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Application News

No. UV-008

Spectrophotometric Analysis

Thin Film Analysis using the Shimadzu UV-2600 and 5 Degree Relative Specular Reflectance Accessory

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■ Introduction

Thin films play a critical role in our everyday lives. They are used in electronics, solar cells, and are applied as coatings in eyeglasses in order to reduce glare as well as increase the amount of transmitted light through the lenses. For example, anti-reflection (AR) coatings are applied to lenses in order to reduce glare that would otherwise be present in uncoated lenses. This has become an attractive feature for many consumers and therefore measurement and control of the AR coating has become increasingly important. Figure 1 shows two reflectance spectra of industry ophthalmic lenses. The black spectrum is the reflectance spectrum of a lens that contains a hard coating as well as an AR coating, whereas the red spectrum is a lens that only has a hard coating.

(a)

(b)

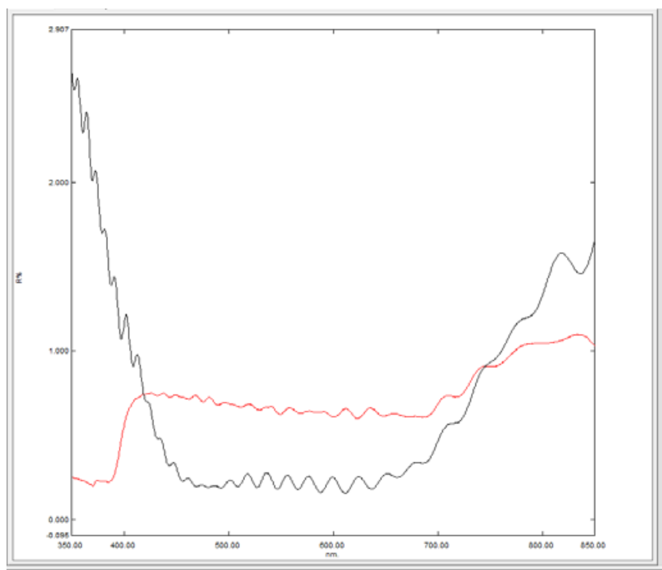


Figure 1: (a) Ophthalmic lens with AR coating and hard coating; (b) Reflectance spectra of ophthalmic lenses. The black spectrum represents a lens that contains both a hard coating and AR coating, whereas the red spectrum represents a lens that contains only a hard coating.

The industry of applying coatings as thin films relies heavily on the ability to determine the thickness of the coating for quality control purposes. In ophthalmics spectral reflectance is used to measure AR as well as hard coating thickness. The ophthalmic industry takes advantage of the capability to add multiple coatings in various combinations in order to provide the best consumer products. Shimadzu offers the ability to analyze a single film on a lens with the Film Thickness software, such as hard coatings on lenses. In figure 1, the area of interest for the hard coating is between 650 and 500 nm.

Film thickness, d, is determined from the wavelength between peaks and valleys in interference patterns. It is required that the refractive index of the coating and the incident angle are known prior to calculating film thickness, as given in equation 1, where n is the refractive index of the film, θ is the angle of incidence, λ_1 and λ_2 are wavelengths of two noticeable peaks (or valleys), and Δm is the number of peaks between $\lambda 1$ and $\lambda 2$.[1]

$$d = \frac{\Delta m}{2\sqrt{n^2 - \sin^2\theta}} \bullet \frac{1}{(\frac{1}{\lambda_2} - \frac{1}{\lambda_1})}$$

In ophthalmics, the area of interest lies in the ability to analyze multiple coatings that are comprised of hard coatings and AR coatings. The industry of applied coatings is broad and diverse. Whether multiple or single coatings are being applied to a substrate, it is of critical importance that the individual coatings by themselves have been analyzed for film thickness prior to making a finished product. This application news focuses on the ability to measure a single protective coating on an acrylic substrate using the Shimadzu UV-2600 with 5 degree relative specular reflectance accessory and film thickness software.

■ Method

Reflectance spectra of an acrylic lens with a single protective coating were acquired on the UV-2600 using the 5 degree relative specular reflectance accessory under the following scan conditions:

- Wavelength Range (nm): 350 to 850 nm
- Scan Speed: Fast
- Slit Width: 5.0
- Sampling Interval: 0.5
- Auto Sampling Interval: Enabled
- Scan Mode: Single

A background scan was obtained by mounting the mirror assemblies on the sample and reference stages with the mirrors face down and then acquiring a baseline scan. It should be noted that for measuring lenses and other acrylic materials on the 5 degree relative specular reflectance accessory the ideal background would be obtained by replacing the sample-side reference mirror with a blank un-coated lens. However, for the purposes of this report an aluminum mirror was used as a sample mirror during the baseline scan in order to acquire a baseline scan. The sample mirror was then removed and replaced with the acrylic lens in order to acquire a reflectance spectrum as shown in figure 2.

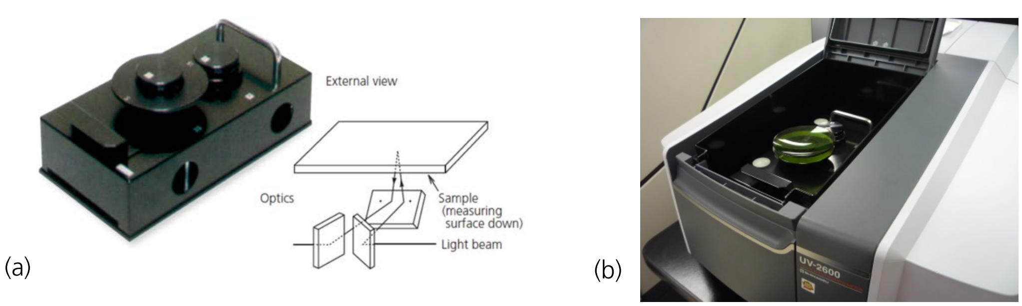


Figure 2: (a) 5 degree relative specular reflectance accessory and external view of light beam path with accessory in place; (b) 5 degree relative specular reflectance accessory sitting in UV-2600 sample compartment with acrylic lens in place.

The refractive index of the protective coating present on the acrylic lens was estimated by etching away a small layer of the coating and suspending it in solutions of various refractive indices and then using the Becke line test to estimate the refractive index of the coating. In analyzing the coating using the Becke line test the refractive index was estimated to be between 1.393 and 1.440.

■ Results and Discussion

Reflectance spectra of the acrylic lens with protective coating are shown in figure 3.

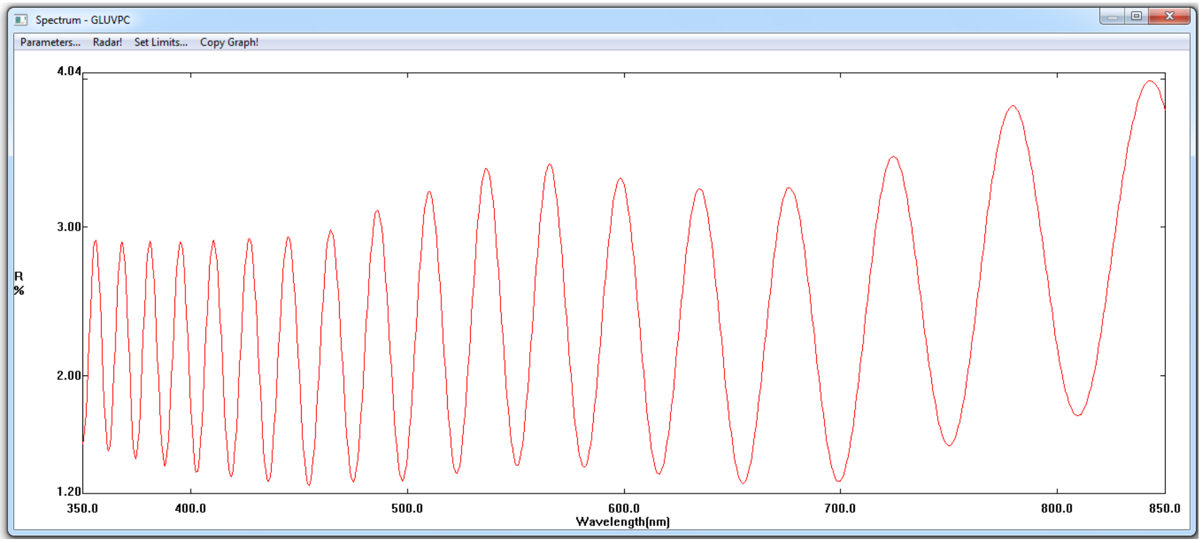


Figure 3: Reflectance spectra of acrylic lens with hardcoat layer.

The thickness of the protective coating can be determined using the Shimadzu Film Thickness software. It is required to know the refractive index of the coating as well as the incident angle of light.

Figure 4 shows the images acquired of the sample and estimating the refractive index using the Becke line test.

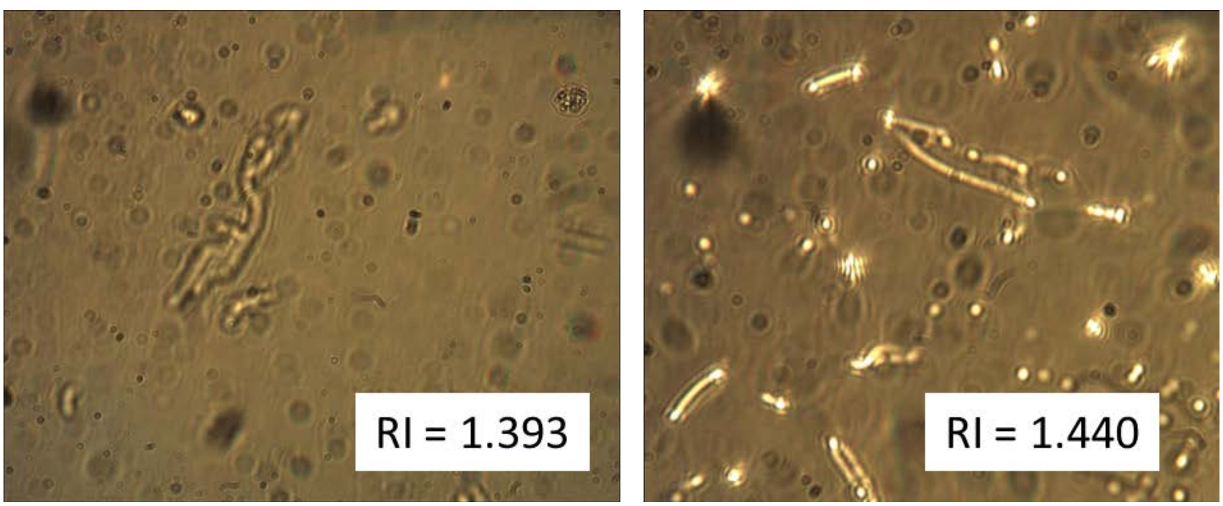
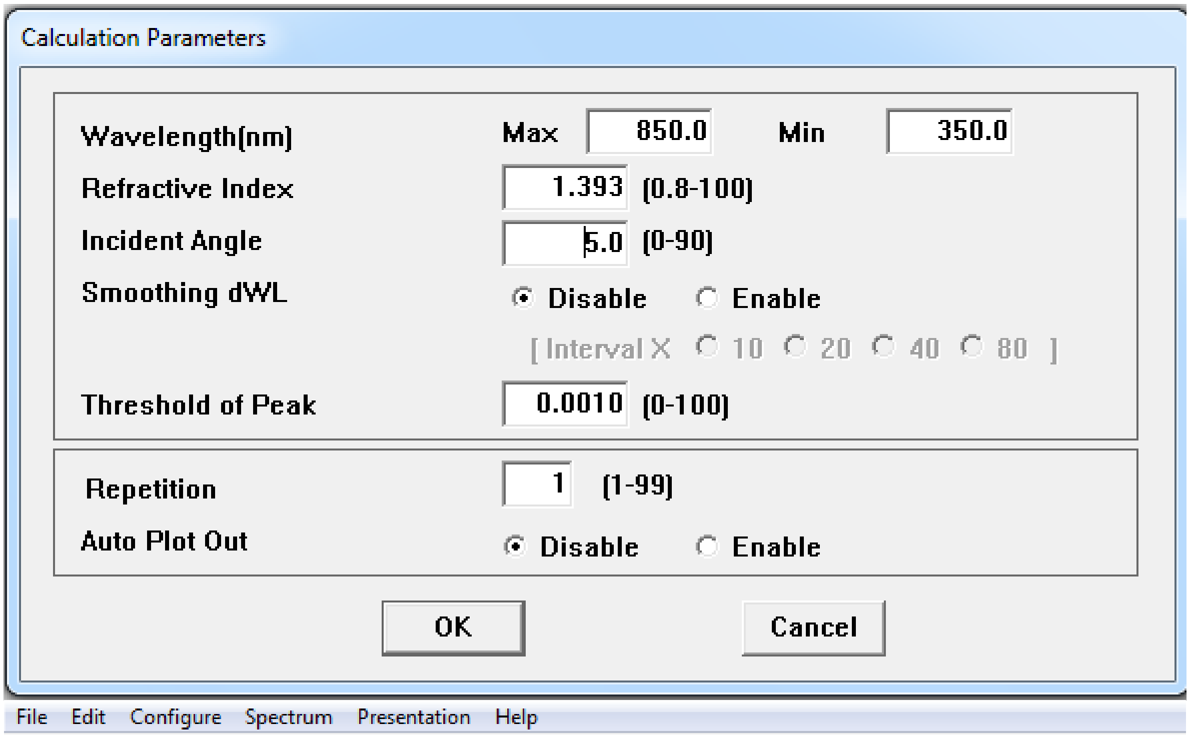


Figure 4: Becke line test of coating particles suspended in solutions with refractive indices of 1.393 and 1.440.

With an incident angle of 5 degrees, the thickness of the coating was calculated to be between 3.638 and 3.761 µm as summarized in figure 5.



Seq. #	Sample ID	Thickness (um)	Peak SD	Refractive Index	Incident Angle	CalcWL(nm) MAX	CalcWL(nm) MIN	File Name
1	1	3.638	3.71	1.440	5.0	850.0	350.0	GLUUPC
* 2	2	3.761	3.71	1.393	5.0	850.0	350.0	GLUUPC

Figure 5: Summary of film thickness calculations by the film thickness software.

■ Conclusion

In conclusion, this application note demonstrates the ability to measure the thickness of a single coating so long as the refractive index and the incident angle of light are known prior to using the Film Thickness software from Shimadzu. The software allows for a quick and easy way to calculate the film thickness of various coatings.

■ References

Instruction Manual. UVPC Optional Film Thickness Measurement Software (P/N 206-66877).

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