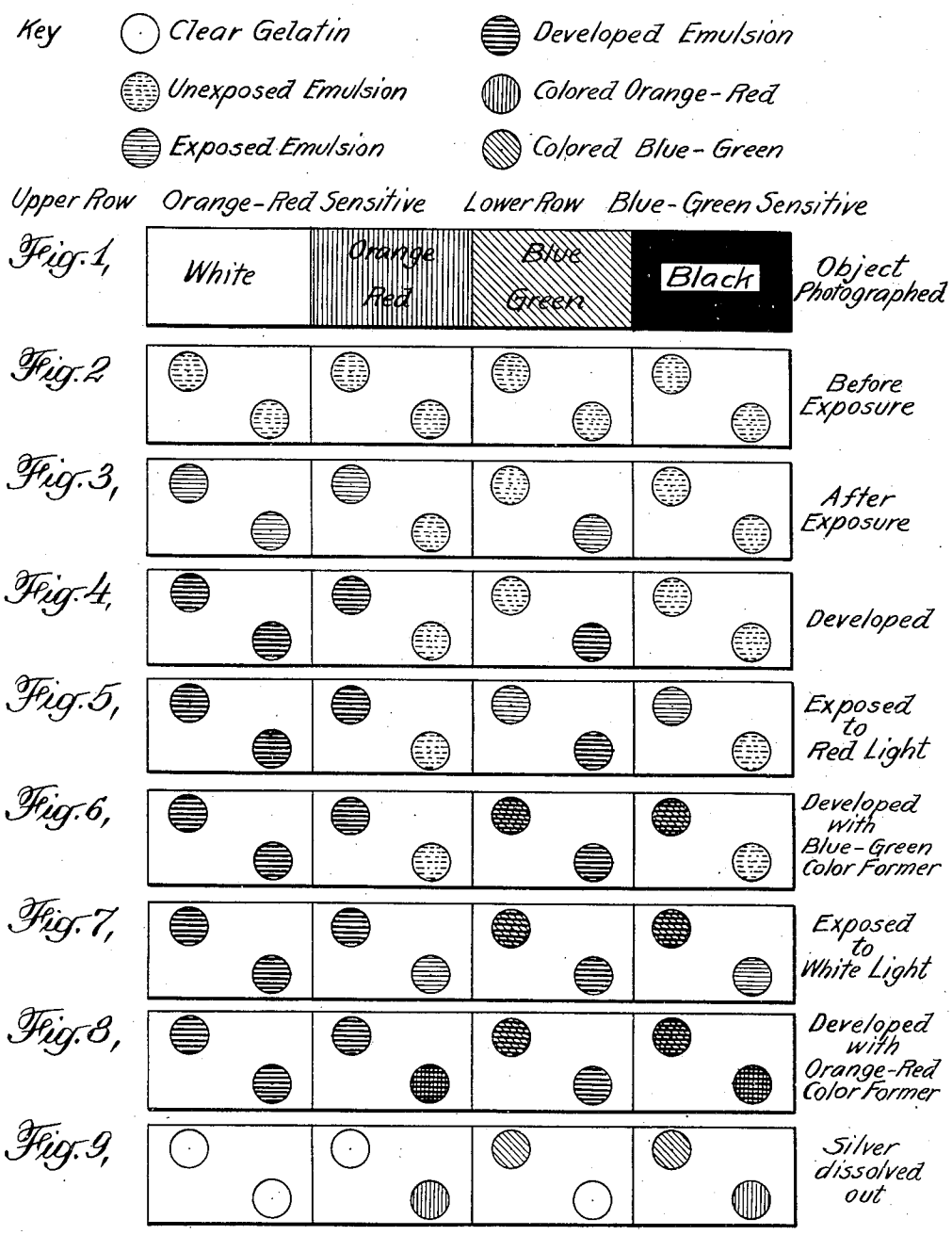
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COLOR PHOTOGRAPHY

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COLOR PHOTOGRAPHY

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This application relates to improvements in color photography and has for its ultimate object the photographic reproduction in color of pictures of good definition and of substantially accurate color values, without the complication of registering a plurality of separate films or producing a plurality of separate images in a multilayer film.

A particular advantage of our improved process is that it does not require any unusual exactitude of formulæ or time of exposure, or any treatment of exceptional delicacy, and color photographs of uniformly good quality may be produced if the work is carried out with no more care and attention than required for producing good black and white pictures.

Prior to the development of the process described in our prior Patent No. 1,516,824, granted November 25, 1924, photographic reproductions in color had been produced by superimposing separate pictures representing the different color values in the object photographed, the separate pictures being colored to correspond with the color values for which they were sensitized. If the individual pictures are not taken by a single exposure through the same lens they are not capable of exact registry, and if produced at a single exposure the subsequent separation for individual coloring requires such great care in execution as not to be capable of use on a commercial scale because of the prohibitive cost of carrying out the process.

Prior to our patented process it had also been proposed to use film having two separate emulsions on its opposite faces to produce the separate images representing the different color values in the object photographed, but this process is faulty in that good definition cannot be obtained and also involves such difficulty in its execution as to preclude its commercial use on any extended scale.

Our patented process is an improvement upon the above described processes in that the separate images representing the different color values in the scene are all recorded in a single emulsion on one side of the film or other support, the emulsion being in layers differently sensitized to record the different color sensations. This process, however, as will be apparent from our patent, involves careful execution both in the preparation of the film and in the developing and coloring of the images, and whereas pictures of good definition and substantially accurate color values are produced by this method, the cost of carrying out the process is considerably greater than producing pictures in black and white.

Our present invention involves the use of a novel form of film wherein separate images corresponding to the separate color values in the scene photographed are produced in a single layer of emulsion. It also involves novel steps in the process of treatment, and the resulting pictures have novel and unique characteristics, all of which novel features will be hereinafter more fully described and claimed.

In carrying out our present invention we employ a photographic film or plate having an emulsion on one surface thereof composed of two or more different emulsions each sensitized to record a particular color value, mixed together and spread in a uniform homogeneous layer on the film or plate. The picture is taken at a single exposure and the film is then so treated as to produce a colored, positive picture wherein the image is made up of differently colored particles uniformly distributed throughout the whole emulsion, whereby the pictures viewed by either transmitted or reflected light present the appearance of a single picture with its different portions colored in various colors made up by combining the two or more basic colors, as the case may be, in varying proportions representing the original colors in the scene photographed.

Our improved process is particularly applicable to the now widely used amateur motion picture processes wherein the film originally exposed in the camera is developed into a positive for use in the projector. In the practice of our process the film is exposed in the camera in exactly the same manner as an ordinary film and when processed according to our present invention, produces a positive film in substantially natural colors adapted for projection in an ordinary projecting machine without the use of color filters, gratings, prisms, or other adjuncts difficult of operation.

Our improved process is nevertheless adaptable for the reproduction of duplicates in the form of films for projection and also paper prints. This is accomplished by printing or projecting through the originally exposed developed and colored film upon a film or other support carrying a similar emulsion, and thereafter developing and coloring the print in substantially the same manner employed in developing and coloring the originally exposed film.

In the accompanying drawing we have diagrammatically illustrated the successive changes which take place in the emulsion on the film as

the successive steps of our process (as a two-color process) are carried out from the exposure of the film to the completed picture, the process, however, being adapted to three-color work by slight modification as fully explained in the following specification.

Fig. 1 is a diagrammatic view showing a multi-color object to be photographed;

Fig. 2 illustrates diagrammatically a section of the film before exposure according to the key which appears in the drawing above Fig. 1;

Fig. 3 is a similar view illustrating the film after exposure in photographing the object shown in Fig. 1;

Figs. 4–8 inclusive indicate diagrammatically in accordance with the key the successive steps followed in the process of producing the picture; and

Fig. 9 is a similar diagrammatic view illustrating the completed picture.

In said drawing, the small circles are supposed to represent separate particles of the emulsion on the film which have been separately sensitized to record different color values, and the nature of such particles at the particular state in the process, that is, whether unexposed, exposed, developed, fixed, colored, etc., is indicated by the shading of the particle according to the key which also appears on the drawing, the drawing being self-explanatory as far as possible.

As stated above, our improved process may be carried out with the photographic emulsion applied to film, glass, paper or other support. This emulsion for two-color work, which is the specific process described in the present application, consists of the usual single homogeneous layer of gelatin through which are uniformly distributed the grains of silver halide which may be of any desired speed within the usual commercial ranges. To all external appearances the emulsion is the same as an ordinary photographic emulsion for producing black and white pictures, and in fact our emulsion may be used for ordinary black and white pictures if the usual developing process be followed instead of the color process herein described.

Our improved emulsion differs from the ordinary photographic emulsion only in that it is composed of two batches, one of which has been sensitized to one of the two colors which are to be used to color the resulting picture, while the other batch has been similarly sensitized to the other color. In accordance with the particular process herein described, the emulsion to be used is divided into two substantially equal parts, and one of the parts is made sensitive to orange-red light by the application of some such dye-sensitizer as pinacyanol or napthacyanol, and the other part is sensitized to green light by the use of a dye-sensitizer such as pinaflavol. After the emulsion is sensitized by the addition of the dye, excess dye is removed by washing, so that the emulsions when mixed will allow each separate silver halide grain to retain its own color sensitivity unimpaired by contact or juxtaposition with a grain which has been sensitized to the opposite color.

After each of the two parts of the batch has been separately color-sensitized and washed as described, they are mixed together and stirred sufficiently to insure a uniform mixture of the two separate parts throughout the batch and then spread on the film or other support in a layer which need be no thicker than the ordinary emulsion layer for black and white work.

The emulsion may be prepared as above described with no further treatment, but in order to get effective color separation with the emulsion just described it is desirable that the exposure be made through a yellow filter in order to remove most of the blue-violet rays, for the reason that the dye sensitizers which make the mixed particles of the two batches of emulsion sensitive to orange-red and blue-green, respectively, do not equally affect the normal sensitization of the silver salt to the blue-violet rays. By employing a yellow filter effective color separation can be obtained, but the resulting picture is not in all respects a faithful reproduction of the natural colors because of the loss of the blue-violet component. To avoid the use of the yellow filter and the resulting loss of the blue-violet rays we preferably desensitize for the blue-violet rays the batch of emulsion which has been red-sensitized before mixing with the other batch.

This desensitizing step is preferably carried out by soaking the emulsion at about 20° C. for ten minutes in a solution consisting of Indian yellow in water, to which some silver nitrate is added, the ingredients being in the following proportions:

Distilled water	10 ounces
Indian yellow	100 grains
Silver nitrate	2 grains

After soaking as described, the emulsion is washed with pure water until any excess of the desensitizer is removed to thereby avoid partial desensitization of the green-sensitized half of the emulsion when the two batches are mixed together. The Indian yellow may be used without the silver nitrate, but we prefer to use the nitrate for the reason that the mixture of the nitrate with the Indian yellow causes the ingredients of the Indian yellow to combine more readily with the silver halide grains in the emulsion and thereby produce a more complete desensitization than can be otherwise obtained.*

* Indian yellow is a natural pigment obtained from India and sold under that name. Its chemical constitution is generally understood to be principally a mixture of the euxanthates of calcium and magnesium. What other ingredients or impurities it contains are not definitely established, nor is it known whether the desensitizing effect is due to the above-mentioned substances or to other ingredients.

To maintain equality of the photo-chemical characteristics of the red-sensitized portion of the emulsion and the green-sensitized portion it is preferable to similarly treat the green-sensitized part with a solution of silver nitrate and water, but this step is of course not necessary and the balance may obviously be obtained by other expedients.

The plate or film coated with the emulsion thus described is exposed in an ordinary camera for an interval depending upon the speed of the silver salt forming the emulsion, the treatment above described adding but little to the time of exposure that an untreated emulsion of the same original speed would require.

In the example depicted in the drawing we have assumed that the object photographed consists of a color card having four areas, namely, white, orange-red, blue-green and black, as shown in Fig. 1. The entire surface of the film is covered with a uniform layer of emulsion made up of particles, half of which are red-sensitized and half of which are blue-green sensitized, and in

Fig. 2 we have represented the four areas of the film corresponding to the differently colored areas of the color card in one particle each of the red-sensitive salt and the blue-green sensitive salt.

Throughout the several views of the drawing the red-sensitized particle is represented by the upper circles and the green-sensitized particle by the lower circles. These particles are indicated in Fig. 2 as unexposed by the dotted line shading, as indicated in the key.

Fig. 3 shows the film after exposure. In the portion of the film where the image of the white end of the color card forming the subject will appear, the particles of both the green-sensitized and the red-sensitized emulsion will be exposed (i. e. affected by the light) as the white light contains both elements. In the portion of the film where the image of the orange-red area of the card will appear the orange-red sensitized particles will be "exposed" while the blue-green sensitized particles will not be exposed. In the portion of the film where the blue-green image will appear the blue-green particles will be exposed, thereby forming a latent image, while the other particles will be substantially unaffected. In the portion of the film corresponding to the black section of the color card the particles of neither group will be affected. The "exposed" particles are indicated by the light horizontal shading.

The next step in the process is to develop the film. Any suitable developer may be used for this purpose, preferably a "soft working" developer, to give detail and harmonious color rendering.

It is also desirable that a developer be selected which produces a minimum of relief effect in the gelatin. To this end caustic alkalies should not be used. Sodium carbonate is preferable as an alkali, and as little as possible should be used. "Metol" and "glycin" are suitable as developing agents, as are also "acid amidol" developers. As will be later explained, it is essential that development at this stage be carried out completely, that is, that none of the latent images be left undeveloped.

In the following description, for the sake of brevity we will refer to the four sections of the film upon which the sections of the color card will be depicted, as the white, red, green and black sections, respectively. Fig. 4 shows the results of the developing step. In the white section of the film both the green-sensitive and red-sensitive particles have been developed into a silver image. In the red section a silver image has been produced in the red-sensitive particles only. The other particles remain in their original condition. In the portion of the film corresponding to the green section of the color card the silver image is composed of the green-sensitive particles only, the other particles remaining red-sensitive as before. In the black section of the film the particles of both groups remain of course unaffected.

The next step in the process is to expose the developed film to a uniform red light. By this step all of the red-sensitive particles not exposed and developed out in the original exposure and first development are exposed. The result of this step is illustrated in Fig. 5. As here shown, the white section remains unchanged, and the orange-red section remains unchanged, the red light having no effect on either the developed silver image or the green-sensitive particles which are still in their original condition. In the portion of the film corresponding to the blue-green section of the color card the particles forming the silver image remain unaffected by the exposure, but the previously unaffected red-sensitive grains are converted into a latent image. Also, in the black section of the film the red-sensitive grains are converted into a latent image.

After exposure to red light, as above described, the film is treated with a color-forming developer, that is, one which forms a colored insoluble precipitate in the gelatin in situ with the silver image simultaneously formed. A color-forming developer producing a blue-green color is employed. A suitable agent is dimethyl-paraphenylene-diamine-hydrochloride with alpha-naphthol, or indoxyl, or paraphenylene-diamine-hydrochloride with trichlornaphthol. After this development the emulsion is well washed.

The effect of this step is to develop and simultaneously color blue-green the latent images formed in the blue-green and black sections of the film by the exposure to red light as above described. Fig. 6 shows the condition of the film after this step. In the white section both the orange-red sensitive and blue-green sensitive emulsions contain metallic silver images. In the orange-red section the orange-red sensitive particles have been converted into a silver image, while the blue-green sensitive particles remain unexposed. In the blue-green section of the film the orange-red sensitive particles have been converted into a silver image and also colored blue-green while the blue-green sensitive particles constitute a developed but uncolored silver image. In the black section the orange-red sensitive particles form a blue colored silver image while the blue-green sensitive particles remain in their original unexposed condition.

The next step in the process is to expose the film to white or blue-green light to thereby form latent images in the remaining unexposed particles, namely the blue-green sensitive particles in the sections of the film in which the orange-red and black portions respectively of the color card are depicted. The result of this step is illustrated in Fig. 7.

The film is then developed with an orange-red color forming developer, such as thio-indoxyl, or paranitrobenzylcyanide with dimethyl-paraphenylene-diamine. The film is then well washed to remove the excess. Fig. 8 indicates the condition of the film at this stage. Both emulsions throughout now contain metallic silver images. In addition the blue-green sensitive emulsion in the orange-red section contains an orange-red image; the orange-red sensitive emulsion in the blue-green section contains a blue-green image, and in the black section both emulsions contain color images corresponding to the color for which the other emulsion was originally sensitized.

The final step in the process is to dissolve out all the silver images. Any suitable solvent such as potassium ferri-cyanide with hypo may be used for this purpose. Fig. 9 shows the result of this step. The white section of the film is transparent. The orange-red section contains a positive orange-red dye image formed in the normally blue-green sensitive portion of the emulsion. Similarly the blue-green section contains a positive blue-green dye image, while the black section contains both an orange-red and a blue-green image and is therefore opaque.

The resulting picture is a true positive of the object photographed in natural colors so far as such colors can be reproduced by any two-color process. Let us consider the orange-red section

of the color card as not strictly orange-red but of a shade predominantly orange-red and slightly blue-green. On exposure and development both emulsions will contain silver images but the image in the blue-green sensitive emulsion will be of an intensity corresponding to the proportion of blue-green in the color on the color card. Likewise the extent to which the blue-green sensitive emulsion is unexposed corresponds to the proportion of orange-red color in the color on the card. Hence when this portion of the emulsion is completely exposed by exposure to white light (Fig. 7) and subsequently developed with the orange-red color forming developer the resultant orange-red image will be of an intensity corresponding with the conversion effected by the second exposure only. In other words the images which are reproduced in color are not the images produced by the original exposure, but the images produced by the subsequent exposures to red light and white. These images are in intensity the complements of the objects in the scene photographed and must therefore be colored respectively with the opposite color.

The above described process is also applicable to three-color work by utilizing an emulsion made up of three batches instead of two, the particles of each batch being sensitized to record one of the three colors. For example, one batch may be made red-sensitive by using a dye-sensitizer such as pinacyanol, the second batch may be rendered green-sensitive by the use of a dye-sensitizer such as erythrosin and the third batch rendered blue-sensitive by means of a dye-sensitizer such as auramine.

In carrying out this three-color process the above described procedure is followed through the step of "exposure to red light" illustrated in Fig. 5. After this exposure the film is subjected to the action of a color-forming developer such as trichlornaphthol with dimethyl-paraphenylene-diamine, which provides a green color suitable for the green component of a three-color picture. The film is then exposed to green light and after exposure is developed with a red color-forming developer such as thio-indoxyl. After this step the film is again exposed, this time to a blue-white light to convert the blue-sensitive particles which still remain unaffected by the previous exposures to red and green light, respectively. The image thus produced is developed with a color-forming developer consisting, for example, of alpha-chlorethylacetoacetate with diethyl-paraphenylene diamine, which produces a suitable yellow for the third component.

After this step the silver is dissolved out in the same manner as above described, producing a transparent colored positive similar to the picture produced by the two-color process but with the more faithful reproduction of the colors in the scene photographed which results from using three colors.

Instead of using color-forming developers as above described, the steps of developing and coloring may be separately performed. In the process as so modified the steps as illustrated in Figs. 2 to 5 inclusive will be carried out as above described, but instead of immediately developing the images produced by the red light exposure, the developed silver images formed by the first development are completely dissolved out. Any well known formula may be used for this purpose, such as potassium bichromate and sulphuric acid or cupric chloride and ammonia. This step does not destroy the still unexposed green sensitive particles nor the undeveloped but exposed red-sensitive particles. This treatment does, however, destroy the color sensitivity of the undeveloped particles, that is to say, it reduces the emulsion back to normal silver haloid grains sensitive to white light. After this step no image will be visible in the emulsion. The particles forming the silver image will be transparent and the remaining particles will correspond with the ordinary exposed but undeveloped film. Before proceeding with the process the bleaching solution used for dissolving out the silver must be thoroughly washed out.

The next step in the process is to again subject the film to the action of development. The exposed particles in the section of film corresponding to the blue-green portion of the color card and the black portion are converted into a silver image. The other particles remain unchanged. Particles of both kinds exposed to the white light reflected from the white section of the color card are transparent. In the orange-red section, the particles which were originally sensitized to orange-red light have been dissolved out, rendering the emulsion transparent. The remaining particles remain unexposed, but their sensitivity to green light has been destroyed. In the green section of the film the red-sensitive particles form a silver image and the original green-sensitive particles have been dissolved out. In the black section the red-sensitive particles form a silver image and the green-sensitive particles remain unexposed, but no longer green-sensitive.

The next step in the process, is to subject the film to a blue-green toning bath to thereby tone the silver images of the second development step to a blue-green color. Any of the well known iron toning formulæ may be used for this purpose, for example, the silver image may be bleached with potassium ferri-cyanide and thereafter toned with a solution of ferrous chloride.

The particles thus affected are the original red-sensitive particles in the portion of the film corresponding to the blue-green and black sections of the color card.

After this toning step the film is thoroughly washed to remove any surplus of the toning solution. The film is then exposed to a white light, to thereby produce latent images in the remaining light-sensitive particles, that is, the original green-sensitive particles in the portions of the film which depict the orange-red color sensation in the scene photographed and the original green-sensitive particles in those portions of the film corresponding to the black sections of the color card or other subject photographed.

The film is then subjected to the action of the developer to develop the latent images formed by this exposure. For this purpose a non-alkaline developer must be used such, for example, as diamidophenol, generally known as amidol. The use of an alkali developer for this development would permanently destroy the blue-green image produced by the toning bath. The amidol developer temporarily bleaches this image, but by thoroughly washing the film after the development is complete, the color is restored.

The final step of the process consists in toning the silver image produced by the last development step to the desired orange-red color. Any well known solution may be used for this purpose, such, for example, as uranium ferro-cyannide, or the image may be colored with a basic aniline dye in conjunction with a mordant such

as copper ferro-cyanide, etc. After this step the film is thoroughly washed and then dried to form a positive transparent picture of the scene photographed with the color values in the scene reproduced as accurately as possible with two colors only.

This modified process involves more steps than the first described process. Also with the preferred process differences of image texture and internal contrasts are minimized. On the other hand the colors produced by color-forming developers are regarded by some as not so nearly complementary as colors which may be obtained with metallic toning solutions or dyes such as may be used in the last described process.

The film produced as above described may itself be used with a projector and the process is thus particularly adapted for so-called amateur motion pictures where reproductions of the film are not usually required. The colored positive may, however, be used in making reproductions by means of ordinary printing methods using white light, in the usual manner and printing on a film of substantially the identical character as the film used for the original picture, and thereafter subjecting it to the identical process above described.

It will of course be understood that the invention is not limited to the use of the particular color sensitizing solutions, developers, color-formers or toning solutions specified above. These may obviously be widely varied. The entire film is saturated with the developer or other solution used, the particles which are not to be affected by the particular solution being in a condition to be impervious to the solution. In this respect the process is a great improvement on prior processes wherein it is necessary to limit the degree of penetration or otherwise protect one image while another image in the emulsion is being acted upon.

We claim:

1. A photographic reversal process comprising developing the negative image in an ordinary photographic developer to produce a silver image, and developing the reversal image in a color-forming developer to produce a silver image with virtually insoluble dye in situ the silver of both negative and positive images being removed as the final step.

2. The method of producing a direct positive photograph which comprises exposing a sensitive emulsion layer to a light image, developing said layer in an ordinary photographic developer without fixing it, reversing the developed image by exposure to light, developing in a color-forming developer, and finally removing the silver from negative and positive images.

3. In a photographic reversal process, the step of developing the reversed image in a color-forming developer.

4. In a photographic reversal process comprising exposure to an image, development in an ordinary photographic developer, re-exposure to light, and re-development, the step of developing the reversed image in a color-forming developer.

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