizing grid 40 had to be positioned very close to said target surface, about 0.5 mm. away. This correspondingly limited the maximum amplitude of the output signal and undesirably increased the output capacity. Further the storage capacity of the two-layer target assembly of FIG. 3 in respect to the accumulation of charges between two scanning periods, was slightly decreased owing to the more homogeneous distribution of charges and the field in the layer. This also tended to lower the useful output signal current. By substituting the preferred form of target assembly described with reference to FIG. 4, these defects were eliminated. The stabilizing grid 40 could be positioned substantially further away from the target surface and connected to a higher voltage, about 50 volts, without any spurious secondary emission being produced by the scanning electrons, because of the heightened divergence threshold energy of the outermost layer 5 in FIG. 4. Thus the potential of the scan surface was allowed to reach higher values and, consequently, the maximum useful signal amplitude was increased. The target gain was maintained substantially at the same value as when the embodiment of FIG. 3 was used.

It will be understood that various modifications in and departures from the embodiments of the invention disclosed and illustrated may be made without exceeding the scope of the invention. As earlier indicated, the invention is applicable to dynode structures, in which case the metal signal plate such as 2 in FIGS. 3 and 4 may be omitted. A wide variety of materials other than those specifically referred to may be used. The theoretical statements and mathematical analysis given herein are believed to present a correct picture of the invention as at present understood, but the invention does not depend on such theory for its operativeness, and the said statements and analysis should accordingly be regarded as illustrative rather than restrictive.

What is claimed is:

1. An electron discharge device comprising:

an evacuated envelope;

means positioned in one section of the envelope for producing a high energy electron beam having a prescribed density pattern;

means positioned in another section of the envelope for producing and deflecting a low energy beam of reading electrons;

a secondary emission conductivity target structure positioned between said beam producing means and having

a plate element of conductive material exposed and permeable to said high energy beam and

a storage layer bonded to the side of said plate element remote from the side thereof exposed to said high energy beam;

means connected for response to the degree of charge neutralization for producing a variable current signal representing said density distribution pattern across the high energy beam; and

means maximizing the secondary emission of electrons in said storage layer by the high energy electrons penetrating therinto, said means comprising forming said storage layer of at least two laminations made of different porous materials of substantially the same porosity, the porosity of each being such that the apparent density of each lamination is less than about 5% of the true density of the material in the compact state, said materials having high resistivity and high secondary emission properties and having different energy values at which the secondary emission ratios are maximal, the material having a higher energy value and forming a first lamination being located closest to the side exposed to said high energy beam, so that the energy values for said materials decrease incrementally in the respective laminations from the side exposed to said high energy beam to the opposite side of the layer whereby the secondary electrons excited by said high energy beam are absorbed by said plate element of conductive material and leave corresponding positive charges in said laminated storage layer in a pattern corresponding to said density distribution pattern across the high energy beam, which charges are neutralized by said low energy beam.

2. A device according to claim 1 wherein the thicknesses of said laminations are so selected that the mean residual energies of said high energy primary electrons with the respective laminations are approximately equal to the energy values at which the secondary emission ratios of the materials are, in the respective elementary layers, maximal.

3. A device according to claim 1, wherein said first lamination is about from 15 to 50 microns thick and a

second lamination is about from 2 to 10 microns thick.

4. A device according to claim 1, which further includes a resistive surface layer bonded to the last of said laminations at the side remote from the side exposed to the high energy beam, which surface layer is composed of a material having a threshold energy value above which the secondary emission exceeds unity, which is substantially higher than said threshold energy value for the material of said last of the first-mentioned elementary layers.

5. A device according to claim 4, wherein said surface layer comprises a material selected from within the class consisting of calcium fluoride, silica and silicon monoxide.

6. A device according to claim 4, wherein said surface layer is substantially less porous than are said laminations.

7. The device defined in claim 1, wherein said signal producing means comprises an output conductor connected to said plate element.

8. The device defined in claim 1, wherein said surface layer materials has a secondary emission ratio less than about 0.7 for incident particle energies of about 15 electrons volts.

9. The device defined in claim 1, which is a picture tube, and said high energy electron beam producing means comprises a photocathode.

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U.S. Cl. X.R.

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