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BOMBARDMENT CONDUCTING TARGET

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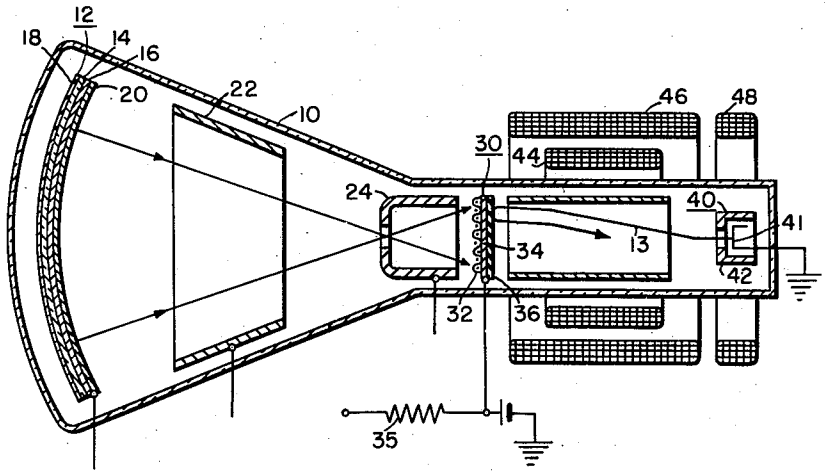


Fig.1.

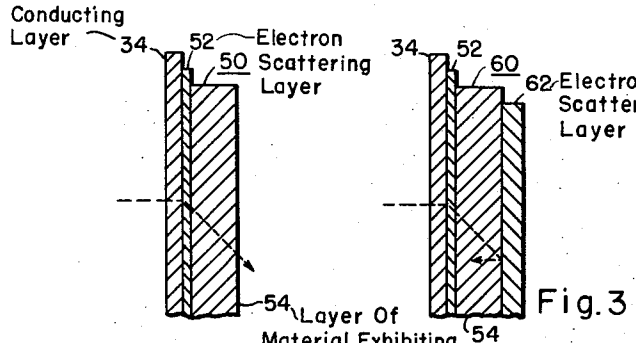


Fig.2.

Fig.3

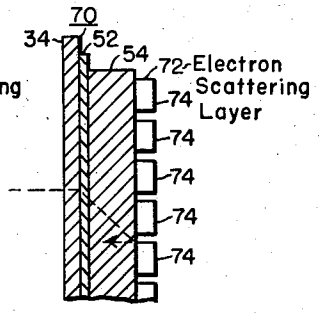


Fig.4.

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BOMBARDMENT CONDUCTING TARGET

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6 Claims. (Cl. 313—355)

This invention relates to bombardment-induced conductivity in insulators and to applications within electrical devices.

The principles of my invention may be employed in an X-ray intensifying device, such as disclosed in my copending application entitled X-ray Image Intensifying Device, Serial No. 416,879, filed March 17, 1954. In X-ray image intensifying devices of this type, the X-ray image is focused upon a fluorescent screen which excites the phosphor therein producing a light image which in turn causes a closely adjacent photocathode electrode to provide photoelectron emission at a rate proportional to the brightness of each element. The photoelectrons are accelerated to a velocity of the order of 10 to 20 kilovolts and focused to a reduced size upon a target electrode including a semi-insulating layer of material exhibiting the property of electron bombardment induced conductivity. The electron image from the photocathode penetrates through a thin electron permeable aluminum backing layer on the target to produce on the insulating layer what may be thought of as a conductivity inverted image duplicating the space distribution of the electron image from the photocathode, and so of the X-ray image.

In the scanning section of the tube, an electron beam is provided on the opposite side of the target with respect to the photocathode and scans the face of the semi-insulating layer to bring the entire surface to a similar potential as the cathode of the electron beam generating gun. With no X-rays projected onto the input screen, the face of the semi-insulating layer facing the electron gun is maintained at cathode potential normally ground while the other surface by means of the aluminum backing layer may be retained at a positive potential with respect to the gun cathode of the order of 50 volts. When the X-ray image is projected onto the input screen, photoelectrons from the photocathode bombard the bombardment surface of the target and induce conductivity in the semi-insulating layer and causes the scanned surface of the insulator to act as a leaky capacitor and change from electron gun cathode potential to some positive potential less than 50 volts. This effect on the semi-insulator may be referred to as a conductive image. The change in potential of elements of the scanned surface is roughly proportional to intensity of bombardment. When the electron scanning beam scans the surface, each element will be restored to gun cathode potential. A signal may be derived from the backing plate in conventional manner for transmission or direct connection to a conventional display device.

In targets of the type described above, it has been found by utilizing materials such as antimony trisulphide and arsenic trisulphide which exhibit electron-bombardment induced conductivity, that the conductivity is dependent on short-range carriers. The electron-bombardment induced conductivity effect is set forth in more detail in an article entitled "Electron Bombardment Conductivity of Dielectric Films" by F. Ansbacher and W. Ehrenberg

in the Proceedings of the Physical Society, London, April 1951, vol. 64, sec. A, pages 362 to 379. The range of these carriers is thought to be of the order of 0.1 micron. The limitation of the short-range carriers within these materials requires that in order to insure conductivity through the entire layer the incident bombarding electrons from the photocathode must substantially penetrate the entire layer. It has been found that a semi-insulating layer prepared by evaporation in a vacuum having the thickness of two microns must be bombarded with electrons of voltages in excess of 25 kv. in order to penetrate the bulk of the material and thereby induce conductivity. If the entire target is not penetrated, then the target has a very low sensitivity due to the short-range charge carriers. It is desirable to attempt to limit the required accelerating voltages of the electrons from the photocathode to below 25 kilovolts. However, even though it is practical to evaporate a thin semi-insulating layer, the target now suffers from high capacity between the scanned surface and the back plate surface or bombardment surface. The high capacity of the target results in that the electron scanning beam cannot fully discharge the stored signals during a single scan, and an objectionable time lag in the transmitted picture is obtained.

It is, therefore, an object of my invention to provide an improved bombardment-induced conductivity target.

It is another object to provide a target of low capacity and thereby remove objectionable time lag within the transmitted picture.

It is another object to provide an improved image pick-up device of high sensitivity.

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

Figure 1 is a schematic view in longitudinal section of a prior art device that may be used to embody the principles of my invention;

Fig. 2 is a view in section of enlarged scale of a part of a target embodying my invention that may be employed in Fig. 1;

Fig. 3 is a view in section of enlarged scale of a modified target embodying my invention; and

Fig. 4 is a view in section of enlarged scale of another modified form of a target embodying my invention.

Referring in detail to Fig. 1, a vacuum-tight enclosure or envelope **10**, which may be of any suitable material such as glass, has an input screen **12** positioned at one end of the envelope **10** which is comprised of a thin glass curved plate **14** coated on its inner concave surface with a thin layer **16** of transparent conductive material, such as stannic oxide, and the latter coated with a photoemissive material **20**, such as cesiated antimony. The convex or outer surface is coated with a layer of fluorescent material **18**, such as zinc cadmium sulphide. It is obvious that in applications where the photoemissive material is sensitive to the radiations such as ordinary light, that the fluorescent layer may be dispensed with.

The X-ray image is projected into the input screen **12** through the wall of the enclosure **10** and light is generated within the X-ray excited fluorescent layer **18** and is transmitted through the glass support member **14** and the conductive layer **16** to the photoemissive layer **20**. The light from the fluorescent layer **18** generates at the surface of the photoemissive layer **20** an electron image which is a replica of the X-ray image incident on the input screen **12**. A suitable electron lens system, such as illustrated by the electrodes **22** and **24** provided with suitable voltages, focuses and accelerates a contracted replica of the electron image onto a target **30**. The target **30** comprises essentially a screen **32** of metal wire

which serves as a support member for the target **30** and has a large ratio of open space to a solid area. If a suitable backing layer is utilized, this support mesh **32** may be dispensed with. The support mesh **32** has an aluminum backing layer **34**, thin enough to be permeable to electrons, deposited on the surface of the mesh **32** opposite to the input screen **12**. The aluminum layer **34** serves as the backing plate of the target **30** and is connected to the exterior of the tube for application of a suitable voltage and from which an output signal may be derived from a resistor **35**. The exposed surface of the aluminum layer **34** is coated with a thin layer **36** of a simi-insulating material or dielectric which exhibits the property of electron-bombardment induced conductivity.

The exposed face of the dielectric layer **36** of the target **30** is scanned by an electron beam **13** directed upon it by a suitable cathode-ray gun **40** comprising at least a cathode **41**, focusing electrodes **42**, deflecting coils **44**, focusing coil **46** and aligning coil **48** of suitable forms. The cathode **41** of the electron gun **40** may be connected to ground.

The mode of operation of the device has previously generally been described within the statement of the invention and a more thorough description may be found in the above-mentioned copending application.

Referring in detail to the structure of the target **30** and specifically to the semi-insulating or dielectric coating **36**, it is conventional to form these coatings by evaporation within a vacuum. The semi-insulating materials utilized within image intensifier application must have characteristics such that the product of its resistivity and specific dielectric constant is equal to or greater than 10^{12}. Resistivity is given in ohm centimeters and specific dielectric constant with air as a reference equal to unity. This figure is necessary in order that the charge placed on the insulator surface will not leak through appreciably to the opposite side or back plate in the absence of any electron bombardment in the standard $\frac{1}{30}$ second TV frame interval. This material may be referred to as a semi-insulator. The semi-insulator material utilized in the layer must also exhibit the property of high electron-bombardment induced conductivity which is exemplified in that on the average for each bombarding electron of the energy of 10 kv. to 25 kv., ten or more electronic charges flow by means of carriers from one surface to the other surface of the target with a field impressed thereon of the order of 5,000 volts/cm.^{2} or greater. This in effect decreases the resistance between surfaces of the target. Suitable materials which possess these properties are antimony trisulphide, arsenic trisulphide and amorphous selenium.

In a conventional method of depositing these insulating layers by evaporation in a vacuum, the deposit that is obtained is of a density that is equal to that normally listed for the bulk material, in the case of arsenic trisulphide 3.43 grames/cm.^{3}. If the insulating material is evaporated in a few millimeters of mecury pressure of an inert gas, such as argon, it will deposit as a smoke-like layer whose average density is much less than that of the bulk material. By this latter method of evaporation, it is, therefore, possible to deposit a layer of insulating material with lower effective dielectric constant resulting in lower capacity due to space between particles and high penetrability to electron bombardment. Although this structure exhibits the properties of low capacitance, it is not satisfactory as a target due to the high penetrability of the electrons without loss of energy. It is found that an electron having a voltage of 25 kv. goes completely through a low density deposit of 2 to 3 microns in thickness with little loss of energy. It is necessary that an appreciable amount of the bombarding electrons' energies must be given up in the insulating material in order to induce conductivity. It is thus seen that a target comprised of a smoke-like or low density deposit of semi-insulating material on an aluminum backing plate alone would have low sensitivity.

In order to fully appreciate the principles of my invention, it is necessary to study the movement of bombarding electrons within a material. For example, when electrons bombard a semi-insulating target, it is found that some of the electrons are completely absorbed in the material, others are altered in direction by successive scattering events and traverse relatively long paths while others may emerge without loss of energy. In materials of relatively low atomic number, such as arsenic trisulphide which has an equivalent atomic number 23, very little scattering of electrons takes place. In the case of a vacuum deposited layer of insulating material of low atomic number, the absorption of energy per unit path length is moderately high, while in the case of the smoke-like layer deposited in the inert atmosphere, absorption is very low. High atomic-numbered materials, such as gold, have a very high absorption per unit length, as well as a high scattering coefficient with respect to electron bombardment. Therefore, if the path of a primary electron is kept short by using a thin film of high atomic-numbered material, the total absorption will be small. However, there will be a considerable amount of scattering of the electrons incident on the gold film, and electrons are scattered over a wide range of angles, both forwards and backwards.

In Figs. 2, 3 and 4, enlarged sections of a very small portion of three different type target structures are shown embodying my invention. The effect of the aluminum back plates on the incident electrons is negligible as far as scattering or absorption. The actual mechanisms of absorption and scattering within a solid are very complex. The dotted lines within Figs. 2, 3 and 4 indicate crude representation of the most probable type of path under existing conditions. As the electron coming from the input screen is absorbed and scattered within the insulating material, it initiates many secondary effects, one of which is the excitation of carriers which drift through the material under the influence of the electric field applied between the back plate and the scanned surface. A representation of the secondary effects within the insulating layer is not shown. It is these carriers that establish conductivity within the insulating layer and, therefore, between the faces of the insulator. It is found that one bombarding electron may excite enough carriers so that 100 electronic charges are transported between the faces of the insulator.

In the case of the vacuum-evaporating coating of given thickness, the electron of a given energy is absorbed by the insulating layer before total penetration occurs, and bombardment-induced conductivity cannot take place under these conditions in materials with short-range carriers, such as arsenic trisulphide and antimony trisulphide. In the case of the smoke-like deposit of similar thickness on the aluminum backing plate, the bombarding electron of similar energy would totally penetrate the layer with small energy loss, and, therefore, only slight bombardment-induced conductivity in the material would take place.

In the specific embodiment shown in Fig. 2, the target comprises a layer of gold **52** of the order of 50 to 100 angstroms in thickness deposited on the aluminum backing plate **34** prior to the evaporation of a smoke-like deposited layer **54**. A bombarding electron striking the thin gold layer **52** is deflected at an angle so that it traverses along a longer path within the insulator **54** than an electron entering the semi-insulator **54** normal thereto. A gold layer 50–100 A. thick will scatter 20 kv. electrons to appreciable angles without their losing appreciable energy. The effect of the deflecting layer **52** may also be obtained by embedding particles within the insulator **54**. Due to the longer path taken by the bombarding electron, the yield of carriers within the insulator **54** is increased and therefore conductivity enhanced.

In Fig. 3, there is shown another embodiment of my invention in which the target **60** comprises a continuous gold film **62** relatively thick with respect to the first gold film **52** of the order of at least 500 A. in thickness evaporated on the scanned side of the insulator **54**. Due to the high reflectivity of the gold layer **62**, the incident electrons after passing through the insulator **54** will be back scattered into the insulator **54**. The back scattered electrons passing through the insulator **54** will give a further increase in yield of carriers and thus increased induced conductivity. The layer **62** should be of sufficient thickness so that no electrons completely penetrate the layer **62**.

In Fig. 4, the target **70** is comprised of a coating **72** applied on the scanned side of the insulator **54** applied in the form of a mosaic which is a large number of separate discrete layer elements **74** laid down side by side and separated from each other of similar thickness to layer **62**. The mosaic coating **72** is necessary in order to form a varying charge pattern on the scanned surface which is required in image intensifier devices. One method of making a mosaic-like layer of gold as shown in Fig. 4 is to evaporate within a vacuum from a concentrated source through a fine mesh screen. The coating or layer **72** may be separated from the semi-insulator **54** limited by the resolution desired.

In the specific embodiments shown and described, the materials listed in the construction of the target are merely representative of a class which have similar properties. Gold is utilized as an example here due to its high atomic-number. It is desirable to use a solid material having a high atomic number of greater than 50, such as tungsten, platinum and lead, which all exhibit high scattering coefficients for electrons.

The back scattering effect is more fully described in a paper entitled "Back-Scattering of 5 to 20K e.v. electrons from Metals and Insulators" by J. E. Holiday and E. J. Sternglass and given at the 15th annual conference on Physical Electronics at M.I.T. on March 25, 1955.

While I have shown my 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.

I claim as my invention:

1. The method of producing a highly sensitive electron target, comprising the steps of evaporating a thin amorphous film of semi-insulating material, exhibiting the property of becoming conductive when bombarded with electrons, within an inert atmosphere to produce a film having low bulk density, and applying a layer of electron scattering material of an atomic number of at least 50 to said film of semi-insulating material.

2. A target electrode for a pick-up tube comprising a thin film of a semi-insulating material selected from the group consisting of antimony trisulphide, arsenic trisulphide and amorphous selenium which exhibit the property of decreased resistivity when bombarded with electrons, said film of semi-insulating material having an amorphous structure and low bulk density and inclusions consisting of a high atomic number electron scattering material within said film of semi-insulating material.

3. A target electrode for a pick-up tube comprising a thin film of semi-insulating material having a thickness of the order of three microns exhibiting the property of decreased resistivity upon electron bombardment, said film having an amorphous structure and of a density less than normal bulk state, said semi-insulating film having a coating of high atomic numbered material of a thickness of about one hundred angstroms upon which the bombarding electrons impinge to deflect said bombarding electrons within said semi-insulating film and a second coating on the opposite surface of said semi-insulating film of a high atomic numbered material of a thickness of about one thousand angstroms to back scatter said bombarding electrons back into the semi-insulator material.

4. The method of producing a highly sensitive electron target of semi-insulating material exhibiting the property of decreased resistivity upon electron bombardment comprising the steps of placing an electron deflecting means on the bombarded front surface of said target to increase the path of said electrons through said semi-insulating material and the positioning of an electron back scattering means on the rear surface of said target to back scatter the bombarding electrons back into said semi-insulating material.

5. A target electrode for a pickup tube comprising a thin film of semi-insulating material exhibiting the property of electron bombardment induced conductivity, said film of material having a density less than that in its normal bulk state and means contiguous with said layer of semi-insulating material, said means comprising a material having an atomic number of at least 50 for deflecting electrons within said layer of semi-insulating material.

6. A target electrode comprising an amorphous layer of semi-insulating material that exhibits the property of decreased resistivity when bombarded with electrons, said layer having a density lower than its normal density, an electron scattering layer disposed on one surface of said semi-insulating layer, and a back scattering material disposed on the opposite surface of said semi-insulating layer, said electron scattering layer and said back scattering layer having an atomic number greater than 50.

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