United States Patent

Wyckoff

[15] **3,663,228**

[45] **May 16, 1972**

[54] COLOR PHOTOGRAPHIC FILM HAVING EXTENDED EXPOSURE-RESPONSE CHARACTERISTICS

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[73] Assignee: **Applied Photo Sciences, Inc.,** Newbury, Mass.

[22] Filed: **Nov. 14, 1969**

[21] Appl. No.: **876,626**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 445,496, Apr. 5, 1965, abandoned, which is a continuation-in-part of Ser. No. 98,176, Mar. 24, 1961, Pat. No. 3,450,536.

[52] **U.S. Cl.** **96/74,** 96/84, 96/68, 96/69

[51] **Int. Cl.** **G03c 1/76,** G03c 1/84, G03c 3/00

[58] **Field of Search** 96/74, 67, 68, 69, 84

[56] **References Cited**

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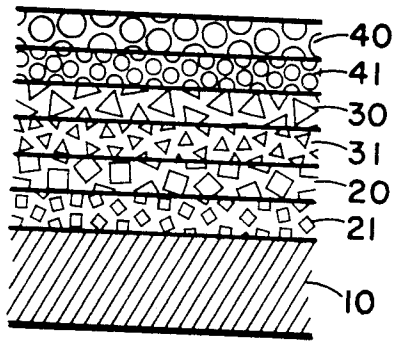
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Primary Examiner—David Klein
Assistant Examiner—Mary F. Kelley
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[57] **ABSTRACT**

A color photographic film with extended exposure response characteristics having a plurality of emulsion layers divided into sets, each set having a different photographic speed. The emulsion layers within a set have the same photographic speed but each layer is responsive to a different region of the spectrum. The emulsion layers are arranged either one above the other or side-by-side in a geometric pattern and all have D-log characteristic curves which have substantially equal slopes. The effective speed of one set is adjusted such that it commences responding to impinging light as another set approaches saturation. This is accomplished either by selection of the basic sensitivities of the various emulsions or by the use of auxiliary means such as attenuating filters. Dye-forming couplers may be incorporated during manufacture in all emulsion layers or may be introduced during processing. The invention may also be incorporated into a number of embodiments employing either the diazo or diffusion transfer processes. In addition apparatus employing the principles of the invention is described.

11 Claims, 17 Drawing Figures



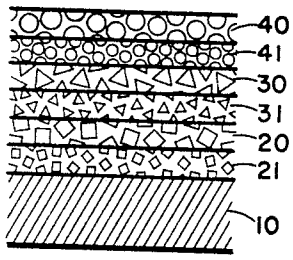


FIG. 1A.

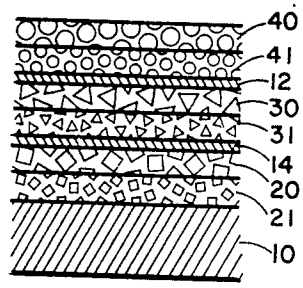


FIG. 1B.

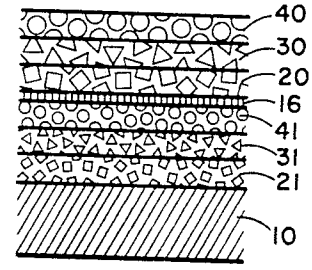


FIG. 1C.

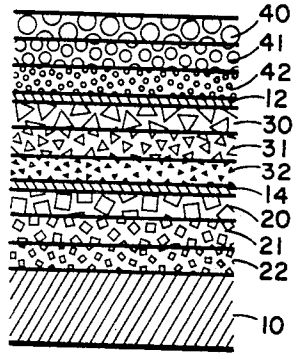


FIG. 1D.

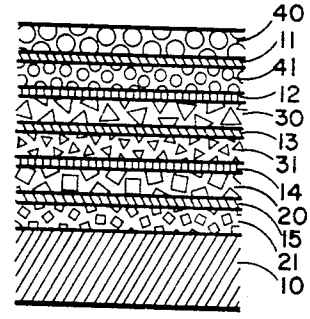


FIG. 1E.

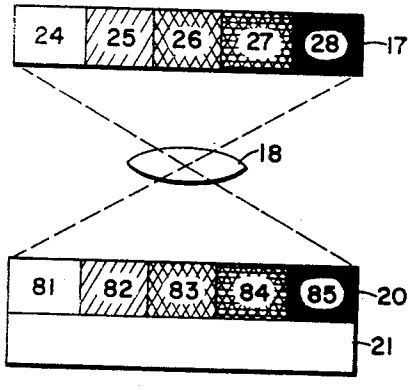


FIG. 2A.

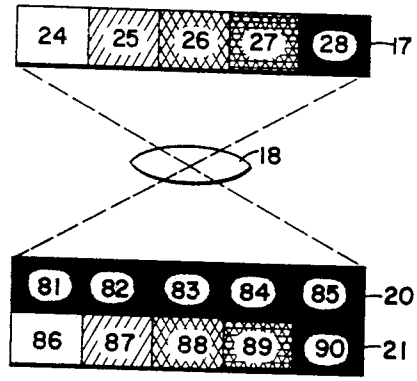


FIG. 2B.

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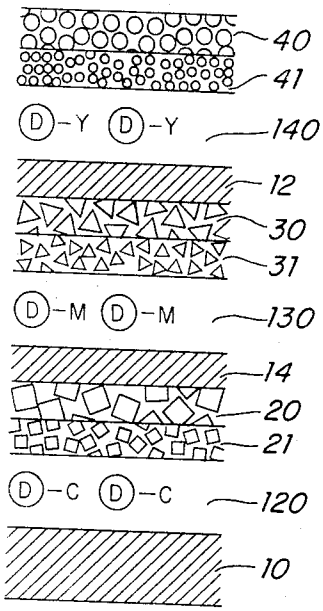


FIG. 1F.

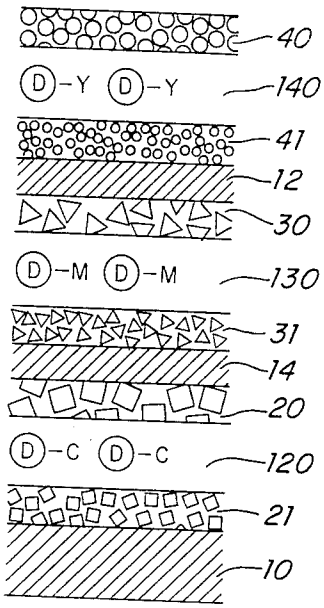


FIG. 1G.

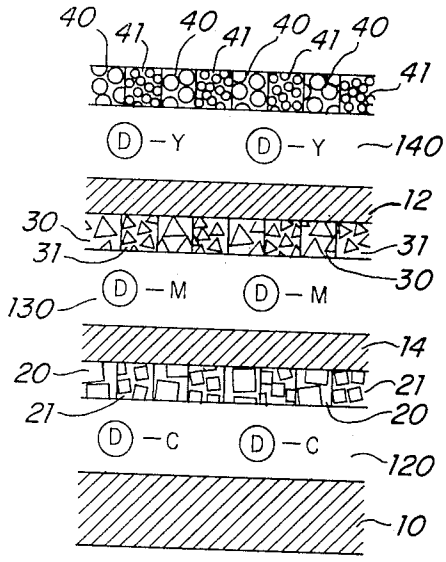


FIG. 1H.

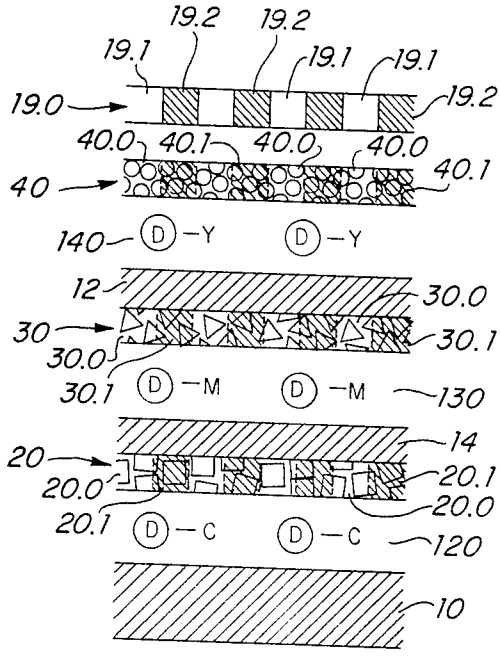


FIG. 1I.

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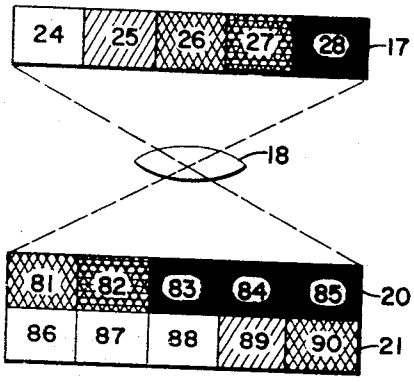


FIG. 2C.

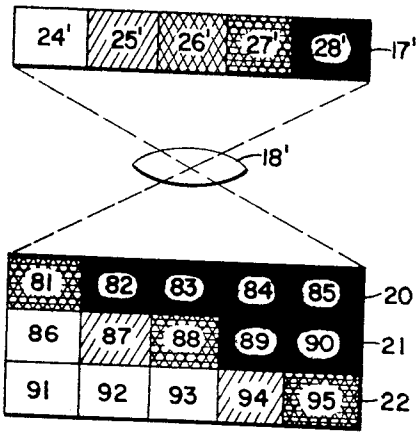


FIG. 2D.

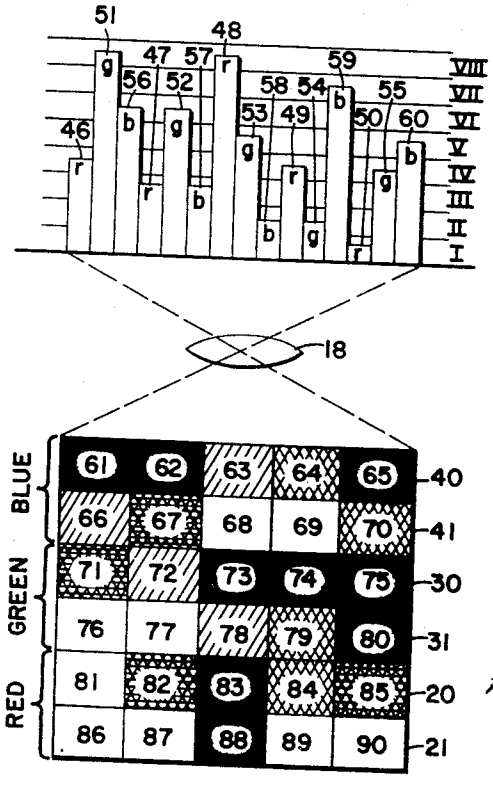


FIG. 2E.

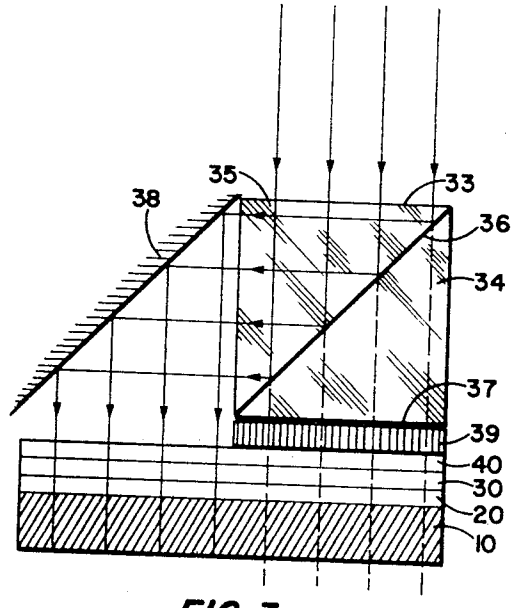


FIG. 3.

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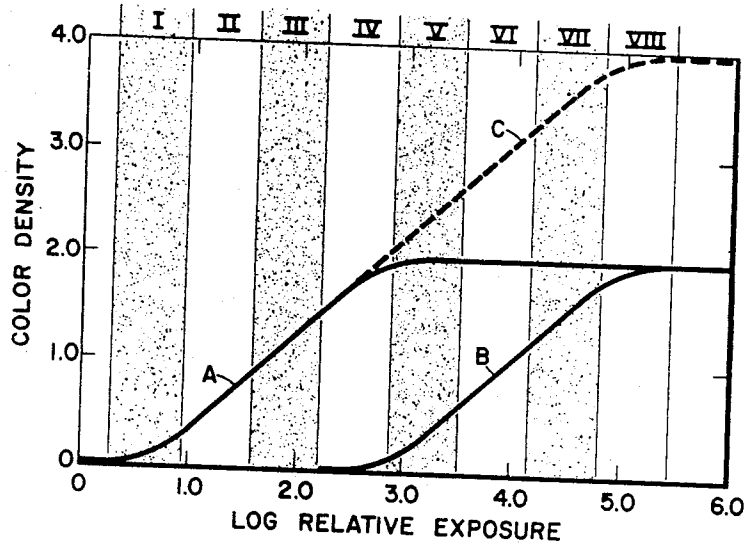


FIG. 4A.

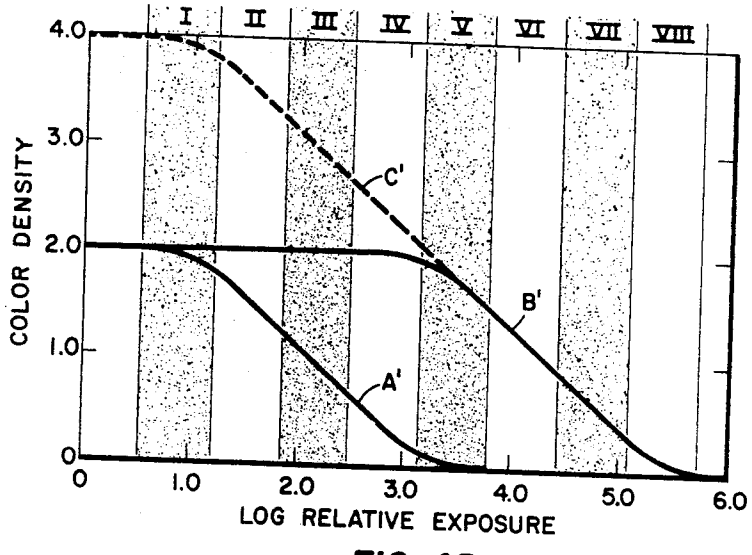


FIG. 4B.

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COLOR PHOTOGRAPHIC FILM HAVING EXTENDED EXPOSURE-RESPONSE CHARACTERISTICS

This application is a continuation-in-part of my copending application Ser. No. 445,496, filed Apr. 5, 1965, now abandoned. Application Ser. No. 445,496 was a continuation-in-part of application Ser. No. 98,176, filed Mar. 24, 1961, which issued as U. S. Letters Pat. No. 3,450,536 on June 17, 1969 for "Silver Halide Photographic Film Having Increased Exposure-Response Characteristics."

This invention relates to photosensitive materials and more particularly to color sensitive photographic films and the like having improved exposure-response characteristics.

The common invention described in said copending application Ser. No. 445,496 **and the present application was made in the performance of work under a NASA contract and is subject to the provisions of Section** 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 State. 435; 42 U.S.C. 2457).

Heretofore, photographic color films have exhibited a useful exposure-response range which was somewhat less than three decades. This response is limited by the physical characteristics of the various emulsions employed in color films. The aforementioned patent teaches a successful photographic film having a tremendous exposure-response range. This is basically a black and white film but color is used in the emulsions to distinguish the images recorded in the various layers. That film has proven to be of great value in the scientific community as well as in other fields where wide exposure latitude was a requirement. It was immediately evident that a color film having an extended exposure-response range would be a valuable and useful tool. The present invention adds the benefit of recording the object with greater color fidelity than the structure of the aforementioned patent permitted.

It is, therefore, an object of this invention to provide a photographic material capable of recording, in color, objects and phenomena having great exposure ranges.

Another object of this invention is to provide a new and very fast photographic emulsion for use in color photography.

A further object of this invention is to provide a simple color photographic film which may be used in simple cameras as well as the most complicated remote control photographing apparatus.

Other and further objects of this invention will be pointed out in the following specifications and appended claims. In summary, this invention is an extended exposure range color photographic film having a plurality of emulsions divided into "pairs" or "groups" and "sets." As used herein the emulsions in a "pair" or "group" have different speeds but similar spectral sensitivities, while the emulsions in a "set" have different spectral sensitivities but similar speeds.

The invention will be more clearly understood by referring to the following description in conjunction with the attached drawings, wherein:

FIGS. 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H and 1I are enlarged, cross-sectional views of various embodiments of this invention;

FIGS. 2A, 2B, 2C, 2D and 2E are schematic views of this invention included for explanatory purposes to indicate various degrees of exposure of certain photographic emulsions;

FIG. 3 is a schematic view of a modification of the invention in which the object is separately recorded on two portions of the same film; and

FIGS. 4A and 4B are Density-log Exposure graphs showing typical sensitivity curves for various emulsions used in negative and reversal films respectively.

Throughout the following description of this invention, various emulsions will be referred to as being sensitive to certain colors such as "red-sensitive," "green-sensitive" and "blue-sensitive." In this regard, these terms are employed in the broad technical sense to mean different portions of the visible spectrum, such as the red region from about 600 to 700 nm, the blue region from about 400 to 500 nm and the green region from about 500 to 600 nm. It is not the applicant's intention to set precise limitations but rather to make useful approximations that will be helpful in understanding this invention. It is important for certain applications that the spectral sensitivity extend into the infrared and ultraviolet regions. Thus, the references to red-sensitive, green-sensitive and blue-sensitive emulsions must not be interpreted to cover these specific wavelengths alone but must be recognized to be broad divisions of the light spectrum, which may include infrared and ultraviolet, or substantial portions thereof. There may also be some overlapping between emulsions sensitive to adjacent regions. Realizing the broader meaning of these terms, the preferred embodiment is a division of the visible spectrum into three substantially equal parts of about 100 nm each starting at 400 nm with blue, followed by green and red, the blue region being sensitive to at least some ultraviolet and the red responding to at least some infrared.

Referring first to FIG. 1A, there is shown a photographic product consisting of a film base **10**, a pair of red-sensitive photographic emulsions **20** and **21**, coated in layers upon base **10**. A second pair of photographic emulsions **30** and **31**, sensitive to light within the green region of the spectrum, are coated in layers above emulsion **20**. The uppermost layers of this film consist of emulsions **40** and **41** which are blue-sensitive emulsions. The photographic emulsions which constitute the various layers of this film may be selected from any of the well-known photosensitive emulsions that perform the necessary functions of this invention. Preferably emulsions **20**, **30** and **40** have substantially the same photographic speed. This means that they respond to the same levels of exposure for light within the region of the spectrum to which they are sensitive. For this reason, curve A in FIG. 4A represents the D-log E curve, for each of emulsions **20**, **30** and **40**. Curve A indicates that these emulsions begin to respond to light at a very low exposure level of about 0.4 on the log Relative Exposure scale. As the exposure increases, the color density in the emulsion increases until it reaches a saturation point at an exposure level of about 3.0 where the color density remains constant regardless of increases in exposure. Note that these emulsions demonstrate a total exposure response of about three decades and a linear range of about two decades. This response range may be increased or decreased by varying the thickness of the emulsions or by the addition of sensitizers or desensitizers but the range indicated is a practical and useful one.

Emulsions **21**, **31** and **41** in FIG. 1A have substantially the same photographic speeds and are represented by curve B in FIG. 4A. These emulsions begin to respond to light within their respective regions of the spectrum at about 2.5 and the color density increases as exposure increases to a saturation point at approximately 5.5. Curve C is the total or accumulated density of the combination of curves A and B. Note that it has a total exposure response of about five decades and a linear response of at least four decades. The feature of curve A leveling off in the region where curve B begins to respond produces a straight line result in curve C which we shall refer to throughout this application as "complementary speeds". Note that curves A and B have substantially equal slopes. Without this novel feature curve C would not have the straight line result illustrated.

Each of these emulsions are preferably color sensitized photographic silver halide emulsion layers. Emulsions **20**, **30** and **40** are the faster emulsions and it is desirable to use a very fast emulsion such as one having an exposure index of 1000. Emulsions **21**, **31** and **41** have complementary speeds to emulsions **20**, **30** and **40**, respectively and thus exposure indexes of **10** are preferred. The silver halide in each emulsion is sensitized to respond to certain regions of the spectrum. Color sensitizers for this purpose are well known. Emulsions **20** and **21** are sensitive to red light and may employ any of a number of red sensitizers such as:

1, 1′ — diethyl - 4, 4′ - carbocyanine iodide (kryptocyanine)

3, 3′ - diethylthiadicarbocyanine iodide

1, 1′ - diethyl - 4, 5, 4′, 5′ - dibenzothiacarbocyanine bromide

1, 1' - diethyl - 2, 2' - cyanine iodide, 2 - (p - diethylaminostyryl) benzothiazole

Color sensitizers for the green-sensitive emulsions **30** and **31** may be any of those well known in the art such as, for example:

1, 1' - diethyl - 6, 6' - diethoxy - 2, 4' - cyanine bromide (pinachrome)

1, 1' - diethyl - 6, 6' - dimethyl - 2, 4' - cyanine bromide (orthechrome T)

1, 1' - diethyl - 2, 2' carbocyanine iodide (pinacyanol)

3, 3' - diethylthiacarbocyanine iodide

3, 3' - diethylselenacarbocyanine iodide

3, 3' - diethyl - 9 - methylthiacarbocyanine bromide

No special color sensitizers need be used for the blue-sensitive emulsions **40** and **41** since most emulsions are naturally blue-sensitive.

In some cases, it is preferable to employ reversal-type emulsions in which the dye-forming couplers are introduced during processing because they can be made photographically faster than emulsions which contain the dye-forming couplers. Curves A' and B' in FIG. 4B show reversal emulsions having substantially the same characteristics as the emulsions shown in FIG. 4A except that at minimum exposure, maximum color density is present. As exposure increases, density decreases until it reaches a minimum density. Curve C' is the accumulated densities of curves A' and B'. The same color sensitizers may be used in reversal film and the same requirement for complementary speeds is present.

FIG. 1B shows an extended-exposure range color-photographic film which employs means to adjust the spectral response of some of the emulsions. This is accomplished by inserting certain color filters between the emulsion layers, specifically between pairs of emulsions, or by incorporating within the emulsions colored dyes of the proper saturation. FIG. 1B shows the three pairs of emulsions shown in FIG. 1A with the addition of color filters **12** and **14**. Emulsions **40** and **41** are blue sensitive and record incident radiation in that region of the spectrum. Color filter **12** is disposed between the blue-sensitive emulsions **40** and **41**, and the green-sensitive emulsions **30** and **31**. Filter **12** is yellow and blocks the passage of blue light which was useful in exposing emulsions **40** and **41** but which could introduce error into emulsions **30** and **31**. Magenta filter **14**, between the green-sensitive emulsions **30** and **31** and the red-sensitive emulsions **20** and **21**, prevents the passage of green light into the red-recording region. In FIG. 1B, the color filters **12** and **14** are introduced to help correct the characteristics of the emulsions to insure greater accuracy in the recording of objects. This is particularly useful when the color sensitivity of the lower emulsions overlap those of the higher emulsions. For example, if the spectral sensitivity of emulsion **30** extends through the green and blue regions, then it is essential to filter out the blue light before it reaches emulsion **30** which has a prime function of recording green light. Yellow filter **12** serves this purpose. The combination of yellow filter **12** and magenta filter **14** insures that only red light reaches emulsions **20** and **21**. Some sets of emulsions may need only a single color filter while other sets may require both filters.

As the aforementioned patent points out, there are times when it is difficult to obtain photographic emulsions having perfectly complementary speeds. The solution to this problem is disclosed in the patent. A neutral density filter is interposed between the emulsion layers to shift the D-log E curve of the lower emulsion so that its effective speed is complementary to that of the upper emulsion. In FIG. 1C there are disclosed two photographic color films or sets with a neutral density filter **16** interposed between them. Neutral density filter **16** may be, for example, colloidal silver dispersed in a gelatin substrate. Other neutral density filters are well-known in this art and may be used. The value of filter **16** is selected to shift the D-log E curve of the slower blue emulsion **41** so that it is complementary to the faster blue emulsion **40**. Similarly, the red and green sensitive emulsions **21** and **31** respectively, are also shifted to become complementary with emulsions **20** and **30**. By the use of this filter, greater flexibility is provided in selecting color films that have the more favorable spectral response without concern for the relative speeds of the films. Any discrepancy in the speeds of the two emulsions is remedied by the use of the proper neutral density filter **16** to make their effective speeds complementary.

FIGS. 1A, 1B and 1E are shown having three pairs of emulsions, each pair being sensitive to a different region of the spectrum. As may be seen from FIG. 4A and curves A and B therein, the use of pairs of emulsions provides total exposure range of nearly six decades or at least 100,000 to 1. If, however, even greater exposure latitude is desired, then a third emulsion having complementary speed to one of the other emulsions may be added as shown in FIG. 1D. In this figure, a third emulsion of low speed has been added for each of the colors. Emulsion **22** is red-sensitive, emulsion **32** green-sensitive and emulsion **42** is blue-sensitive. In fact, the only serious limitation to the number of photographic emulsions that may be used is the scattering effect produced by the total thickness of all the emulsion layers and the dispersion of light passing therethrough. It should be pointed out that various combinations may be made utilizing the principles described herein.

FIG. 1E shows a photographic product having three pairs of emulsions and a number of color filters interposed between the layers to control the exposure of the emulsions. The top layer is a blue-sensitive emulsion **40** which responds to incident blue light as shown by curve A in FIG. 4A. Blue-sensitive emulsion **41** is disposed beneath emulsion **40** but may have the same speed as emulsion **40**. To shift the D-log E curve or the effective speed of emulsion **41** so that it has a complementary speed to emulsion **40** without affecting either the photographic speed or the spectral sensitivity of any lower layers, a yellow filter **11** is inserted between emulsions **40** and **41**. Filter **11** will attenuate blue light only, thus permitting the green and red images to freely pass therethrough. It must have a predetermined color density to attenuate the correct proportion of the incident blue light to effectively shift the speed of emulsion **41** until it is complementary to that of emulsion **40**. The attenuation of filter **11** must be selected in accordance with the speeds of emulsions **40** and **41**. As an example, it may pass 10 percent of the blue light incident thereupon and attenuate 90 percent, thus producing the effect of a density 1.0 filter. If it passed only 1 percent of the incident blue light then it has the effect of a density 2.0 filter. The degree of attenuation is dictated by the speeds of the emulsions and how far the D-log E curve of the slower emulsion must be shifted.

A second yellow filter **12** is disposed intermediate emulsions **41** and **30**. This yellow filter **12** completely blocks the passage of any blue light but permits red and green light to pass therethrough. Intermediate the two green sensitive layers **30** and **31** is a magenta filter **13**, designed to block a predetermined portion of the green light and freely pass red light. The attenuation provided by filter **13** must be sufficient to shift the effective speed of emulsion **31** to render it complementary to emulsion **30**. A magenta filter **14** is disposed between emulsions **31** and **20** to block all green light at this point. The effect of yellow filter **12** and magenta filter **14** is to allow only red light to expose emulsions **20** and **21**. Intermediate emulsions **20** and **21** is a further filter **15** to attenuate this red light, thus shifting the effective speed of emulsion **21** until it is complementary to emulsion **20**. This filter **15** may be either cyan or neutral. A cyan filter blocks red light. It may be neutral because the only light passing therethrough is red, due to the effect of the yellow and magenta filters **12** and **14** above. In using the construction shown in FIG. 1E, the benefits mentioned with regard to FIGS. 1B and 1C are combined. The speeds of emulsions **21**, **31** and **41** need not be complementary to emulsions **20**, **30** and **40** originally. The filters will shift their effective speed to make them complementary. The spectral sensitivity of emulsions **20**, **21**, **30** and **31** need not be limited to their precise spectral region. Corrections in both speed and spectral sensitivity are provided by the filter elements. In the film of FIG. 1E, the speeds of emulsions **21**, **31** and **41** need

not be similar because they are individually shifted by different filters which do not affect other emulsions. In fact, the speeds of emulsions **20**, **30** and **40** may also be adjusted by color filters if necessary, but such filters would also affect the slower emulsions, which would be shifted by the total effect of such a filter and the filter of the same color mentioned above.

This invention may also be utilized in other physical structures than those described above. One such embodiment is a number of thin emulsion layers for each color, coated on the film support. The size of the silver grains are predetermined to be substantially uniform within each emulsion but to vary from emulsion layer to emulsion layer to produce different and complementary speeds. Although it is not essential, it is preferable to coat the emulsion with the smallest silver grains closest to the film support. Additional layers are coated in sequence above this first layer and the silver grains in each layer are progressively larger. The total amount of silver in each emulsion should be substantially equal to the silver content in each of the other emulsions. As is well known, the sensitivity of an emulsion with large silver grains is considerably faster than those with small silver grains. The silver content of each emulsion is intentionally made sparse in order to reduce light dispersion and associated scattering. Preferably the thin emulsions are ½ to 2 microns thick, more or less, and the number of emulsion layers is determined by the total response range and the purity of spectral sensitivity desired. To equate this type of film with those defined above, a total response range of five decades on the log E axis is recommended and five thin layers accomplish this goal.

As an example, the top layer may contain large silver halide grains with thiourea sensitization for maximum speed. Such a layer, upon exposure and development, would yield a D-log E curve of low slope and density. It would have an exposure range of 10 or more to 1. The next lower thin emulsion will contain smaller crystals about one quarter the size of the top layer and these will also be sulphur sensitized to produce about one-tenth the sensitivity of the top emulsion layer. The actual speed may be adjusted to make the exposure start where the top emulsion ceases, thus producing the effect of an extended D-log E curve. The slope of all layers is kept substantially identical by maintaining the same silver concentration and grain size ratio in each layer.

Another embodiment of this invention is a single blended emulsion layer for each color. The blend would have a low silver content and have substantially uniform quantities of each grain size of silver halide to produce a response range in the region, for example, of five decades.

The low silver content in the above-mentioned photographic products would develop to a low contrast silver image. Thus, it is important that during the color development stage, a greater concentration of dye be employed in order to compensate for this low contrast. The color D-log E curve for each of these emulsions may be shown by curves C and C′ in FIGS. **4A** and **4B** respectively. Each emulsion layer has incorporated therein a color sensitizer as previously described.

The neutral density filter **16**, in FIG. **1C** and the color filters **11**, **12**, **13** and **14** in FIGS. **1B**, **1D** and **1E** and filter **15** in FIG. **1E**, which may be either neutral or cyan, are preferably of a soluble or bleachable material that may be dissolved and washed away or otherwise disposed of during processing. This is important because these filter materials could interfer with the viewing and printing of the image recorded therein. In FIG. **1C**, for example, filter **16** would upset the complementary speeds of the emulsions produced by the filter itself during exposure. In FIG. **1B** and **1D** color filters **12** and **14** (and in FIG. **1E**, color filters **11** and **13**) would prevent the images recorded in each emulsion from being properly viewed or printed, thus greatly reducing the film's usefulness. By using soluble or bleachable color filters, these materials are removed or rendered colorless during the processing stage. Bleachable color filters are preferred over their soluble counterparts because they may be made colorless quite simply in developing and processing. In the case of neutral density filters, however, the soluble type has proven satisfactory and may have equal status with bleachable neutral density filters. These elements are removed or rendered colorless during processing so that they perform their function during exposure but do not lessen the usefulness of the product during viewing and printing.

There are many well-known forms of color filters that may be used for the color filters **11**, **12**, **13**, **14** and **15** in FIGS. **1B**, **1D**, and **1E**. The yellow filters **11** and **12** may be, for example, a bleachable yellow colloidal silver. Dyes may also be used in the filter layers of a photographic film. One example of a yellow filter made from a dye is Aniline Yellow, C. I. No. 11,000 (Absorption Peak about 457nm). A magenta filter may be made from Acid Red 12, C. I. No. 14,835 (Absorption Peak about 550nm). During the processing of the film, these dyes, which are colored as shown, could be made colorless by treating them in a reducing agent solution such as sodium hydrosulfite. This would reduce the dye to a permanently colorless substance.

FIGS. **2A**, **2B** and **2C** show only one of the three pairs of emulsions of FIGS. **1A**, **1B**, **1C** or **1E** to simplify the explanation of the applicant's invention. The red-sensitive emulsions **20** and **21** have been selected for discussion, but the explanation applies to the other pairs of emulsions as well. FIG. **2A** illustrates sufficient light passing from object **17** through lens **18** to expose only the more sensitive emulsion **20**. The object **17** is shown consisting of five areas identified by the reference designators **24** to **28** inclusive, where area **24** emits an intense level of red light and area **28**, a low level, and areas **25** and **26** and **27** are of intermediate intensities, area **27** being the weakest area and area **25** the brightest of the three. Lens **18** reverses the relative positions of the areas **24** to **28** when the emulsion is exposed to light coming therefrom. The image of area **28** falls in film portion **81**. Since little light arrives from darkest area **28**, this film portion **81** is only slightly exposed and therefore is shown clear. The light from clear area **24** totally exposes film portion **85** which is shown black in the figure to indicate total exposure of the emulsion. The intermediate areas **25**, **26** and **27** of object **17** produce exposures of different degrees as shown by film portions **84**, **83** and **82** respectively. It should be pointed out that the areas of object **17** are shown with different degrees of blackening to indicate different levels of intensity while emulsion **20** is shown with different degrees of blackening to depict different degrees of exposure.

In FIG. **2A**, the light from the object **17** is sufficient to expose only the more-sensitive emulsion **20** but not sufficient to expose the less-sensitive emulsion **21**. In other words, the range of light energy striking emulsions **20** and **21** would all be found along curve A of FIG. **4A** to the left of the point where curve B begins to respond. Here, the range of light levels striking the emulsion is perfectly matched to the exposure-response of emulsion **20**. Therefore, emulsion **21** does not respond at all, due to the fact that it is insensitive to the level of light energy passing through emulsion **20**.

Now consider the case where the light energy striking the film is increased many times. This may be done by greatly increasing the light energy incident upon object **17** or by greatly extending the time during which the emulsions are exposed to light. FIG. **2B** shows the effect of such an exposure upon emulsions **20** and **21**. The more-sensitive emulsion **20** is totally saturated as indicated by the blackening of film portions **81** to **85** inclusive. The light energy which passes through emulsion **20** and is available to expose emulsion **21** causes the same degree of exposure of film portions **86** to **90** of emulsion **21** as was produced in film portions **81** to **85** respectively of emulsion **20** of FIG. **2A**. FIG. **2B** indicates that the range of light energy incident upon the emulsions would all fall along curve B in FIG. **4A** to the right of the point where curve A levels off. In this case, we can see that the range of light intensity striking the emulsions is perfectly matched to the exposure-response range of emulsion **21**.

A third case to be considered is the instance where the range of light intensity striking the emulsions is not perfectly matched to the exposure-response range of either of emulsions 20 or 21 but is in the range including portions of curves A and B of FIG. 4A. FIG. 2C shows the effect of this third case on emulsions 20 and 21. Light from darkest area 28 of object 17 partially exposes film area 81 of emulsion 20. More light comes from area 27 to partially expose to a greater degree film portion 82. The light from areas 27 and 28 is insufficient to expose film portions 86 and 87 of emulsion 21. The light passing from 26 is sufficient to totally expose film portion 83 but is not sufficient to expose film portion 88 of emulsion 21. The light from area 25 is not only sufficient to expose film portion 84 of emulsion 20 but also to partially expose film portion 89 of emulsion 21. The light from the lightest area 24 of object 17 saturates film portion 85 and partially exposes film portion 90 to a greater extent than film portion 89.

It can thus be seen that with tremendous differences in the light intensity, useful and accurate reproductions of object 17 can be made from the negatives shown in FIGS. 2A, 2B and 2C. In the case of the negative in FIG. 2A, a positive image of object 17 can be printed from the exposure of emulsion 20, after the negative has been developed. The image recorded in emulsion 21 of FIG. 2B may also be printed. The saturated red-sensitive emulsion 20 becomes a uniformly deep cyan, and to print the cyan image recorded in emulsion 21, the additive effect of the two emulsions must be considered and thus the light used in printing must be either very intense or its time duration extended. With reference to the negative of FIG. 2C, a print of the two combined emulsions can be made by adjusting the printing exposure to reproduce object 17 from portions of emulsions 20 and 21.

FIG. 2D shows, schematically, the exposure of a set having three emulsions such as red-sensitive emulsions 20, 21 and 22 in FIG. 1D to an object 17' where there is a tremendous difference between the light from the lightest area 24' and the light from the darkest area 28'. This light range is in excess of the exposure-response range of each of emulsions 20, 21 and 22, considered individually.

Light from the darkest area 28' of object 17' almost completely exposes film portion 81 of emulsion 20 but does not expose film portions 86 or 91 of emulsion 21 and 22. The light from areas 27' and 26' saturates film portions 82 and 83 and partially exposes to different degrees film portions 87 and 88 but does not expose film portion 92 or 93. The light from area 25' and the lightest area 24' saturates film portions 84, 85, 89 and 90 and partially exposes to different degrees, portions 94 and 95.

The extreme range of exposure of object 17' has been recorded by the three emulsions in its proper degree of exposure and by adjusting the exposure in the printing process, a good reproduction of any portion of object 17' can be made. It has been shown that the three emulsions recorded the tremendous difference in light levels from the object 17'. It is not, however, possible to accurately print such an exposure because of the limited exposure range of currently available printing material, and not because of any limitation of the multi-emulsion film itself. Any particular portion of the emulsion falling within the range of the printing material may, of course, be printed. By decreasing the effect of the chemical processing, the density contrast can be reduced, thereby providing a means for printing the entire exposure, but the resulting print would not be an accurate reproduction of the original object 17'.

Thus far we have been discussing the exposure of the emulsions shown in FIGS. 2A, 2B, 2C and 2D in terms of one color only. FIG. 2E shows the effect of various exposures upon the different emulsion layers. The elements of the bar graph indicate the relative intensities of the different colors on the object. The range may be in the order of 100,000 to 1 but for simplicity, it shall be shown in eight increments identified by Roman Numerals I to VIII in FIG. 2E and in FIGS. 4A and 4B as well. The photographic film is shown as a six-layer film having three pairs of emulsions, each pair being sensitive to a different color. Emulsions 20 and 21 are red-sensitive and have complementary speeds with emulsion 20 being faster than emulsion 21. Green-sensitive emulsions 30 and 31 also have complementary speeds with emulsion 30 being the faster. The top two emulsions 40 and 41 are blue sensitive and emulsion 40 saturates in the region that emulsion 41 begins to respond to blue light. A lens 18 is shown which reverses the exposure of the film by focusing the light from the left end of the object on the right end of the film segment. Thus, the light from the left end of the object is shown divided into its three components, namely red light 46, green light 51 and blue light 56, and focused upon the right hand column of film segments consisting of segments 65, 70, 75, 80, 85 and 90. For easy reference, the letters "r," "g" and "b" have been placed in the color bars to indicate red, green and blue color, respectively. The light from the red portion of the object, designated 46, passes through blue-sensitive film emulsions 40 and 41 without having any affect upon film segments 65 and 70. Similarly, the light from the red portion of the object passes through segments 75 and 80 of emulsions 30 and 31 because these emulsions are sensitive only to light in the green region of the spectrum. When the red light 46 strikes film segment 85 of emulsion 20 it causes an exposure to be recorded there. This exposure is in proportion to the intensity of the red light from the object and causes the exposure to be slightly less than saturation in the region of, for example, IV of FIG. 4A. This red light 46 continues and passes through film segment 90 of emulsion 21 without producing any response therein. Although emulsion 21 is red sensitive, the red light 46 produces no exposure therein, because its intensity is less than the emulsion's threshold of sensitivity. This is evident from a view of FIG. 4A, which shows that region IV is at a position where emulsion B is not activated.

The green light 51 from the object is very intense and not only saturates film segment 75 of emulsion 30, but also exposes segment 80 of emulsion 31 to its point of saturation. This is shown as region VIII of FIG. 4A. This saturation of film segments 75 and 80 by the green light 51 does not affect film segments 65, 70, 85 and 90 because these emulsions are not sensitive to green light. The blue light 56 is of an intermediate intensity and as such saturates film segment 65 in emulsion 40 and also causes a moderate degree of exposure of film segment 70 of emulsion 41. The intensities of blue light 56 fall in the region VI on the graph of FIG. 4A.

The red light 47 causes an exposure on film segment 84 of emulsion 20 but is not sufficiently intense to cause the exposure of segment 89. This level of exposure is shown as region III in FIG. 4A. Other exposures caused by the spectral component of the object's light are recorded in the various segments of the film and correspond to the regions set forth in FIG. 4A. It is noteworthy to observe that the saturation of certain film segments, for example, film segment 61 in emulsion 40, does not interfere with the recording of a minimum exposure of the emulsions in a different color-sensitive pair, such as film segments 81 and 86 in emulsions 20 and 21. The pairs of emulsions are responsive to their respective color components and in effect are completely insensitive to the other colors.

Thus far, we have been discussing the invention in terms of negative type color film, all layers of which contain dye-forming couplers. It has been pointed out, however, that reversal type color film may also be used and, in fact, may even be preferred. In reversal films, density saturation is found at minimum exposure and it decreases as exposure increases until at the limit of its capability, it has a minimum or substantially no opaqueness. This is clearly shown by reference to curve A' in FIG. 4B. Note that maximum density is found at minimum exposure on the left side of the graph. As the exposure increases, the density decreases as indicated by the downward slope of curve A'. When curve A' commences to level off at maximum exposure, curve B' begins to respond, thus providing the above mentioned complementary speed. Similarly, curve C' is effectively the sum total of the densities

of the emulsions producing curves A' and B'. A third reversal type emulsion may be added to the two shown in the manner described in relation to FIG. 1C. In such a case, the exposure response is increased by approximately three decades or to more than a million to 1.

When reversal film is developed, a positive image is formed which may be read directly. This may be desirable in certain applications. The film structures, shown in FIGS. 1A to 1E may be used with reversal film as readily as with negative film. The exposures shown in FIGS. 2A to 2E accurately apply to reversal film if one remembers that the darkening of the film portions is a measure of exposure and not a measure of film density and after completion of the reversal processing the tones or darkening will be the reverse of those shown in FIGS. 2A and 2E. FIG. 4B has also been marked off to show the exposure regions I to VIII as they relate to the exposure shown schematically in FIG. 2E.

Utility of the invention is improved by using very fast emulsions. Extremely fast speed has been attained by using a fast emulsion of the ammoniacal-type having an exposure index of about 1,000. A sensitizer is added to render the emulsion sensitive to a particular region of the spectrum, for example, red-sensitive. No dye-forming coupler is added to the emulsion. The cyan dye will be added during developing. By eliminating the dye-forming coupler from the emulsion, the speed is greatly increased. Actually, it would be more accurate to say that the speed is held at its high level and not slowed by the addition of the dye-forming coupler. There is another benefit to such a high-speed emulsion without a dye-forming coupler which is a decrease in the scattering effect by dispersion of light waves. The more chemicals suspended in the emulsion, the greater the scattering effect.

In using this high-speed emulsion, a film structure such as that shown in FIG. 1C is preferred. In this way, three high-speed emulsions **20**, **30** and **40** are the three top-most layers. The impinging light passes through a minimum of layers, which of necessity, introduce some attenuation. It is preferable to place the blue-sensitive emulsion **40** on top with green-sensitive emulsion **30** immediately underneath and red-sensitive emulsion **20** beneath emulsion **30**. This arrangement is preferred because red light passes through emulsion layers more freely than blue and green light. Blue light is most susceptible of attenuation and scattering and therefore belongs on top.

The three top layers, emulsions **20**, **30** and **40**, in FIG. 1C could be coated alone upon a film support **10** and would provide a new and highly useful color film which is faster than any such film now commercially available. Such a film would add a new dimension to color photography. Although such a photographic emulsion has been known, it has never been used as an emulsion in a color film without the incorporation of the speed-decreasing dye-forming couplers. As mentioned above, this element may slow the emulsion speed by as much as 50 percent.

The exposed emulsions such as those shown schematically in FIGS. 2A to 2E, may be developed in any of the well-known methods for developing negative and reversal type color films, such as those disclosed in C. E. K. Mees, "The Theory of the Photographic Process," Revised Edition, 1954, The MacMillan Company, New York, N. Y., page 584 et seq. (especially 587 and 588). As mentioned above, such a tremendous range of exposure cannot be printed on current photographic printing papers because of the inherent limitations thereof. A reason for using reversal type film, since the emulsions develop as positives, is for direct viewing or projection. In order to reproduce the object, as shown in FIG. 2E, the intensity of the light passing through the developed film must be varied to distinguish details in the highlights which may be found in a highly exposed portion of the film, such as film segment **80** in emulsion **31**. It will be noted that the exposure in this segment corresponds to the very intense green portion **51** of the object. To note the highlights in a low intensity area or the shadows, such as film segment **81** of emulsion **20**, considerably more light is required. By varying the intensity of the exposing light, all the features recorded in the six emulsions of this photographic film can be observed and studied. It is also possible to compensate by varying the spectral composition of the exposing light if it is desired to increase or to attenuate the particular exposure of one color with respect to another.

An alternate method of recording objects having extended exposure ranges on color film may be accomplished by the apparatus shown in FIG. 3. Three color-sensitive emulsions **20**, **30** and **40** are shown coated on a film support **10**. Each of these emulsions has substantially the same speed, but each is responsive to a different portion of the spectrum. Emulsion **20** is a red-sensitive emulsion, emulsion **30** is green-sensitive and emulsion **40** is blue-sensitive. A pair of right angle prisms **34** and **35** appearing as a cube with a reflecting-transmitting coating applied to the common surface **36**, is disposed in the path of the light from the object en route to the photographic film. The prisms **34** and **35** act as a beamsplitter. The incident light striking surface **33** of prism **35** passes therethrough and strikes surface **36** and is divided in approximately equal proportions; one part passing directly through prism **34** and out through surface **37**. The other portion is reflected off surface **36** and passes through prism **35** parallel to the film until it strikes totally reflecting mirror **38**. From mirror **38** the light passes through emulsions **40**, **30** and **20**, in that order, and causes exposures within the emulsion in proportion to the intensity of the light. The light that passes through prism **34** also passes through emulsions **40**, **30** and **20** but between the prism and the film is a neutral density filter **39**. The neutral density filter **39** acts substantially in the same manner as filter **16** in FIG. 1C. It shifts the D-log E curve of the portion of the film beneath it a predetermined distance along the exposure axis (see FIGS. 4A and 4B). The distance is predetermined so that the exposures produce complementary speeds in the emulsions. Since the photographic emulsions **20**, **30** and **40** are employed to record the image formed by light passing through the neutral density filter **39**, and the image formed by light reflected from mirror **38**, the degree of attenuation produced by neutral density filter **39** must be proportional to the exposure response range of the photographic film. In the case of the photographic emulsion shown in FIGS. 4A and 4B, the emulsion has a linear exposure response range of approximately log 2.0. The attenuation produced by filter **39** must be about log 2.0 which means that 99% of the incident light is attenuated and 1 percent is passed.

An alternate arrangement for producing the same result, that is side-by-side photographic images on photographic emulsions having complementary speeds, is produced by varying the transmission-reflection characteristic of the reflecting prism surface **36**. A partially silvered surface **36**, having an attenuation effect proportional to the exposure response of the film completely eliminates any need for the neutral density filter **39**. This so because the impinging light is divided into two parts, the intensity of each being determined by transmission-reflection characteristics to produce images of different speeds.

In using the arrangement of FIG. 3, the film, after development has a series of exposures which are double images. These double images must be reassembled to accurately reproduce the object. There are many ways in which this may be done, but, if the preferred reversal type film is used, the simplest solution is to superimpose the two images in register, such as by projecting through a similar beamsplitter or cutting the film apart.

In FIG. 3, it is immaterial what reflecting surfaces are employed as long as the image is not distorted nor serious light losses introduced. Instead of prisms, a particularly useful reflecting surface is a thin reflecting pellicle film which is capable of reflecting and transmitting the impinging light with a minimum of wasteful internal reflections. A pellicle film may be coated to produce the desired filtering effect.

A photographic film as disclosed herein has great capabilities and may be used in many applications. It is particularly

useful where great exposure ranges are encountered, such as the detonation of high-power explosives, the study of astronomical bodies in the sky and flame studies of rockets and similar devices. The film, of course, may be produced in the form of plates, motion picture film or any of the well-known photographic products.

While the foregoing discussion has been slanted in terms of silver halide photographic emulsions, arranged in layers, it should now be obvious to those skilled in the art that various other photosensitive materials may now be used in place of silver halide. For example, the normally short exposure latitude of diazo materials, when used as duplicating media, may be significantly broadened by utilizing more than one layer of such material, if the resultant film is constructed in accordance with the principles of my invention wherein the speed of one emulsion layer, of the group of blue sensitized layers, is shifted so as to commence responding to impinging light when another emulsion layer (having the same color sensitivity) approaches saturation. However, it should be understood that the diazo materials are spectrally sensitive only to blue-ultraviolet wavelengths.

In the case of the diazo dye, this may be accomplished by means of a neutral density filter layer interposed between the layers or, as an alternative to the neutral density filter layer, a yellow colored diazo dye can be utilized which will serve to attenuate the impinging blue-ultra violet energy thereby effectively reducing the speed of the layer beneath it. This filter layer may be incorporated in one or both of the diazo layers instead of being in a separate layer and should have the property of becoming colorless either upon exposure to the blue-ultra violet energy or when subjected to ammonia or the ammonia fumes used for development of a normal diazo dye image.

To produce a multi-colored duplicate utilizing diazo materials one starts with a first monochrome record indicating the spectral reflectance of the scene in a first region of the spectrum. Thereafter, one adds as many other monochrome records of other, different portions of the spectrum as is necessary to achieve a color facsimile of the scene. Thus, one may have three black and white records, one representing the red content of the scene, another representing the green content and, the last, representing the blue content.

The black and white record representing the red content is then used to produce a cyan colored diazo transparency image. The black and white record representing the green content is then used to produce a magenta colored diazo image while the black and white record representing the blue content is used to produce a yellow colored diazo image. Thereafter the separate colored diazo image records are registered resulting in a composite colored facsimile of the original scene.

Assuming the three black and white records are positive reproductions of the scene, the following diazo compounds would be used to produce the multicolored facsimile:

Cyan	
4-ethylamino-3-methyl benezene-diazonium borofluoride	1.2 parts
Tartaric acid	4 parts
H acid	1.9 parts
Water	100 parts
Magenta	
1-diazo-2-naphthol-4-sulphonic acid	1.0 parts
Aluminum sulphate	3.0 parts
Resorcin	0.6 part
Water	100 parts
Yellow	
4-ethyl-amino-3-methyl-benzene-diazonium-borofluoride	1.2 parts
Tartaric acid	4.0 parts
Phenol	0.5 part
Water	100 parts

If a two color image is desired, the cyan image above is combined with one made using the following orange-red sensitizing solution:

1-diazo-2-naphthol-4-sulphonic acid	1.5 parts
1-phenol-3-methyl-5-pyrazolone	0.9 part
Sulphuric acid	7.2 parts
Water	100 parts

If instead the three black and white records are negative reproductions of the scene, the following diazo compounds would be used to produce the multicolored facsimile:

Cyan	
Dianisidine-tetrazo-disulphone	1 part
Sodium hydroxide, 3% solution	2.5 parts
Alcohol	400 parts
Glycerin	3 parts
H Acid	1 part
Water	200 parts
Yellow	
2-methyl-benzidine-tetrazo-disulphonate	4 parts
Alcohol	200 parts
Water	200 parts
Glycerin	20 parts
Aceto-acetic ester	2 parts
Magenta	
Anisidine-diazo-sulphonate	2 parts
Sodium hydroxide, 1% solution	200 parts
Alcohol	100 parts
Glycerin	3 parts
Beta-oxy-haphthoic acid	2 parts

After reviewing the embodiments shown in FIGS. 1A, 1B, 1D and 1E, it should become obvious that the principles herein set forth apply to the image formation process commonly referred to as the "diffusion transfer process," wherein the developing agents and color dyes are incorporated into the film as layers separated from the silver halide emulsion layers. It will be apparent to those skilled in the art that the light-sensitive emulsions do not contain dye-forming couplers. The configurations that may be brought to mind are shown in the following FIGS. 1F, 1G, 1H and 1I.

Referring now to FIG. 1F, there is shown a photographic product utilizing the layered technique of various speeds in the layers, as applied to the diffusion transfer process. In this embodiment, the film is provided with a base member **10**, and adjacent thereto, is a layer **120** of a linked developer-colored dye having a cyan color. Coated in layers above the developer layer **120** is a first pair of emulsions wherein layer **21** is the slow speed red-record emulsion while layer **20** represents the faster speed record sensitive to light within the red portion of the spectrum. A retardation interlayer **14** is placed atop layer **20** and may serve for one of its purposes the same function as layer **14** in FIG. **1B**, 1D and 1E. Layer **14** is placed between the green sensitive emulsions **30**, **31** and the red sensitive emulsions **20**, **21** principally to provide means for preventing the premature excursion of linked developer-color dye layer **130** from migrating into red-record layers **20** and **21**. In addition, it may contain a magenta dye so as to prevent the passage of green light into the red-recording region.

Layer **130**, containing a linked developer-magenta dye is placed above layer **14** and green-record layers **30** and **31** are placed atop developer layer **130**. As in the previous embodiments, layer **30** has a faster speed than layer **31** so that the speed of one commences to respond to impinging light when the other emulsion layer approaches saturation.

The green-record layers **30** and **31** are provided with an overlayer **12** which may include a yellow filter so that any blue light which may have passed through the outer emulsions will be filtered before it reaches emulsion **30**, whose prime function is that of recording the green light present in the scene. Layer **12** serves the primary purpose of preventing premature migration of developer of layer **140** into green-record layers **30** and **31**.

Layer **140**, having a linked developer-yellow dye, is placed atop layer **12**, and the blue-record layers **40** and **41** applied thereto. The blue-record layer **40** has a faster speed than blue-record layer **41**, in accordance with the principles hereinbefore set forth.

Referring now to FIG. 1G, there is shown a slightly different embodiment than that presented in FIG. **1F**. In the embodi-

ment of FIG. 1G, instead of placing the two record layers (40 and 41 or 30 and 31 or 20 and 21) adjacent to each other, I separate them by the appropriate linked developer-colored dye layers 140, 130 and 120, respectively. A layer 12 is placed between blue layer 41 and green layer 30 to prevent premature migration of any developer other than the layer associated therewith from migrating to an undesired layer. In addition it may contain a yellow dye to minimize the passage of any blue light beyond layer 12. Similarly, layer 14 is disposed between green-sensitive layer 31 and red-sensitive layer 20 to prevent premature migration of either layer 130 into layer 20 or of layer 120 into layer 31. In addition, layer 14 may contain a magenta dye to block the passage of any green light into the red-recording region.

As in the prior embodiment, my device is provided with a base 10, which may not, in all cases, be necessary.

Referring now to FIGS. 1H and 1I, there is shown still another embodiment of a photographic product utilizing the layered technique as applied to the diffusion transfer process. In these next two embodiments each layer is broken up or divided into discrete fast and slow speed portions. For example, in FIG. 1H, the film is provided with a base member 10, and adjacent thereto is a linked developer colored dye layer 120, having a cyan color. Coated above the developer layer is a pair of emulsions wherein stripes or dots 21 may represent the slow, red-record emulsion while stripes or dots 20 represent the faster speed red-record. Retardation layer 14 is placed atop layers 20, 21 and may serve, for one of its purposes, the same function as layer 14 in FIGS. 1B, 1D, 1E, 1F and 1G. Layer 14 is placed between the green-sensitive emulsions 30, 31 and the red-sensitive emulsions 20, 21 principally to provide means for preventing any premature excursion of linked developer-color dye particles of layer 130 from migrating into red-record layers 20 and 21. In addition, it may contain a magenta dye so as to prevent the passage of green light into the red-recording region.

Layer 130, containing a linked developer-magenta dye is placed above retardation layer 14 with green-record layers 30 and 31 placed atop developer layer 130. As in the previous embodiments, layers 30 have faster speeds than layers 31 and may be applied in the form of dots or stripes, the important consideration being that the speed of one emulsion be adjusted so as to commence responding to impinging light when the other layer approaches saturation.

The green-record layers 30 and 31 are provided with an over layer 12 which may include a yellow filter so that any blue light, which may have passed through the outer emulsions, will be filtered before it reaches emulsions 30 and 31. It being recognized that the prime function of emulsions 30 and 31 is that of recording the green light present in the scene being photographed. However, the primary purpose of layer 12 is that of preventing premature migration of developer of layer 140 into green-record layers 30 and 31.

Developer layer 140, having a linked developer-yellow dye, is placed atop layer 12, and the blue-record layers 40 and 41 applied thereto in the form of either dots or stripes. Blue-record layers 40 have a faster speed than blue-record layers 41, in accordance with the principle hereinbefore set forth.

Referring now to FIG. 1I, there is shown still another embodiment, utilizing much the same rationale as in FIG. 1H. However, in this latter embodiment, the integrity of the complementary characteristics has been maintained by providing a neutral density filter 19.0 which has alternate light and dark areas 19.1 and 19.2, respectively. In this embodiment, neutral density filter 19.0 is placed atop or adjacent a film which has a base 10, a linked developer-cyan dye 120, a red-record layer 20, a retardation interlayer 14, a developer-magenta dye layer 130, a green-record layer 30 atop layer 130, a retardation interlayer 12 atop layer 30, a layer 140 of linked developer-yellow dye atop layer 12 and a blue-record layer 40 atop layer 140. Thus, arranged one above the other, discrete complementary speed areas are formed. For those emulsion portions under area 19.2 a slow blue-record portion 40.1, a slow green-record portion 30.1 and a slow red-record portion 20.1 is formed. The remaining blue-record portions 40.0, green record portions 30.0 and red-record portions 20.0, not having been exposed through neutral density filter area 19.2, therefore result in a faster speed than its adjacent portions 40.1, 30.1 and 20.1, respectively.

Although I have disclosed my invention in terms of its preferred embodiment, many variations and modifications will occur to those skilled in this art, and all such are deemed to fall within the spirit and scope of this invention.

What is claimed is:

1. A color photographic film comprising

a film support;

three pairs of silver halide photosensitive emulsions coated in layers upon the film support, the top pair being responsive to one region of the spectrum only, the middle pair being responsive to at least a second region of the spectrum and the third pair being responsive to at least a third region thereof;

a first color filter interposed between the two emulsion layers of the first pair, said filter blocking a predetermined proportion of light within said one region, the attenuation of said filter being predetermined to shift the speed of the lower emulsion of the first pair to provide complementary speeds in the emulsions of the top pair;

a second color filter interposed between the top pair and the middle pair of emulsions, said filter blocking substantially all the light within said one region;

a third color filter interposed between the two emulsion layers of the second pair, said filter blocking a predetermined proportion of the light within said second region, the attenuation of said filter being predetermined to shift the speed of the lower emulsion of the second pair to provide complementary speeds in the emulsions of the middle pair;

a fourth color filter interposed between the middle pair and the lower pair of emulsions, said filter blocking substantially all the light within said second region of the spectrum; and

a fifth color filter interposed between the two emulsion layers of the third pair, said filter blocking a predetermined proportion of the light incident thereupon, the attenuation of said filter being predetermined to shift the speed of the lower emulsion to provide complementary speeds in the emulsions of the third pair.

2. A color photographic film as claimed in claim 1 in which the total spectral response of said pairs of photosensitive emulsions extends through at least the visible spectrum.

3. A color photographic film as claimed in claim 1 in which said fifth filter is a color filter for blocking said predetermined proportion of the incident light in said third region of the spectrum.

4. A photographic film as claimed in claim 1 in which said fifth filter is a neutral density filter for blocking said predetermined proportion of incident light.

5. A color photographic film comprising

a film support;

three pairs of silver halide photosensitive emulsions coated in layers upon the film support, the top pair being responsive to blue light only, the middle pair being responsive to at least green light, and the third pair being responsive to at least red light;

a first yellow filter interposed between the two emulsion layers of the first pair, said filter blocking a predetermined proportion of the blue light to shift the speed of the lower emulsion of the first pair to provide complementary speeds in the emulsions of the top pair;

a second yellow filter interposed between the top pair and the middle pair of emulsions to block substantially all the blue light from passing therethrough;

a first magenta filter interposed between the two emulsion layers of the second pair, said filter blocking a predetermined proportion of the green light to shift the speed of

the lower emulsion of the second pair to provide complementary speeds in the emulsions of the second pair;

a second magenta filter interposed between the middle pair and the third pair of emulsions to block substantially all the green light from passing therethrough; and

a further filter interposed between the two emulsion layers of the third pair to block a predetermined proportion of the red light incident thereupon to shift the photographic speed of the lower emulsion to provide complementary speeds in the emulsions of the third pair.

6. A color photographic film as claimed in claim 5 in which said further filter is a cyan filter.

7. A color photographic film as claimed in claim 5 in which said further filter is a neutral density filter.

8. A color photographic film comprising:

a film support;

a first set of silver halide photosensitive emulsions coated in layers upon said film support; each emulsion in said first set being responsive to a different region of the spectrum, the emulsions within said set having substantially the same speed;

a second set of silver halide photosensitive emulsions coated in layers above said first set, the emulsions in the second set having substantially the same spectral response as the emulsions of the first set; and

a neutral density filter disposed intermediate the two sets, the attenuating effect of said filter being to shift the speed of the emulsions of the lower set a predetermined amount to provide the sets of emulsions with complementary speeds.

9. A color photographic film as claimed in claim 8 in which said first and second sets of emulsions have substantially the same photographic speed.

10. A color photographic film as claimed in claim 8 in which the second set of emulsions are fast ammoniacal emulsions.

11. A color photographic film comprising:

a film support;

two sets of silver halide photosensitive emulsions coated in layers upon said film support, each set containing a red-sensitive emulsion, a green-sensitive emulsion and a blue-sensitive emulsion; and

a neutral density filter disposed between the two sets of emulsions, the attenuating effect of the filter being, to shift the speed of the lower set of emulsions a predetermined amount to provide the two sets of emulsions with complementary speeds.

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