Characterisation of Au and ITO coatings on glass substrates

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This application note demonstrates the principle of measuring and characterising gold and ITO coatings on glass substrates using the Aquila nkd Spectrophotometer.

Indium oxide doped with tin oxide (ITO) is used to make transparent conductive coatings for applications which include touch panel contacts, electrodes for LCD and electrochromic displays, energy conserving architectural windows, defogging aircraft and automobile windows, heat-reflecting coatings to increase light bulb efficiency, gas sensors, antistatic window coatings and wear resistant layers on glass.

Traditional methods for measuring these coatings on a transparent substrate would suffer from problems arising from unknown incident polarisation and multiple reflections from the front and back surfaces of the substrate. Unless the measurement is made at normal incidence, a multitude of transmitted and reflected beams would be present, some of which may escape detection giving inaccurate results. Aquila's nkd-series spectrophotometers are designed specifically for analysis of thin-film coatings and offer accurate measurement of total transmittance and total reflectance in a precisely defined experimental geometry with known polarisation. This is used to powerful advantage by the integrated analysis software (Pro-Optix™) which can determine the thickness and complex refractive index of a coating from the measured data.
Many other techniques require the back of the substrate or component to be coated or treated to remove the secondary reflections, sothat they do not have to be treated in the analysis. Samples analysed in the nkd spectrophotometer require no treatment and in fact a transmissive sample is an advantage as the measured transmission spectra provides vital information on thematerial absorption.

An essential step in determining the optical properties of any subsequent layers, is to accurately characterise the glass substrate. If we were to just assume that the properties of the glass were the same as the database and enter them into our analysis, then any deviations would result in a build up of errors in the analysis of the coatings.

Transmittance and reflectance spectra for a typical float glass substrate of thickness 1.25mm, is shown in Figure 1 across. This material is commonly known as greenplate – so called because of the absorption peak at 380nm which causes a dip in the transmittance spectra. Also shown on the plot is the dispersion model which has been fitted automatically to the measured spectra by the Pro-Optix™ analysis software, which has many types of float glass in its database and is able to model these automatically and extract the optical constants from the fit. Figure 2 shoes the calculated optical properties of the float glass measured in Figure 1.

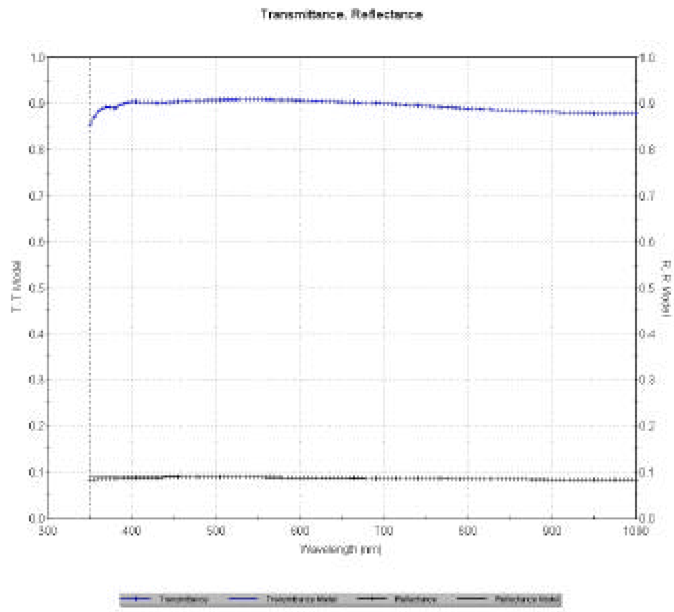

Figure 1. T & R spectra for glass substrate + model fit

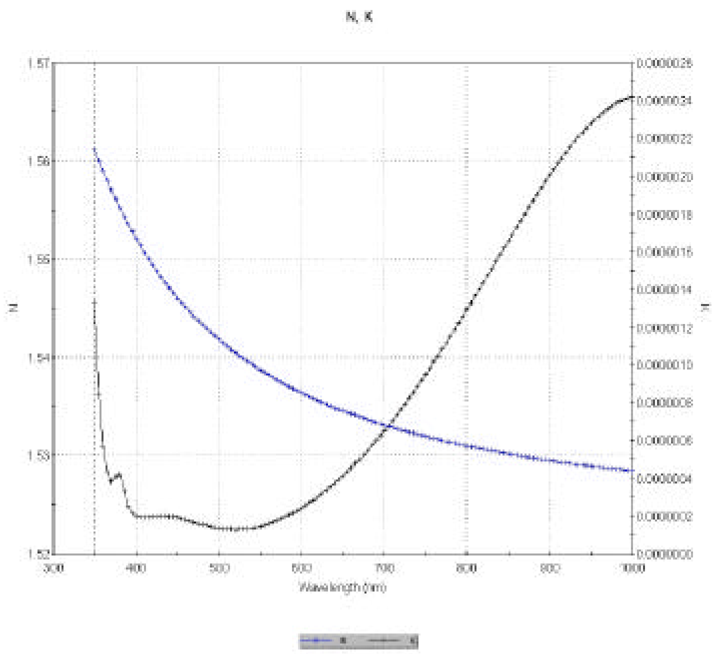

Figure 2. n & k plots for the float glass

A sample of the same float glass with a 464nm coating of ITO has been measured on the nkd and is presented in Figure 3 below. Pro-Optix™ database values for the substrate and the ITO have been loaded and used in the analysis to achieve the model fit shown overlayed on the measured spectra.

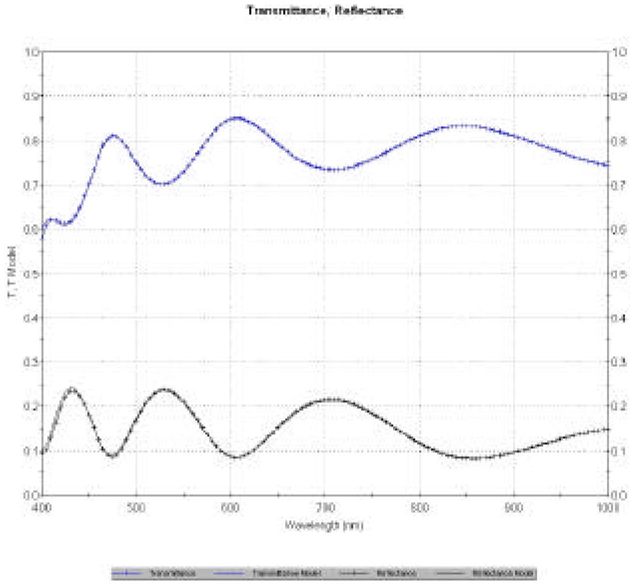

Figure 3. T & R spectra for a float glass substrate with a 464nm layer of ITO showing the model fit

the optical properties of the ITO layer extracted from the fit, are presented in Figure 4 below and show that the ITO layer exhibits low absorption in the visible region and increased absorption into the UV and IR. Pro-Optix™ was also able to ascertain the layer thickness of the ITO to be 464nm.

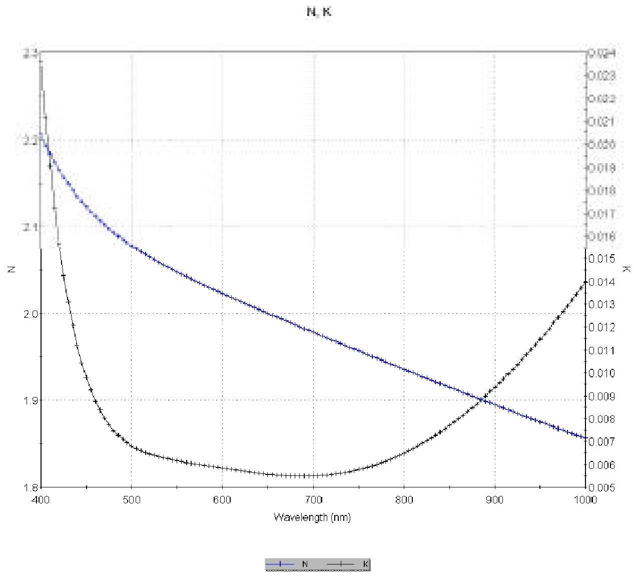

Figure 4. n & k for a 464nm layer of ITO

The optical and electronic properties of ITO films are dependent on the deposition parameters and there is often a trade off between percentage transmission and electrical conductivity, depending on the application. At longer wavelengths ITO films become reflecting and the IR reflectance can be correlated with the sheet resistance of the film. The ITO actually behaves more like a metal in the IR.

We can see from this one simple, non destructive measurement, that the nkd is able measure the transmittance and reflectance of the whole layer system, while providing the refractive index, absorption and layer thickness of the ITO film automatically. The measurements taken for the ITO were performed at 30°, but the nkd spectrophotometer could easily have been configured to measure T and R at an angle to suit the application.

Thin layers of gold are often used in the same applications for corrosion resistance or as an electrical conductor in a multi- layer stack. Few techniques exist to determine the thickness of gold coatings of the order of 100Å. The nkd spectrophotometer is able to determine the refractive index, absorption and layer thickness of these thin films without ambiguity, by measuring the transmittance and reflectance spectra of the sample for the p- and s-polarised incident components. The additional information supplied by such a polarisation-resolved measurement removes the freedom for errors in one parameter to be compensated by errors in another parameter during the analysis, providing an absolute measurement of the film.
Figure 5 below shows T and R measurements for s- and p-polarisations, taken from a sample of float glass coated with an adhesion promoter layer and a thin gold layer. Pro-Optix™ has special algorithms which cater for metal films and was able to fit a model to the measured spectra to give the optical properties for the gold layer shown in Figure 6. The analysis also determined a thickness for the gold layer of 10nm.

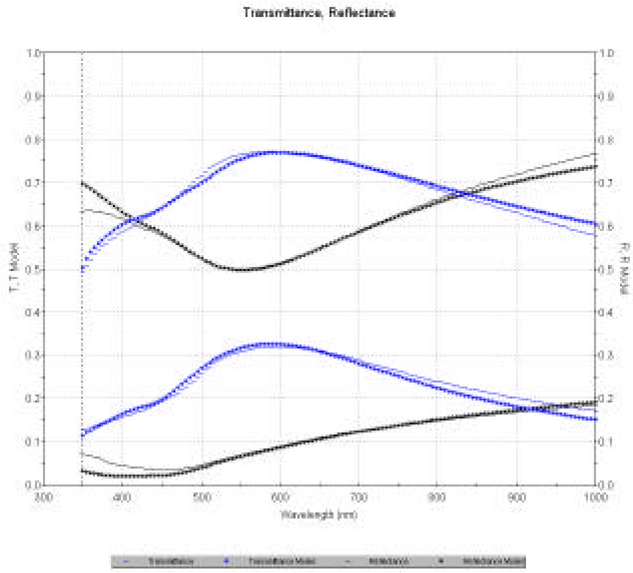

Figure 5 . T & R for a 10nm layer of gold on float glass showing the model fit

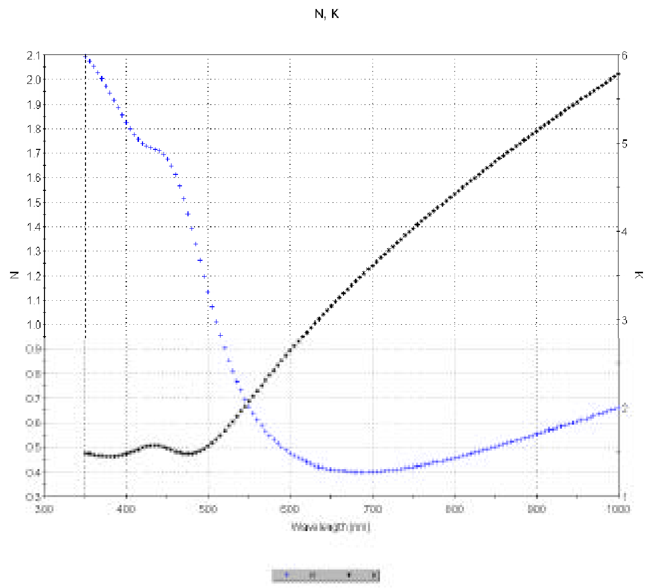

Figure 6. n & k for the 10nm layer of gold

The refractive index for the gold drops to less than 1 and the very high absorption values are characteristic of metallic conduction and suggest that the film is continuous over the region probed.
This measurement principle can also be applied to multiple layers so that a picture of the whole layer system can be established,