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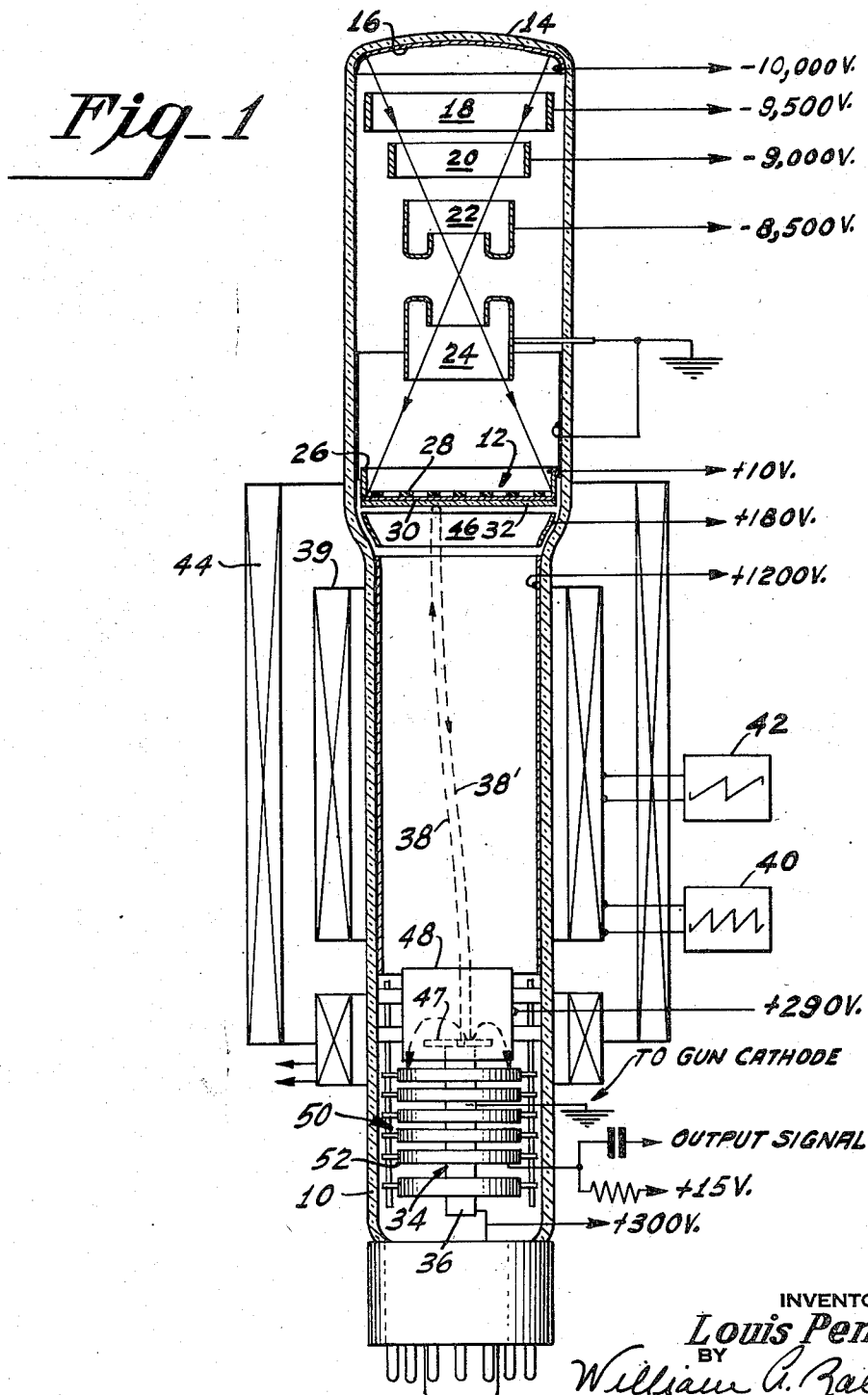
L. PENSAK

2,776,387

PICK-UP TUBE WITH INDUCED CONDUCTIVITY TARGET

Filed July 30, 1951

2 Sheets-Sheet 1



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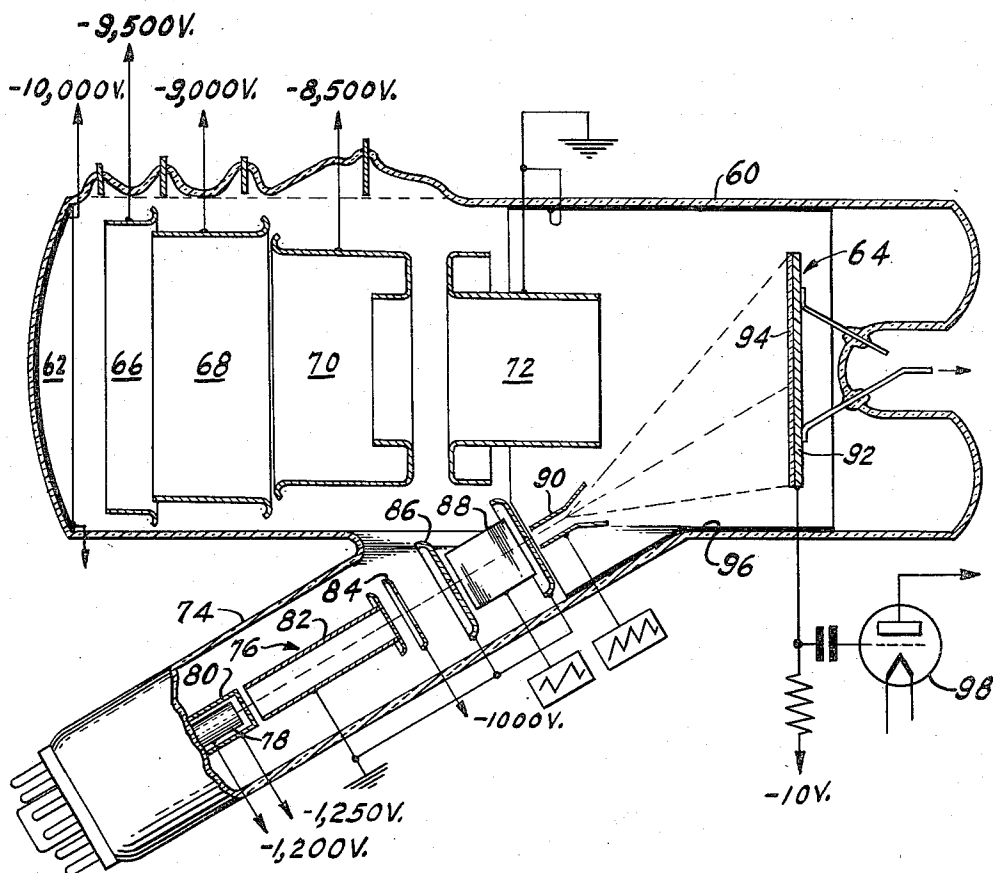


Fig-2

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2,776,387

PICK-UP TUBE WITH INDUCED CONDUCTIVITY TARGET

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Application July 30, 1951, Serial No. 239,203

13 Claims. (Cl. 313—65)

This invention is directed to electron discharge devices and more particularly to pickup tubes which may be used for television or other purposes.

One well known type of pickup tube is the image orthicon. This tube has a target structure formed of a thin film of glass. Spaced from the target is a photocathode and electrode means for directing photoelectrons onto one surface of the target film to provide a charge pattern thereon corresponding closely to the pattern of light focussed upon the photocathode of the tube. An electron beam is used to scan the opposite face of the glass target film to deposit charges on each elemental area of the target in proportion to the charge pattern established on the opposite surface. The remainder of the electron beam is returned to a collector electrode where it provides voltage charges which constitute the output signal of the tube. In the image orthicon pickup tube the photoelectrons when they strike the glass target film initiate a secondary emission therefrom greater than unity to produce on the glass surface a charge 3 or 4 times as large as would be obtained by direct photoemission from the glass target itself.

As set forth in the copending application, Serial No. 29,746 of Louis Pensak, which is now abandoned, there is disclosed a group of materials which are normally insulating but when bombarded by high velocity electrons will momentarily provide conductive paths therethrough. This phenomenon is known as bombardment induced conductivity. The sensitivity of such materials is such that under bombardment a current flow through the material will take place in the order of 100 times as large as the current of the bombarding electron beam.

Therefore, it is an object of my invention to provide a television camera tube of increased sensitivity to light.

It is a further object of my invention to provide a pickup tube utilizing the induced conductivity of insulating materials.

It is another object of my invention to provide a pickup tube having a target electrode depending upon the induced conductivity of insulating materials.

In particular, the invention is directed to a pickup tube having a photoemissive surface and a high voltage electron lens as a means to focus photoelectrons from this surface onto a target electrode. The target is formed of a thin metal film spaced from the photocathode. The metal film is electron permeable and is coated with a film of an insulating material on the side opposite from the photocathode. A low velocity scanning electron beam maintains the exposed surface of insulating coating at a fixed potential different from the potential established on the metal film. The high velocity photoelectrons induce conductivity through the target between the surface scanned by the electron beam and the metal film, to establish, on the scanned surface, a charge pattern corresponding to the optical pattern focussed on the photocathode. The electron beam scanning the target surface provides an output signal in the tube corresponding to the charge pattern on the target surface.

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In the drawing Figure 1 is a sectional view of the pickup tube in accordance with the invention;

Figure 2 is a modification of a pickup tube in accordance with the invention.

Figure 1 discloses a pickup tube comprising a glass envelope 10, divided into two sections by an intermediate target structure 12. One end of the envelope 10 is closed by an optically transparent face plate or wall portion 14, on the inner surface of which is formed a photoemissive film 16. Such a film may be of any well known type such as that disclosed in the copending application Serial No. 79,328 of Ralph E. Johnson filed March 3, 1949, and which is now U. S. Patent 2,682,479, granted June 29, 1954. Between the target 12 and photocathode 16 are a plurality of electrodes 18, 20, 22 and 24 formed and arranged as disclosed in Figure 1. When these electrodes have established thereon suitable potentials, such as those indicated in Figure 1, there is formed a high voltage electron lens for accelerating and focussing the photoelectrons from film 16 onto the adjacent surface of target 12.

Target 12 consists of a support ring 26, across the open center of which is fixed a fine mesh screen support 28 of high transparency. A thin metal film 30 is formed on the surface of screen 28 away from photocathode 16. The metal film 30 is electron permeable and is approximately 0.1 micron thick. On the surface of metal film 30 is formed, in any appropriate manner a thin film 32 of an insulating material, approximately 0.03 mil in thickness.

At the other end of the tube envelope 10 is an electron gun structure 34 for producing a low velocity electron beam to be scanned over the surface of the target electrode 12. Electron gun 34 is a conventional type consisting of a cathode, control grid, and an accelerating grid, which are not shown but are mounted in a tubular accelerating electrode 36. These gun electrodes form an electron beam 38 directed at the target 12. Two pairs of coils are formed into a deflection yoke 39. The coils of each pair are connected in series respectively to voltage sources 40 and 42 for producing line and frame scanion of the electron beam over the target surface. The method of beam scanion is well known in the prior art and is not further described here. The electron beam 38 is focussed by a single magnetic coil 44 to a small spot at the target surface.

Briefly, the operation of the tube is as follows:

As indicated in Figure 1, potentials are applied to the several electrodes. The values of the potentials indicated in Figure 1 are examples of operating voltages which may be used and are not meant to be limiting. The electron beam 38 is scanned over the target surface 32. The retarding field between target film 30 and a decelerating electrode 46 reduces the velocity of the electron beam 38 so that it approaches the target surface at low potential. Electrons are deposited from the beam on the target film 32 and drive the surface of that film to an equilibrium potential which is substantially equal to that of the cathode of gun 34. Metal film 30 is maintained during tube operation at a few volts positive to that of the cathode of gun 34.

An optical image is focussed upon the photocathode 16 and photoelectrons are emitted from each portion of the photocathode 16 in proportion to the amount of light falling on it. This photoemission is focussed by the electrostatic fields of electrodes 18, 20, 22 and 24 on the target surface 12. The photoelectrons are accelerated to a sufficiently high velocity that they penetrate through both the metal film 30 and the insulating film 32 and produce electrical conductivity through the insulating film. Due to the difference of potential between the positive film 30 and the scanned surface of film 32, a current flow

will take place in those areas bombarded by the photoelectrons. The current flow in each portion of the target is many times greater than the current of the electrons inducing the conductive effect. This produces on the scanned surface of film 32 a pattern of positive charged areas in those regions where the photoelectrons have penetrated and negative areas in those regions where no photoelectrons have induced conductivity. The charge pattern corresponds to the pattern of light focussed on photocathode 16. The electron beam 38 upon scanning the surface of film 32, in the positive charged areas, will deposit electrons to drive those areas back to equilibrium or gun cathode potential. The remainder of the beam is reflected by the discharged areas of the target and forms a portion of a return beam 38', which is reflected from all portions of the target at equilibrium potential. The field of coil 44 directs beam 38' back toward the electron gun 34 where it strikes an exposed surface 47 of the accelerating gun electrode 36. This surface 47 provides a secondary electron emission which is directed by a persuader electrode 48 into an electron multiplier 50 consisting of several dynodes producing several stages of multiplication. The beam electrons amplified by passing through the multiplier 50 are collected by an electrode 52 and amplified to produce the output signal of the tube.

The induced conductive effect produced by the photoelectrons striking through the thin insulating film 32 provides a pattern of charged areas on the scanned target surface, which is much greater than can be obtained by other means. This is due to the fact that the current flow from the positive signal plate 30 to the scanned surface of film 32 is many times greater than the actual current flow of the photoelectrons passing through film 32. Because of this induced conductivity effect, a pickup tube of the type of Figure 1 is much more sensitive than a conventional pickup tube. Most insulating materials, which can be put down in a very thin film, may be used to form film 32 of the target. Materials which have been used are silica, magnesium fluoride, and zinc sulfide.

If the tube of the type shown in Figure 1 is to be used for television pickup it is desirable that the thickness of the insulating film 32 be in the order of 1 mil to provide the necessary capacity between the signal plate 30 and the scanned surface of film 32, which must be for each picture element of a value that the scanning beam 38 will be able to restore the picture element to equilibrium potential during a single scan. As described above, film 32 is normally formed with a thickness in the order of 0.03 mil. This requires a voltage of around 10,000 volts between photocathode 16 and target 12 to provide sufficient energy for the photoelectrons to penetrate film 32. A target film 32 of 1 mil thickness would roughly require a voltage in the order of 100,000 volts to provide penetration of the photoelectrons through film 32. Such a high voltage is difficult and expensive to obtain for normal television pickup uses. However, a tube similar to Figure 1 used with a voltage difference of 10,000 volts between photocathode 16 and target 12 and with a film 32 having a thickness of 0.1 mil can be used as a storage tube in which the charge pattern on the target requires many scans of beam 38 to become discharged.

It has been found that there is a class of materials exemplified, by amorphous red selenium which will provide the induced conductivity effect with a film thickness in the order of 1 mil. Furthermore, the use of this material requires only voltages in the order of 10,000 volts between photocathode 16 and target 12, since with such a material, it is not necessary that the photoelectrons penetrate through the film 32. These materials, such as amorphous red selenium, are known as "hole"-type conductors. It is observed, when such a film as amorphous red selenium is bombarded by photoelectron from photocathode 16 that a positive charge pattern is established on the scanned surface of the selenium film 32 in the same manner as if the photoelectrons had penetrated complete-

ly through the film and established a conductive path between the positive signal plate 30 and the negative scanned surface of film 32. Because of the thickness of the selenium film and the energy of the photoelectrons striking the film which is in the order of 10,000 volts, it is known that the photoelectrons themselves do not penetrate through the selenium film. One explanation of the effect which is produced is that the photoelectrons striking film 32 knock valence electrons off the selenium atoms producing positively charged particles or ions. This produces a concentration of electrons adjacent signal plate 30. These electrons are collected by the positive plate 30 leaving behind the positively charged ions or "holes." Due to the electric field between the surfaces of film 32, electrons from adjacent atoms on the side away from the positive electrode 30 move over to neutralize these positive ions and in turn leave positive "holes" behind them. This action is repeated by electrons adjacent the new "holes" and in this way, the "holes" migrate towards the negative surface of film 32. These "holes" arrive at points on the negative surface of film 32 and raise the potential of the scanned film surface at those points. Many more "holes" are produced than the number of photoelectrons striking film 32. Thus, there is established on the scanned surface of film 32 an amplified charge pattern. It has been established that the number of "holes" generated are in the order of 100 times the number of electrons bombarding film 32. This then provides a much more sensitive pickup tube than is possible without this bombardment effect. A tube of this type with an amorphous selenium film provides signals equal to those of an image orthicon, described above, but with about $\frac{1}{100}$ the amount of light.

The amorphous selenium is put down on the metal film 30 by evaporation. The method of forming such a target electrode is discussed and claimed in the copending application of P. K. Weimer, Serial No. 203,860, filed January 2, 1951. Target film 32 may be also formed from other materials having "hole"-conduction similar to that of the amorphous red selenium.

Amorphous red selenium is a long range positive or "hole" type carrier material, as the "holes" or positive charge carriers will travel across the selenium film in response to an electric field impressed between the surfaces of the film as described above. If film 30 were operated at ten volts negative relative to the scanned side of target 12, no charges pass through film 32. Thus, selenium does not appear to have long range negative charge carriers which would travel across to the positive surface.

Silica, magnesium fluoride and zinc sulfide are a class of materials with short range excited charge carriers, since charges will be conducted through thin films of these materials only when the bombarding electrons penetrate through the films. The short range charge carriers produced in these materials are both types—positive and negative. Selenium also has this property of producing positive and negative short range charge carriers under electron bombardment.

If the tube of Figure 1 were used with a material having long range negative charge carriers, then the electrode potential values would be set to provide a beam 38 of high velocity to produce secondary emission with an emission ratio greater than unity from the scanned surface of the target. The beam in scanning the target will drive the surface of target 12 to a positive equilibrium potential. Signal plate 32 is held at a potential of some ten to fifty volts negative to the equilibrium potential to provide a field across film 32. High energy photoelectrons from photocathode 16 penetrate into film 32 and excite both positive and negative charge carriers. Due to the direction of the field across film 32, the negative charge carriers will move across to the scanned surface of film 32 and form a charge pattern corresponding to the light pattern focussed on photocathode 16. Beam 38 on scanning will successively drive all portions of the target back to equilibrium potential. The video output signal

of the tube may be taken from the conductive film 30. Since film 30 is closely coupled to the scanned surface of film 32 signal pulses will be initiated in the circuit of film 30 as the charged areas of film 32 are discharged by the beam. A film of antimony trisulfide (Sb_2S_3) has long range negative charge carriers and may be used in the modification described.

Figure 2 discloses a modification of the tube of Figure 1. In this form, both the photoelectrons and the electron beam strike the target from the same direction. The tube consists of an envelope 60 having a photocathode 62 on the inner surface of an end wall thereof. The target electrode 64 is mounted in spaced alignment with the photocathode surface 62 and positioned to receive photoelectrons therefrom. Between the photocathode 62 and target 64 there is positioned a plurality of electrodes 66, 68, 70 and 72 which form an accelerating and focussing system for projecting the photoelectrons from film 62 onto the target 64.

Envelope 60 is provided with a tubular extension 74, arranged in alignment with target 64 and at an angle thereto. Positioned in the envelope extension 74 is an electron gun 76 having a conventional type cathode 78, control grid 80 and accelerating and focussing electrodes 82, 84 and 86. The gun 76 provides an electron beam which is directed and focussed on the surface of target 64. Two pairs of electrostatic deflecting plates 88 and 90 provide line and frame scan of the electron beam over the surface of target 64 in a well known manner. In Figure 2 there are indicated leads extending from the various electrodes to sources of potential whose values are indicated on the drawing. These potential values represent a set of voltages which may be used with a tube of this type and are in no way limiting.

Target 64 consists essentially of a heavy metal supporting plate 92 having a thin film 94 coating the surface of plate 92 facing photocathode 62. The film 94 corresponds to film 32 of Figure 1 and may consist of a thin film of insulating material of approximately 0.1 mil thick. Surrounding the target 94 there is provided a collector electrode 96 comprising a conductive film or coating on the inner surface of the envelope 60. The electron beam formed by the gun 76 is scanned over the surface of target 94 and strikes the target with an energy above first crossover to provide a secondary emission from the target. The secondary emission is greater than unity so that the target surface is driven to an equilibrium potential which is substantially that of the potential of the collector electrode 96. The supporting signal plate 92 of target 64 is maintained during tube operation at a potential in the range of 10 volts to 50 volts negative with respect to the potential of collector 96. The high velocity photoelectrons from photocathode 62 strike the surface of film of 94 and penetrate therethrough to provide conductive paths between the surfaces of film 94. In the areas of film 94 combarded by the photoelectrons the scanned surface of the film is discharged to the potential of the signal plate 92. An optical image pattern focussed on photocathode 62 will establish a corresponding charge pattern on the scanned surface of the target film 94. The electron beam in scanning the charged surface areas of the target will drive them instantaneously back to equilibrium or collector potential and will simultaneously establish a voltage pulse in the circuit of plate 92 which is amplified in any manner such as by an amplifier tube 98. This then provides the video output signal of the tube.

From the foregoing, it will be apparent that the present invention provides an improved camera pickup tube and a storage tube which are characterized by their increased sensitivity.

I claim:

1. An electron discharge device comprising a target electrode including a sheet of normally insulating material and having the property of being electrically conduc-

tive when struck by electrons having energies above a predetermined value, means for directing electrons having energies below said predetermined value at one surface of said insulating target sheet to establish said surface at an equilibrium potential, a conductive sheet in contact with the opposite surface of said target sheet to maintain said opposite surface at a fixed potential different from said equilibrium potential, means including a photocathode spaced from said target for directing electrons having energies greater than said predetermined value at one of said surfaces of said insulating target sheet to establish an electrically conductive path between said target surfaces.

2. An electron discharge device comprising a target electrode including a sheet of normally insulating material having excited charge carriers when struck by electrons having energies above a predetermined value, means for directing electrons having energies below said predetermined value at one surface of said target sheet to establish said surface at an equilibrium potential, a conductive sheet in contact with the opposite surface of said target sheet to maintain said opposite surface at a fixed potential different from said equilibrium potential, a photocathode spaced from said target, electrode means between said photocathode and said target for directing photoelectrons onto one of said surfaces of said insulating target sheet at energies greater than said predetermined value to establish an electrically conductive path between said target surfaces.

3. An electron discharge device comprising, a target electrode including a film of silica and a conductive sheet on one surface thereof, an electron gun for providing an electron beam along a path intercepting said target electrode, means for scanning said beam over the exposed surface of said silica film to establish said exposed target surface at an equilibrium potential, lead means connected to said conductive sheet to maintain said one silica film surface at a fixed potential different than said equilibrium potential, and means including a photocathode for directing electrons at one of said silica film surfaces to provide electrically conductive paths between said silica film surfaces.

4. An electron discharge device comprising, a target electrode including a film of selenium and a conductive sheet on one surface thereof, an electron gun for providing an electron beam along a path intercepting said target electrode, means for scanning said beam over the exposed surface of said selenium film to establish said exposed target surface at an equilibrium potential, lead means connected to said conductive sheet to maintain said one selenium film surface at a fixed potential different than said equilibrium potential, and means including a photocathode for directing electrons at one of said selenium film surfaces to provide electrically conductive paths between said selenium film surfaces.

5. An electron discharge device comprising, a target electrode including a film of magnesium fluoride and a conductive sheet on one surface thereof, an electron gun for providing an electron beam along a path intercepting said target electrode means for scanning said beam over the exposed surface of magnesium fluoride film to establish said exposed target surface at an equilibrium potential, lead means connected to said conductive sheet to maintain said one magnesium fluoride film surface at a fixed potential different than said equilibrium potential, and means including a photocathode for directing electrons at one of said magnesium fluoride film surfaces to provide electrically conductive paths between said magnesium fluoride film surfaces.

6. An electron discharge device comprising, a target electrode including an electron permeable metal film and a coating of normally insulating magnesium fluoride on one surface of said metal film, an electron gun spaced from said coated target surface, for providing an electron beam intercepting said surface, means including a photocathode spaced from the opposite surface of said metal

