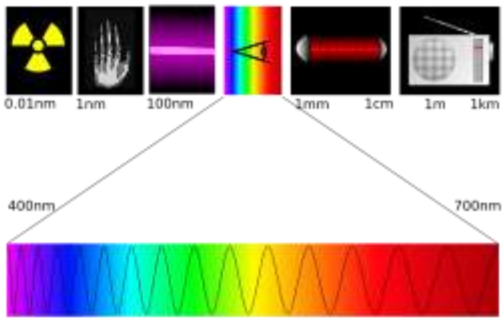
Four Colour Process

1. Basics:

Three things are needed to see color: a light source, a detector (e.g. the eye) and a sample to view.

1.1 What is light?

Light is electromagnetic radiation of a wavelength that is visible to the human eye in the range of 380 nm to 780nm.



Three primary properties of light are:

Intensity
Frequency
Polarization or direction of the wave oscillation.

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Natural light is a mixture of electromagnetic radiation of different wavelength. By using a prism the polychromatic light can be divided into the monochromatic parts. Every single monochromatic light components corresponds to one specific human colour impression the so called spectral – or “rainbow” colours.

1.2 How works the detector - the human eye and brain?

A 'red' apple does not emit red light. Rather, it simply absorbs all the frequencies of visible light shining on it except for a group of frequencies that is perceived as red, which are reflected. An apple is perceived to be red only because the human eye can distinguish between different wavelengths. The light power is transformed into electrical impulse of
nerve pathways and these are guided into the brain.

The outcome of this is a image of the original inside the human brain.

The different spectral absorption factors of the pigment molecules (blue, green-yellow, orange-red) inside of the three different types of rods and cones in the retina (V(λ)-chart) enable human to see colours.

2. How to describe the colourspace

2.1 Colour mixtures

An additive color model involves light emitted directly from a source or illuminant of some sort. The additive reproduction process usually uses red, green and blue light to produce the other colors. See also RGB color model. Combining one of these additive primary colors with another in equal amounts produces the additive secondary colors cyan, magenta, and yellow. Combining all three primary lights (colors) in equal intensities produces white. Varying the luminosity of each light (color) eventually reveals the full gamut of those three lights (colors). Computer monitors and televisions are the most common application of additive color.

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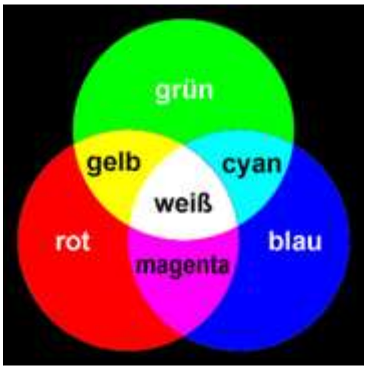
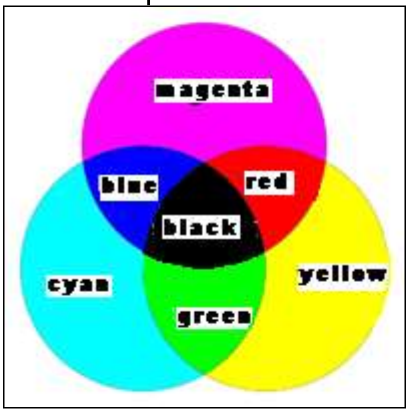


additive color model

A subtractive color model explains the mixing of paints, dyes, inks, and natural colorants to create a range of colors, where each such color is caused by the mixture absorbing some wavelengths of light and reflecting others. The colour that an opaque object appears to have is based on what parts of the electromagnetic spectrum are reflected by it, or by what parts of the spectrum are not absorbed.



subtractive color model

Subtractive Colour Synthesis
Cyan + Magenta = Blue
Magenta + Yellow = Red
Cyan + Yelow = Green
Cyan + Magenta + Yellow = Black

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2.2 Colour space models

For industrial applications it is necessary to measure colours exactly and to be able to determine color differences very exactly.
The reason is that a customer expects that a delivered part fits exactly to another second part from a former already existing production.

For standardisation of colours different colour models (colour spaces) have been established, in which the colours can be represented by a certain position in a 3-dimensional space.

Especially the following colour space models are in use:

LCH-colour space model:

L = Lightness, C = Chroma, H = Hue

Lab-colour space model:

L = Lightness (0 = black, 100 = white)
a = red/green-axis (+a = rot, -a = green)
b = yellow/blue-axis (+b = yellow, -b = blue)

3. Four colour process

3.1 Introduction

The method used to print a full range of colours), such as for reproducing a colour photograph, is referred to as four-colour process printing because it used three primary ink colors - cyan, magenta, and yellow, plus black (abbreviated as CMYK). Another emerging method of full-color printing is six-colour process printing (for example, Pantone's Hexachrome system) which adds orange and green to the traditional CMYK for a larger and more vibrant gamut, or color range.
The Four colour process based on the subtractive color model.

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Four colour process printing can also use "spot color" inks in combination with the four-colour process method. Spot colour inks are specific formulations that are printed alone. The range of available spot colour inks, much like paint, is nearly unlimited. and much more varied than the colours produced by four-color process. Think about of metallic colours, cadmium red and Precious metal preparations.

The colour impression by mixing colours in four-colour-priniting, is achieved by a combination of raster (halftone) dots of the basic colours yellow, magenta and cyan. A "perfect eye" would perceive these raster dots as different colour dots no matter how large or small they were. The human eye has only a limited resolution and therefore different coloured raster dots within an area, join together as a compact colour impression. An area of yellow and cyan raster dots seems "green" A certain relation between the size of the raster dots and the distance of the viewer to the decorated object is necessary.

3.2 Color separation process

The process of color separation starts by separating the original artwork into red, green, and blue components (for example by a digital scanner). Before digital imaging was developed, the traditional method of doing this was to photograph the image three times, using a filter for each color. However, this is achieved, the desired result is three grayscale images, which represent the red, green, and blue (RGB) components of the original image:

Image when separated into RGB components.

The next step is to invert each of these separations. When a negative image of the red component is produced, the resulting image represents the cyan component of the image. Likewise, negatives are produced of the green and blue components to produce magenta and yellow separations, respectively. This is done because cyan,

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magenta, and yellow are subtractive primaries which each represent two of the three additive primaries (RGB) after one additive primary has been subtracted from white light.

CMY separations of image derived from the RGB separations.

Cyan, magenta, and yellow are the three main pigments used for color reproduction. When these three colors are combined in printing, the result should be a reasonable reproduction of the original, but in practice this is not the case. Due to limitations in the ink pigments, the darker colors are dirty and muddied. To resolve this, a black separation is also created, which improves the shadow and contrast of the image. Numerous techniques exist to derive this black separation from the original image; these include grey component replacement, under color removal, and under color addition. This printing technique is referred to as CMYK (the "K" being short for "key." In this case, the key color is black).

Cyan, magenta, yellow, and black (CMYK) inks when printed separately. During normal print production, these would be printed on top of one another.

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3.3 Actual procedure of scanning

The art-work is scanned and data stored in a suitable Computer System and the four colours are separated.
For best reproduction of the pattern a revision of the scanned pattern is necessary. Mostly the following interventions to the picture structure are required:
colour correction, picture retouch (z B masking, sharpness, crowding etc.), specific tone value correction, size adjustment, possibly inclusion of decorative colours (especially intensive colour shades (red, orange, metallic, precious metal preparation), flesh colour, larger homogeneous colour layers)

3.4 Screen-printing

Inks used in color printing presses are semi-transparent and can be printed on top of each other to produce different hues. For example, green results from printing yellow and cyan inks on top of each other. However, a printing press cannot vary the amount of ink applied except through "screening," a process that represents lighter shades as tiny dots, rather than solid areas, of ink. This is analogous to mixing white paint into a color to lighten it, except the white is the paper itself. In process color printing, the screened image, or halftone for each ink color is printed in succession. The screen grids are set at different angles, and the dots therefore create tiny rosettes, which, through a kind of optical illusion, appear to form a continuous-tone image. You can view the halftone screens that create printed images under magnification.

Cyan, magenta, yellow, and black (CMYK) separations with halftone. (Exaggerated to show details.)

Finalcomposite image.

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Cyan	75°	15°	105°
Magenta	15°	45°	75°
Yellow	0°	0°	90°
Black	45°	75°	15°

Typical angel of raster dots used for the 4-colour process

The coarser the screen, the lower the quality of the printed image. The measure of how much an ink dot spreads and becomes larger on paper is called dot gain. This phenomenon must be accounted for in photographic or digital preparation of screened images. Dot gain is higher on more absorbent and uncoated paper.

3.5 Stochastic screening

CMYK image with stochastic screen enlarged to show detail.

Digital imaging technology has also given rise to new approaches to the screening process. The best-known is stochastic screening or FM screening (frequency modulation, contrasted with the "amplitude modulation" or AM screening of the conventional screening described above). Because the dots are the same size and randomly placed, the moiré effects that are generated by traditional half-tones are eliminated. The best quality of all results from combined screening, in which the mid-

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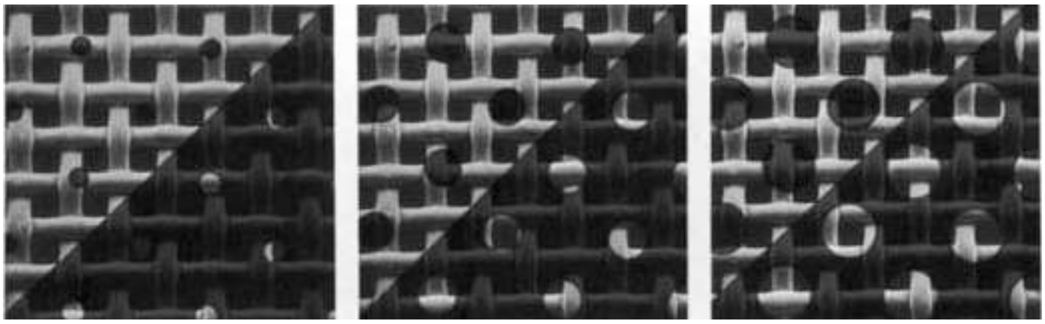
tones are generated by stochastic screening, but the extreme light and dark tones use AM screening.
A side benefit of stochastic screening is the ability to obtain a wider gamut of colors using additional inks such as orange or green (hexachrome).

3.6 Raster ruling

The total pattern is analysed into a regular geometric grid.
The fineness of the raster ruling (L/cm) is always linked with the fineness of the mesh and the type of stencil.

The finest details should properly adhere to the gauze. Areas with the highest ink coverage, i.e. where the smallest dots of emulsion must cling to the fabric, are particularly critical. The smallest points should not be allowed to rest on just one thread, or even fall through the mesh opening.



Strictly speaking, the diameter of the smallest half-tone dot on the diapositive should be microscopically measured, in order to select a mesh of the correct fineness.
From the examples above, it is clear that the diameter of the smallest dot must correspond to two threads plus one mesh opening, if the raster dot is to be adequately supported by the mesh.

3.7 Screen – Tone value – Coating

With this, the size of the scanning element is not defined. This is fixed with the colour tone value. The tone value defines the actually size of the colour scanning element in comparison to the possible colour area at 100 % colour coverage of the defined grid area.
This means: By definition of the tone value, the colour intensity of the printed scanned colour is fixed.

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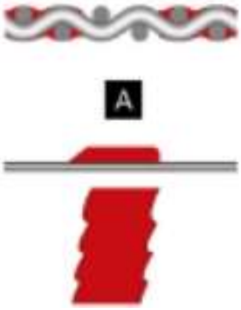
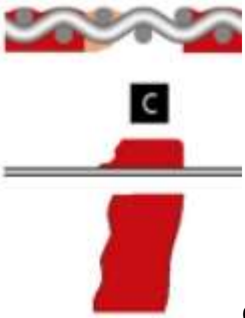
The type of coating and the choice of the screen are of great importance for the quality of the four-colour-printing decoration. A thin coating can lead to insufficient colour intensity and to a uneven surface of the raster dots.

The coating thickness on the printing side should be approx. 10 - 20% of the mesh thickness. (for halftone print 10%)
The thinnest possible coat of 4 - 8 µm results in the thin ink volume required for half-tone prints.



coating too thin

coating correct



coating too thick

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In principle steel as well as polyester screens are suitable. In practice often 130 up to 165 (330 up to 420 mesh) polyester- or corresponding steel screens are used. A wide range of screens, photo-emulsions and soft-ware for image screening and colour separation on the market.

4. Special advices for the ceramic four colour process :

Ceramic colours for glass and ceramic have different colour values to the Euro scale. In so far a perusal selection of the original pattern and an intense work for the image by using a suitable software is necessary.
Patterns with a rough surface, intense red/orange colour and pattern with weak colour intensity and graduation as well as areas with metallic colours and PM are moderately suitable.
The maximum grain size of the colour particles should be 35 to 50% of the open mesh size of the screen.

Rüger & Günzel colours have an average particle size of D90 = 12 microns.

For pasting of the colours thixotropic media are suitable. The preparation of colour pastes has to be done with a 3-roll mill.

As mixing ratios between colour powder and medium we recommend:

Glass colours, lead-containing: 100 : 60 to 70 parts
Porcelain colours, lead-containing: 100 : 70 to 80 parts
Leadfree colours: 100 : 80 to 85 parts

The sequence of colour printing is normally as follows:

1. Yellow
2. Magenta (or cyan)
3. Cyan (or magenta)
4. Black

If a white is printed, it should be done before the yellow print.
A flux can be printed for levelling the surface after the second colour print or as last step for protection. For printing the flux a flowing medium (not thixotropic) should be used.

Grids from 40 to 54 dots/cm are possible.
Tone values of 5% up to 85% are achievable.

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The fixing of the colour screen angle starts with yellow 0° and increase as mentioned above.
Screens: 130 up to 165 mesh/cm(330 up to 420 mesh/inch) polyester- or corresponding steel screens are used.
Squeegee recommendation: hardness 75-85 shore
Squeegee angle: 15-25°
To avoid the risk of flaking of, not more then 4 colour layers should be overprinted.
During the print all parameter must be constant as possible.
For some colour series (mainly for glass) instead of magenta a cadmium red is recommended.

5. Products

Rüger & Günzel Colours and Auxiliaries for Ceramic 4-Colours Screen-printing:

Serie "S" / Colour for Porcelain, lead-containing for 820 – 900 °C:

F 3350/S	Yellow	Alternative Cadmium-Yellow F 3101/S
F 2490/S	Cyan	
P 7097/S	Magenta	Alternative Cadmium-Red F 7906/S
F 4059/S	Black	

Serie "BA" / Colour for Porcelain, leadfree for 800 – 900 °C:

BA 3580	Yellow
BA 2581	Cyan
PBA 7880	Magenta
BA 4180	Black
BA 9277	Flux

Serie "BF" / Colours for Bone China and soft Glazes, leadfree for 800–880°C:

BF 3348	Yellow
BF 2458	Cyan
BP 540	Magenta
BF 4101	Black

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Serie "Meissen" / **Colours for Porcelain, lead-containing, low meling (not resistant):**

RGF 102	yellow
F 2487	Cyan
P 7210	Magenta
F 4113	Black

Serie "IS" / **Colours for Porcelain, lead-containing, Inglaze-Fastfiring, 1200°C:**

IS 3800	Yellow
IS 2426	Cyan
IS 7802	Red
IS 4094	Black

Serie "IB" / **Colours for Glass, lead-free, Universal Glass Colours for 550 – 580°C:**

F 3610	Yellow
F 2620	Cyan
F 7677	Magenta
F 4640	Black

Serie "U" / **Colours for Glass, lead-containing, Universal Glass Colours, for 550 – 580°C:**

F 3453	Yellow
F 2472	Cyan
F 7064	Red
F 4044	Black
F 9143	White (as underlayer print)

Serie "W" / **Colours for Glass, lead-containing, half resistant, for 570 – 600°C:**

F 3212/W	Yellow
F 2481/W	Cyan
F 7193/W	Red
F 4112/W	Black
F 9112	White (as underlayer print)

Serie "R" / **Colours for Glass, lead-containing, resistant for 580 – 620 °C:**

F 3723	Yellow
F 2462	Cyan
F 7723	Red

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F 4723 Black
F 9723 White (as underlayer)

Transparent Colours for Glass, lead-containing, for 560 – 600 °C:
P 3031 Yellow
F 2471 Cyan
C 60/I Purple
F 4100 Black

Serie "BG" / Colours for Glass, leadfree, for 600 – 620 °C:
BG 3357 Yellow
BG 2475 Cyan
BG 7319 Red
BG 4110 Black
BG 9192 White (as Underlayer print)

Serie "BR" / Colours for Glass, leadfree, for 600 – 650 °C:
BR 3901 Yellow
BR 2901 Cyan
BR 7962 Red
BR 4900 Black
BR 9920 White (as Underlayer print)

Screenprinting media and -covercoats:

Medium for Decal-Printing: 0782 thix
Covercoats for Decal-Printing: 0601 oder 0601 thix
Medium (thermoplastic) for Direct printing on glass: 0515

5. Further Links

www.colorsystem.com

www.wikipedia.org

www.sefar.com

www.cielab.de

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www.cie.co

www.couleur.org

www.binder-muc.de

www.farbmetrik-gall.de

www.esma.com

www.fespa.com

www.screenweb.com

www.paco-filter.de

www.color.org

www.colorconcept.de

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