Case Study

KONICA MINOLTA | SENSING AMERICAS

THE STANDARD IN MEASURING COLOR

Whiteness Indices and UV Standards

General Information

The evaluation of the whiteness of a product is dependent upon the materials and the application in which it is used. Natural materials, for instance, cotton or wool, tend to yield a yellowish tint, so the industry will make modifications to the materials to compensate for this effect. A yellowish tint in a product is most often seen as a quality flaw, e.g., yellowing due to aging or dirt, and businesses will attempt to make the appearance of their products more white.

Bleaching is a process that chemically removes colors from materials and results in a more uniform spectral reflectance. Optical brightening agents, or fluorescents, are also used to compensate for the absorbance of yellowish products. This creates a "whiter than white" appearance with the help of the fluorescents.

Optical brighteners absorb energy from the electromagnetic spectrum in the non-visible UV area (mostly below 400nm) and emit that energy in a wider spectrum than was absorbed in the range between 400-480nm. This results in reflectance curves that may rise higher than 100% between 400-480nm, making the material appear slightly bluish. As the eye will judge slightly bluish materials of otherwise uniform reflectance as brighter than the ideal reflecting diffuser, these colorants are a very common way of adding additional whiteness to products, and are often used in paper and textiles. "White" is not compliant to what we judge "color," as both sensations are independent from each other.

While the measurement of non-optically brightened material is common practice, the evaluation of UV content in a material often raises questions. Measurements of whiteness are subject to the overall setup of not only the instrument, but also the references used.

CM-3700A Spectrophotometer

CM-2600D Spectrophotometer

CM-3600A Spectrophotometer

Questions & Answers

Q: Is there a difference between the available indices?
A: Yes, there is!

Almost several dozen formulas exist on the market to describe what the human eye perceives as “whiteness”. As the eye tends to describe materials with a slightly bluish tint as “whiter”, e.g. the compensation of yellowish colors of raw materials with the help of blue colorants or optical brighteners became common practice compared to former times, so existing formulas needed adjustment. Since different applications define their own white standards or white references, several approaches to satisfy the appropriate market needs were taken. This results in indices for e.g. paper, textile or food industries, all of them using various mathematical calculations to describe what “their” white is.

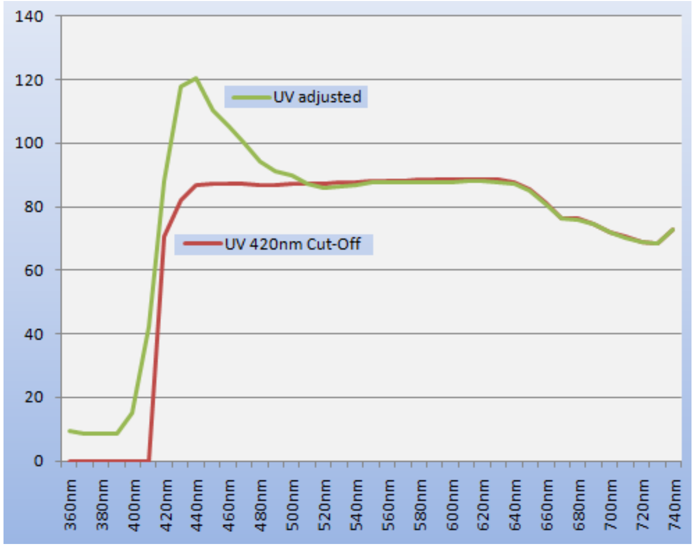
Q: Which UV reference standard should I use to calibrate my instrument?
A: This depends on the material you are going to evaluate!

As different materials do have different optical properties, the appropriate material should be used to correctly calibrate your instrument. Use a paper standard for paper application, a textile standard for textile application, or a plastic standard for plastic application, e.g. using a plastic standard for textile application may result in erroneous values.

A list of manufacturers for reference standards are given later in this document.

Q: How do I see whether my product contains optical brighteners?
A: Take a look at the spectral curve!

Optical brighteners absorb energy below the visible spectrum and emit the absorbed energy in the lower visible spectrum, up to 480nm. This results in reflectance curves with a hump in the bluish area. Take a look at the picture below.



In this picture you can see the influence of optical brighteners on a white plastic tile. While the red curve displays the “normal” color the white tile would have if seen under lighting that does not contain UV energy (in this case realized using a 420nm cut-off filter), the green curve shows clearly the effect optical brighteners have on a material, raising the spectral curve over 100% reflectance.

Whiteness Indices

Whiteness Indices

A wide variety of indices is available for those industries that need to evaluate the whiteness of their products, e.g. paper or textile fibers. Due to the fact that some indices are used to communicate values, choosing the correct index for your application is important.

This document shall help you selecting the correct indices for your application and focuses on the most used ones in today's market.

Whiteness Index CIE

Published in 1986 with the 2nd edition of Publication 15 by the CIE Colorimetry committee, this formula was presented "to promote uniformity of practice in the evaluation of whiteness of surface colours" and it is recommended to "be used for comparisons of the whiteness of samples evaluated for CIE standard illuminant D65" [CIE Technical Report 2004 Colorimetry] on a rather relative scale. The formula used is

$$W_{CIE} = Y + 800(x_n - x) + 1700(y_n - y)$$

Where Y is the Y-tristimulus value of the sample, x and y are the x, y chromaticity coordinates of the sample, and x_n , y_n are the chromaticity coordinates of the perfect diffuser for the CIE 1964 standard colorimetric observer.

Although it might be used with C/2 illuminant/observer condition, it is strictly valid for D65/10 and shall be used in that fashion.

Whiteness Index ASTM E313-00

While the original index ASTM E313 described the evaluation of whiteness using colorimeter readings of G and B so that $W_{E313} = 4B - 3G$ was defined, the latest ASTM E313-00 references to the CIE Whiteness index, using a table for the values of C, D50 and D65 as well as 2° and 10° observer.

The AATCC textile committee defines ASTM E313-00 with the use of ill. C and 2° observer.

Whiteness Index Ganz-Griesser

Not only an index but a complete procedure, the Ganz-Griesser method to evaluate whiteness is currently the only index on the market that takes care of instrument specific factors using a defined calibration scale of fluorescent standards to measure reliable values on different systems. Defined to be used with D65/10 and reference wavelength 470nm, the formula the index is calculated with is as follows:

$$W_{Ganz} = Y - 1868.322\,x + -3695.690\,y + 1809.441$$

UV Measurement Technology

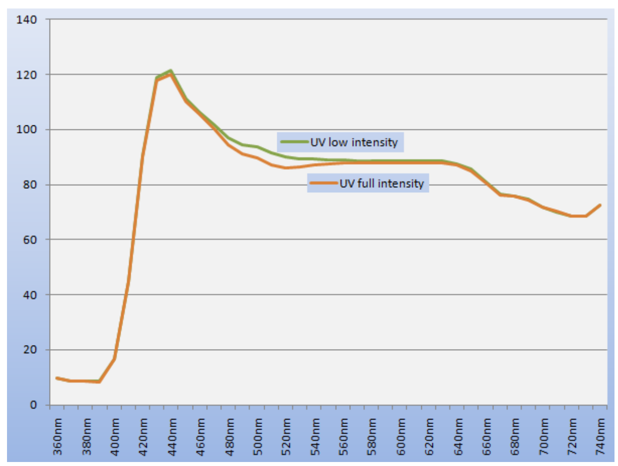
The use of mechanically driven UV filters is the most commonly used method to control the UV content of a light source. UV energy is abundantly available in the light source found in Konica Minolta spectrophotometers. The CM-3700a is used in the paper, plastic and textile industries to accurately measure the amount of fluorescent energy that is re-emitted in a paper, plastic or textile product. This UV energy is absorbed in the UV range, below 400nm and is re-emitted in the visible range of the electromagnetic spectrum. The UV filter is used to calibrate a spectrophotometer with a UV standard. The UV Standards contain what is known as Fluorescent Whitening Agents (FWA). The UV standards contain a known amount of FWA's and are labeled with a specific CIE Whiteness and/or Tint value. The Standards are used to calibrate the spectrophotometer so it can precisely report the amount of fluorescence in a finished sample. The fluorescent standards are checked periodically with the instrument to verify the accuracy of the UV standard. The UV filters are critical when measuring fluorescence in any sample.

An alternate, patented, NUVC (numerical UV control) technology offers the possibility not only to calibrate to a UV standard but also to control the amount of UV with each measurement and thus keeping the results stable. NUVC is a standard feature on the CM-3600a and the CM-2600d. The NUVC is done by using three independently sequenced xenon lamps, one unfiltered for full UV content, two filtered at 400 and 420nm. This setup not only allows for choosing the correct filtering method without any moving parts but also for having the calibrated UV content checked during each measurement. Apart from the unmatched calibration and control feature, this setup also allows for an accurate periodic check, of UV content of the UV standard, over time.

Unique in the market is also the possibility to not only use the appropriate filtering method, but to combine the filters with a soft flash method, that reduces the xenon lamp power to 30%. This setup prevents the unwanted triplet effect seen in several samples or references, where the higher energy of xenon lamps as compared to e.g. natural daylight or tungsten illumination modifies some of the molecules of the optical brighteners and brings them to an energetically lower level. As the time between flash and analysis of the measurement is shorter than the transit of the molecules to their energetically correct state, the reflectance curve shows lowering and rising after the peak of FWAs - a "triplet effect" occurs.

Compare both curves below and you can see the orange curve decreasing around 520nm and then ascending again until reaching a somewhat stable state around 560nm.

Whatever technology you use – be sure to calibrate your system correctly using the appropriate filtering procedure and choose reference standards that suit your application!



CM-3600A
Numerical UV Control

CM-3700A
Traditional Filter Method

CM-2600D
Numerical UV Control

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Fluorescent Reference Standards

Fluorescent reference standards for different applications and their suppliers

In order to deliver reliable and ISO compliant reference standards, the ISO technical committee 6 has created a workflow to define 3 levels of accuracy, called ISO reference standards of level 1, 2 or 3, abbreviated as IR1, IR2 and IR3.

IR1 is only achievable by national metrology institutes and the IR 1 standards are referenced as ultimate standards against the “perfect reflecting diffuser” (in accordance with the CIE).

IR2 standards are created using IR1 standards by “standardizing laboratories”, (equipped for absolute reflectance factor measurements in accordance with ISO 4094) to provide references to “authorized laboratories”, which need to have the necessary equipment and competence to be appointed by ISO/TC 6 as such.

Authorized laboratories use IR2 standards to calibrate their reference instruments in order to issue working standards for calibration, IR3.

IR3 is the reference for industrial usage to calibrate the working instruments in companies. Standardizing laboratories are required to exchange IR2 standards at intervals of no longer than five years, while authorized laboratories are required to do the same at intervals of not more than 2 years with IR3 standards.

This procedure is used to achieve the accuracies suggested in the "Expression of results" clause in the International Standards dealing with the determination of specific optical characteristics.

Apart from the ISO compliance, some suppliers issue reference standards that can be used for either relative evaluation of indices or might be send in to those institutes offering a user calibration to the norms in order to receive a reliable and compliant standard reference.

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