

Nov. 25, 1958

M. PLOKE ET AL
RADIATION SENSITIVE SEMI-CONDUCTIVE
LAYER OF AMORPHOUS SELENIUM

2,862,126

Filed Aug. 28, 1953

3 Sheets-Sheet 1

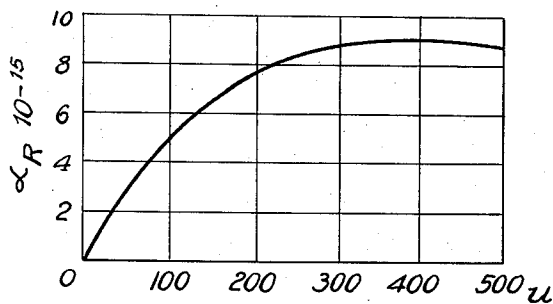


Fig. 1

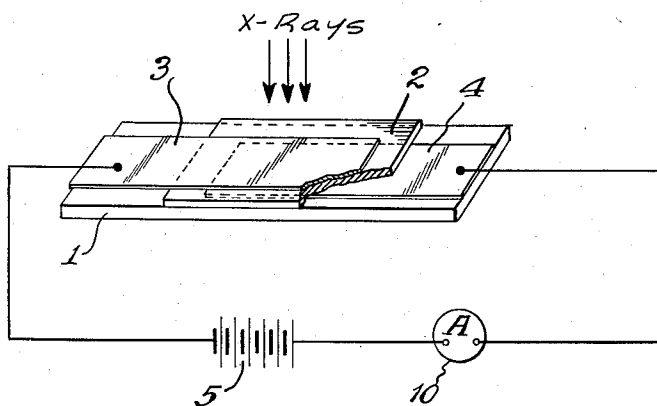


Fig. 2

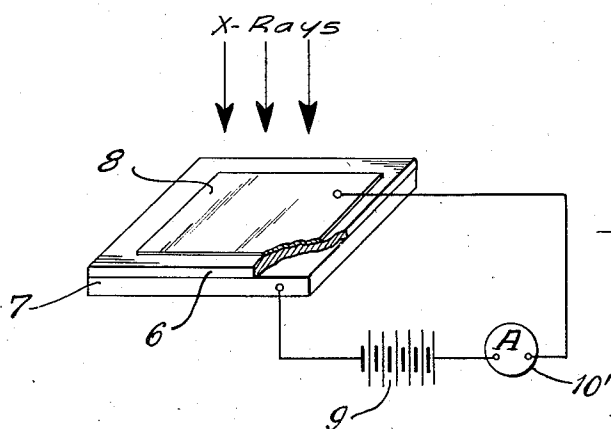


Fig. 3

Inventors
Manfred Keller
Martin Ploke
by Singer, Stern & Harburg
Attorneys

Nov. 25, 1958

M. PLOKE ET AL
RADIATION SENSITIVE SEMI-CONDUCTIVE
LAYER OF AMORPHOUS SELENIUM

2,862,126

Filed Aug. 28, 1953

3 Sheets-Sheet 2

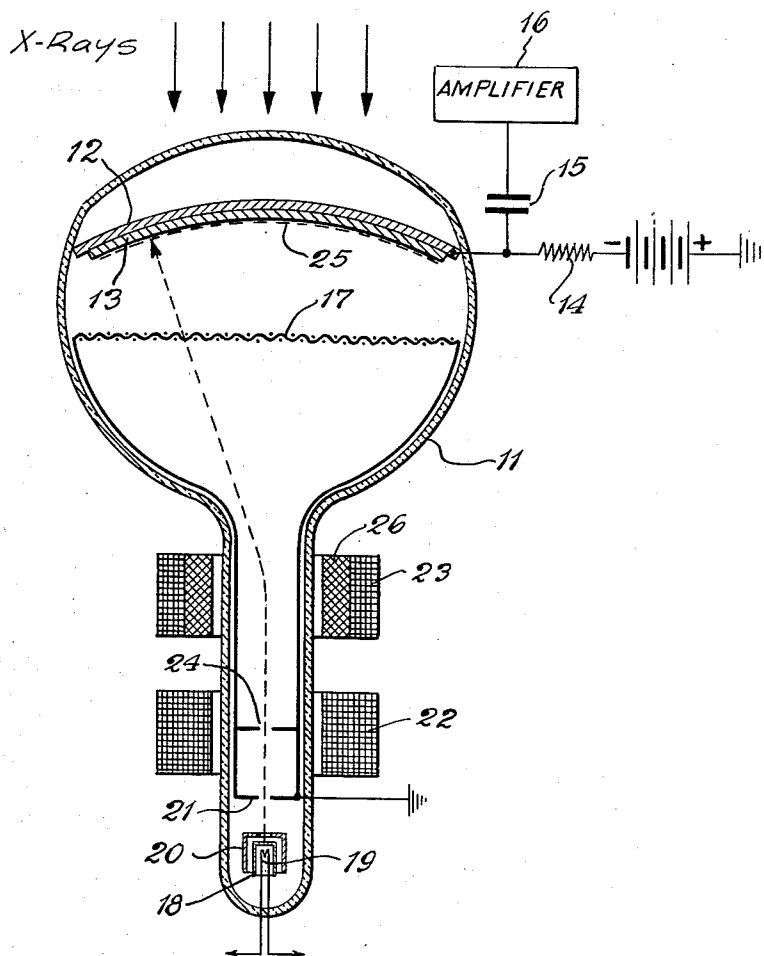


Fig. 4

Inventors
Manfred Keller
Martin Ploke
by Singer, Stern & Carlberg,
Attorneys

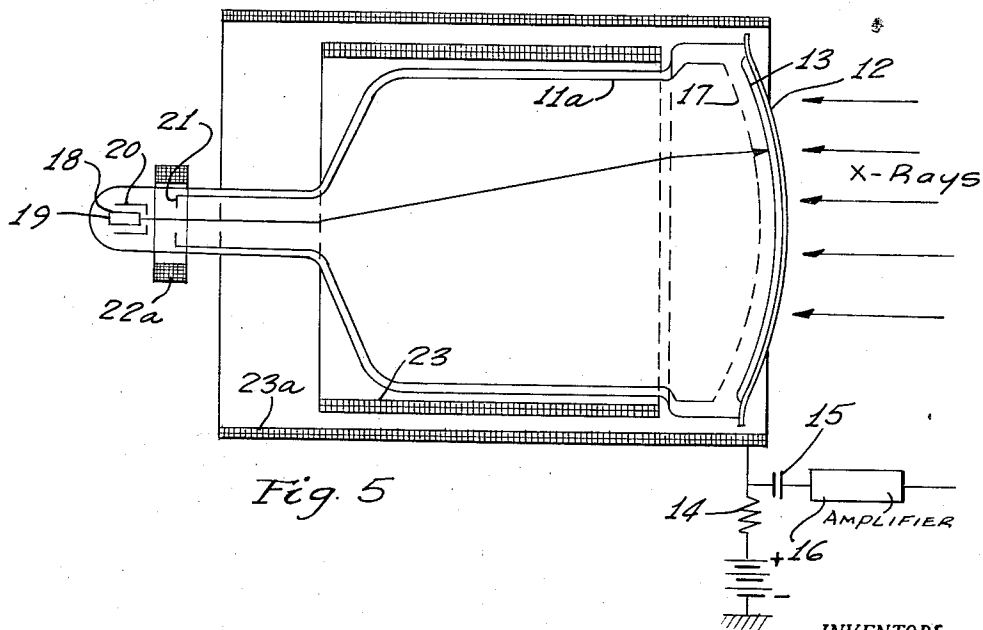
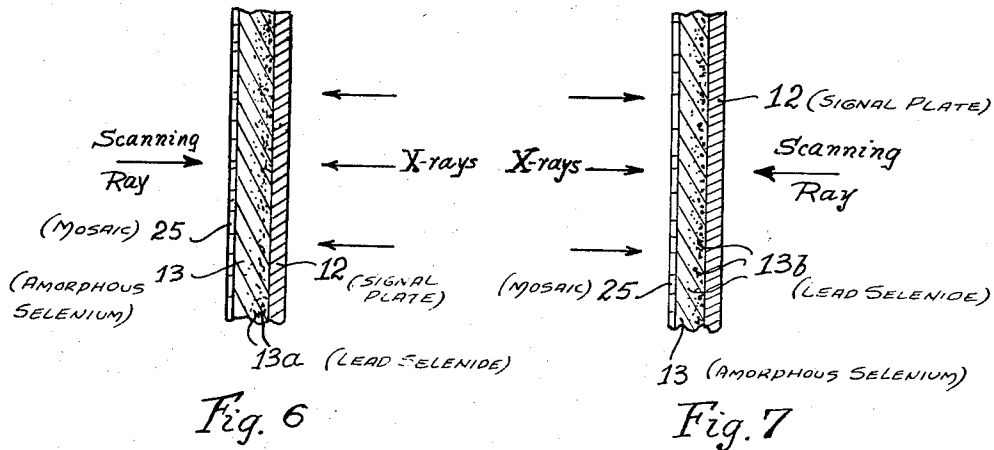
Nov. 25, 1958

M. PLOKE ET AL
RADIATION SENSITIVE SEMI-CONDUCTIVE
LAYER OF AMORPHOUS SELENIUM

2,862,126

Filed Aug. 28, 1953

3 Sheets-Sheet 3



INVENTORS
Manfred Keller
Martin Ploke
BY *Singer, Stern & Carlberg*
Attorneys

1
2,862,126

RADIATION SENSITIVE SEMI-CONDUCTIVE LAYER OF AMORPHOUS SELENIUM

Martin Ploke, Stuttgart, and Manfred Keller, Stuttgart-Birkach, Germany, assignors to Zeiss Ikon A. G., Stuttgart, Stuttgart, Germany

Application August 28, 1953, Serial No. 377,214

9 Claims. (Cl. 313—66)

This invention relates to a semi-conductive layer preferably consisting of selenium which has been evaporated in vacuum at a temperature below 125° F. as disclosed in the German Patent 898,641.

Semi-conductive layers consisting of amorphous selenium have hitherto been used for measuring of radiation only. Merely for quantitative indication of the presence of X-rays, semi-conductive layers consisting of amorphous selenium were used which had been made sensitive for X-rays through a prolonged special treatment of the selenium. Said special treatment consisted at least partially in transformation of the amorphous character of the selenium into the crystalline condition, whereby a selenium was obtained which had a low ohmic resistance. Such selenium resistant cells known as Fürstenau Roentgen radiation intensity measuring devices show too great an inertia, fatigue and ageing in connection with X-rays. The reason for these phenomena is connected with the crystalline intercalation of amorphous selenium layers. The required inertia-free receptivity for X-rays is due to the fact that, the X-ray electric effect, contrary to the radiation-electric effect, depends upon an intra-atomic process for the inception of which the small amount of energy in the radiation is insufficient. Therefore, the radiation sensitivity is, according to earlier perceptions, coupled with the crystalline condition of the matter even if in small traces only.

In order to enable the carrying out of X-ray measuring and X-ray image strengthening free from inertia, fatigue and ageing phenomena, it is suggested, according to the present invention, to employ a semi-conductive layer consisting of amorphous selenium as an X-ray sensitive semi-conductive layer. The formation of crystalline selenium which, according to the above explanations, is the cause of the established inertia and ageing, is avoided when the amorphous selenium layers are evaporated under avoidance of such crystallization, in vacuum upon a support which is maintained at a temperature below 125° F.

It is true that such cold-evaporated layers are extremely insensitive to light as distinguished from layers which have been evaporated on a support having a temperature of, for example, 175° F. Said cold-evaporated layers have the additional advantage that their resistance in the dark is one to two units higher than that of hot-evaporated layers, which is of essential importance for their use as a charge feeding layer.

Another not before recognized quality of the amorphous selenium layers in connection with X-rays is that such layers do not show either inertia, fatigue or ageing. It has been established that initiation and termination periods of the change in conductivity at a sudden change in the intensity of the X-ray radiation are of the order of 10⁻³ seconds.

In the drawings,

Fig. 1 is a diagram showing the relation between X-ray conductivity and thickness of a selenium layer according to the invention,

Fig. 2 is a perspective view, partly in section, of a longitudinal cell comprising an amorphous selenium layer,

Fig. 3 is a perspective view, partly in section, of a high-ohmic X-ray resistance cell according to the invention,

2

Fig. 4 shows an X-ray image iconoscope according to the invention,

Fig. 5 shows the invention applied to a conventional orthicon tube,

Fig. 6 shows a cross sectional view of a modified construction and arrangement of the semi-conductive layer and support of the invention, and

Fig. 7 shows a modified arrangement of the construction shown in Fig. 6.

In order to achieve that the X-ray sensitive element which, according to the invention, consists of a layer of amorphous selenium, has a high sensitivity for X-rays, said layer has to be applied in relatively great thickness. The fact is, that experiments have shown that contrary to this, the earlier light sensitive semi-conductive layers of selenium which were applied in a thickness from 1 to 10 microns have very low X-ray sensitivity. Furthermore, it has been established that the X-ray conductivity of the amorphous selenium layers is dependent upon the layer thickness to an extremely high degree. Fig. 1 shows the established X-ray conductivity coefficient α_R in relation to the layer thickness. For the investigation a great number of so-called longitudinal cells were produced with amorphous selenium layers of different thickness in accordance with Fig. 2. A glass plate 1 served as carrier for these layers. The amorphous selenium layer 2 is disposed between two evaporated aluminum electrodes 3 and 4. By means of a battery 5 and a galvanometer 10, a circuit is closed. From the current and the imposed voltage the conductivity change in the cell under X-ray radiation is calculated and therefrom also the X-ray conductivity coefficient α_R in

$$\frac{1}{\Omega \text{ cm. mr./sec.}}$$

(mr.=milli-Röntgen=dosage unity). The X-ray radiation was obtained as a 60 kv. continuous radiation from an X-ray tube with a wolfram anti-cathode. The X-ray conductivity coefficient is thereby related to the received dosage effect in mr. per second. No appreciable dependence of the X-ray conductivity coefficient upon the hardness of radiation exists between 50 and 100 kv. The dependency of the X-ray conductivity coefficient upon the thickness of the layer runs approximately parallel with the absorbed X-ray radiation in the selenium layer. With the radiation employed, the highest X-ray conductivity coefficient is obtained at a thickness of the selenium layer of about 300 microns and, therefore, it is not advisable to make the layers thicker than 300 microns.

X-ray sensitive amorphous selenium layers may be used in a variety of apparatus, two embodiments being described below. Fig. 3 shows a perspective view, partly in section, of a high-ohmic X-ray resistance cell according to the invention. This cell is produced by precipitating an amorphous selenium layer 6 of a thickness of, for example, 200 microns on a metal support plate 7. A metal layer 8 penetrable by X-ray radiation is placed on said selenium layer as a counter-electrode. As electrodes, materials are used which do not react with selenium such as, for example, aluminum, nickel, lampblack, graphite, or carbon. With the two metal electrodes 7 and 8 a circuit is produced over the X-ray sensitive layer and the battery 9, an ammeter 10' being connected in said circuit which shows a current dependent upon the X-ray intensity with which the cell is irradiated.

Fig. 4 shows an X-ray image iconoscope, the semi-conductive layer of which is formed according to the invention as an X-ray sensitive amorphous selenium layer, so that the X-ray image may be scanned in a direct way, i. e. without light transformation. The iconoscope has a bulb 11 of glass or aluminum which for the purpose of less absorption of the X-ray image is spherical, so that

it may be produced with less wall thickness. For the bulb, or the image window, through which the X-ray image penetrates to the amorphous X-ray sensitive selenium layer, preferably a material having a lower absorption coefficient than glass is used, for example, beryllium glass or so called Lindemann glass. The screen electrode has a conductive signal plate 12 which is transparent for X-ray radiation. As a signal plate, for example, a thin aluminum sheet may serve. Said signal plate carries the X-ray sensitive selenium layer 13. The experiments with X-ray image iconoscopes have shown that a suitable thickness of the amorphous selenium layer 13 is between 50 microns and 300 microns. The signal plate and the X-ray sensitive selenium layer may also be applied directly to the tube bulb.

Over the operational resistance 14 the signal plate is supplied with a biasing potential. According to the thickness of the amorphous selenium layer, said biasing potential may be -600 v. or more. In order to interrupt the induced conductivity produced by the scanning ray, it may be advisable to provide the free surface of the amorphous selenium layer with a mosaic 25 which is impenetrable for the electrons of the scanning ray. The load images produced on the free selenium surface through change of resistance in the X-ray sensitive selenium layer are supplied to the image amplifier 16 through the scanning by means of the electron ray in a known way over the coupling condenser 15. An acceleration electrode 17 suitably comprising a fine mesh net or metal ring is disposed between the signal plate 12 and the scanning aperture 24 of the ray system. In the neck of the glass bulb suitable elements are provided for producing an electron ray bundle. They consist of a cathode 18 with a heating wire 19, the Wehnelt cylinder 20 and the anode 21. Through the scanning aperture 24, the electron ray is finely restricted in order to improve the resolving power of the iconoscope. Parts of the inner surface of the glass bulb are coated with a conductive material so as to deflect charges on the glass wall. Since the X-ray images reach the selenium layer in their natural size, a good dissolution capacity can be obtained with the iconoscope. Due to the large deflecting amplitudes, it is necessary to provide for particularly good magnetic screening.

Besides the function as an iconoscope with high scanning ray velocity, a function with orthicon electron optics is also possible as shown in Fig. 5. In this Figure the X-ray sensitive layer 12 with its support 13 is mounted in the envelope of a conventional orthicon tube 11a which is surrounded by the customary longitudinal focusing coil 23a, while in place of the coil 22 employed in Fig. 4 there is used with the orthicon tube 11a an adjustment coil 22a.

In order to make the selenium more sensitive or, in other words, to decrease its electrical inertia, heavy metals or heavy metal selenium compounds may be mixed with the selenium such as, for example, lead or lead selenide. Lead selenide is known as a high-ohmic light sensitive substance.

The proportion of said heavy metals in the amorphous selenium layer should be variable from minimum amounts to the stoichiometric relation of the corresponding selenide in order to obtain the most advantageous composition for the responsiveness of the resistance layer to X-rays under all conditions.

Within the framework of the invention also the usability of said foreign ingredients transversely to the maximum extension of the layer is included, for example, so that the side of the layer opposite to the X-rays consists of pure selenium, while the side of said layer facing the X-rays has an increasing proportion of foreign ingredients or selenides 13a, respectively as shown in Fig. 6. Among the selenides having advantageous photoelectric qualities, silver selenide occupies a prominent position.

With regard to the employment of the cells as resistance scanners, it may also, under certain circumstances, be suitable to enrich the side opposite the X-ray with foreign metals 13b (Fig. 7) since the side facing the scanning ray, that is, the side opposite the X-ray, must have the lower conductivity. Said two considerations may be combined if the scanning takes place from the side of the X-ray radiation. With regard to the surface activation of selenium layers with foreign metals, it may be advisable to apply the same through cathode spraying in air whereby, in addition to the interior photo effect, an arrest layer effect occurs, which influences the photoelectric qualities of the cells in an advantageous direction. As an additional mixing ingredient for the selenium layer, tellurium should also be mentioned, which, as is well known, reduces fatigue phenomena of the photo-effect in selenium.

In contrast to the known arrest layer cells of selenium, the X-ray sensitive photo-element according to the invention has the advantage of high ohmic resistance which is of advantage, particularly with regard to the use for the resistance scanner.

What we claim is:

1. A semi-conductive element, comprising a radiation sensitive semi-conductive layer of amorphous selenium having a thickness of about 200 microns, said layer having been formed by evaporation in vacuum under avoidance of crystallization at a temperature below 125° F. to make it sensitive for X-rays, and foreign materials having been added to said amorphous selenium which serve for sensitizing, i. e. for reducing the electric inertia of said selenium.

2. An element as in claim 1, in which said foreign materials comprise heavy metals.

3. An element as in claim 2, in which the proportion of said heavy metals is variable from minimum values to the stoichiometric relation of the corresponding selenide.

4. An element as in claim 1 in which said foreign materials comprise heavy metal compounds with selenium.

5. An element as in claim 1, in which the proportion of foreign ingredients in the selenium layer is variable transversely to its maximum extension in such a way that the side of the layer opposite to the X-rays consists of pure selenium, while the side of said layer facing said X-rays has an increasing proportion of said foreign ingredients.

6. An element as in claim 1, in which said foreign materials comprise selenide of silver.

7. An element as in claim 1, in which the side of the selenium layer opposite to the X-rays is enriched with said foreign materials, while the side of said selenium layer facing the X-rays has less proportion of said foreign materials.

8. An element as in claim 1, including a proportion of tellurium in said selenium layer in order to avoid fatigue phenomena.

9. A photoelectric element comprising a semi-conductive layer consisting of amorphous selenium formed by evaporation in vacuum under avoidance of crystallization at temperatures below 125° F. and having a thickness of about 200 microns so as to render the resistance of the layer sensitive to X-ray radiation, and large area electrodes in contact with said layer at both sides of said layer, said electrodes consisting of material which does not react with selenium and at least one of said electrodes being penetrable by X-rays.

References Cited in the file of this patent

UNITED STATES PATENTS

1,491,040	Hart	Apr. 22, 1924
2,010,712	Coolidge	Aug. 6, 1935
2,569,872	Skehan et al.	Oct. 2, 1951
2,608,611	Shiver	Aug. 26, 1952
2,654,853	Weimer	Oct. 6, 1953