Colour Analysis on the nkd Optical Coating Measurement System

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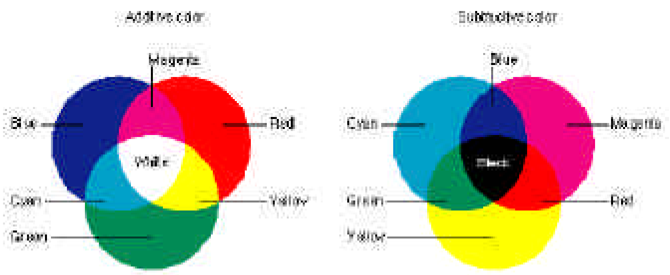
This application note Illustrates the use of the nkd optical coating measurement system for determiningthedeviceindependentcolourofreflectiveandtransmissivesamples.

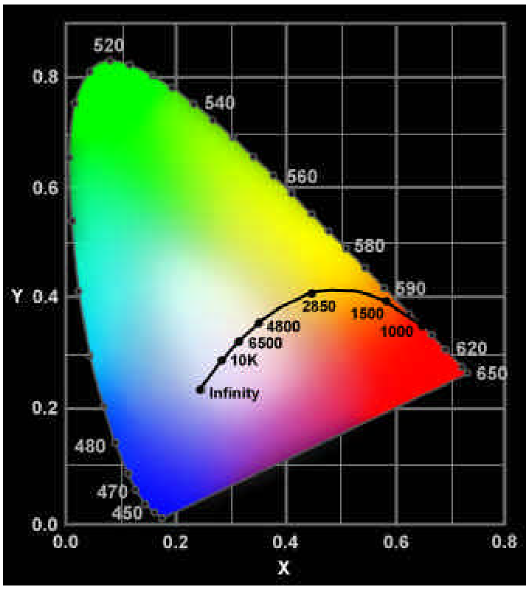
Colour can be expressed in a number of different ways and is highly dependent on the way it is viewed. While RGB (additive) colours varywith display and scanner characteristics and CMYK (subtractive) colours vary with printer, ink, and paper characteristics – our human perception of colour remains the samenomatterwhatdeviceweareviewing.



Colours

In1931theCommission Internationale d'Eclairage (CIE), carried out work todescribe 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 betruerepresentations of coloursasperceivedbythehumaneye.

TheCIEcreatedasetofcolourspacesthatspecifycolourinterms ofthehuman perception, basedon threeprimaryconstituents of colour, denoted the tristimulus values. These describe numericallytheresponseofthreetypesofcoloursensingelement inthehumanretina,broadlyspeaking – thethreeprimarycolours.

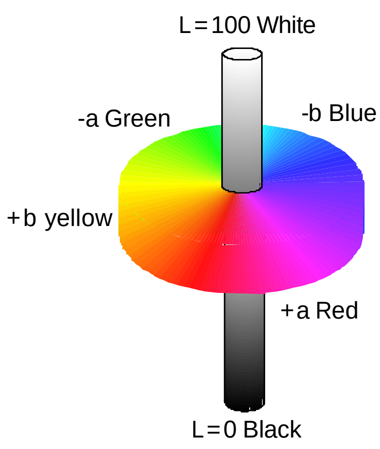


CIE Chromaticity Diagram

The first stage in establishing a purely numerical description of colour, is toappreciatethatofthethreetristimulusvalues, 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 basiccolourreferencemodel.Howeverwithoutthethirdelementof colour perception - the intensity, we would never be able to describe the difference between yellow and gold for example, whichhavethesamechromaticitycoordinatesbutvaryingdegrees ofintensityorblackness.

There are a number of CIE models which introduce this third elementtothe colourdescription.

OnesuchCIEcolourspace,denoted **L*a*b***, is usedtorepresent 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; andvalue **b*** represents theyellowness/blueness.Thisisapopular colour space for use in measuring reflective and transmissive objectsandidentifyingdominantwavelengths.



*L*a*b* Model*

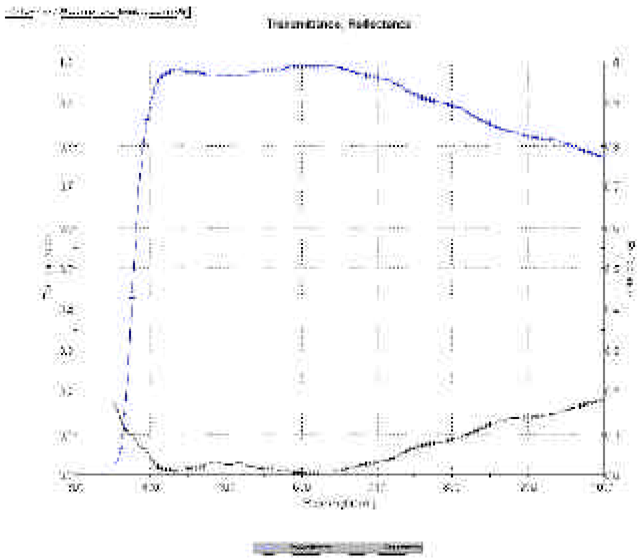
For additive colour systems such as coloured lights and displays, theCIE **L*u*v*** colourspaceisused.

L*u*v* space and **L*a*b*** space represent colours relative to a referencewhitepoint,whichisa specificdefinitionofwhitelight 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.Twonumerically equalcoloursareonlytrulyidentical,iftheyweremeasuredrelative tothesamewhitepoint.

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 lensmatching.

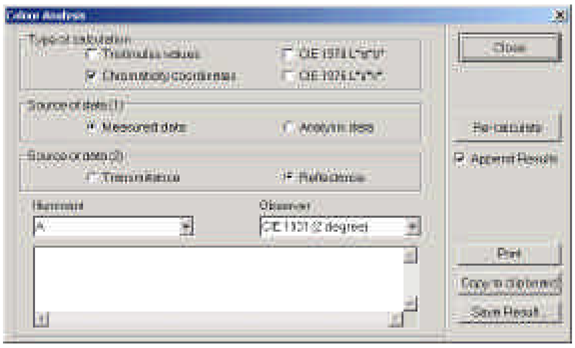
In this application note, we demonstrate the use of the versatile nkd spectrophotometer for making colour measurements on a variety of samples. In addition to providing precise measurements of total transmittance and reflectance over a wide wavelength range, the nkd has a built in colour measurement facility for calculating tristimulus values, chromaticity co-ordinates, **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 a colour measurement is made for a coated ophthalmic lens. T and R spectra for the lens were measured on the nkd spectrophotometer from 350-1000nm and are presented below.



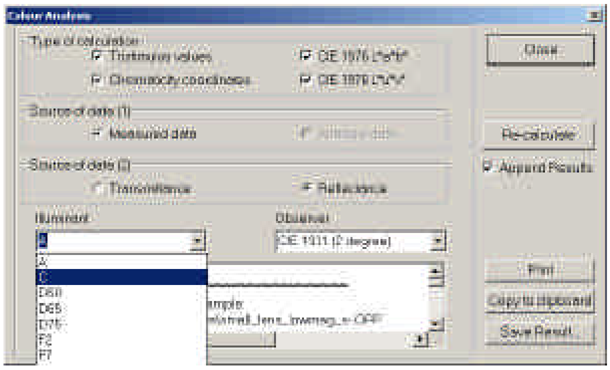
T & R Spectra for the lens

From the "Analysis" menu we select "Colour Calculations" and a dialogue 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 dialogue 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.

<u>Result of colour analysis for sample:</u>
C:\polymer\sample2_on_s_30.opp
Data were available on 5.0 nm intervals from 350.0 nm to 1000.0 nm.
This calculation was performed from 380.0nm, to 780.0nm on 5nm 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 (2degree)
Illuminant: CIE standard illuminant C

CIE Tristimulus values: X = 7123.82764, Y = 7090.485352.5, Z = 6475.50977

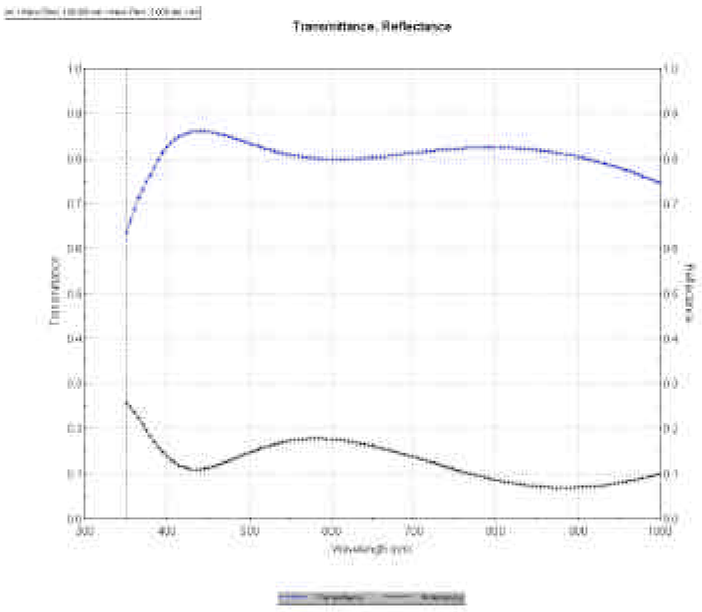
CIE Chromaticity coordinates: x = 0.34432, y = 0.34270, z = 0.31298

*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.



T & R Spectrafor thepolymer

<u>Result of colour analysis for sample: C:\small lens lowmag s-.OPP</u>
Data were availableon5.0 nm intervals from 350.0 nm to 1000.0 nm.
Thiscalculationwasperformedfrom380.0nm,to780.0nmon5nm intervalsaccordingtoASTMstandardE308.

Calculationperformed onbandpass-correcteddatafrom an nkd-seriesinstrument
Datacorrespondtoreflectanceat30.00degreesincidencewiths-polarisedlight.

Observer:CIE1931(2degree)
Illuminant:CIEstandard illuminantC

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

*CIEuniform colourspaceL*a*b*:L*=17.46356, a*=-18.66916, b*=7.35679*

*CIE uniform colourspace L*u*v*: L*=17.46356, u*=-12.96731, v*=8.86198*

Colour Calculations for the polymer sample

The results shown demonstrate the functionality of the nkd spectrophotometer series, which provide not just, transmittance and reflectancedata from which dispersion, absorption and layer thickness can be determined but also colour measurements, usefulin awidevarietyofapplications.

It is worth noting that in determining colour with the nkd, we measurethefullspectralresponseofthematerial.Comparethisto a simple colourimetry device which uses colour filters tomake a single measurement of the tristimulus values. Whilesimple,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 - suchasroomlighting,butonelensmightappeartobedifferent in daylight. This important change can be measured on the nkd simply by selecting a different illuminant type and calculating the variationinthelenscolourwithrespecttotheincidentillumination. Another example of the superb functionality of the nkd spectrophotometer.