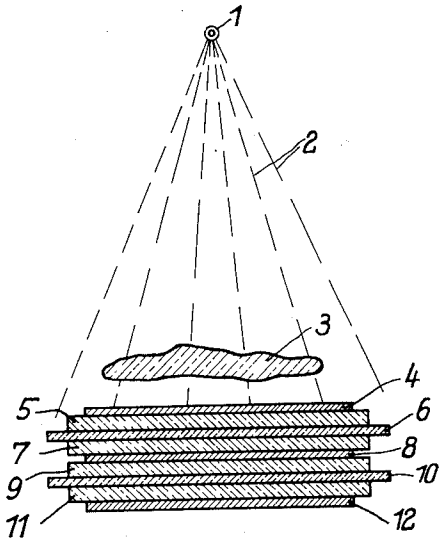
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ARRANGEMENT FOR REPRODUCING THE INTENSITY DISTRIBUTION IN A RAY OF SLOW NEUTRONS

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ARRANGEMENT FOR REPRODUCING THE INTENSITY DISTRIBUTION IN A RAY OF SLOW NEUTRONS

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The present invention relates to arrangements for reproducing the intensity distribution in a ray of slow neutrons, especially for representing objects by irradiation, in which a layer consisting of, or containing, gadolinium is placed in the neighborhood of a fluorescent substance or a light-sensitive substance or a fluorescent substance and a light-sensitive substance which, in the case of the fluorescent substance, is energized by the soft radiation emitted by the gadolinium under the influence of the impinging slow neutrons, or which (in the case of the light-sensitive substance) is directly or indirectly darkened by said soft radiation. In the following the term "sensitive substance" is employed to include as a group fluorescent substances and light-sensitive (e. g., photographic) substances.

It has been proposed (our copending application Serial No. 298,336 and our Patent No. 2,245,797) to make visible, or to record photographically, the intensity distribution in a ray of slow neutrons, especially for the purpose of passing radiation through objects, by the method according to which the slow neutrons are caused to act on an intermediate reaction layer in which they release heavy particles, electrons or gamma-rays, and the latter act again on a fluorescent substance or a photo-sensitive substance or a fluorescent substance and a light-sensitive substance in which they then produce a visible, or photographic, representation of the intensity distribution inside the ray of slow neutrons.

It has been found advisable to form the substance reacting with the neutrons while emitting heavy particles, etc., as a layer, and to arrange a fluorescent layer or a photographic layer or a fluorescent layer in association with a photographic layer in its immediate proximity. The neutron-sensitive substance could likewise be incorporated with the substance of the fluorescent layer or with the substance of the photographic layer. A drawback of these arrangements is that, due to the range of the particles and the sharpness of the representation, the effective layer is very thin and therefore, in this thin layer, only a small fraction of the impinging neutrons is absorbed. In mixing neutron-sensitive substance with the light-sensitive or fluorescent layer, moreover, so little neutron-sensitive substance can be embedded that the absorption of the slow neutrons is always much too small. It is, therefore, highly desirable to use a substance which absorbs slow neutrons as strongly as possible.

Gadolinium is such a substance. It has an especially large cross section relative to slow neutrons. This element, when reacted with slow neutrons, emits a very intensive but very soft, little-penetrating, radiation. Its radiation is especially suitable for the representation of the intensity distribution in a ray of slow neutrons, since it energizes fluorescent substances, or darkens photographic layers, especially strongly, and thereby expedites the production of sharp pictures.

In accordance with the invention, therefore, as improvement of the heretofore proposed processes a ray of slow neutrons is directed on gadolinium or a substance containing this element, in the neighborhood of which is placed a fluorescent substance or a photo-sensitive material or a fluorescent substance in association with a photographic substance. The soft radiation already mentioned, apparently electrons of about 70 kv. energy for the greater part, is released in the gadolinium by the slow neutrons. This radiation energizes the adjacent fluorescent substance, or darkens the photo-sensitive layer, considerably, and in this way produces a visible, or photographic, representation, or both, of the intensity distribution in the neutron ray.

There are a number of particularly advantageous arrangements according to the invention. In this connection it should be taken into account that $\frac{1}{100}$ gr. gadolinium per cm.^{2} weakens the neutron intensity to about one-half the original intensity. The soft radiation emitted by gadolinium is, however, already absorbed by about $\frac{1}{300}$ g. of the substance per cm.^{2}, i. e., in the case of pure gadolinium by about $\frac{1}{300}$ g. gadolinium per cm.^{2}, and in the case of a substance that consists only in part of gadolinium by correspondingly less than $\frac{1}{300}$ g. gadolinium per cm.^{2}. The half-absorption thickness for neutrons is therefore substantially larger than the distance within which the soft radiation is absorbed.

When it is desired to produce, in a fluorescent screen, a visible representation of the neutron intensity distribution, the following arrangements are advisable according to the type of investigation and nature of the fluorescent substance employed. A fluorescent screen is covered on one side with gadolinium. Since gadolinium is opaque, the screen must be covered with gadolinium on the side away from the observer, i. e., mostly on the side turned towards the source of neutrons. This layer, however, cannot be made much thicker than the distance within

which the soft radiation is absorbed, since only from a layer (directly adjacent to the luminous screen) of about this thickness (called effective layer in the following) does the soft radiation impinge on the fluorescent screen. If the layer be made thicker, the neutron radiation is absorbed noticeably by the gadolinium that is located between the effective layer and the source of neutrons, and fewer neutrons penetrate into the effective layer than before and the intensity of the soft radiation produced is therefore less. There is, therefore, an optimum thickness of the gadolinium coating that is of the magnitude of the thickness accomplishing the absorption of the soft radiation. Instead of pure gadolinium, a substance containing gadolinium can be used: in such case, however, the intensity of the representation is, then, less since less gadolinium nuclei are present in the effective layer than in pure gadolinium, the foreign atoms contributing noticeably in stopping down the soft radiation. Here, likewise, there is an optimum thickness of the coating, that is of the magnitude of the thickness accomplishing the absorption of the soft radiation. Finally, the fluorescent screen can be furnished, on the side turned towards the observer, with a transparent substance that contains gadolinium. The intensity of a layer of this kind, however, is less than that of a pure gadolinium layer. Its thickness can be whatever desired, since in this case the side resting directly against the fluorescent screen is always impinged on to the greatest extent by neutrons independent of the thickness of the layer. Preferably, a fluorescent screen is employed that is coated on both sides with substance containing gadolinium, the thickness of the layer turned towards the source of neutrons being the magnitude of the thickness of absorption of the soft radiation.

Under certain conditions it is advisable to add gadolinium to the fluorescent mass. The linear extent of the gadolinium-containing particles mixed with the fluorescent mass must then be much smaller than the thickness necessary for absorbing the soft gadolinium radiation, since otherwise a considerable part of the radiation produced by the neutrons is absorbed in these particles without energizing the fluorescent screen. Moreover, it is often unsatisfactory to mix more than $\frac{1}{100}$ g. gadolinium per cm.^{2} with the fluorescent mass. In a relatively thin fluorescent screen (e. g., thinner than $\frac{1}{100}$ mm.), if it is not desired to absorb a considerable part of the fluorescent screen radiation, certainly it is possible to apply only considerably less than $\frac{1}{100}$ g. per cm.^{2}. If it is desired, therefore, to produce the greatest possible intensity, the fluorescent screen will be made thicker. In many cases it is unsatisfactory to have it so thick that $\frac{1}{100}$ g. or more gadolinium per cm.^{2} is present, since then the neutrons would cause energizing chiefly on the side of the fluorescent screen turned towards the source of neutrons. In order to reach the observer, the fluorescent screen radiation must then traverse the greater part of the fluorescent mass, whereby it is absorbed and partially dispersed, with the result that the observer perceives a fuzzy and weak picture.

The conditions are similar in producing photographic reproductions with the use of soft radiation emitted by gadolinium. It is possible to permit the soft gadolinium radiation produced by neutrons to act directly on a photo-sensitive layer, or a fluorescent screen can first be energized by the same and then the radiation from the fluorescent screen can be allowed to act on the photosensitive layer. It is especially simple to coat a photographic emulsion with a fluorescent screen on the side turned away from the source of neutrons. This fluorescent screen can contain as much gadolinium—either in the form of a layer or as an admixture—as desired, since the fluorescent screen radiation issues at the side of the screen turned towards the source of neutrons. It is preferable to use, as the photo-sensitive element of this combination, a support coated on both sides with light-sensitive layers, and to coat both the latter with fluorescent screens of the above-mentioned type. The fluorescent screen located at the side towards the source of neutrons carries a gadolinium-containing layer which is about as thick as the absorption thickness of the soft radiation. With gadolinium admixture, it is advisable to use less than $\frac{1}{100}$ g. gadolinium per cm.^{2} of fluorescent screen surface. The gadolinium content of the fluorescent screen located on the other side of the photo-sensitive element can be whatever desired.

It is still better to use two double-coated photographic layer supports and three fluorescent screens. For the fluorescent screen located at the side towards the source of neutrons the above statements hold good. The fluorescent screen located between the two photographic layers can contain admixed gadolinium and then as far as possible less than $\frac{1}{100}$ g. per cm.^{2} of fluorescent screen surface. In employing a gadolinium layer in this combination it is advisable to make the same of a thickness of the order of the absorption thickness of the soft radiation, in the middle fluorescent screen, and to coat it on both sides with fluorescent mass. The third fluorescent screen, on the side turned away from the source of neutrons, can again contain as much gadolinium as desired. The use of more than two photographic layers and more than three fluorescent layers is of advantage only in a few cases, since the total intensity of the reproduction increases constantly less strongly with increasing number of layers, due to the absorption of the neutrons, whereas the fuzziness of the image increases greatly.

What is stated in the foregoing holds good for the photographic reproduction with the aid of gadolinium, with direct instead of indirect action of the soft gadolinium radiation on the photosensitive layers. The work can be carried on here likewise with a number of layers and the gadolinium can likewise be admixed with the material of the photo-sensitive layers.

A constructional example of an arrangement according to the invention is shown in diagram in the figure of the accompanying drawing. The source 1 of neutrons sends out the neutron radiation 2 which partially penetrates the object 3 to be represented. The neutron radiation coming from the object 3 impinges on an arrangement according to the invention which is constituted by the combination of the layers 4 to 12. Two double-coated films 6, 10 are arranged between fluorescent screens 5, 7, 9, 11, which latter are coated with the gadolinium layers 4, 8, 12. The neutron radiation issuing from the object 3 impinges on the gadolinium layer 4, and there produces soft radiation which energizes the fluorescent screen 5. The radiation proceeding from this fluorescent screen darkens the neighboring photographic layer 6. The neutron radiation not absorbed in the gadolinium layer 4

falls on the gadolinium layer 8, there excites soft radiation which energizes the two adjacent fluorescent material layers 7 and 9. The radiations proceeding from the latter fluorescent masses darken the photographic layers 6 and 10. The neutron radiation not absorbed in the gadolinium layers 4 and 8 produces soft radiation in the gadolinium layer 12, which soft radiation energizes the adjacent fluorescent screen 11, the radiation proceeding from the latter darkening film 10. In this way, a photographic representation of the intensity distribution of the neutron ray impinging on the arrangement according to the invention (layers 4 to 12), and thereby a representation of the object 3, is produced on films 6 and 10.

We claim:

1. A method for showing a representation of the distribution of the intensity in a beam of slow neutrons, especially for the representation of an object by means of neutron radiation passing through the same, which comprises impinging such slow neutrons on a layer containing gadolinium whereby soft radiation is emitted by the gadolinium, and causing said soft radiation to act upon a sensitive layer of the group consisting of a fluorescent layer and a light-sensitive layer whereby a visual representation of the distribution of the intensity in the beam of slow neutrons is produced in said sensitive layer.

2. The method defined in claim 1, in which soft radiation from said gadolinium-containing layer is caused to energize a fluorescent layer and the resulting radiation from said fluorescent layer is caused to act upon a photographic layer whereby to darken the latter.

3. The method defined in claim 1, in which the content of gadolinium in the gadolinium-containing layer is less than about 0.01 gram per square centimeter of surface.

4. A device for showing a representation of the distribution of the intensity in a beam of slow neutrons, especially for the representation of an object irradiated by such slow neutrons, which comprises a mass containing gadolinium arranged in the neighborhood of a sensitive substance of the group consisting of a fluorescent substance and a photographic substance.

5. A device for showing a representation of the distribution of the intensity in a beam of slow neutrons, especially for the representation of an object irradiated by such slow neutrons, which comprises a layer containing gadolinium adjacent a layer of a sensitive substance of the group consisting of a fluorescent substance and a photographic substance, the content of gadolinium in the gadolinium-containing layer being less than about 0.01 gram per square centimeter of surface.

6. The device defined in claim 4, in which the gadolinium-containing layer is adapted to be turned toward a source of slow neutrons.

7. The device defined in claim 4, in which the gadolinium-containing layer is adapted to be turned away from a source of slow neutrons.

8. A device for showing a representation of the distribution of the intensity in a beam of slow neutrons, especially for the representation of an object irradiated by such slow neutrons, which comprises a plurality of gadolinium-containing layers separated from each other by intervening layers selected from the group consisting of fluorescent layers and photographic layers.

9. The device defined in claim 8, in which a photographic layer enclosed between two fluorescent layers is arranged between each two gadolinium-containing layers.

10. The device defined in claim 8, in which a photographic layer enclosed between two fluorescent layers is arranged between each two gadolinium-containing layers, all of the gadolinium-containing layers, except that adapted to be turned away from a source of slow neutrons, containing less than about 0.01 gram of gadolinium per square centimeter of surface.

11. The device defined in claim 8, in which a double-coated photographic layer enclosed between two fluorescent layers is arranged between each two gadolinium-containing layers.

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