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Sugiyama et al.

[11] **3,753,714**

[45] **Aug. 21, 1973**

[54] **IMAGE FORMATION BY RADIATION AND INTENSIFICATION**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **96/45.1,** 96/82, 250/80

[51] **Int. Cl.** **G03c 1/92**

[58] **Field of Search** 96/82, 45.1; 250/80

[56] **References Cited**

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[57] **ABSTRACT**

A method for forming an image by radiation, which comprises:

a. closely contacting a photographic light-sensitive material having a silver halide emulsion layer on only one side of a support thereof with a fluorescent intensifying screen, and
b. subsequently subjecting the light-sensitive material to the steps of:
c. radiation
d. development
e. fixation, and
f. intensification,

said resulting combination characterized in that the emulsion surface and fluorescent surface are facing each other.

17 Claims, 8 Drawing Figures

FIG. 1

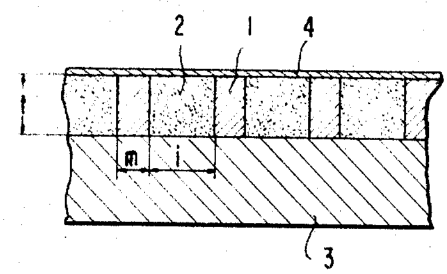

FIG. 4

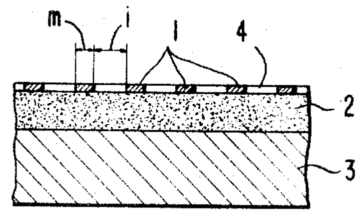

FIG. 2

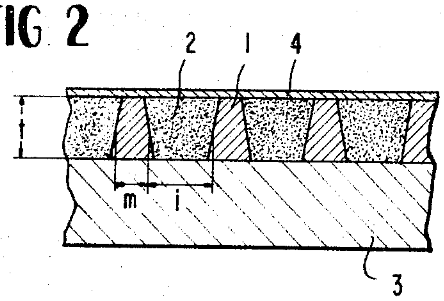

FIG. 5

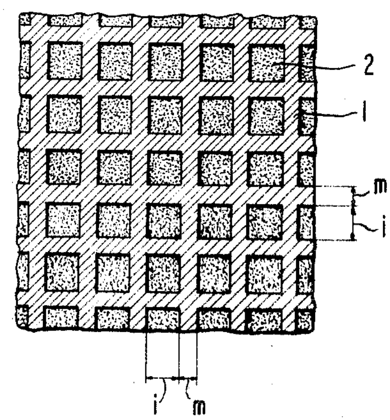

FIG. 3

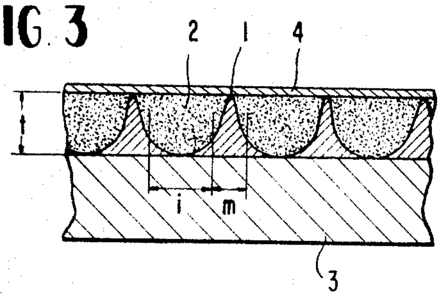

FIG. 6

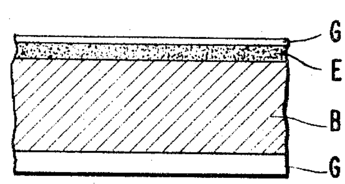

FIG. 7

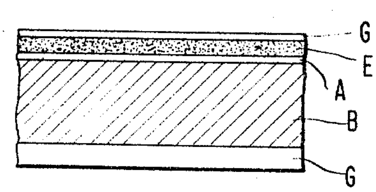

FIG. 8

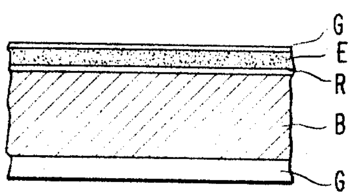

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IMAGE FORMATION BY RADIATION AND INTENSIFICATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for forming an image by radiation.

2. Description of the Prior Art

More particularly, it is concerned with a method for raising markedly the quantity of information about an X-ray transmission image of an object as compared with the prior art system. This invention provides a new system wherein a fluorescent intensifying screen capable of reducing scattered X-ray and decreasing the coarseness of image grains due to various factors, is combined with a silver halide light-sensitive material capable of raising the sharpness correspondingly and giving a high covering power image.

In light-sensitive materials for radiography, such as X-ray films for direct photographing as used in medical examinations, gelatino-silver halide emulsion layers are applied to both surfaces of a support to obtain a sufficient sensitivity and gradiation. When photographing with such light-sensitive material by radiation, extensive radiation is necessary for the above-mentioned two emulsion layers and, consequently, a human body to be photographed is in danger of radiation injury. Therefore, the effective use of radiation energy is ordinarily carried out by holding both emulsion layers between fluorescent screens. The fluorescent screen has generally a coating of fluorescent substance, such as calcium tungstate on a mount, which is capable of converting the radiation energy applied into a fluorescent energy effective for the image formation in a silver halide emulsion. When the above-mentioned light-sensitive material for radiography is radiated, light emitting from one of the fluorescent screens holding the two emulsion layers acts upon the emulsion layer in contact therewith. A part of this emitted light penetrates the emulsion layer and support, spreads and reacts with the other emulsion layer. This is followed by a reflection on the other fluorescent screen and repetition of the foregoing actions. That is to say, there occurs a blurring of light due to the so-called multiple reflection, resulting in the lowering of the quality of a silver image obtained by developing this light-sensitive material. This phenomenon is due to the use of the light-sensitive material having two emulsion layers on the both surfaces of a support and the two fluorescent intensifying screens holding them.

Since emulsion layers are provided on the both sides of a support, an extensive amount of silver salt is necessary. In addition, processing steps, such as coating steps, are increased. Hence, the methods of the prior art are disadvantageous from an economical as well as technical point of view.

SUMMARY OF THE INVENTION

It is, therefore, the principal object of the present invention to provide a method for forming a radiographic image enriched in information by radiating a photographic light-sensitive material having a silver halide emulsion layer on one side of a support only.

Accordingly, this object can be accomplished by the following procedures in combination. The first, is to use a light-sensitive material having a silver halide emulsion layer on one side only. The second, is to carry out radiation of the fluorescent intensifying screen containing a metal mesh inside or having a lattice pattern printed on the surface, which will hereinafter be illustrated in detail, in close contact with the above-mentioned light-sensitive material. The third, is to carry out an intensifying treatment after exposure and development of one side of the emulsion layer in order to obtain an optical density equal to that of the prior art's both side emulsion layers. These three procedures, may with some advantage be applied individually. However, a combination is preferred.

When the intensifying treatment is carried out to raise the optical blackness, the graininess of the image often deteriorates the image quality. However, the deterioration of the image quality can be prevented by the second procedure employed in the present invention. That is, using the intensifying screen containing a metal mesh inside or having a lattice pattern on the surface, in order to provide a lattice pattern to the image. Moreover, the metal mesh plays an important role in reducing scattered X-rays. Accordingly, this procedure may have a multiple effect in obtaining a radiographic image rich in information.

DETAILED DESCRIPTION OF THE INVENTION

Exposure of the above-mentioned photographic light-sensitive material is preferably carried out by applying radiation from the side of the mount of the intensifying screen while the emulsion surface provided on the support and the fluorescent surface of the sensitizing screen are in close contact. However, the radiation may be carried out from the side of the support of the photographic light-sensitive material as well.

The intensifying screen used in the invention is obtained by filling in a fluorescent material between parallel walls, concentric walls or lattice walls of metal provided on a mount and, if necessary, further coating thereon uniformly. The intensifying screen may also be obtained by providing on the surface of a fluorescent material layer coated uniformly on a mount, a protective layer having a pattern of parallel lines, concentric circles or lattice. The color must be such that a light of wavelength capable of acting upon a silver halide light-sensitive material is hardly penetrated or by printing the same thereon. As the metal for making the metal wall, a heavy metal such as lead, copper, nickel or chromium or light metal such as aluminum, may be employed. From the standpoint of X-ray absorption, a heavy metal is preferred.

The invention will now be illustrated in detail by the accompanying drawings in which **FIG. 1** to **FIG. 5** are vertical sectional views and plane views of fluorescent sensitizing screens used in the method of the invention and **FIG. 6** to **FIG. 8** are vertical sectional views of the layer structure of the light-sensitive materials used in the method of the present invention. **FIG. 1** illustrates a fluorescent intensifying screen wherein metal walls **1** are arranged on mount **3** at identical intervals and fluorescent substance **2** is filled in between them, onto which a protective layer **4** is coated. In **FIG. 2**, the shape of metal wall **1** is a trapezium and in **FIG. 3**, metal wall **1** is formed into a wave. In these Figures, t denotes the thickness of the fluorescent substance layer, i denotes the distance between the metal walls, and m denotes the thickness of the metal wall. The relation of t, i and m depending on the combination of an object to be photographed and the photographing means, may be represented as follows:

$$t = 10\ \mu \sim 300\ \mu$$

$$i = 10\ \mu \sim 200\ \mu$$

$$m = 5\ \mu \sim 100\ \mu$$

FIG. **4** illustrates a cross section of a fluorescent intensifying screen, in which the fluorescent substance **2** is uniformly coated onto a mount **3**. On the surface thereof, is provided a surface protective layer **4** having lattice pattern **1** in such a color and thickness that the transparency of an actinic light for a silver halide light-sensitive material is 0–30 percent. FIG. **5** is a plane view of the lattice pattern, the shaded portion being the above mentioned lattice that light scarcely penetrates. It is desirable that the relation of the width of this portion m and the width of space portion i is $i = 2m$. Such a lattice screen gives such a good effect that three to 12 pairs of stripes $(i + m)$ are present per 1mm.

Papers and resins such as cellulose acetate and polyethylene terephthalate may be used as a mount, which have a strength sufficient to hold the fluorescent substance and metal walls.

The ordinary gelatino-silver iodobromide emulsion for radiographic film may be used as a gelatino-silver halide emulsion. Other emulsions may of course be employed. This includes sensitized emulsions as well. Protective colloids other than gelatin, for example, polyvinyl alcohol, polyvinyl imidazole and their mixtures with gelatin may be employed.

According to the present invention, the photographic light-sensitive material has a coating of silver halide emulsion on only one side of the support. On the other hand however, there may be favorably coated, an antihalation layer or curl balancing layer; otherwise, an antihalation layer or light reflecting layer may be provided between the support and emulsion. FIG. **6** to FIG. **8** illustrate examples in which E is a light-sensitive emulsion layer, B is a support, A is an antihalation layer, G is a gelatin layer and R is a light reflecting layer. As the support, glass, baryta paper, cellulose acetate film, polyethylene terephthalate film, synthetic paper or laminated sheets thereof, may be employed. In the preparation of the photographic material of the present invention, the addition of additives, such as stabilizer, hardeners and coating aids, as well as coating and drying methods are not limited.

Similarly, the developers and fixing solutions are not particularly limited. However, known developers, such as hydroquinone or p-amino-phenol and fixing solutions such as ammonium thiosulfate or sodium thiosulfate are preferred.

The photographic light-sensitive material thus developed, fixed and if necessary, washed with water and dried, has a black image only on one side. Accordingly, the quantity of information as a radiograph is less than that in the prior art. The intensifying treatment is carried out in order to raise the blackness. This is another feature of the present invention. "Intensification" is a means required when exposure or development is not carried out sufficiently. In the method of the present invention, however, the intensifying treatment is carried out even when a suitable exposure and development are accomplished. The object of the intensifying treatment according to the present invention is different from that of the prior art intensification. However, both treatments are common in the aspect of raising the degree of blackness. Accordingly, the intensifying treatment may be carried out in a conventional manner, for example, by using compounds of metals other than silver, such as mercury, chromium, iron, copper, lead and uranium. In general, the intensifying treatment comprises a two bath treatment wherein the silver image is oxidized with the above-mentioned metal compound and subsequently blackened with a reducing substance. A water-washing treatment is also employed. This two bath treatment may be carried out in one bath as well. (Cf. Mees, "The Theory of the Photographic Process," revised edition, 1963, pages 744–753).

Each of the procedures according to the present invention, e.g., providing a silver halide emulsion layer on one side of a support only, using a fluorescent sensitizing screen such that a fluorescent substance is filled in a metal mesh and the intensifying treatment in general, is not necessarily known. However, the salient feature of the present invention resides in the overall combination of these procedures whereby enhanced effects over the prior art are achieved. That is to say, it is possible to reduce the number of silver halide emulsion layers from two layers to one layer as well as to increase the quality of a radiographic image without increasing the quantity of radiation absorbed by the human body.

A better understanding to the present invention will be attained from the following examples, which are merely intended as illustrative and not limitative of the present invention.

EXAMPLE

On side of a blue-colored polyethylene terephthalate film support was coated in a conventional manner with a high sensitivity, ammonia process, silver iodobromide gelatin emulsion having an average grain size of about 1.5 μ and then dried. The quantity of silver coated was about 60 mg/100 cm^2. A gelatin protective layer was coated onto the surface in a thickness of about 2 μ. Another side of the support was coated with a gelatin layer of suitable thickness and dried for the purpose of curl balance with the silver halide emulsion layer. On the other hand, a sensitizing screen was made by closely contacting a copper net of the structure shown in FIG. **1**, having a dimension of i=80 μ, $m = 20\ \mu$ and $t = 120\ \mu$, with a mount, filling in with calcium tungstate as a fluorescent substance and applying a protective layer of cellulose diacetate of about 5 μ to the surface. A radiographic cassette on which the sensitizing screen was placed was charged with the light-sensitive material in such a manner that the fluorescent substance layer and silver halide emulsion layer was contacted.

As the prior art system, a double-sided radiographic film as generally used was charged in a cassette on which two intensifying screens were oppositely placed. To measure the quality of the radiographic images of both systems, radiation with X-rays of 60 kvp, 200 mA and 0.02 second was carried out using a X-ray resolving power test plate of lead as an object to be photographed and adjusting the distance between the focus of the X-ray tube and the film to 180 cm. Both the films were developed, fixed and washed with water under the standard X-ray film processing conditions. The film of the prior art system was dried. The film of the new system, having a coating of silver halide on one side only, was subjected to the following intensifying treatment, followed by water washing and drying:

Intensifying solution (I)

KBr	20g
$HgCl_2$	20g
H_2O	1000ml

Intensifying solution (II)

3 percent ammonia water

The intensifying treatment was carried out by immersing the film developed and fixed, in the solution (I) at 34° C., for 1 minute 30 seconds, washing with flowing water for 3 minutes, immersing in the solution (II) at 34° C., for 1 minute 30 seconds, washing with flowing water for about **10** minutes and then drying.

From a curve illustrating the relationship between the spacial frequency the resulting radiographic image and the response in the amplitude of the image density thereto, the resolving power was estimated by the spacial frequency at which the response was lowered to 50 percent. The results are shown below:

Comparison of Resolving Powers (spacial frequency at response 50 percent number/mm)

System	Image density at a spacial frequency of 0	
	about 1.8	about 2.5
System of the invention	30	11
System of the prior art	17	10

As is evident from this table, the resolving power at a point where the response is lowered to 50 percent is improved by about two times as much as that of the prior art. That is, from 17 to 30/mm when the uniform image density is about 1.8.

Although the present invention has been adequately described in the foregoing specification and examples included therein, it is apparent that various modifications and changes may be made without departing from the scope thereof.

What is claimed is:

1. A method for forming a high quality image by radiation, which comprises:

1. closely contacting a photographic light-sensitive material consisting essentially of a silver halide emulsion coated on a support with a fluorescent intensifying screen, said silver halide emulsion facing said intensifying screen; said photographic light-sensitive material having said silver halide emulsion layer on only one side of said support; said intensifying screen consisting essentially of a support, a metal lattice coated thereon and fluorescent material filling the spaces in the metal lattice; the metal walls of said metal lattice having a width *m* forming a distance *i* between said metal walls wherein from 3 to 12 stripes $i+m$ are present per millimeter; and

2. subsequently subjecting the photographic light-sensitive material to the sequential steps of:

3. radiation,

4. development,

5. fixation, and

6. intensification, wherein, the resulting combination, said silver halide emulsion and the fluorescent material are facing each other.

2. The method of claim **1** wherein said intensification is carried out with a heavy metal salt.

3. The method of claim **2** wherein the heavy metal is a member selected from the group consisting of Hg, Cr, Fe, Cu, Pb and U.

4. The method of claim **1** wherein said intensifying screen further consists essentially of a protective layer coated on said metal lattice.

5. The method of claim **1** wherein the thickness of the fluorescent material ranges from 10 μ – 300 μ.

6. The method of claim **1** wherein the distance *i* between the metal walls of the lattice ranges from 10 μ – 200 μ.

7. The method of claim **1** wherein the width m of the metal wall of the lattice ranges from 5 μ – 100 μ.

8. The method of claim **1** wherein the silver halide emulsion is a gelatino-silver halide emulsion.

9. The method of claim **8** wherein the silver halide is a gelatino-silver iodobromide.

10. The method of claim **1** wherein the silver halide emulsion contains a protective colloid selected from the group consisting of polyvinyl alcohol, polyvinyl imidazole and mixtures thereof with gelatin.

11. The method of claim **1** wherein the support of said photographic light-sensitive material is composed of a member selected from the group consisting of glass, baryta paper, cellulose acetate film, polyethylene terephthalate film, synthetic paper and laminated sheets thereof.

12. The method of claim **1** wherein the metal making up the metal walls of the lattice is a member selected from the group consisting of heavy metals and aluminum.

13. The method of claim **1** wherein the developing step is carried out with a developer selected from the group consisting of hydroquinone and p-amino-phenol.

14. The method of claim **1** wherein the fixation step is carried out with a fixing solution containing as the essential component, a member selected from the group consisting of ammonium thiosulfate and sodium thiosulfate.

15. The method of claim **1** wherein said intensifying screen consists essentially of a support, a layer of fluorescent material coated thereon and a protective layer containing a metal lattice pattern therein coated on said layer of fluorescent material.

16. The method of claim **15** wherein said metal lattice pattern has a transparency to actinic light of from 1 to 30 percent.

17. The method of claim **1** wherein the transparency of said metal lattic to actinic light is from 0 to 30 percent.

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