Transparent Substrates: How To Suppress Reflections from the Back Surface

By Ron Synowicki

Working with Transparent Samples

Thin film coatings are commonly deposited on transparent substrates, such as glass or plastic, which are smooth and reflective on both sides. Normally we want to measure the properties of coated films, but avoid unwanted reflections, such as from the back surface. If you can see through a sample, you need to consider effects of backside reflections.

Sometimes the substrate is thick enough to spatially separate beams reflected from the front and back surfaces, but for thin glass or plastic sheets the two beams can overlap. In this case the detector measures light from both beams. The measured data contains polarization information from both front and back surfaces, so we need to account for backside reflections. Backside reflections can be accounted for in the analysis model, but in most cases it is helpful to suppress them during data acquisition.

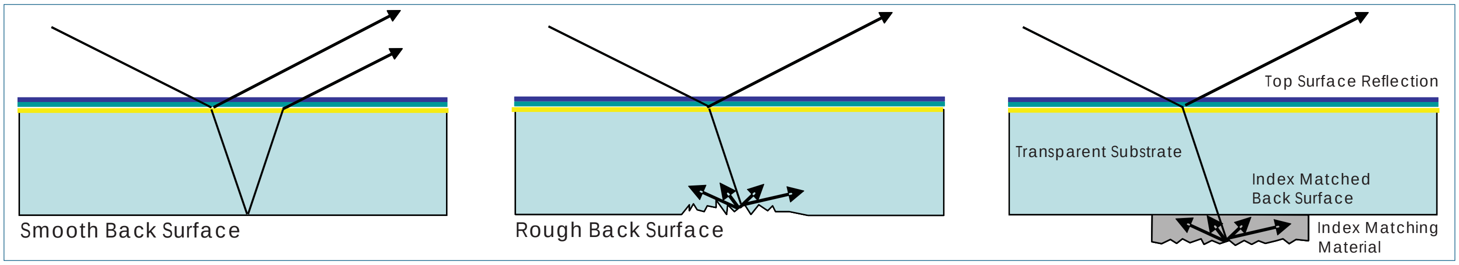

Figure 1. Unwanted reflections from the back surface suppressed by roughening or index matching.

Coherence

Why are backside reflections a problem? The answer is coherence. For thin coated films reflections from the top and bottom of the film are "coherent", meaning the phase difference is maintained between light reflected from the upper and lower surfaces of the film. Both intensity and phase information are retained in the psi-delta data acquired by the ellipsometer.

For transparent substrates additional reflections occur from the back surface which complicates the measured spectra and needs to be accounted for as it affects the spectra acquired by the instrument. Note the beam reflected from the back surface must travel through the substrate twice. This extra long path length makes reflections from the back surface "incoherent" or "partially coherent" with the front surface reflection. Phase information is lost since the path length through the substrate is much greater than through a thin coated film. Light intensity from both reflections is still present at the detector, but the phase information from backside reflection cannot necessarily be added to the phase information from the front side reflection. Totally incoherent beams can only be added together as intensities, but not with phase information. This occurs when path lengths are very long, such as often happens in substrates.

Suppressing Back Surface Reflections

It is possible to suppress reflections from the back surface of glass and plastic substrates using a variety of simple methods. These are shown in the table. Translucent (cloudy looking) Scotch tape seems to work well. It is easy to apply and remove, and index matches very well

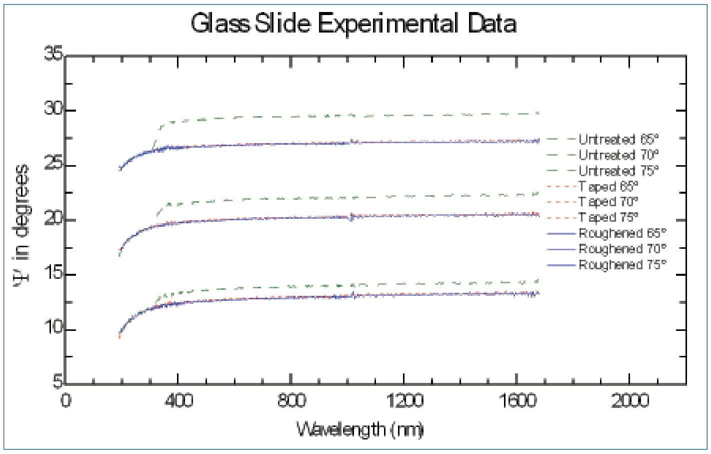

Figure 2. Ellipsometric Ψ data acquired on a glass slide. Note the slide is absorbing below 300 nm so all three data sets are identical. Beyond 300 nm the untreated slide data show backside reflection effects. Note the taped and roughened data are effectively identical.

with most glass and plastics. When applying the tape just make sure to work out any air bubbles between the tape and the substrate. Instead of reflecting from the back surface, light enters the tape and is scattered by the cloudy translucent material.

An additional benefit of applying translucent tape to the back of thin plastic sheets such as food plastic wrap can also make the sample more rigid and lie flat, making for easier alignment on the instrument.

Backside Treatment	Glass Index n(633nm)	Roughness, nm	Comments:
Roughened	1.520	2.78	Used mechanical grind-er. Reference value.
Translucent Adhesive Tape	1.521	2.41	Excellent adhesive bond. Translucent surface scatters.
Clear Adhesive Tape (sanded)	1.522	1.76	Good. Sanding created scattering surface.
Double-sided Adhesive Tape	1.518	1.67	Good, but sticks to stage.
Black Enamel Paint	1.520	2.44	Good.
Red Nail Polish	1.517	4.07	Good.
Silicone Grease	1.521	3.30	Good.
Vaseline	1.521	2.49	Good.
White Hand Lotion	1.517	3.62	Good.
Toothpaste	1.520	4.14	Good, but messy.
Elmer's White Glue	1.519	4.81	Good! Water soluble white glue.
Weldbond White Glue	1.519	4.60	Good! Water soluble white glue.
Super Glue (Cyanoacry-late)	1.516	3.82	Smeared to be translucent while drying.
Rubber Cement	1.516	3.77	Smeared to be translucent. Very easy.
Modeling Clay	1.518	2.65	Good.
Stick Tack Putty	1.522	2.86	Good.
Water	1.537	1.89	Bad. Water index too low.
Clear Glycerin Lotion	1.531	3.19	Bad. Lotion index too low.
Gel-Pak Adhesive	-	-	Bad. Caused anisotropic effects.
Adhesive Paper Post-it Note	-	-	Bad. Incomplete adhesive coverage.
Black Ink Marker	-	-	Bad. Semitransparent ink. Backside reflections still present.

For very thin, brittle substrates, such as microscope cover slips, various creams and pastes work well to suppress backside reflections. The tacky surface can be affixed to paper or other rigid surface and mounted on the instrument. Creams and pastes can be wiped off once the measurement is complete. Elmer's Rubber Cement is also very easy to apply and remove and makes good contact with the substrate.

Suppressing Anisotropic Effects

Data acquired from substrates such as plastic sheets often show complicated anisotropic effects due to ordering of the polymer molecules in the material. These bulk anisotropic effects can be removed or minimized by suppressing the beam which travels through the substrate via index matching techniques or roughening. This is an additional benefit of index matching techniques.

What about High Index Materials?

The techniques mentioned in the table work well for common glass and plastic materials with refractive index values in the range of n~1.35 to n~1.60. For higher index materials, such as PET (n~1.7) or high index glasses, taping does not work as well and some spectral artifacts will still be present due to the imperfect index match, but still may work well enough to perform a useful analysis.

For very high index materials, roughening a small area on the back surface opposite the measurement beam is always an option. This can be done using a rotary tool such as a Dremel with a pumice grinding stone, or using a pressurized grit sandblaster commonly used for frosting glass or dental materials.

If you want to try your own techniques to suppress backside reflections you can compare measured data to data acquired from a backside roughened test sample.

Further Reading

A more detailed technical article on this topic has been published[1]. Please contact the Woollam Company if you would like a copy, or to discuss backside reflection effects on specific samples.

[1] R.A. Synowicki, *Phys. Stat. Sol. (c)* **5**, No. 5, 1085–1088 (2008).