Optical Compensation in Variable Angle Transmission Measurements of Thick Samples

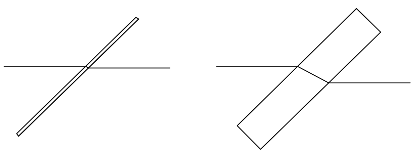

Figure 1. Beam offset for a 1-mm thick (left) and 10-mm thick (right) sample.

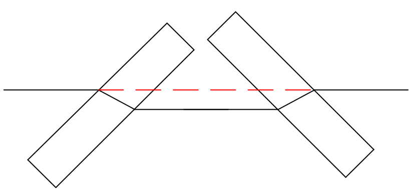

Figure 2. Use of a compensator to eliminate the beam offset.

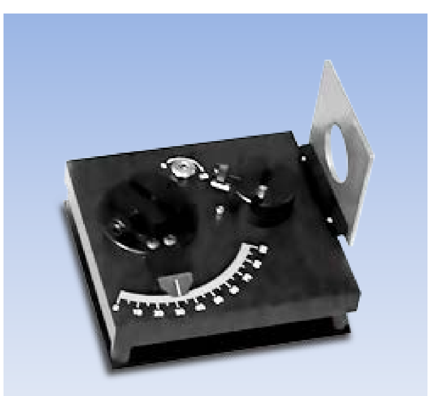

Figure 3. The Variable Angle Transmission Accessory.

Variable angle transmission spectroscopy is used extensively to extract film thicknesses and refractive index data. For thin films, the sample is merely placed in the spectrometer at a known incident angle. The infrared or UV-Vis beam refracts through the sample, but the resulting offset in the position of the beam is negligible and does not affect transmittance collected by the detector.

However, extending this method to thick samples can be problematic. If the offset of the beam due to refraction through the sample is significant, not all the transmitted radiation is collected by the detector, resulting in erroneous measurements.

This application note illustrates the spurious results and an alternate method to avoid them.

Theory

Consider, for example, two pieces of an organic material (n=1.5), one 1 mm thick and the other 10 mm thick. Light passing through these materials at a 45° incident angle refracts according to Snell's Law as shown in Figure 1.

For the 1-mm thick sample, the beam that transmits through the sample is offset approximately 0.5 mm while the offset for the thicker sample is roughly 5 mm.

In most optical designs, only the inner 80% of any optic is filled, so there is reasonably chance that the refracted beam will all be captured by the detector if the offset is small. So it is much more likely that the all the refracted radiation beam will be collected in the case of a thin sample than a thick one.

For more accurate measurements of thick samples, a second one of identical thickness or a refractive index-matched material can be used to refract the beam back, so it is properly centered on the detector, as shown in Figure 2.

Experimental

The measurements were carried out using a Variable Angle Transmission Accessory (see Figure 3) in conjunction with a commercial UV-Vis spectro-meter with a nominally collimated beam. Spectra were collected from 190 nm to 900 nm with a full aperture and a scan interval of 1 nm.

Two pieces of Plexiglas were used as the samples. Both were cut from the same sheet of material and had a thickness of 13.84 mm.

The Variable Angle Transmission Accessory was used with either one sample installed, as shown in Figure 1, or with two installed (see Figure 2). Data were collected every 5° from 0° to 60°. The double-transmission spectra were then adjusted for comparison to the single-transmission data.

RESULTS AND DISCUSSION

The results of the single transmission experiment are shown in Figure 4. The transmittance decreases as the incident angle changes away from normal (0°) incidence. This is expected because the reflectance losses increase at higher angles. However, the magnitude of the effect is surprising. A visual comparison of the intensity of the white light or zero order beam before and after the sample shows a more intense transmitted beam than would be expected for a 5% transmittance level, indicating that some of the transmitted radition is not reaching the detector.

Figure 5 shows the corrected transmission spectra as measured with a compensator. It is clear that the change in transmittance as a function of angle is significantly less, as expected.

CONCLUSION

Variable angle transmission with beam compensation can be used to improve the

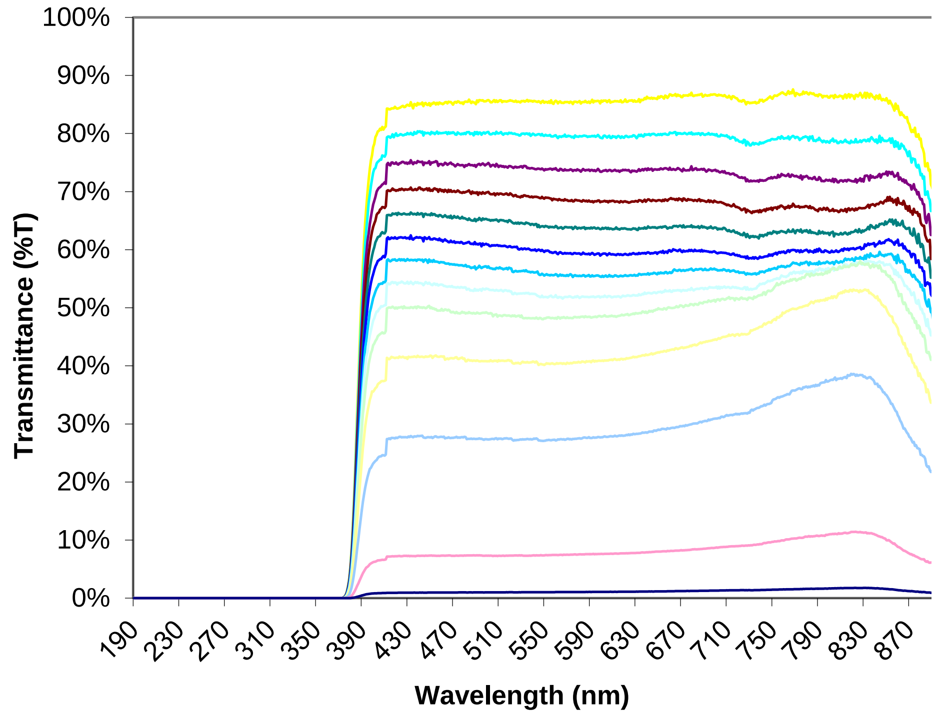

Figure 4. Transmission Spectra of a Single Plexiglas Sample. Measured in 5° increments from 0° (upper curve, yellow) to 60° (lowest curve, blue).

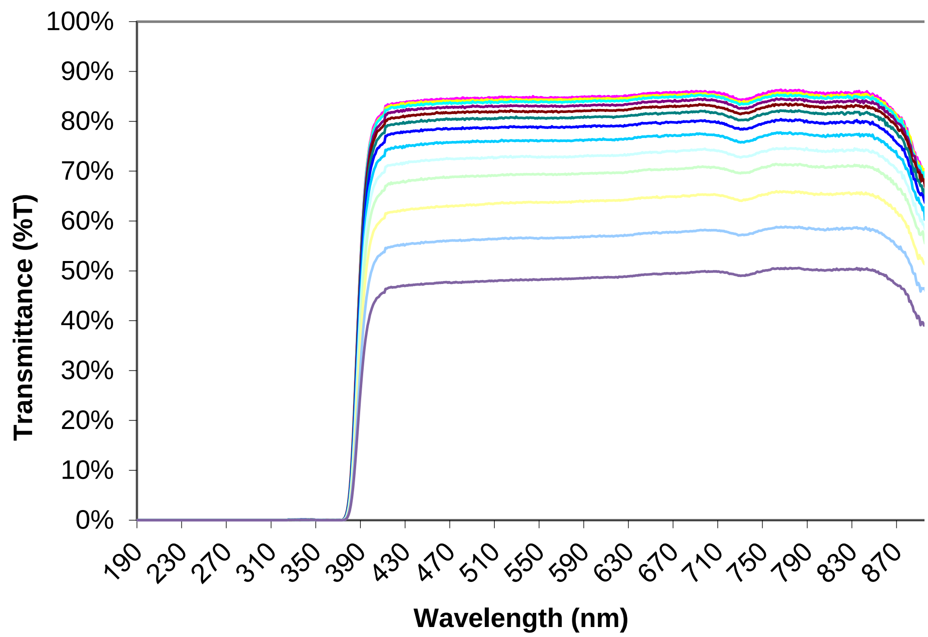

Figure 5. Corrected Transmission Spectra of a Two Plexiglas Samples. Measured in 5° increments from 0° (upper curve, pink) to 60° (lowest curve, purple).

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measurement accuracy for thick samples which significantly refract the beam. This method works well for spectrometers with nominally collimated beams. However, it does not compensate for defocusing effects and is therefore likely to be less effective for the spectrometers with focused beams in the sample compartment.

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