

Colour Analysis on the nkd Optical Coating Measurement System



This application note illustrates the use of the nkd optical coating measurement system for determining the device independent colour of reflective and transmissive samples.

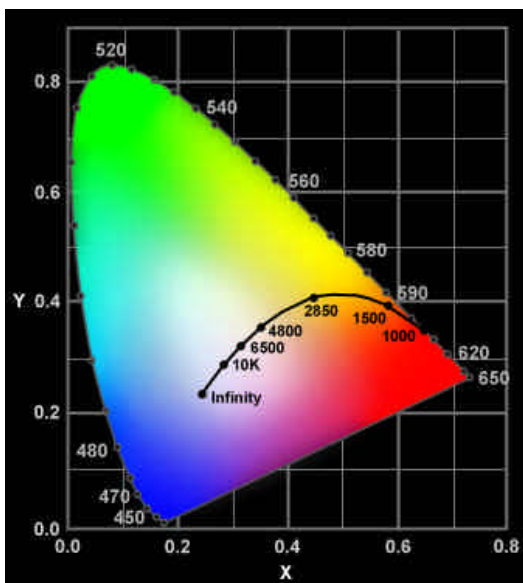
Colour can be expressed in a number of different ways and is highly dependent on the way it is viewed. While RGB (additive) colours vary with display and scanner characteristics and CMYK (subtractive) colours vary with printer, ink, and paper characteristics – our human perception of colour remains the same no matter what device we are viewing.



Colours

In 1931 the Commission Internationale d'Eclairage (CIE), carried out work to describe colour in a way that is independent of any device. The result was a series of models called device-independent colours which are said to be true representations of colours as perceived by the human eye.

The CIE created a set of colour spaces that specify colour in terms of the human perception, based on three primary constituents of colour, denoted the tristimulus values. These describe numerically the response of three types of colour sensing element in the human retina, broadly speaking – the three primary colours.

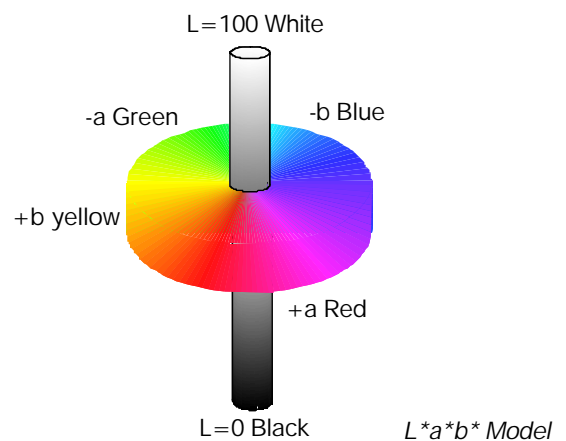


CIE Chromaticity Diagram

The first stage in establishing a purely numerical description of colour, is to appreciate that of the three tristimulus values, only two pieces of information are needed to succinctly describe the sensation of colour. This two dimensional description of colour is represented by the CIE chromaticity diagram, which provides a basic colour reference model. However without the third element of colour perception - the intensity, we would never be able to describe the difference between yellow and gold for example, which have the same chromaticity coordinates but varying degrees of intensity or blackness.

There are a number of CIE models which introduce this third element to the colour description.

One such CIE colour space, denoted $L^*a^*b^*$, is used to represent subtractive systems, where light is absorbed. The values L^* , a^* and b^* are plotted at right angles to one another to form a three dimensional coordinate system. Equal distances in the space approximately represent equal colour differences. Value L^* represents lightness; value a^* represents the redness/greenness; and value b^* represents the yellowness/blueness. This is a popular colour space for use in measuring reflective and transmissive objects and identifying dominant wavelengths.



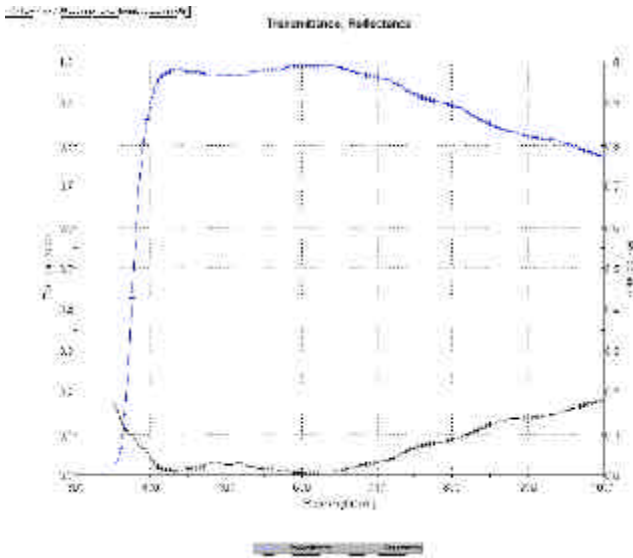
For additive colour systems such as coloured lights and displays, the CIE $L^*u^*v^*$ colour space is used.

$L^*u^*v^*$ space and $L^*a^*b^*$ space represent colours relative to a reference white point, which is a specific definition of white light in the model space and is based on the whitest light that can be generated by a real device. As such, $L^*u^*v^*$ and $L^*a^*b^*$ colour spaces, are not completely device independent. Two numerically equal colours are only truly identical, if they were measured relative to the same white point.

Measuring colours in relation to a white point allows for colour measurement under a variety of illuminations. The use of $L^*u^*v^*$ space or $L^*a^*b^*$ space is common in applications where closeness of colour must be quantified, such as colourimetry and lens matching.

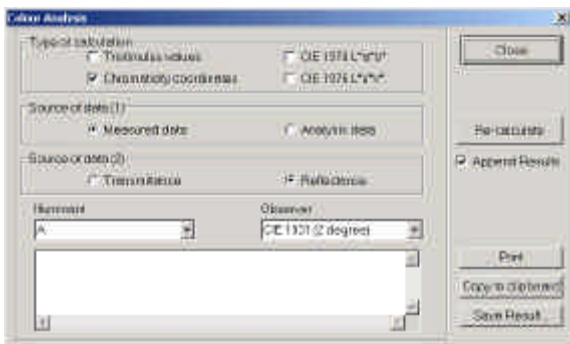
In this application note, we demonstrate the use of the versatile nkd spectrophotometer for making colour measurements on a variety of samples. In addition to providing precise measurements of total transmittance and reflectance over a wide wavelength range, the nkd has a built-in colour measurement facility for calculating tristimulus values, chromaticity coordinates, $L^*a^*b^*$ and $L^*u^*v^*$ colour co-ordinates from either the measured or calculated curves, in transmission or reflection.

We begin by obtaining a transmittance and reflectance spectra from the sample of interest. This is plotted in real-time by the Pro-Optix™ control software. In this example, colour measurements were made for a coated ophthalmic lens. T and R spectra for the lens were measured on the nkd spectrophotometer from 350-1000nm and are represented below.



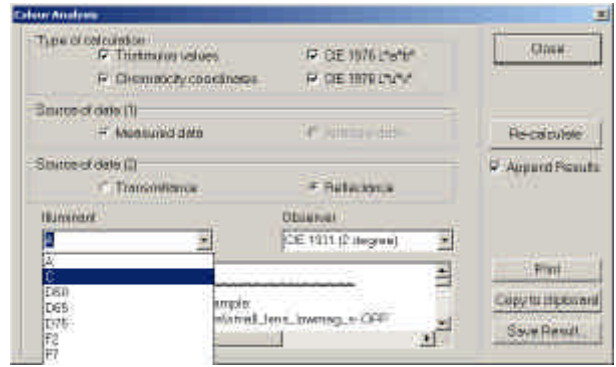
T & R Spectra for the lens

From the "Analysis" menu we select "Colour Calculations" and a dialog window is presented. The type of calculation required is selected by ticking the options in the various check-boxes.



Select required calculation

Colour calculations always depend on the type of illumination being used to make the observation and the way in which the sample is being observed. The CIE has defined standards for various illuminants (daylight, fluorescent light or incandescent light-bulb) and observers. Pro-Optix™ has built-in data on all common illuminants and observers, so the user simply has to select the required combination from the drop-down lists.



Select Illuminant

For our purposes here we have selected C, a CIE Standard for T illumination for partial daylight. When using tristimulus data to describe a colour, the illuminant must also be defined.

Once the parameters of the calculation have been selected, we simply click "Re-calculate" and the results of the analysis are presented in text form in the scrolling window at the bottom of the dialog box.

The output is formatted in report-style and may be copied to the clipboard, printed or saved to the disc as a text file. If several calculations are required, they can be appended and saved in the same file.

Result of colour analysis for sample:

C:\polymer\sample2_on_s_30.op
Data were available on 5.0 nm intervals from 350.0 nm to 1000.0 nm.

This calculation was performed from 380.0 nm, to 780.0 nm on 5 nm intervals according to ASTM standard E308.

Calculation performed on bandpass-corrected data from an nkd-series instrument

Data correspond to reflectance at 30.00 degrees incidence with s-polarised light.

Observer: CIE 1931 (2 degree)
Illuminant: CIE standard illuminant C

CIE Tristimulus values: X = 7123.82764, Y = 7090.4853525, Z = 6475.50977

CIE Chromaticity coordinates: x = 0.34432, y = 0.34270, z = 0.31298

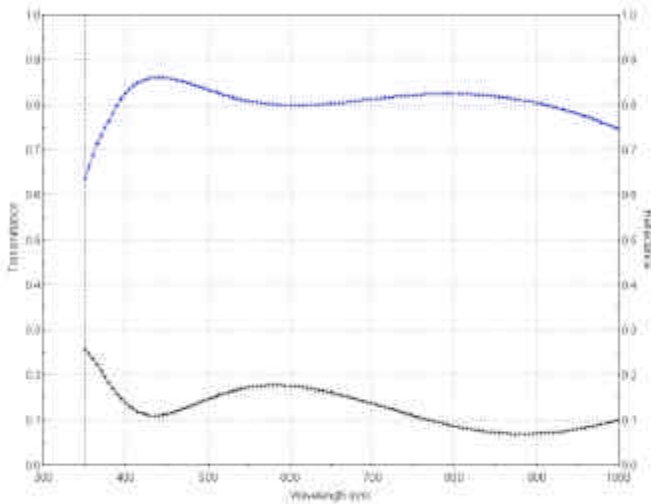
CIE uniform colour space $L^*a^*b^*$: $L^* = 46.49564$, $a^* = 2.17792$, $b^* = 8.88423$

CIE uniform colour space $L^*u^*v^*$: $L^* = 46.49564$, $u^* = 8.16523$, $v^* = 11.63665$

Colour Calculations for the lens sample

Another excellent usage is the measurement of coloured polymers, increasingly used in display applications. In the following illustration a sample of polymer coated glass was first measured and then a colour analysis performed as before. The measured spectra and resulting analysis are presented overleaf.

Transmittance, Reflectance



T & R Spectra for the polymer

The results shown demonstrate the functionality of the nkd spectrophotometer series, which provide not just, transmittance and reflectance data from which dispersion, absorption and layer thickness can be determined but also colour measurements, useful in a wide variety of applications.

It is worth noting that in determining colour with the nkd, we measure the full spectral response of the material. Compare this to a simple colourimetry device which uses colour filters to make a single measurement of the tristimulus values. While simple, these photometer measurements do not provide the whole story – for example, two lenses which give the same tristimulus values, may have very different spectral responses. This difference would mean that they might appear the same under one illumination - such as room lighting, but one lens might appear to be different in daylight. This important change can be measured on the nkd simply by selecting a different illuminant type and calculating the variation in the lens colour with respect to the incident illumination. Another example of the superb functionality of the nkd spectrophotometer.

Result of colour analysis for sample: C:\small lens_lowmag_s-
_OPP

Data were available on 5.0 nm intervals from 350.0 nm to 1000.0 nm.

This calculation was performed from 380.0 nm, to 780.0 nm on 5 nm intervals according to ASTM standard E308.

Calculation performed on bandpass-corrected data from an nkd-series instrument

Data correspond to reflectance at 30.00 degrees incidence with polarised light.

Observer: CIE1931 (2 degree)
Illuminant: CIE standard illuminant C

CIE Tristimulus values: $X=704.36499$, $Y=1088.536865.5$, $Z=854.74261$

CIE Chromaticity coordinates: $x=0.26603$, $y=0.41113$, $z=0.32283$

CIE uniform colour space $L^*a^*b^*$: $L^*=17.46356$, $a^*=-18.66916$, $b^*=7.35679$

CIE uniform colour space $L^*u^*v^*$: $L^*=17.46356$, $u^*=-12.96731$, $v^*=8.86198$

Colour Calculations for the polymer sample