Sept. 15, 1959 F. J. MASI ET AL 2,904,689

FLUORESCENT X-RAY SCREENS

Filed June 1, 1956

FIG. 1

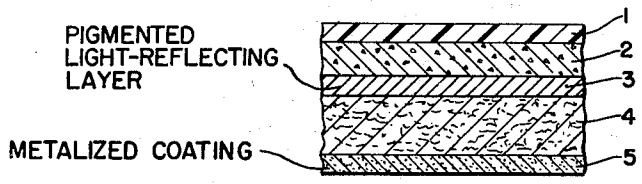


FIG. 2

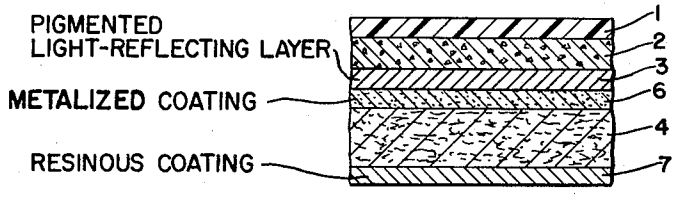


FIG. 3

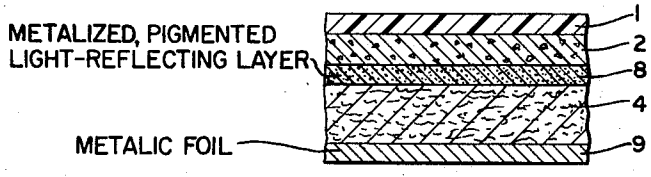


FIG. 4

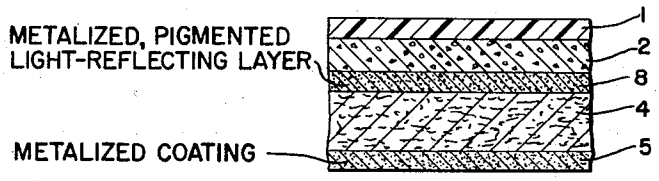
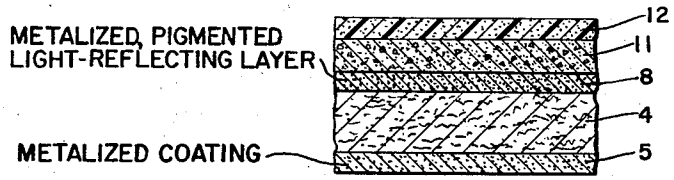


FIG. 5



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FLUORESCENT X-RAY SCREENS

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4 Claims. (Cl. 250—80)

This invention relates to fluorescent screens employed to intensify the image produced by X-rays on a photositive film or plate. More especially the invention relates to the reduction of undesired exposure of the photosensitive emulsion by local static discharges between such screens and the film or plate.

Intensifying screens are employed to increase the exposure of the sensitized plate or film (hereinafter referred to as a "negative") without increasing the exposure time or the X-ray concentration. These screens are customarily inserted on both sides of the negative, and the resulting "sandwich" is secured in a light-tight holder known as a cassette. In exposing the negative, the X-rays pass through one side of the cassette, through one entire intensifying (front) screen, through the sensitized negative and thence into the fluorescent layer of the second intensifying (back) screen. This causes both screens to fluoresce, and the resulting light combines with the X-rays in exposing the negative.

Radiologists are aware of the fact that, in addition to the intentional exposure of the negative by the process above summarized, X-ray negatives frequently are mottled by spurious exposures which have been found to be due to local static discharges. These discharges are more prevalent in dry climates and they appear also to be related to the materials employed in the negative and in the intensifying screen, some materials being more prone than others to the generation of static charges. Explanations of static charges and discharges and the relation of the characteristics of materials thereto, especially dielectric characteristics, are to be found in chapters on static electricity in text books on physics. In general, two types of static electricity have been observed in connection with X-ray screens and negatives or films: (1) friction static which results from relative movement (usually sliding) between the negative and the adjacent screen, and (2) pressure static which results when the screen is pressed tightly against the negative. Both types of static are discharged when the negative is separated from the screen, because the work in so doing induces a high potential difference. The friction type of static produces dark streaks or crow-foot designs on the developed negative and the pressure static produces dark spots which are usually denser than the first type, but both interfere with an accurate reading and interpretation of the radiograph. Heretofore, no successful means has been proposed to overcome the undesired exposure by static discharge.

We have discovered that this undesired exposure can be substantially reduced by introducing into the intensifying screen structure one or more discrete layers of suitable material which is electrically conductive in the manner below described, and sufficiently transparent to X-rays. It has been found that satisfactory results can be achieved by interposing separate conductive layers or by modifying previously employed layers so as to be sufficiently conductive.

The invention will be more fully understood from the following description considered in connection with the accompanying drawings in which:

Fig. 1 illustrates in cross section, an embodiment of the invention which is generally preferred because it is of simple construction and is especially effective in minimizing static discharges;

Fig. 2 is an alternative construction of an intensifying screen in which a conductive layer is interposed near the center;

Fig. 3 shows another alternative in which the pigmented light-reflecting layer is modified to comprise a conducting layer;

Fig. 4 shows a third alternative embodiment employing two layers of metallic foil; and

Fig. 5 illustrates an embodiment in which all of the layers except the backing sheet are conductive. The various layers are not drawn to scale in any of the figures.

In the preferred embodiment of Fig. 1 an intensifying screen is shown which comprises a backing and supporting sheet 4 which is coated with four different layers. Layer 2 includes a phosphor material (indicated by angular particles) which fluoresces when energized by X-rays. Layer 3 is a pigmented light-reflecting layer. Layer 1 comprises a thin protective covering layer which is substantially transparent to visible light in both directions and is arbitrarily represented by the symbol for plastic. Layer 5 comprises a metallized coating preferably of aluminum flakes secured in a binder, and is represented by stippling. The materials employed in the various mentioned layers and their relative locations are important in connection with the present invention. Consequently, the nature of the mentioned layers and the principles by which the desired results can be achieved will now be described.

The material of which the supporting or backing sheet 4 is made can be chosen from several substances having various characteristics. The better known materials are paper and certain plastics. Some plastic materials are not suitable for intensifying screens because they absorb too much X-ray energy. We presently prefer thick paper as a backing material because it has the required mechanical characteristics, viz., is firm but suitably flexible, is comparatively cheap and is highly permeable to X-rays. For the present purpose we employ paper of thickness in the range between 0.005 inch and 0.020 inch, the preferable thickness being from 0.014 inch to 0.016 inch. Substantially the only disadvantage of paper is that it is subject to absorption of moisture which tends to alter its dimensions and reduces its dielectric qualities. However, when coated in accordance with the present invention, the paper backing sheet is substantially unaffected by moisture conditions usually encountered.

Among the plastic sheet materials suitable as a backing support are cellulose acetate or nitrate, polystyrene, polymethracrylates, rubber, the polyesters and cloth of vegetable or glass fiber coated or impregnated with any of these materials. The thickness required would depend, of course, upon the characteristics of the particular material, but, in general, thicknesses of the order mentioned in connection with paper are useful. One plastic material which we have used with good success for backing sheets comprises white-pigmented polyvinyl acetate-polyvinyl chloride copolymer sheet, 0.015 inch thick.

On top of the backing layer is a pigmented reflecting layer 3 which is employed, as shown in this embodiment, for the purpose of reflecting visible light toward the photographic negative. Although some intensifying screens presently employed in the art do not include such a reflecting layer, we prefer to employ it, because it improves the overall efficiency of the screen. Its X-ray ab-

sorption is negligible, but its reflection of light on the negative is considerable. This pigmented layer comprises titanium dioxide stirred with a small amount of binder and solvent. Such a layer has high dielectric properties.

The fluorescent layer 2 may comprise any of the phosphor materials commonly employed for the purpose. Obviously, the material should be one which actively fluoresces when energized by X-rays, and should have light-emitting properties which match as closely as possible the light-sensitivity characteristics of the photographic emulsion employed in the negative. These characteristics are now well known in the art and need not be discussed here. Usually the phosphor employed comprises calcium tungstate in finely divided form and applied as a suspension in a solution of a suitable binder such as cellulose nitrate or acetate in a suitable solvent. To provide high X-ray efficiency it is preferable that a minimum amount of binder be employed, preferably less than 5% by weight calculated on the mixture. However, the less the proportion of binder material the more brittle is the layer. Consequently, there is an optimum relationship, readily ascertained, between the amount of binder required and the stiffness of the backing sheet 4. In general, flexibility is an advantage.

The cover layer 1 is for the purpose of protecting the fluorescent layer. Such a coating is customarily employed in intensifying screens and, like the fluorescent layer itself, need not be described in detail. It should be as transparent as possible to visible light, as well as X-rays, and should have a hard surface and be moisture resistant. Customarily such a layer is comprised of a solution of cellulose acetate in any suitable solvent in sufficient quantity to produce a very thin film when dry. This coating protects the phosphor surface against abrasion, dirt and moisture, and it comprises a dielectric material.

In accordance with the invention, a "conductive" layer 5 is applied to the rear surface of the backing sheet 4. Although many different conductive materials of various physical forms may be employed in this layer, we have found that aluminum appears to be the most satisfactory because, in the thickness required to produce adequate conductivity, its X-ray absorption is tolerable, it is readily available in a variety of forms, and is inexpensive.

It appears that in order to minimize the above-described effects of static discharges in undesirably exposing the photographic negative, it is necessary to construct the screen so that in itself it constitutes a condenser, or an aggregation of condensers, of sufficient electrostatic capacity to dissipate the local charges built up on the front surface of the screen due to the pressure or to the relative movement between the screen and the negative with which it is in contact. Consequently, a conductive layer, viz., a layer comprising conductive material, is added to the screen in juxtaposition to the front surface but separated therefrom by dielectric material. The various layers commonly employed in the more recent forms of intensifying screens themselves are of material having reasonably good dielectric properties. It is feasible to provide a conductive layer at various stratum levels in the screen structure either as a discrete conductive layer interposed for the purpose, or as a layer which is made partially conductive by introducing conductive material into a layer also employed for another purpose. Several alternative constructions are therefore possible to provide the anti-static effects in accordance with the invention. By using a suitable metal or non-metallic conductive material of small particle size, mixed with a suitable resin or plastic binder, the layer not only provides the required conductivity but, if applied to the rear surface of the supporting sheet 4, tends to seal it against moisture, thus stabilizing the product as to dimensions and anti-static qualities. For this reason, it is preferable that the edges of the backing material, especially if it is of a fibrous nature, be coated also.

We have found that, in general, material having a certain degree of conductivity is required to produce the necessary effective electrostatic capacity. However, since the absorption of X-rays increases with increased density of such materials, there is an optimum relationship between the quantity of metal and its physical form required to provide sufficient conductivity with minimum, or at least tolerable, X-ray absorption. In employing aluminum, which we presently prefer, it appears that a given weight in flake form, for example, provides at least as effective anti-static qualities as does the same weight of aluminum employed in the form of thin foil.

The aluminum layer 5 shown in the screen structure of Fig. 1 preferably is formed as follows: Aluminum flake, of which approximately 98% passes through a 325 mesh screen, is dispersed in a resin binder dissolved in methyl ethyl ketone. An example is as follows:

	Parts by weight
Methyl ethyl ketone	70.0
Vinyl chloride-acetate copolymer	30.0
Aluminum flake	6.0

The aluminum flake is stirred into a binder solution composed of the vinyl chloride-acetate copolymer dissolved in the methyl ethyl ketone. A proportion of aluminum of the mentioned particle size in the range of between approximately 16% and 17% of the total solids appears to provide the most effective anti-static qualities. The dry film thickness of the mentioned coating may, with satisfactory results, vary between 0.0001 inch and 0.002 inch, a coating of 0.0013 inch having been determined to be a satisfactory mean. The linear conductivity is low in such a coating, but the static-reducing effect according to this invention appears not to depend substantially on linear conductivity because the static potentials comprise localized charges which can be dissipated by localized capacitive effects contributed by individual conductive particles, or by small groups thereof, suitably separated by dielectric material. As above stated, this coating also provides excellent protection against moisture absorption by the backing material and incidentally enhances the appearance of the product.

Other resins which may be used as binding materials for the conductive layer include cellulose esters and ethers, acrylic and methacrylic polymers, and other organic soluble thermo-plastic or thermo-setting resins, if capable of furnishing suitable film-forming properties which are compatible, under the conditions of application with the materials employed in the adjacent layers. Additional binding materials which can be employed for the purpose, although probably not so desirable, include methyl cellulose, hydroxy methyl cellulose, polyvinyl alcohol, alcohol-soluble and water-soluble resins and gums, if capable of furnishing suitable film-forming properties and which can be rendered insoluble in water by special treatment. It is undesirable in screens of the nature herein described to employ substances which in their final condition are hygroscopic.

The proportion of aluminum, or other metal, or non-metal, powder or flake which will be required to provide the optimum effect will vary to some degree in accordance with the particular binding material employed and to the treatment which it must be given in the course of the fabrication of the conducting layer. However, this proportion can readily be ascertained by a worker in the art once he has made a selection of the specific materials to be used. Likewise it is unnecessary here to specify the exact solvent to be employed with any selected binder because satisfactory solvents for the various binders are well known in the organic chemistry art.

The electrically conductive material may be any of a variety of substances, including metals and non-metals such as carbon and silicon. Most, if not all of these, are likely to be more expensive than aluminum, and their characteristics are, for the most part, not useful for the purpose as are those of aluminum. However, other metals including iron, nickel, copper, silver, tin, lead and

bismuth, can be used in back screens, viz., behind the X-ray negative. Carbon is less dense and absorbs X-rays less. If the electrically conductive layer is positioned so that X-rays must pass through it in order to penetrate and expose the photographic emulsion on the negative, as in front screens, then it is preferable to use a stable metal of low density, such as aluminum. Satisfactory X-ray transmission can be taken to be that which produces an exposed emulsion density within 2% of the control density. However, the X-ray absorption is immaterial if the conductive metal is placed on the back of the screen, as in Fig. 1, and this screen, in turn, is disposed on the far side of the negative away from the X-ray source, as above mentioned.

The embodiment illustrated in Fig. 2 differs from that of Fig. 1 in two respects. First, an aluminized layer or coating **6** is interposed between the back sheet **4** and the pigmented reflecting layer **3**, and second, the rear surface of the backing sheet is coated with a layer **7** which may comprise any desired moisture-resistant resin, but it may be thicker than layer **1**. The object of this layer **7** is, as before, to seal the paper or cardboard or other backing material, if necessary, against the absorption of moisture or other substances. If desired, the aluminized layer of Fig. 1 can also be employed on the rear surface instead of the resinous layer **7**.

The interposition of an aluminized layer **6** between layers **3** and **4**, as in Fig. 2, is satisfactory in its anti-static effects, especially if either the pigmented layer **3** or the fluorescent layer **2**, has good dielectric properties. This layer may be formed of any of the materials or combinations of materials above described in connection with conductive layers.

The screen structure of Fig. 3 differs from those of Figs. 1 and 2 in two novel respects. Instead of employing a pigmented layer such as layer **3** in Figs. 1 and 2, the pigmented reflecting layer **8** in this embodiment is made conductive by the addition of aluminum particles. It appears to make little difference whether the particles are of flake or granular form, if of the same preferred particle size, although the flake is usually less expensive. The results of tests indicate that the addition of the aluminum to the pigmented layer, if in the same quantity as above mentioned, provides substantially the same anti-static qualities in the arrangement of Fig. 3 as it does in the arrangement of Fig. 2. However, the specular light-reflecting properties of the layer **8** are somewhat decreased by the addition of the aluminum, and for that reason a light-reflecting layer without the metal particles is preferred, if maximum light output be required. Nevertheless, the structure of Fig. 3 is useful and eliminates the additional layer in the embodiment of Fig. 2. In the structure of Fig. 3 the rear surface of the backing sheet **4** is covered with a thin layer **9** of aluminum as illustrated. Foil of a thickness of 0.002 inch cemented to the backing sheet **4** is suitable for the purpose, although, as above stated, it is more readily damaged than is a coating of aluminum flake in a binder, such as **5** in Fig. 1.

The screen structure illustrated in Fig. 4 is similar to that of Fig. 3 except that the conductive foil on the rear surface of backing sheet **4** here comprises a resinous layer containing aluminum particles as described in connection with Fig. 1. Although the light-reflecting properties of layer **8** are, as above mentioned in connection with Fig. 3, somewhat decreased by the addition of the aluminum particles, the anti-static properties of the structure are at least as good as those of any of the preceding structures because the dielectric backing sheet has a conductive layer on each side of it. The improved charge-absorbing characteristics of this structure are believed to result from the presence of a conductive layer **8** below the dielectric layers **1** and **2** and of another conductive layer **5** below the dielectric layer **4**.

The intensifying screen illustrated in Fig. 5 is different from all of the others in the respect that aluminum (or other conductive) particles are dispersed in all of the layers, except the backing sheet. Here, the rear surface of the backing sheet **4** is coated with an aluminized layer **5**, as in Fig. 1, and the front surface of the backing sheet **4** is coated with a mixture of titanium dioxide and aluminum particles in a suitable binder forming a coating **8** which is the same as that illustrated in Fig. 3. Additionally, in the present embodiment, the fluorescent layer **11** and the protective coating **12** both contain conductive particles, but preferably in lesser quality than in the other layers. The electrical effect of this construction is that the three top layers **8**, **11** and **12** act as a single conductor or electrode, and the layer **5** on the rear of dielectric sheet **4** acts as the second conductor, or electrode, of the condenser. Electrically this construction is effective in eliminating the undesirable effects of static, but the addition of conductive particles in the layers **11** and **12** reduces the transmission of light. This embodiment illustrates the fact that substantially any one or a combination of the layers above or below the backing sheet can be made conductive, if separated by a dielectric layer, in order to dissipate the deleterious static charges, as above explained. It is also to be understood that metallic foil, especially if of low X-ray absorption, can be substituted for the conductive particles in any discretely conductive layer.

We claim:

1. An X-ray intensifying screen comprising: a backing sheet of cardboard, a moisture resistant and electrically conductive coating of aluminum particles in a resin binder on the back and edges of said sheet, a light-reflecting layer containing titanium dioxide on the front of said sheet, a fluorescent layer on the reflecting layer, and a smooth, thin, transparent, protective dielectric coating film over the fluorescent layer, whereby to minimize static discharges when the surface of said protective dielectric coating film is pressed against a radiographic film and subsequently removed therefrom.

2. An X-ray intensifying screen comprising in the order named: a translucent, moisture-resistant protective coating film of dielectric material, a fluorescent layer, a dielectric backing sheet and a moisture resistant and electrically conductive coating comprising metallic aluminum particles in a binder on the rear surface of said backing sheet, whereby to minimize static discharges when the surface of said protective coating film is pressed against a radiographic film and subsequently removed therefrom.

3. An X-ray intensifying screen comprising a backing sheet having dielectric properties, a coating between .0001 and .002 inch thick on the rear surface of said sheet comprising aluminum particles substantially of 325 mesh in a binder of vinyl chloride-acetate copolymer in proportion of the order of 1:5 by weight, a pigmented layer on the front of said sheet comprising titanium dioxide, a fluorescent layer on said pigmented layer comprising a phosphor material in a resin binder, and a protective film comprising transparent material having dielectric properties covering said fluorescent layer, whereby to minimize static discharges when the surface of said protective film is pressed against a radiographic film and subsequently removed therefrom.

4. An X-ray intensifying screen comprising a backing sheet of dielectric material, a moisture-resistant coating layer on one side of said sheet, a pigmented light-reflecting layer over the other side of said sheet, a fluorescent layer on said pigmented layer, and a static-forming translucent protective layer including a dielectric resinous material on said fluorescent layer, said moisture-resistant coating layer being characterized in that it contains metallic particles in quantity sufficient to impart electrical conductivity thereto such as to minimize localized static discharges when the face of said screen which bears said

protective layer is pressed against a photographic negative and subsequently removed therefrom.

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CERTIFICATE OF CORRECTION

Patent No. 2,904,689 September 15, 1959

Frank J. Masi et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, lines 16 and 17, for "photositive" read -- photosensitive --; column 5, line 17, for "back" read -- backing --; column 6, line 11, for "quality" read -- quantity --.

Signed and sealed this 1st day of March 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents