

An Introduction to Color Photographs: Technology, Terminology and Identification

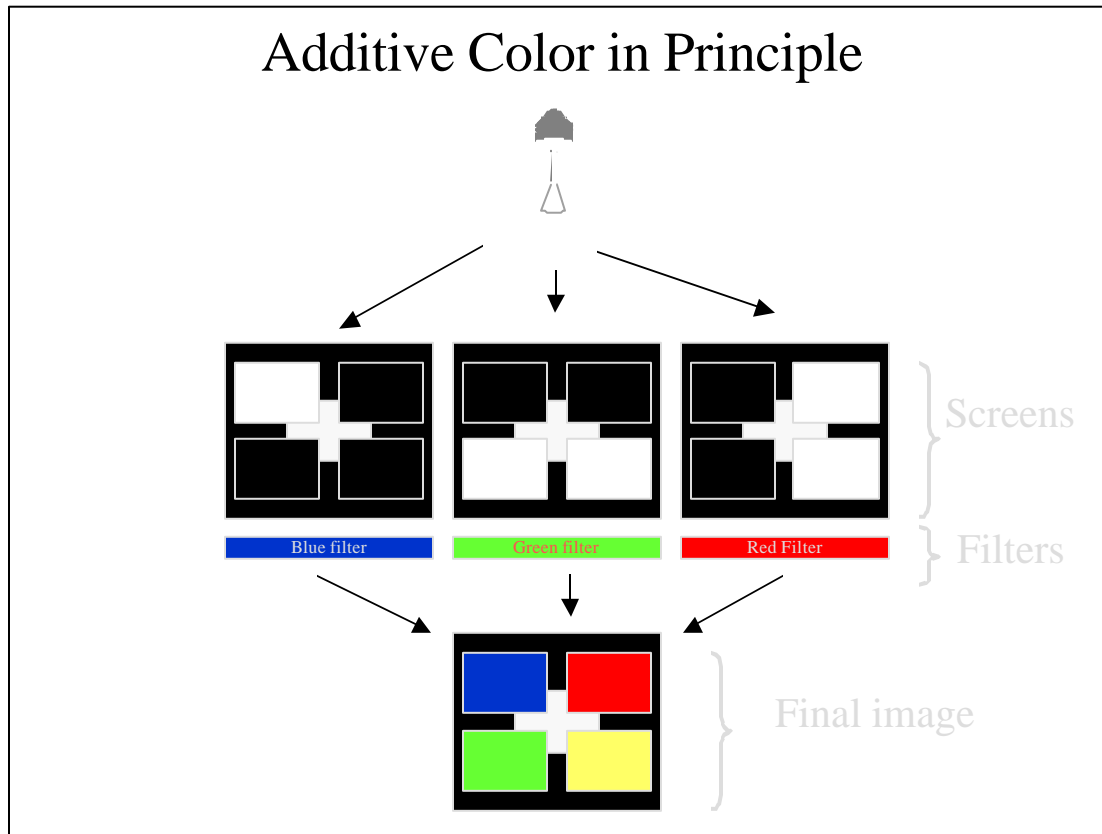
Paul Messier

Conservator of Photographs & Works on Paper

pm@paulmessier.com

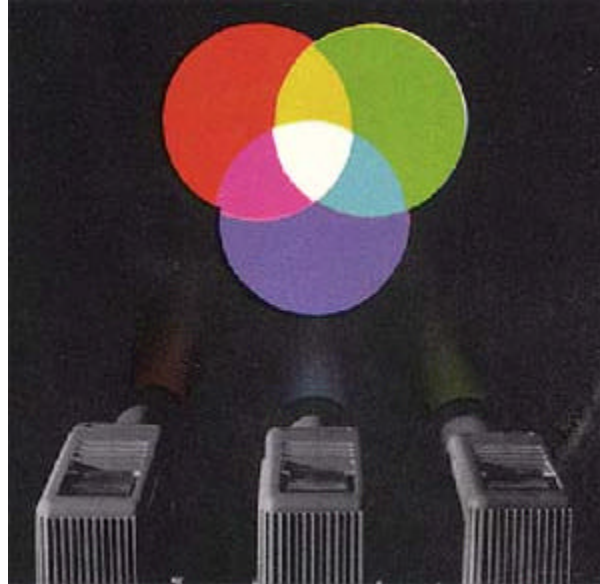
<http://paulmessier.com>

This lecture was originally presented by videoconference from M.I.T to the students at the graduate art conservation programs at Buffalo State College and Queen's University and to the Los Angeles County Museum of Art on December 2, 1999. This lecture is not a comprehensive look at every color photographic process made over time, but instead provides an overview of the most significant, widely used, processes and products.



For the additive processes, the image is the result of dividing white light into red, green and blue then *adding* or mixing controlled portions of these colors to form the final image. The only practical manifestations of photography using additive color were the various screen-filter processes. These processes required light transmitted through red, green and blue filters. The image is formed by selectively transmitting or blocking the light by a screen.

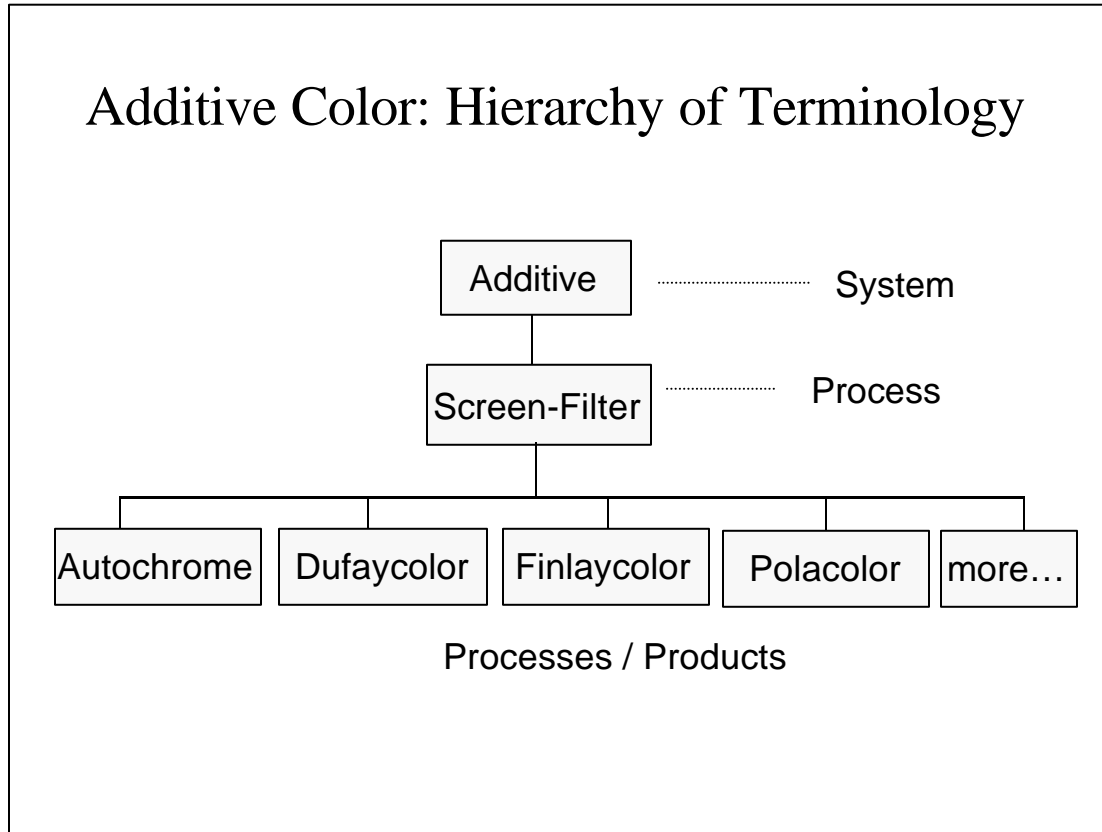
Additive Color: Based on Combinations of Red, Blue and Green Light



This illustration shows the mixing of the additive primary colors, red green and blue to form white and the secondary colors of cyan, magenta and yellow. “Additive color” can be thought of relative to white, where red, green and blue combine or “add” to form white.

Illustration taken from The Encyclopedia of Photography, William Morgan, General Editor, Greystone Press, New York, 1967, Volume 5, page 802.

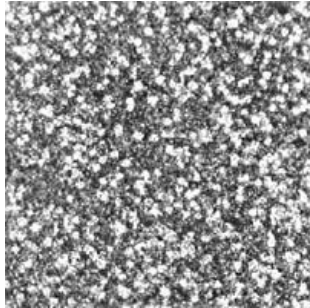
Additive Color: Hierarchy of Terminology



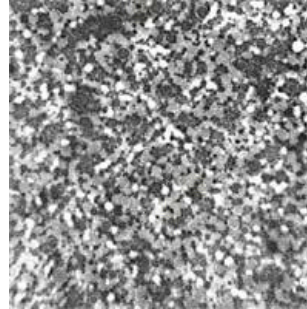
For the additive system there is one image making process: the “screen filter” process. There are several manifestations of the screen filter process made by different manufacturers. The most common additive processes are listed above.

Screen Patterns: Additive Color Processes

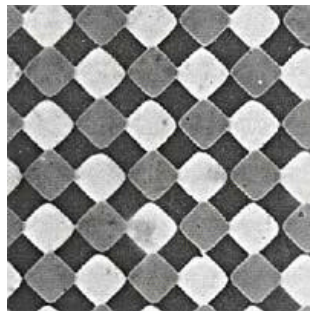
Autochrome



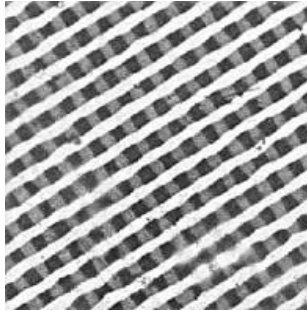
Agfa Color



Finlay



Dufaycolor



The illustration shows the screen patterns used by four manufacturers of additive color processes. The photomicrographs are magnified 100 times.

Illustration taken from *A Half Century Of Color*, Louis Walton Siple, Macmillan Company, New York, 1951, page 79.

Photomicrograph of an Autochrome Showing Red, Green and Blue Filters

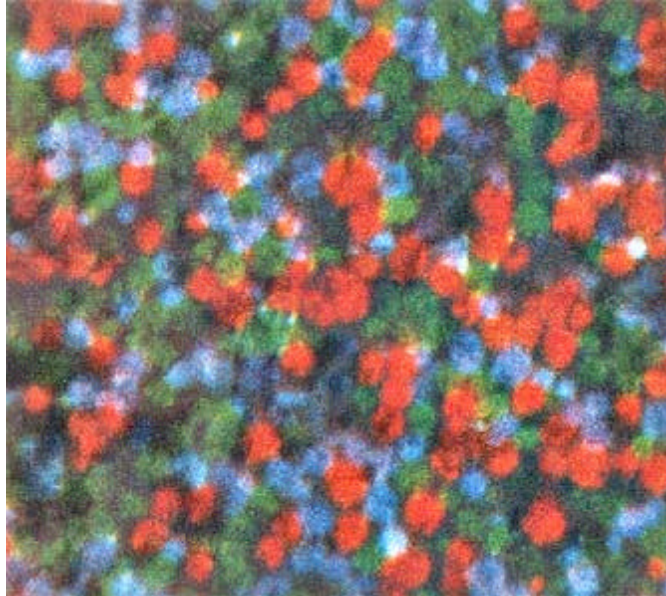
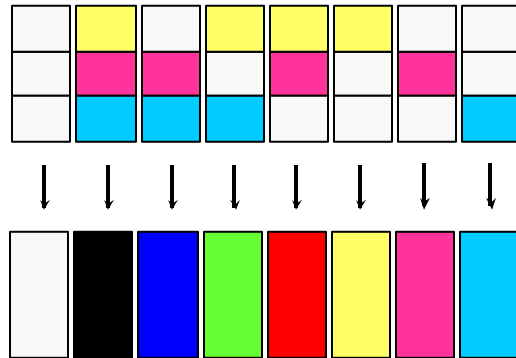


Illustration taken from The Complete Guide to Cibachrome Printing, Peter Krause & Henry Shull, H.P. Books, Tucson, AZ 1982, page 18. The original caption reads “This is a photomicrograph of the color screen of an Autochrome plate. The filter elements consisted of potato starch granules of 12nm to 16 nm diameter. Granules were dyed violet-blue, green and orange red. The unavoidable spaces between the granules were filled with carbon black powder. Clumping of granules could not be prevented and increased the average size of each filter element.”

Subtractive Color in Principle

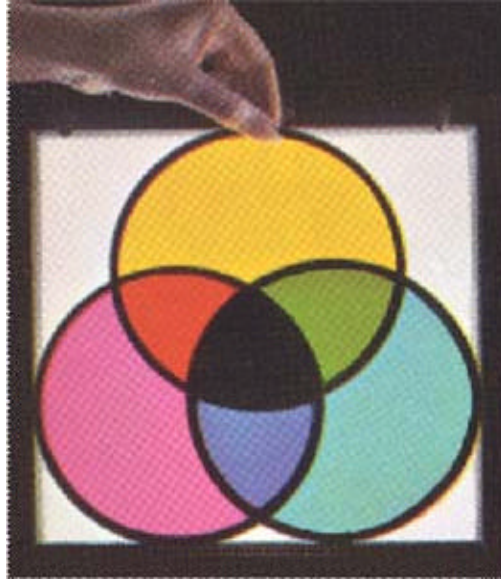
Three dye layers consisting of the three subtractive primaries (cross section)



Colors rendered in the final image
(either a transparency or a reflective print)

For the subtractive processes, the image is the result of *subtracting* red, green and blue from white light using superimposed layers of **cyan** (minus red), **magenta** (minus green), & **yellow** (minus blue) dye. For all the subtractive processes, these dye layers are formed in, or deposited on, the emulsions of photographic paper or film.

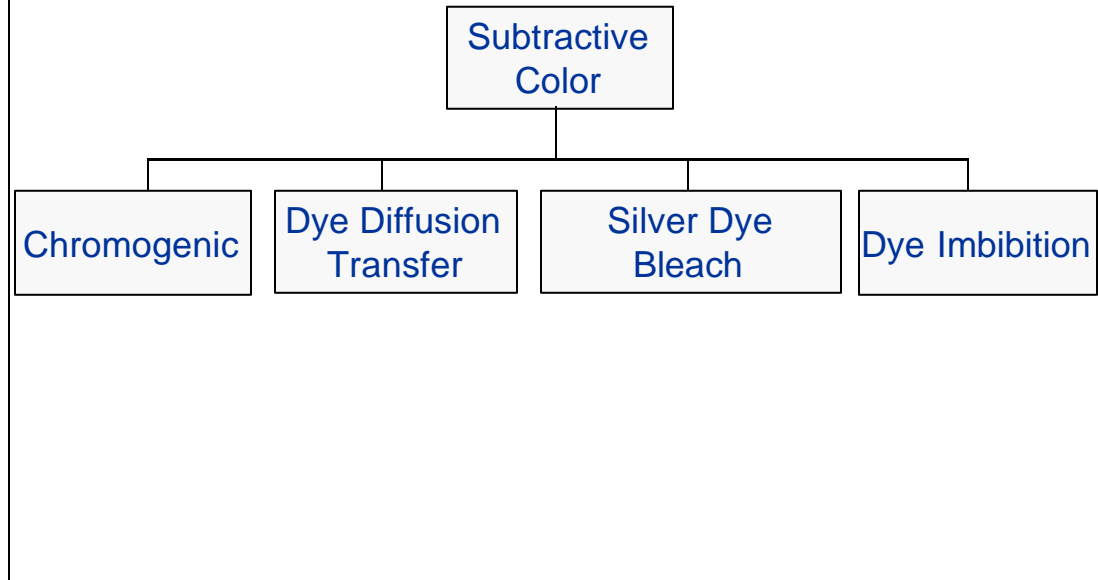
Subtractive Color: Based on Combinations of Cyan, Yellow and Magenta Dye



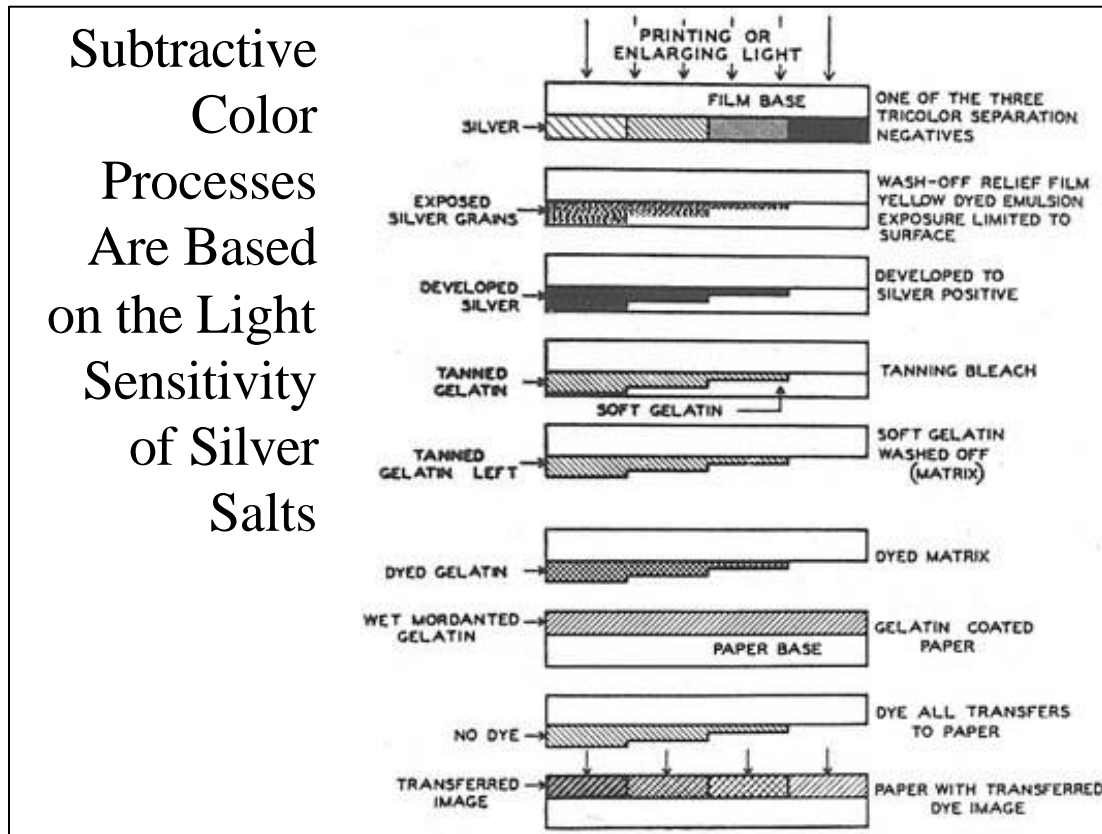
Subtractive color can also be thought of as relative to white light as the absence of the three primaries (or their “subtraction”) equals white, while the combination of the three makes black. Cyan, yellow and magenta proportionately combine to form black, red, green and blue.

Illustration taken from The Encyclopedia of Photography, William Morgan, General Editor, Greystone Press, New York, 1967, Volume 5, page 802.

Subtractive Color: Four Major Processes



For the subtractive system there are four image-making process: the chromogenic process; the dye diffusion transfer process; the silver dye bleach process; and the dye imbibition process.

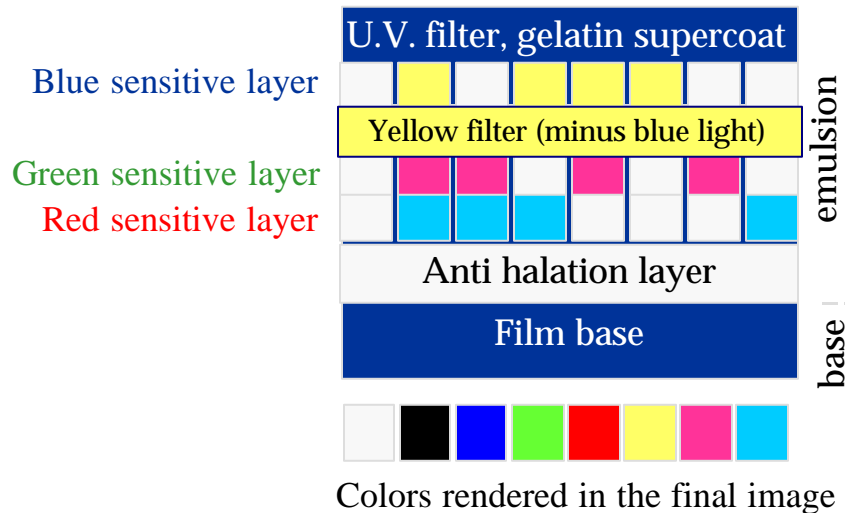


For all subtractive processes, the result is an image formed using cyan magenta and yellow dye. Interestingly, all of the subtractive processes share a dependence on the light sensitivity of silver halides (the primary difference between the four main subtractive processes lies in how the dyes are formed and deposited).

The illustration above shows how an early dye imbibition process (Kodak's Wash Off Relief Process) uses a monochrome silver image to selectively deposit the component dyes. For the chromogenic process, the formation of the dyes is literally "coupled" to the reduction of the silver halide after being contacted by light.

Illustration taken from *A Half Century Of Color*, Louis Walton Siple, Macmillan Company, New York, 1951, page 101.

Chromogenic Processes - Cross Section



The diagram shows a simplified structure for a color transparency. Negatives often use a similar layer sequence while prints typically have the cyan or magenta layers on the top and the yellow layer on the bottom.

In the chromogenic processes, three selectively light sensitive layers in the silver halide emulsion are exposed to light. Initially, a black and white, silver halide, latent image is chemically developed to form a negative on all three layers. During this stage, the developer used to convert the exposed silver halide to metallic silver becomes oxidized. The oxidized developer combines with color couplers initiating the selective formation of cyan, magenta and yellow dyes within discrete layers of the emulsion. The image silver is then bleached and unexposed silver halide is removed by fixing.

For transparencies or other direct positives, a second development step is required. The second step develops the remaining silver halide not developed in the first step. Dye coupling is linked to the metallic silver developed in this second step. This two step development process is known as reversal processing.

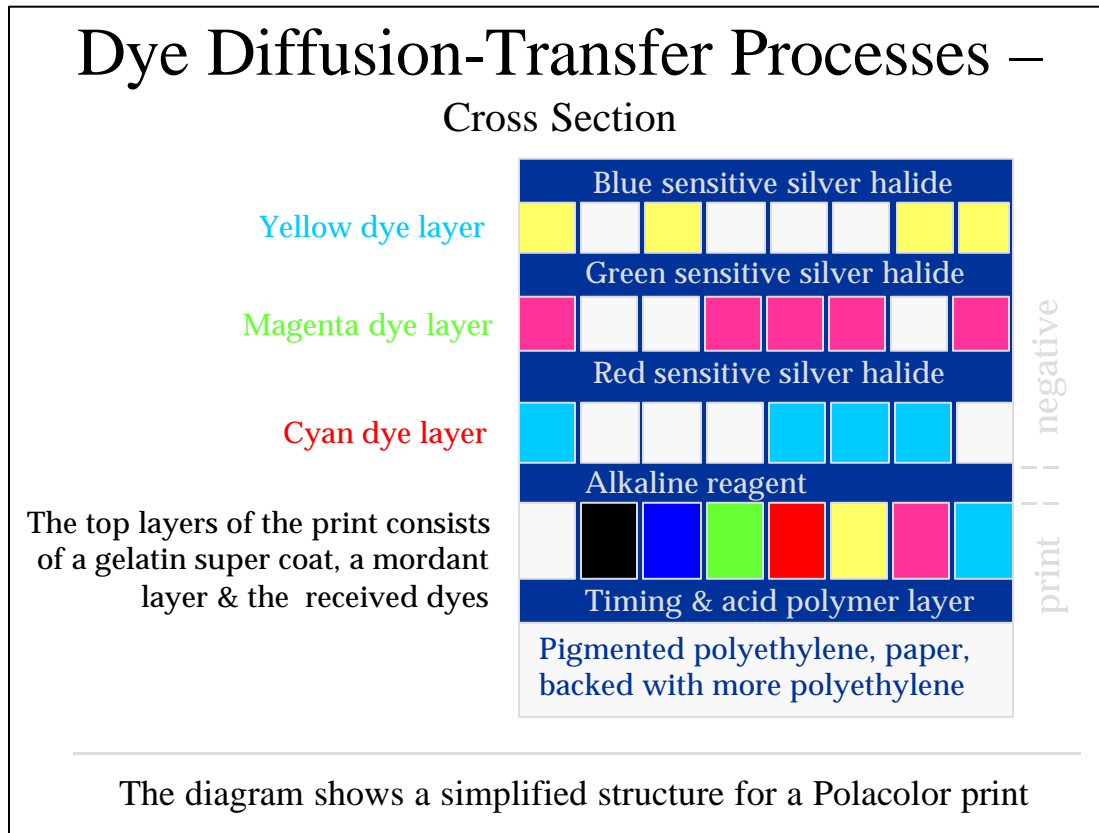
Chromogenic materials are used for making transparencies, color negatives and color color prints from color negatives.

Example of a Chromogenic Print, Kodak Kodachrome



THIS IS A
KODACHROME PRINT
MADE BY
LITMAN KODAK COMPANY
1, 10, 100, U. S. PAT. OFF.
Week of Aug-9, 1954

An example of a Kodachrome print in good condition. This print is stamped on the reverse, identifying the process and giving the date, August 9, 1954.

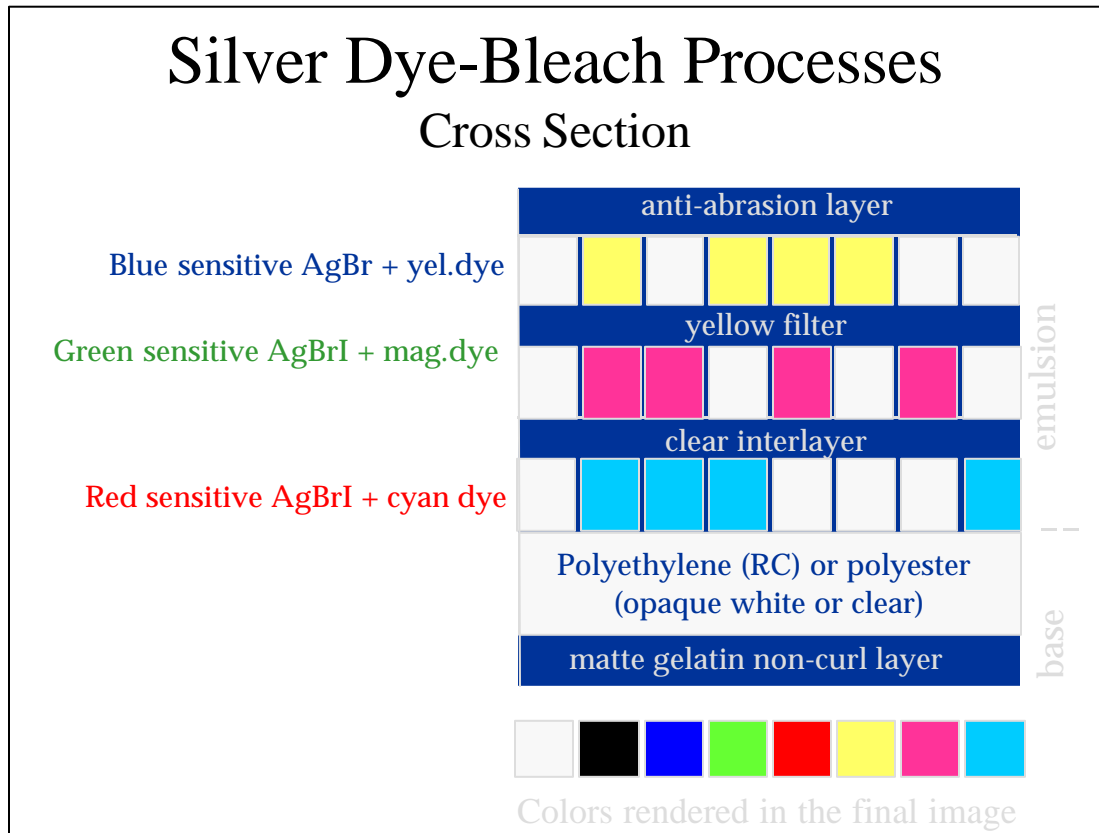


Known as “instant prints,” negative, positive and processing chemistry are provided in a self-contained package. In the negative, discrete layers of silver halide in the emulsion bind associated dyes. The bound dyes and associated silver form a negative image. Dyes which are not bound in the negative literally diffuse and transfer to the print’s emulsion / mordant layer to form the positive image.

Example of “Integral” Dye-Diffusion Transfer Print

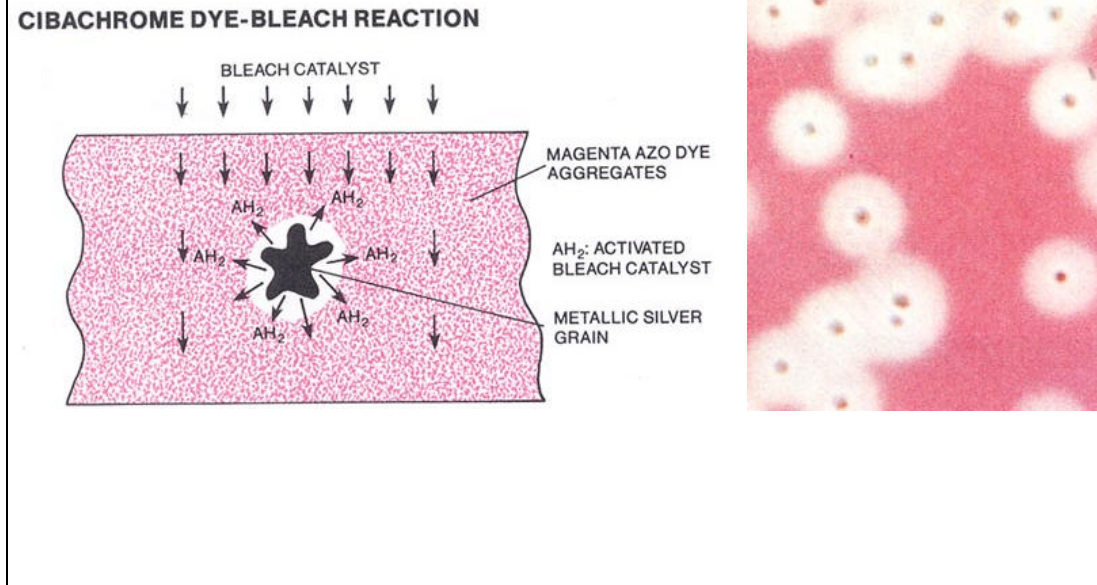


The illustration shows the front and back of an “integral” dye diffusion transfer print made by the popular Polaroid SX-70 camera. The image is formed by dyes that diffuse and transfer from the negative held at the back of the laminate structure. An integral system, the negative remains a permanent part of this laminate structure. Polaroid also manufactures “peel apart” systems where the negative and the processing chemistry is removed from the face of the print after the dyes have been transferred.



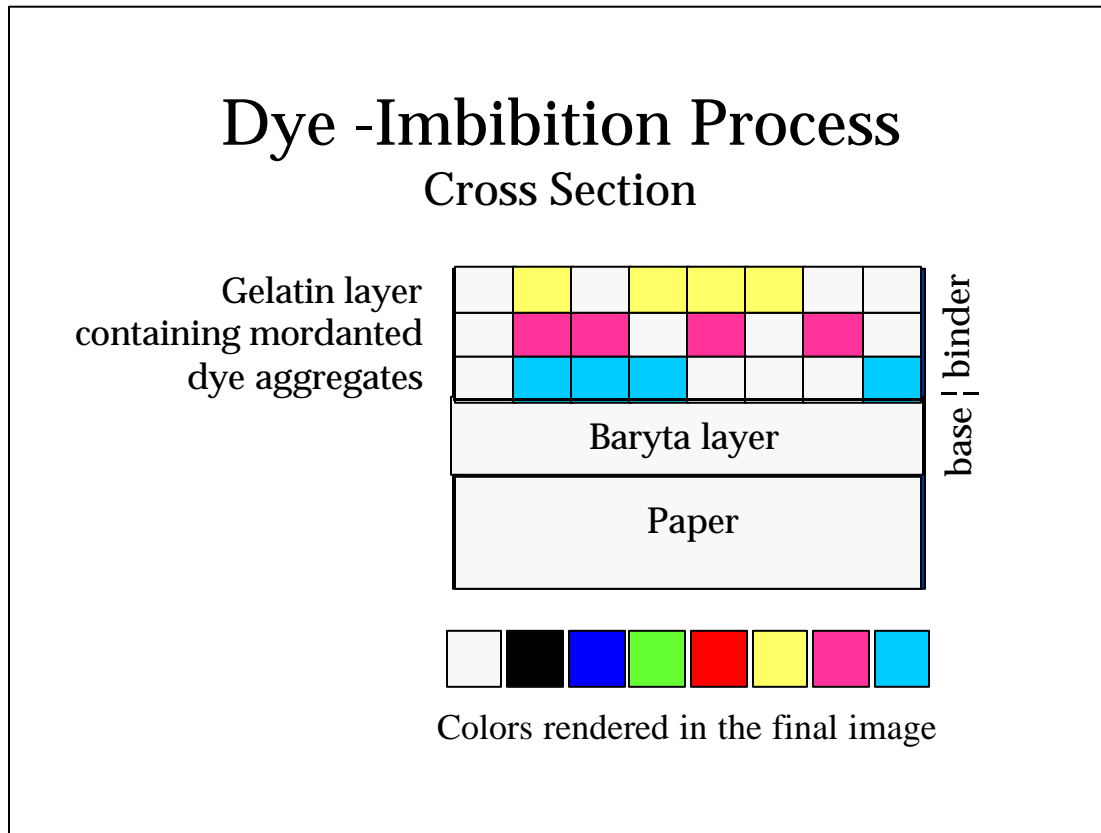
In the silver dye bleach process, three layers in the emulsion contain cyan, magenta and yellow dyes. Each layer also contains silver halide. The silver halide is selectively sensitive to either blue, green or red light. When exposed to light, a latent image forms which is reduced by the developer to form metallic silver. The silver metal and associated dye in each discrete emulsion layer is then bleached. The image is formed by the remaining dyes. This is a direct positive process most often used to print from (positive) transparencies.

Example of Silver-dye Bleach – Cibachrome / Ilfochrome



The illustration at left shows the penetration of the bleach catalyst into the magenta dye layer. The bleach catalyst reacts with the metallic silver (through oxidation) and bleaches surrounding dye. At right is a photomicrograph showing bleach halos surrounding the silver particles. The silver particles are removed in the finished print through bleaching, fixing and washing.

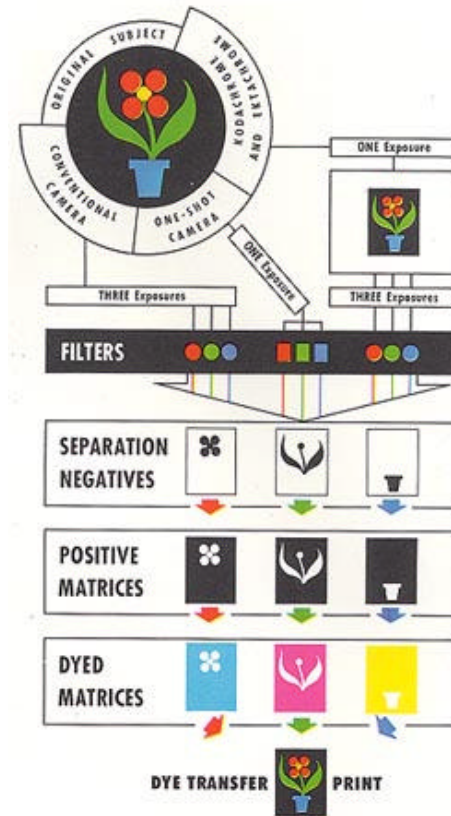
The illustrations are taken from The Complete Guide to Cibachrome Printing, Peter Krause & Henry Shull, H.P. Books, Tucson, AZ 1982, page 30.



Since 1945 Kodak's Dry Transfer process has been the dominant Dye Imbibition Process (see slide 10 for a description of an earlier dye imbibition process, the Wash Off Relief Process).

A Dye Transfer is made by using red, green and blue filters to make three black and white, silver halide separation negatives. Each resulting negative corresponds to either red, green or blue in the original subject. The negatives are then printed onto individual gelatin-silver emulsion matrix films. The matrix films are soaked in the appropriate dyes: yellow dye for the blue negative; magenta dye for the green; cyan dye for red. Areas of silver image development proportionally absorb dye. Each in its turn, these matrix films are then pressed onto a gelatin / mordant layer. The usual sequence for applying the matrix films is cyan, magenta then yellow. For the purposes of illustration the diagram above show the dyes in discrete layers, indicating typical the sequence of application. In reality, the dyes are deposited in a single, un-stratified layer of gelatin.

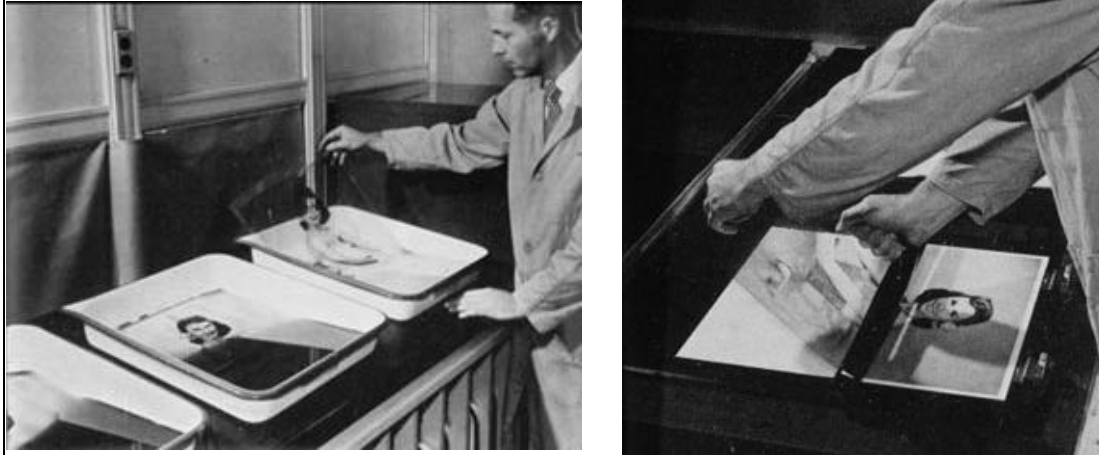
Example of the Dye Imbibition Process – Kodak's Dye Transfer Process



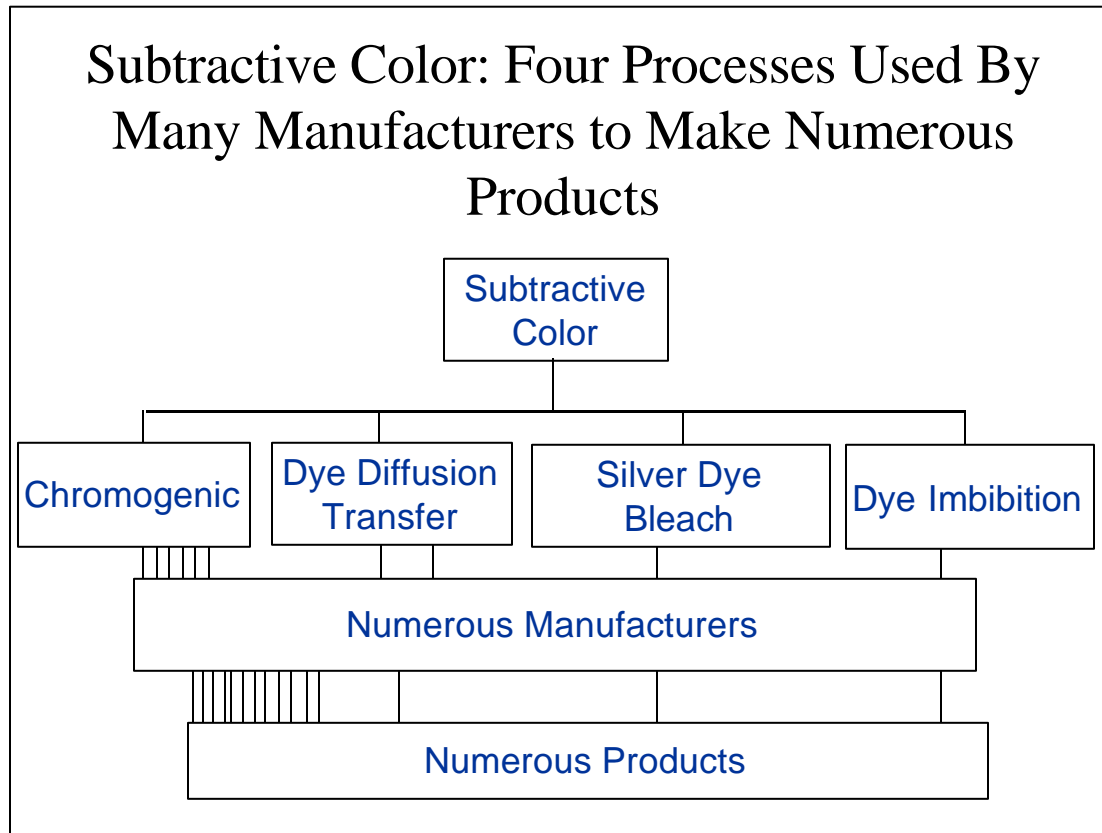
The illustration shows the basic steps for creating a Kodak Dye Transfer print, the dominant dye imbibition process.

Illustration taken from The Encyclopedia of Photography, William Morgan, General Editor, Greystone Press, New York, 1967, Volume 5, page 808.

Dye Transfer -- Dying Matrixes and Transferring Dyes to Print



On the left, the photographer is soaking the three matrixes in separate baths of cyan, magenta and yellow dye. Typically, the cyan matrix is removed first. On the right, the photographer places this matrix over the gelatin-coated paper. A brayer transfers the dye to the gelatin layer. This process is repeated for the magenta and yellow matrixes.



The four major subtractive processes are utilized by a wide range of manufacturerers using numerous brand names.

- By far, the chromogenic processes dominate with numerous manufacturers making a wide range of products. In the marketplace Kodacolor, Kodachrome, Fujicolor and Fujichrome are some widely recognized brand names.
- Today, products using the dye diffusion transfer process are made exclusively by the Polaroid Corporation (at one point Kodak briefly marketed dye-diffusion transfer products).
- Ilford markets the only silver dye bleach process, now know as Ilfochrome (formerly known as Cibachrome).
- Until fairly recently, Kodak was the sole supplier for supplies need to make dye imbibition prints, known by the trade name “Dye Transfer.” Kodak discontinued manufacture of Dye Transfer materials, though the materials are still available.

Chromogenic Materials: Commonly Encountered Manufacturers & Brand Names.

- **Agfa**
 - Agfacolor
 - Agfachrome
- **Fuji**
 - SFA 4
 - Fujicolor
 - Fujichrome
- **Ilford**
 - Ilfocolor Deluxe
 - Colorlux
- **Kodak**
 - Ektacolor
 - Ektachrome
 - Duraflex
- **Konica**
 - Konica Color QA
 - Konica Color PC
 - Konica Chrome Paper
- **Mitsubishi**
 - Mitsubishi Color Paper SA
 - Mitsubishi Color Paper KER

Commonly encountered contemporary manufacturers and brand names for chromogenic materials. The suffix “color” usually indicates a color negative or print paper. For the chromogenic processes, the suffix “chrome” usually indicates a transparency or print made through reversal processing.

Brand Names: Silver-Dye Bleach, Dye Diffusion & Dye-Imbibition.

Silver-Dye Bleach

- **Ilford**

- Ilfochrome (previously called Cibachrome)

Dye Diffusion Transfer

- **Polaroid**

- Time Zero Prints (SX-70, Type 778)
- Polacolor II Prints (types 88, 108, 668, 58, 808)
- 600 Plus

- **Polaroid (cont.)**

- Autofilm 330
- Type 990
- Spectra HD
- Polaroid Image Prints
- ER (types 59, 559, 669, 809)
- Polacolor 64T & 100 prints
- Polacolor Pro 100

Dye-Imbibition

- **Kodak**

- Kodak Dye Transfer Prints

Contemporary manufacturers and brand names for silver-dye bleach, dye diffusion transfer & dye-imbibition processes. The Kodak Dye Transfer process is no longer manufactured by Kodak, though the materials are still available.

Identification: Additive Processes

- Date: most popular between 1907 and the 1930's.
 - First widely used process: Lumière Autochrome, introduced in 1907.
 - Last widely used process: Dufaycolor, introduced 1935.
- Viewed only by transmitted light or by projection.
- Will have a discernable matrix of red, green and blue filters, apparent using no or low magnification.

Identification of the additive processes is usually straightforward as they are viewed by transmitted light. The screen patterns (see slide 5) are often identifiable under magnification.

Identification: Subtractive Processes

– Image Characteristics and Key Dates

- Continuous tone reproduction (no grid or other discrete filter particles).
- Key Dates:
 - Chromogenic: Kodachrome transparency film, 1935.
 - Dye imbibition: Eastman Wash Off relief, 1935 and Kodak Dye Transfer, 1945.
 - Dye diffusion transfer: Polacolor (1963) and SX-70 (1972) were the first real successes in the marketplace.
 - Silver dye bleach: Cibachrome, 1963.

Subtractive processes render continuous tones without the use of screen / filters used in additive processes. The dates and processes cited above are the introduction dates of key, widely utilized products. For example, the Land One-Step process, introduced in 1947 was a breakthrough dye-diffusion transfer process. However, it wasn't until the introduction of Polacolor in 1963 before a practical implementation of the dye-diffusion transfer process became widely available.

Identification: Subtractive Processes – Base and Borders

- **Fiber base:**
 - Chromogenic, pre-1968
 - Dye Imbibition
- **Resin coated paper:**
 - Chromogenic, post 1968.
 - Silver dye bleach (Ciba / Ilfochrome).
 - Dye diffusion transfer.
- **Borders:**
 - Proportionally, dye diffusion transfers have a white larger border usually on the bottom edge.

Dye imbibition prints and chromogenic prints made prior to 1968 are almost always made on fiber based paper. Chromogenic prints dating after 1968, silver dye bleach and dye diffusion transfer prints are almost universally made on resin coated papers.

Chromogenic prints, silver dye bleach prints and dye imbibition prints may or may not not incorporate a white border. Dye diffusion transfer prints always incorporate white borders that are usually proportionally wider along the bottom edge.

Identification: Subtractive Processes – Labels and Fluorescence

- **Manufacturer Markings:**
 - Silver dye bleach (Ciba / Ilfochrome): no label on reverse.
 - Chromogenic: labeled on reverse (i.e. Kodak Paper”).
- **Fluorescence**
 - Silver dye bleach (Ciba / Ilfochrome): both sides will fluoresce. Paper contains brighteners and no U.V. blocking layer.
 - Chromogenic: usually only back will fluoresce (Paper contains brighteners but also incorporates a U.V. blocking agent in super coat).

The silver dye bleach papers “Cibachome” and “Ilfochrome” are not labeled on the reverse. Chromogenic prints are usually labeled by the manufacturer. Polaroid dye diffusion transfer prints may bear identifying marks on the reverse. Dye imbibition prints usually are not labeled on the reverse.

Photographic papers made after the mid 1950’s will often contain optical brightening agents and will fluoresce strongly under near ultraviolet illumination. At some point, manufacturers of chromogenic materials began incorporating a U.V. blocking agent in the super coat for the purposes of image stability. As a consequence, these prints will not fluoresce on the reverse but not on the image side.

Sources and Further Reading

- Joseph S. Friedman. History of Color Photography. Boston: The American Photographic Publishing Company, 1944.
- Peter Krause & Henry Shull. The Complete Guide to Cibachrome Printing. Tucson, AZ: H.P. Books, 1982.
- Paul Messier, et.al. Cleaning Color Photographs, Kent Workshop, 1998.
- William Morgan, General Editor. The Encyclopedia of Photography, New York: Greystone Press, 1967, Volume 5.
- James Reilly. Storage Guide for Color Photographic Materials, New York: University of the State of N.Y., N.Y. State Education Dept., N.Y. State Library, N.Y. State Program for the Conservation and Preservation of Library Materials, 1998.
- Louis Walton Siple. A Half Century Of Color, New York: Macmillan Company, 1951.
- Robert Sobieszek et. al., Color as Form, A History of Color Photography. Rochester: International Museum of Photography at George Eastman House, 1982.
- Henry Wilhelm. The Permanence and Care of Color Photographs. Grinnell, Iowa: Preservation Publishing Co., 1993.

The Cleaning Color Photographs paper is available at <http://paulmessier.com/PM/PDF/CleaningColor.pdf>. You will need an installed copy of the Adobe Acrobat reader. If you don't have a reader, you can get one free at <http://www.adobe.com/products/acrobat/readstep.html>

Useful links for out of print books:

- Bibliofind, <http://www.bibliofind.com>
- Alibris, <http://www.alibris.com>
- Advanced Book Exchange, <http://www.abebooks.com>

The Reilly book can be ordered through the Image Permanence Institute

<http://www.rit.edu/~661www1/>

The Wilhelm book can be ordered through Light Impressions

<http://www.lightimpressionsdirect.com/>