Evaluation of Backing Material for Colorimetric Measurement in Non-Impact Printers

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Abstract

For measuring black-and-white reflective media output, ISO recommended to use black backing material in "ISO 5-4 4.7 Backing Material in density measurements". However, in general office and SOHO markets, customers normally observe reflective media output with a stack of the same media as a backing material. In this paper, backing material has been evaluated for colorimetric measurement of color hard copy output. As a result, white backing material and a method of measurement are recommended.

1. Introduction

The primary objective of density measurement is to estimate an amount of black ink and the black backing is recommended for the most appropriate backing material to avoid an effect of backing material in density measurement readings as shown in the Fig.1[1]. For the same objective, black backing can be applied to color inks as well.

But in case of colorimetric measurement, the primary objective is not to estimate an amount of colorant, but to estimate an appearance of color by using CIELAB or other colorimetric coordinates.

In this case, quantitative representation of human eye response is required. If one wishes to estimate amount of colorant, CIELAB or other colorimetric coordinates are not adequate.

In other words, in order to estimate an amount of colorant using colorimetric coordinates, one must use a color model to convert colorimetric measurement result to amount of colorant, no matter what a backing materials are.

Therefore, the most important point in quantitative colorimetric measurement using spectro-photometeter or colorimeter is to have the same condition as human eye observation as far as backing material is concerned.

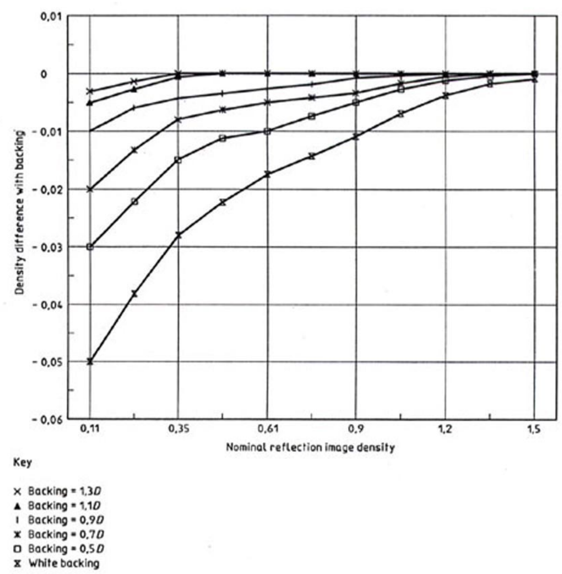

Figure 1. Reflection density differences for a series of backing materials (transmission density of paper = 0.3)

In the real world, the population of the manufacturers who use either white and black backing material are approximately the same and some manufacturers use both of them in different products.

For general office and SOHO applications, however, customers normally observe reflective media output with a stack of the same media as a backing material. In this case, in order to estimate appearance of printed color in a quantitative manner, preferable backing material is white backing.

In order to make people's dream come true in WYSIWYG Color management, it is important to at least define what kind of backing material be used to create printer color profile, and further more, some additional arrangements needed in printer color management for the above applications.

This paper is to consider backing material for spectro-photometetric or colorimetric measurement for general office and SOHO applications.

The first step is to evaluate a difference of spectral reflectance between black and white backing material.

The second step is to evaluate spectro-photometric characteristics of the various papers (white backing materials) for the above applications.

The third step is to evaluate difference of the spectro-photometric characteristics among various white backing materials.

Finally, a simple way is investigated to estimate spectro-photometric characteristics of the backing dependency.

Difference of Spectral Reflectance Between Black and White Backing Material

According to Fig. 1, backing material affects more strong in lighter image density area and it is true in visual observation. So, either no image area (background) or saturated yellow image are suitable to check backing material effect.

Fig. 2 shows spectral reflectance curve of backing material itself and images with backing materials.

There are about 10% difference in spectral reflectance between white backing and black backing and is about CIELAB ΔE of 10.

This is a big difference and it is one of the big issue for the low end color printer color management.

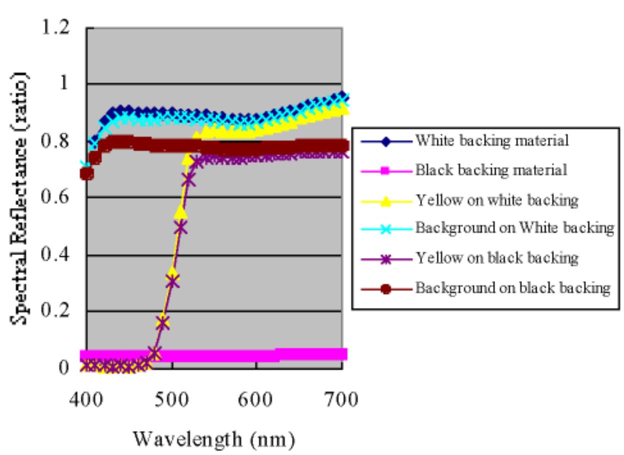

Figure 2. Spectral reflectance curve of backing material itself and images with backing materials

Spectro-Photometric Characteristics of the Various Papers

Spectro-photometric characteristics of the various papers are shown in the Fig. 2.

Tested papers were XL exclusive 90gsm paper, Colortech FS 90gsm paper, Neusiesler 100gsm paper, XC xpression 90gsm paper, FX J, Kishyu 88gsm paper, Fujitsu color copier paper, Sharp JX-8200 paper, Ricoh full color PPC 90W paper, Canon color laser copier paper, Ricoh PPC 70W paper, Minolta CF 80gsm Paper and Konica color copier paper.

10 sheets of the same paper as measured sample are used as a backing material.

Measurements done by the spectro-photometer and measurement conditions were 0-45, 2 degree observer, 400nm-700nm.

Some of the paper's spectral reflectance exceeds 100 % in a shorter wavelength and is due to fluorescence added in the paper.

The difference of various paper's spectral reflectance are about 25 % in range. In general, even having this much of difference, no big changes appear in perception of colors. It is due to chromatic adaptation of human eyes such as von Kries effect, and it adjusts appearance of color.

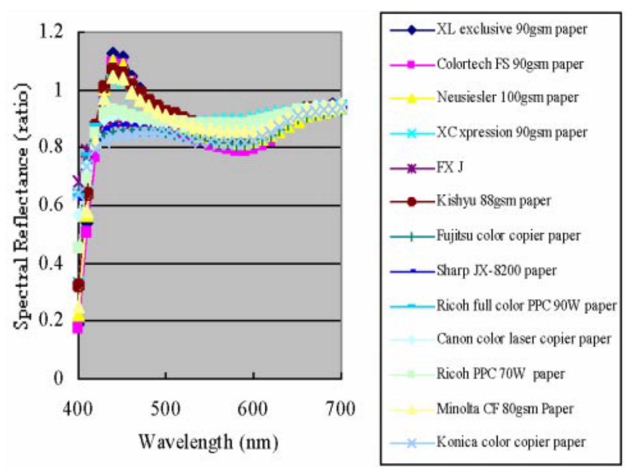

Figure 3. Spectro-photometric characteristics of the various papers

Difference of the Spectro-Photometric Characteristics Among Various White Backing Materials

One might think of defining one backing material and this idea is commonly used among manufacturers. In the high end market, it is possible and is already defined. But in the low end market, there are various marking technologies such as Ink Jet, Sublimation transfer, Electro-photography etc. hence it is impractical to use common backing material. Here, backing material effect in saturated yellow image on FX J paper is shown in the Fig. 3.

The difference of spectral reflectance of saturated yellow image with various backing materials are about 3 % in range and about CIELAB ΔE of three or more is expected with a common backing material concept.

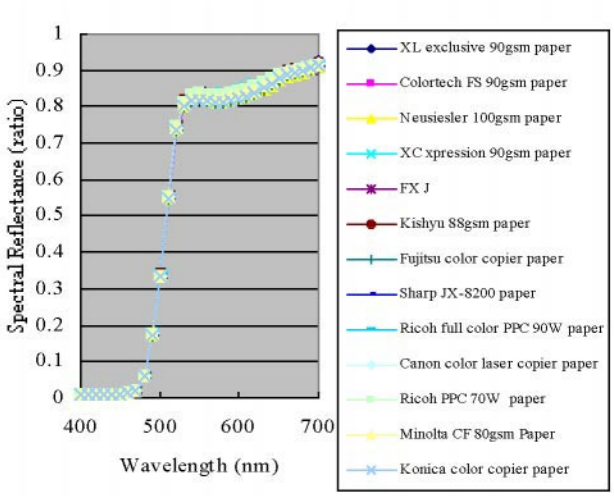

Figure 4. Spectro-photometric characteristics of saturated yellow image with various backing materials

Simple Way To Estimate Spectro-Photometric Characteristics Of Backing Material Change

One might encounter several cases where the backing material is not the same as it's own substrate such as sample posted on a wall. Also in case of duplex print, sometimes a dark images on back side affects to an appearance of front side images. So, it might be useful to know a way to estimate spectro-photometric characteristics of backing material change.

Let's assume that the difference between "X" backing and white backing density of an image is constant along the wavelength and various tones as,

$$\Delta D = XBD\, i(\lambda) - WBD\, i(\lambda) \qquad (1)$$

Where,

$XBDi(\lambda)$ is "X" backing spectral density of *i th* image.

$WBDi(\lambda)$ is white backing spectral density of *i th* image.

Therefore, "X" backing spectral density of *i th* image can be estimated from white backing spectral density distribution of *i th* image and the difference between "X" backing and white backing spectral density as,

$$XBD\, i(\lambda) = WBD\, i(\lambda) + \Delta D \qquad (2)$$

To check the assumption that ΔD is constant along the wavelength, XC xpression 90gsm paper is suitable as it has a widely distributed spectral reflectance curve along a wavelength and it has a fluorescence.

Fig. 5 shows XC xpression 90gsm paper's white and black backing spectral density.

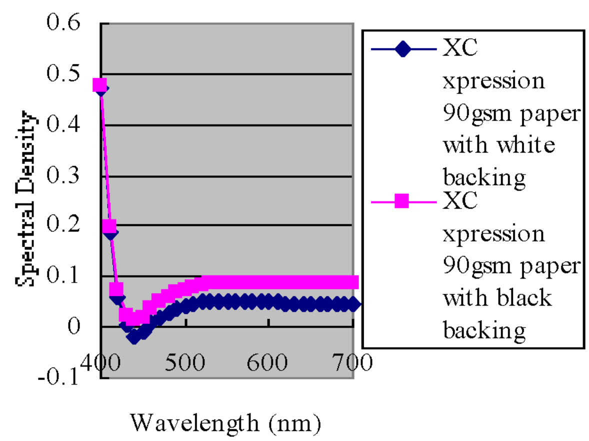

Figure 5. XC expression 90gsm paper's white and black backing spectral density distributions

According to Fig.5, obviously, ΔD is not a constant and therefor Equation (2) should be modified as,

$$XBD\, i(\lambda) = WBD\, i(\lambda) + \Delta D(\lambda) \qquad (3)$$

The reason why ΔD is a function of wavelength must be fluorescence which absorbs light energy in shorter wavelength region.

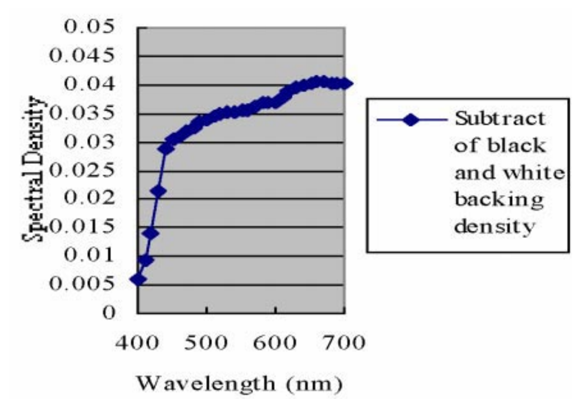

Figure 6. Spectral distribution of Subtract of white and black backing density(XC xpression 90gsm paper)

Fig. 6 shows the spectral density distribution of ΔD.

Spline functions are appropriate to fit ΔD which has a sudden slope change.

Third degree spline functions are adopted.[2] They are, when $|\lambda|$ is less than or equal to ω ,

$$C(\lambda) = \frac{\{\omega^3 + 3\omega^2(\omega - |\lambda|) + 3\omega(\omega - |\lambda|)^2 - 3(\omega - |\lambda|)^3\}}{6\omega^3}$$

when $|\lambda|$ is greater than or equal to ω and less than or equal to 2ω,

$$C(\lambda) = \frac{(2\omega - |\lambda|)^3}{6\omega^3}$$

when $|\lambda|$ is greater than or equal to 2ω,

$$C(\lambda) = 0 \qquad (4)$$

Where, $C(\lambda)$ is a spline function and ω is a constant which defines a width of $C(\lambda)$. $\Delta D(\lambda)$ is described as a linear combination of series of $C(\lambda)$ as,

$$\Delta D(\lambda) = \sum_{j=1}^{m} x_j C_j(\lambda) \qquad (5)$$

Where, m is a number of spline functions layied out along with the wavelength equally distanced, $C_j(\lambda)$ is j th spline function and x_j is a weighting factor for it.

Fig. 6 also shows the result of spline fitting. In this case, m is 18 and ω is 20.

Tone Levels Dependency of Estimation

To check the assumption that $\Delta D(\lambda)$ is constant along tone levels, three primary colors and a mid-tone level image on FX J paper selected.

Figure 7 shows the result of 4 ΔD spectral density distributions with spline fitting curves.

Figure 8 shows the above 4 spline fitting's weighting function x_j.

The variation of x_j is reasonably small, and therefore, $\Delta D(\lambda)$ can be constant along tone levels.

Conclusion

Difference of black backing and white backing spectrophotometric measurement is about 10% and is too big for printer color management.

Preferable backing material for spectro-photometetric measurement in general office and SOHO applications is, with it's own market characteristics, white backing material such as a pile of the same media as substrate of images to be measured.

The variation arround 3% is expected with a common white backing material concept.

Finally, a linear combination of spline functions is recommended to estimate spectro-photometric characteristics of backing material change. Further evaluation needed such as two color and three color estimation, screen dependency and so on. This method might be applied to colorimetric measurement.

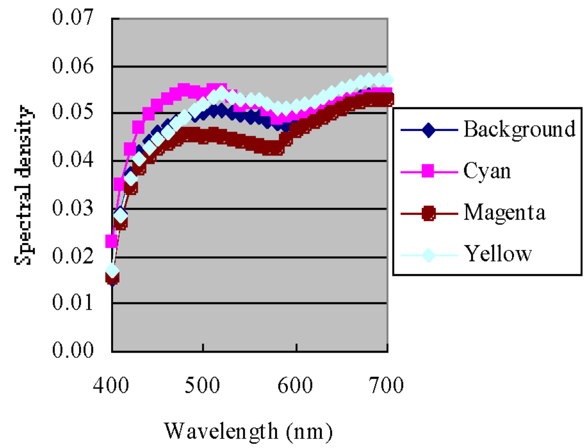

Figure 7. ΔD spectral density distributions with spline fitting curves

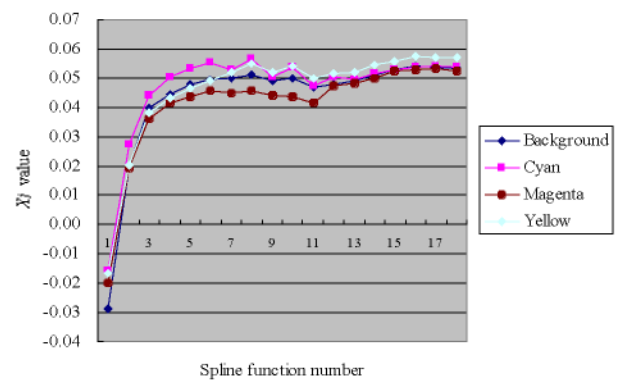

Figure 8. Spline fitting weighting function x j for ΔD spectral density distributions

Acknowledgements

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References

1. ISO 5-4, "Backing Material in density measurements", P.3 (1995)
2. N.Ohta, Introduction to Color Reproduction Technology, CORONA PUBLISHING CO., LTD., 4-46-10 Sengoku Bunkyo-ku Tokyo Japan, 1997, p. 240.