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R. J. SCHNEEBERGER

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LOADED DIELECTRIC X-RAY DETECTOR

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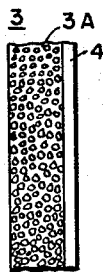
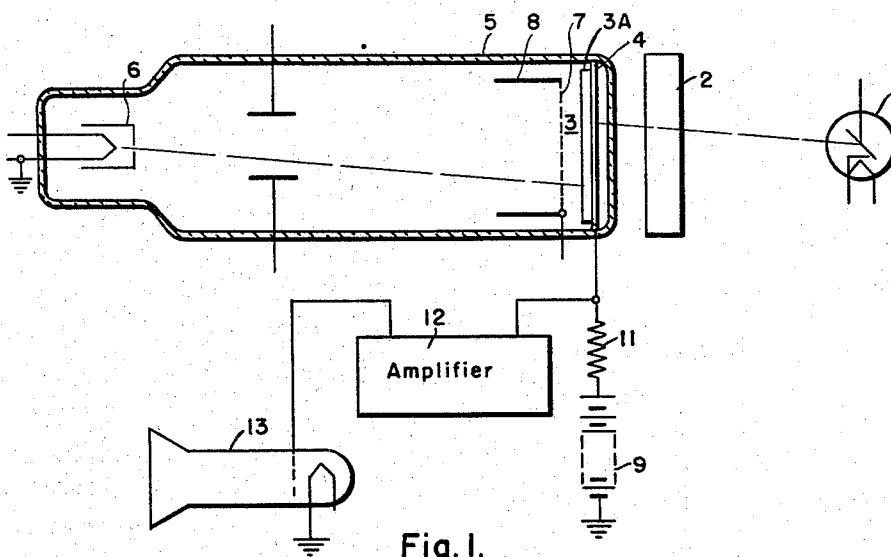


Fig. 2.

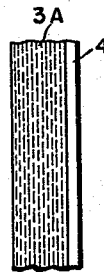


Fig. 3.

WITNESSES

Edwin E. Bassler

Leon M. Gorman

INVENTOR

Robert J. Schneeberger

BY *F. E. Browder*
ATTORNEY

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LOADED DIELECTRIC X-RAY DETECTOR

Robert J. Schneeberger, Pittsburgh, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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6 Claims. (Cl. 250—83.3)

My invention relates to radiation sensitive screens and in particular relates to screens comprising a thin layer of a photoconductive material, i.e. a material the electrical resistivity of which undergoes a large temporary decrease of electrical resistivity in the neighborhood of a point where a photon of radiation has just been incident. Such an action may be referred to as bombardment conductivity or bombardment-induced conductivity. Examples of such a substance are selenium and the sulphides of arsenic and of antimony which undergo such a decrease in resistivity at a point where they have been struck by an X-ray photon. It is possible to use screens of this character to form visible replicas of X-ray fields or images, one such arrangement being described in my application Serial No. 280,073, filed on or about April 2, 1952 (now abandoned), for System of Intensifying and Transmitting X-ray Images. While I have mentioned X-rays as one type of radiation to the detection of which such screens are adapted materials exhibiting photo-conductivity with respect to other types of radiation are known in the arts, and the principles of my present invention will be seen to be applicable to such materials. It will also be evident that those principles are applicable to apparatus which merely detects and registers the presence and incidence of radiation instead of mapping the distribution of intensity of the radiation over the cross section of a wide beam as is done in reproducing an image or radiation-field picture.

While selenium, arsenic sulphide, cadmium sulphide and antimony sulphide have the desirable properties of high resistivity and ease of evaporation to form thin layers, their linear absorption coefficients for high-energy photons, such as those of X-rays used many times in medical roentgenology, are undesirably low. This means that only a small fraction of the incident high-energy photons will be absorbed and induce conductivity in the thin photoconductive layer by producing high speed electrons therein. The sulphide of a high atomic-numbered element such as lead has a higher linear absorption coefficient and in a layer of given thickness will absorb a larger fraction of high-energy photons but it does not possess the high resistivity, ease of evaporation to form films and other properties desired for photoconductive screens.

It is accordingly one object of my invention to provide a new and improved type of photoconductive screen for radiation fields.

Another object is to provide a new and improved screen of the photoconductive type for use with radiation fields comprising high energy photons.

Another object is to provide a new and improved screen of the photoconductive type for use with X-ray fields.

Still another object is to provide a new and improved type of radiation-field image-intensifying device.

Yet another object is to provide a new and improved device for detecting electromagnetic radiations.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawings, in which:

Figure 1 is a schematic representation of an X-ray image intensifier tube of the type described in my above-mentioned application except that it embodies an image screen of the type of my present invention;

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Fig. 2 is a cross-sectional view of a portion of an image screen in accordance with my present invention; and

Fig. 3 is a similar view of a modified form of an image screen embodying the principles of my present invention.

Referring in detail to Fig. 1, an X-ray source 1, which may be of conventional type, projects its beam through an object 2 to be studied into impact with the screen 3 of a high-vacuum tube 5. The screen 3, which is shown in more detail in Fig. 2, comprises a layer 3A or slab containing some semiconductive material which is rendered locally more conductive electrically for a period when, and where, an X-ray or other photon from source 1 is absorbed in it. Such a semiconductor may be termed photoconductive. The layer or slab may be supported on a suitable conductive backing-plate 4 attached to the walls of tube 5, and made of any conducting substance such as aluminum which is reasonably transparent to the X-rays from source 1. An electron gun 6 which may be of conventional type is arranged to scan the opposite face of screen 3 from that facing source 1 with an electron beam which is accelerated through a screen 7 and focussing anode 8. The cathode of electron-gun 6 is grounded and the backing-plate 4 is made positive to ground by connection to the positive pole of a direct-current source 9 through a resistor 11. The backing-plate 4 is connected through a suitable video amplifier 12 to the input electrode of a suitable kinescope 13 which may be of conventional type. The electron gun of kinescope 13 and the negative pole of source 9 may be grounded. The output screen of kinescope 13 is arranged to be scanned in synchronism with the scanning by electron gun 6 of screen 3 in tube 5.

When the X-ray source 1 is not turned on, the electrons from electron gun 6, scanning the exposed face of screen 3, bring its entire area to ground potential. The photoconductive layer 3 has a resistance high compared with that of resistor 11.

When now an X-ray field is projected onto the photoconductive layer from source 1 through object 2, the photoconductive layer 3 becomes conductive at those points on its area where object 2 is transparent to X-rays, and remains non-conductive at points where the object 2 is opaque to X-rays. As a result the aforesaid electric field falls to zero opposite the transparent spots on object 2, and the exposed face of screen 3 approaches at those transparent spots the potential of backing-plate 4 while it stays at ground potential opposite the opaque spots. A potential-image of the X-ray transmission of object 2 thus appears on the exposed face of screen 3. The elementary area of the photoconductive layer where the transmitted X-ray beam is intense will have a positive potential; those areas where the X-ray beam is weak a lower positive potential relative to ground.

Now when the electron beam from electron-gun 6, in scanning screen 3, strikes a point on the photoconductive layer 3 which has a positive potential some of its electrons will be absorbed and will neutralize the positive charge at that point, and a corresponding pulse of current will flow from backing-plate 4 to ground through resistor 11. This will produce a voltage pulse which will be impressed on the input-electrode of kinescope 13 and modulate the electron-beam of the latter. This scanning beam moves across its output screen in synchronism with the movements of the scanning beam of tube 5 across screen 3 therein, and so produces a light-image on the kinescope output screen which is a replica of the distribution of the X-rays transmitted by object 2.

The image screen of Fig. 2 comprises a thin layer of metal 4 supporting a layer which is an intimate physical mixture of a photoconductive substance 3 such as selenium, cadmium sulphide, arsenic trisulphide or antimony trisulphide with a substance having a high adsorp-

tion coefficient for the incident radiation, such for example as gold or other substance containing atoms of high atomic number higher than 51. Such a mixture may be formed by evaporating gold and the photoconductor simultaneously by heating them in vacuo and permitting them to condense on the metal layer 4. Alternatively the layer may be produced by heating in alternation for successive short periods a crucible of gold and a crucible of the photoconductive substance, the gold evaporation being carried out in an atmosphere such as helium to which it is inert; and the photoconductor evaporation being carried out in vacuo. The diameter of the gold particles should preferably not exceed two-tenths of a micron; however, the screen will not be useless if this size is exceeded, and the optimum size will depend upon the wave length of the radiation which the screen is to receive.

In the alternative type of screen shown in Fig. 3 the gold is in the form of thin layers with their flat surfaces parallel to the face of the screen and subdivided in length and width into areas not greater than the maximum value that would permit adequate resolution of the image. One way of producing such a structure is to first deposit a layer, e.g. by evaporation in vacuo, of the photoconductor 3 on the support-plate 4, then to place a mask with holes of the dimension needed to give adequate picture resolution against the surface just deposited, and then to deposit gold by evaporation to a thickness of the order of two-tenths of a micron. The mask is then removed and another layer of photoconductor deposited to a thickness such as 0.2 micron. A program of such steps is then continued until a screen of the desired thickness is obtained. In applications where mere detection or measurement of incident radiation rather than an image of its space-distribution is desired, a continuous layer of gold may be deposited and the use of the screen be dispensed with.

It is desirable to have the gold particles close to each other so that relatively low energy electrons (i.e. even three to ten kilovolts) set free in the gold particles by the incident radiation, can traverse the photoconductor from one gold particle to the next. For example, a layer of arsenic trisulphide two microns thick requires electrons liberated in the gold by the radiation, to be of at least thirteen kilovolts energy to produce conductivity if the electrons have to traverse the entire thickness of the layer. However, if the layers of gold particles in that photoconductor are only two-tenths of a micron apart, the electrons ejected from the gold need only have an energy high enough to traverse a layer of the latter thickness to establish a conductive bridge through the two micron layers. In the case of arsenic trisulphide this energy is only 5.5 kilovolts. The duration of the conductive state established by X-ray photons of densities usual in radiography will be sufficient to produce a conductive path through the entire thickness of the two micron layers.

My present invention may be applied, not only to X-ray or other image-reproducing screens as described above, but also to screens merely intended to detect the presence of radiation, or to register the incidence of each photon, without indicating the distribution of its intensity in space as is necessary for radiation image reproduction.

I claim as my invention:

1. A device for detection of high energy photons not less than the energy from X-rays used in medical roentgenology comprising fine particles of a first material containing atoms of atomic number higher than 51 distributed through a layer of a second material exhibiting temporary decrease of electrical resistivity in the neighborhood of photon incidence due to electron bombardment induced conductivity means for impressing a field across said layer and means for deriving an electrical signal from said layer corresponding to the modification of electrical

resistivity of said layer in response to photon incidence on said layer.

2. An image screen for detection of high energy photons not less than the energy from X-rays used in medical roentgenology comprising solid fine particles of a first material containing atoms of gold distributed through a layer of a second material exhibiting temporary decrease of electrical resistivity in the neighborhood of photon incidence due to electron bombardment induced conductivity means for impressing a field across said layer and means for deriving an electrical signal from said layer corresponding to the modification of electrical resistivity of said layer in response to photon incidence on said layer.

3. A device for the detection of radiation energy equal to or greater than X-ray photons used in medical roentgenology comprising a first material exhibiting temporary decrease of electrical resistivity in the neighborhood of photon incidence due to electron bombardment induced conductivity and particles of a second material having a higher atomic number than said first material imbedded within said first material for enhancing the electron bombardment induced conductivity means for impressing a field across said layer and means for deriving an electrical signal from said layer corresponding to the modification of electrical resistivity of said layer in response to photon incidence on said layer.

4. The method of enhancing the response of a photoconductive material exhibiting temporary decrease of electrical resistivity in the neighborhood of photon incidence of energies not less than X-ray photons used in medical roentgenology due to electron bombardment induced conductivity comprising imbedding particles of an absorbing material containing atoms of an atomic number greater than 51 within said photoconductive material.

5. The method of enhancing the response of a layer of photoconductive material exhibiting a decrease of electrical resistivity in the neighborhood of photon incidence of energies not less than X-ray photons used in medical roentgenology due to electron bombardment induced conductivity, comprising the steps of imbedding particles of photon absorbing material containing atoms of an atomic number greater than 51 within said photoconductive material and positioning said particles such that the carriers liberated by the particles in response to photon incidence produce conductivity between particles across said layer of photoconductive material.

6. A device for the detection of radiation energy equal to or greater than X-ray photons used in medical roentgenology comprising a layer of photoconductive material exhibiting a decrease of electrical resistivity in response to said radiation energy due to electron bombardment induced conductivity within said layer, said layer including a plurality of particles for enhancing the absorption of said radiation energy of a material containing atoms of an atomic number greater than 51, said particles distributed through said layer so that carriers liberated by said particles in response to said radiation produce conductivity between said particles across said layer of photoconductive material, means for impressing a field across said layer, and means for deriving an electrical signal from said layer corresponding to the modification of electrical resistivity of said layer in response to said radiation energy.

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