Sept. 27, 1949. F. URBACH 2,482,814

PHOTORECORDING

Filed March 26, 1946

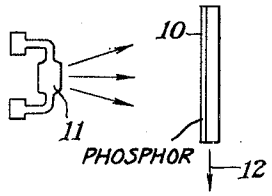


FIG. 1.

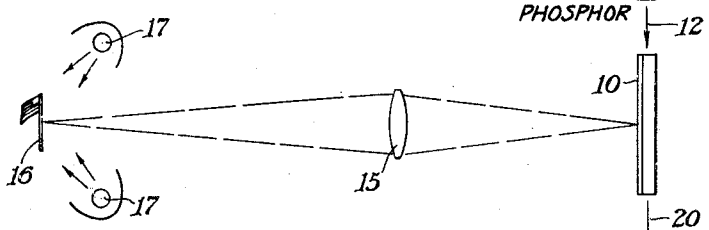


FIG. 2.

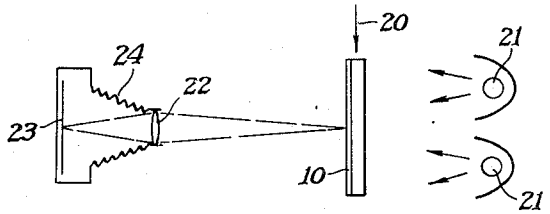


FIG. 3.

FIG. 4.

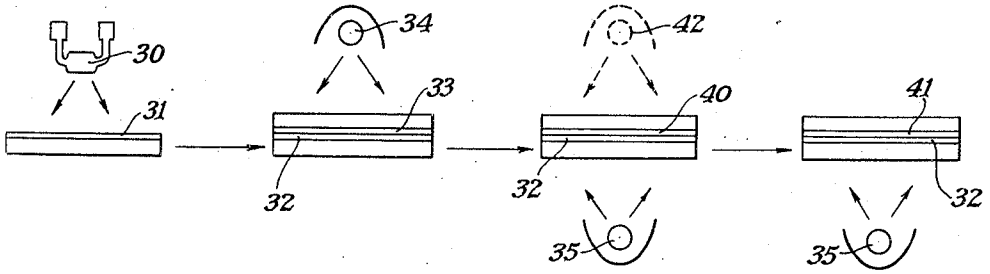
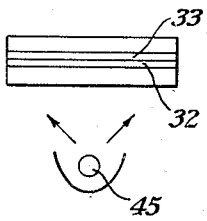


FIG. 5.



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PHOTORECORDING

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Application March 26, 1946, Serial No. 657,136

6 Claims. (Cl. 250—65)

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This invention relates to photorecording and has for its main object the provision of a method of delayed action photorecording.

The term photorecording is here used to refer to the recording of light, usually photographic, but in some cases the final step may be actually a manual one. The process here described should be compared to that described in my application Serial Number 657,135 filed concurrently herewith, the two processes having different advantages for different purposes. Reference is also made to my concurrently filed application Serial No. 657,137 having to do with a third system of photography, particularly for infrared photography, by using in part phosphors of the same type as used in the present invention. The infrared photography case is limited in its utility to relatively long wavelength infrared light because at shorter wavelengths, photographic emulsions can be directly sensitized. However, the present invention has advantages which make it useful in the visible as well as in the infrared regions.

For certain purposes the present invention is the most useful of the three. It is particularly useful for photocopying and, because of the high gamma (approaching 2) inherent in the process, it is useful for reflex copying.

According to the invention, a phosphor of the type to be described below is uniformly excited with short wavelength radiation and then an image is formed on the phosphor, either by contact or projection printing using light of non-exciting wavelength in order to exhaust the excitation of the phosphor layer in proportion (not necessarily linear proportion) to the image intensity. This exhausting may be entirely due to the stimulating of the phosphorescence or it may be due to stimulation combined with the quenching effect which occurs with some phosphors (or even to quenching alone by non-stimulating wavelengths but this is quite rare). In either case the phosphor is exhausted where illuminated by the image and now contains in amounts of excitation, a negative image relative to that which was exposed. It will be noted that the phosphor layer could be stored either after the excitation or following the image exhaustion, if any reason for storing occurs. In any case the next essential step of the invention is to place the excited phosphor layer containing the latent exhaustion image in printing relation (contact or projection printing) to a layer of material on which a permanent record can be made. In general this is a photographic layer, but hand tracing of simple images may be useful in some cases.

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With the recording layer in place, the phosphor layer is then uniformly illuminated with stimulating light, preferably red or infrared light to produce on the recording layer by stimulation, an optical image in the wavelength which the phosphor emits. The illumination may be over one area of the phosphor layer at a time. The wavelength emitted is longer than that of the exciting radiation and when red or infrared is used as the stimulating radiation, the wavelength emitted is shorter than the stimulating radiation. The luminous image formed on the recording layer is negative to the image which exhausts the phosphor layer. In the case where the recording layer is a photographic one, normal processing will produce an image positive with respect to the exhausting image.

When the exhausting is carried far enough to reduce the excitation (stimulable brightness) of the least exhausted areas to ⅓ of the unexposed value, the later stimulated image will have a relatively high gamma approximating 2. It will be noted that the exhausting exposures are of reasonably short time when using the highly sensitive phosphors described below.

The following examples are given of the composition of infrared sensitive phosphors which are particularly useful in the present invention. There are others which will work, but perhaps not as well as those here listed. As pointed out in my copending applications relative to the preparation and composition of phosphors themselves, each phosphor must include a base, a flux and at least one activator. The flux is used in the usual way in small percentages to bond the materials during firing. The concentrations of the activators appear in parts per million by weight relative to the whole phosphor after firing. The exact value depends on the specific details of the preparation and the quantities may be varied from those given without materially affecting their use for the present invention. The preparation of these phosphors follows the conventional methods used in preparing ordinary phosphors, it being noted that the sensitivity can be varied depending on the degree of oxidation of the sulfides or selenides.

This list is not as long as in my other case, only the ones most useful for the present invention being here included, but of course any of them could be used. The phosphors most easily exhausted are preferable in the present case.

	Base	Flux	Activators
1	SrS	CaF_2	Eu 100 Sm 100
2	do	LiF	Ce 100 Sm 40
3	do	do	Cu 100 Sm 20
4	do	do	Ce 100 Sn 10,000
5	do	do	Cu 100 Bi 100
6	CaS	Na_3BO_4, $Na_2S_2O_7$, CaF_2	Pb 100
7	ZnS	NaCl	Mn 200 Cu 1
8	do	do	Pb 40,000 Cu 1
9	do	do	Pb 40,000 Cu 20
10	SrSe-$SrSO_3$	CaF_2	Eu 100 Sm 100
11	do	do	Eu 100 Bi 100

In my copending application Serial Number 657,137, item No. 6 was recommended for use at Dry Ice temperatures, but for the present invention, it is quite useful at room temperature since it is easily exhausted.

Some of these particular phosphors were developed by me as is indicated by my copending applications referred to above.

The manner in which the present invention may be performed will be fully understood from the following description when read in connection with the accompanying drawings in which:

Figs. 1, 2, and 3 constitute a flow chart illustrating one embodiment of the invention.

Fig. 4 similarly illustrates another embodiment of the invention.

Fig. 5 shows an arrangement alternative to one of the steps illustrated in Fig. 4.

In Fig. 1 light from an ultraviolet lamp **11** uniformly excites a phosphor **10**, which either immediately or after sufficient relaxation time to allow the spontaneous afterglow to die down, is moved as indicated by the arrow **12** into printing relation with an object **16**, a picture of which is desired. The object is illuminated by yellow, red and infra red light by lamps **17** and light from the object is brought to focus by a lens **15** on the phosphor **10** as shown in Fig. 2. This is allowed to continue long enough to exhaust the excitation in the phosphor **10**, preferably by stimulation alone since the best phosphors are those which have a high stimulation effect, but the exhaustion may be at least partly by a quenching effect. The layer **10** containing the latent negative image in degrees of exhaustion may be stored or may be moved directly as indicated by the arrow **20** into printing relation with a permanent recording layer **23**. The layer **10** is then uniformly illuminated with infra red light from lamps **21** and the negative image therein is photographed by lens **22** of a camera **24** onto the photographic film **23**. The film **23** is then developed directly to an image positive with respect to the object **16** of Fig. 2. As in my copending application Serial No. 657,135 referred to above this permanent recording may, in the case of simple line images, be traced manually rather than photographically. The photographic embodiment is the most important in this case however and is therefore the one illustrated here.

A particularly useful embodiment of the invention is illustrated in Fig. 4. In this case ultraviolet or short wavelength visible light from lamp **30** uniformly excites a phosphor **31** which is moved to the position **32** in contact with a positive record **33** which may be a printed page or the like. The printed page is then floodlighted with infra red from a lamp **34** which stimulates and thus exhausts the excitation in the phosphor **32**.

The phosphor **32** containing the latent exhaustion image is then placed in contact with a photographic layer **40** and printed by flooding with infra red light from a lamp **35**. The flooding illumination may be either from below as shown or through the photographic layer **40** as from lamp **42** shown in broken lines. Successive prints may be made as shown by moving the phosphor layer into contact with another photographic layer **41**. Preferably the intensity of the lamp **35** is increased for successive printings in order to keep the brightness of the phosphorescent image at a high level. I have found that a plurality of prints may be made from a single phosphorescent image in this manner.

Because of the high gamma obtained with this method it is quite possible to make the exposure to the original image **33** by reflex printing as illustrated in Fig. 5. That is, infra red light from the lamp **45** passes through the phosphor layer **32** and is reflected from the printed page **33**. The phosphor is uniformly exhausted by the light directly from the lamp **45** but is differentially exhausted by the light reflected from the printed page. The over all flooding tends to reduce the contrast, of course, but the process has adequate contrast to allow for this.

Having thus described the preferred embodiments of my invention I wish to point out that it is not limited to these structures but is of the scope of the appended claims.

I claim:

1. The method of delayed action photorecording of a long wavelength image which comprises (*a*) substantially uniformly exciting with short wavelength radiation a layer of a phosphor of the type which stores the excitation energy and releases at least part of it, in trigger fashion, when stimulated by longer wavelength light, the released energy being light of wavelength intermediate between the exciting and stimulating radiation wavelength, (*b*) forming an image in said longer wavelength light on the phosphor layer to exhaust the excitation of the phosphor layer in proportion to the image intensity at least partly by stimulating then (*c*) placing the excited phosphor layer containing the latent exhaustion image therein in printing relation to a layer of material on which a permanent record can be made; (*d*) illuminating the phosphor layer with said longer wavelength light to produce on the recording layer by stimulation an optical image in said intermediate wavelength light negative to said longer wavelength image and (*e*) producing a permanent record in accordance with the negative image on the recording layer.

2. The method according to claim 1 in which the permanent recording material is a photographic material and the record is produced therein by direct processing to a positive relative to said longer wavelength image.

3. The method according to claim 1 in which the image forming is done by placing a picture to be recorded in contact with the phosphor layer and exposing the layer through the picture by said longer wavelength light.

4. The method according to claim 1 in which the image forming is done by placing a picture to be recorded in contact with the phosphor layer and then reflex exposing the layer by said longer wavelength light through the layer to the picture and reflected therefrom, the exhausting of the excitation being carried to the point where the least exhausted area has dropped to less than one third of its original excitation value whereby the

later stimulated image will have a relatively high gamma.

5. The method of delayed action photorecording of a radiant image which comprises (*a*) substantially uniformly exciting with radiation of a given wavelength a layer of a phosphor of the type which stores the excitation energy and releases at least part of it, in trigger fashion, when stimulated by a different wavelength light, the released energy being light of wavelength longer than said given wavelength (*b*) forming an image in a wavelength different from said given wavelength on the phosphor layer to exhaust the excitation therein in proportion to the image intensity, then (*c*) placing the excited phosphor layer containing the latent exhaustion image therein in printing relation to a layer of photosensitive material, (*d*) illuminating the phosphor layer uniformly with light of stimulating wavelength to produce an optical image which exposes the photosensitive layer and (*e*) processing the photosensitive layer to a record positive relative to said different wavelength image.

6. The method of delayed action formation of a visible image from a long wave length image which comprises substantially uniformly exciting with short wave length radiation, a layer of a

phosphor of the type which stores the excitation energy and releases at least part of it, in trigger fashion, when stimulated by longer wave length light, the released energy being visible light of wave length intermediate between the exciting and stimulating radiation wave length, forming an image in said longer wave length light on the phosphor layer to exhaust the excitation thereof in proportion to the image intensity and then later illuminating the phosphor layer with said longer wave length light to produce by stimulation an optical image in said visible intermediate wave length light negative to said longer wave length image.

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