Application note

Analyzing Curved Surfaces with UV-Visible Techniques: Measuring Blue-Light Reductions Lenses

Introduction

Solid-state materials can be manufactured in a myriad of sizes and shapes. Often, the UV-Visible spectrum of these materials can provide valuable information about a substance's characteristics, including the color of a material or whether a material possesses the ability to block transmission of light at specific wavelengths. Solid phase samples, unlike solution phase samples, are able to reflect a non-negligible portion of incident light. Consequently, UV-Visible techniques are often employed to analyze not only the transmissive or absorptive properties of a sample, but the reflective properties as well.

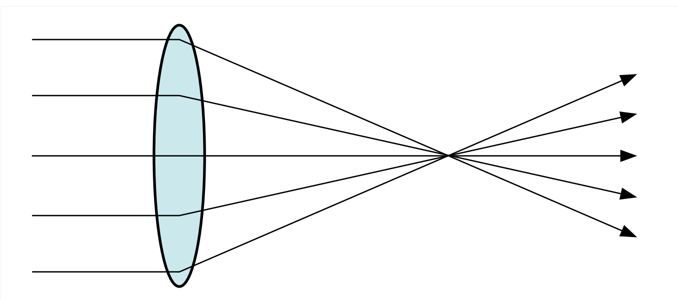

Figure 1. Light refraction from a focusing lens.

For materials which are curved or contain non-flat surfaces, refraction can cause light to be directed in a non-collimated fashion. This is the phenomenon which lenses utilize to allow for light to be focused or to diverge from the original collimated beam (Figure 1). These types of samples are often analyzed to learn more about a materials' transmissive and reflective behaviors in the UV-Visible spectral range. In traditional UV-Visible transmission measurements, a given sample is not expected to change the direction of the beam to a large degree; however, samples like lenses can alter the course of the beam significantly. This can lead to possible losses of transmitted light as the diverging beam is unable to be fully directed towards the detector.

To avoid possible errors in the collection of the true transmission spectrum, the addition of an integrating sphere accessory can aid in ensuring the transmitted light can reach the detector, resulting in an accurate transmission measurement. The interior of the sphere is coated with a highly reflective material to allow for the collection of light directed or scattered in non-uniform directions. The scattered light will diffusely reflect off the sphere walls many times until it is eventually able to reach the detector, which is held at an angle off the axis of the incident light beam (e.g., at 90° with respect to the incident beam).

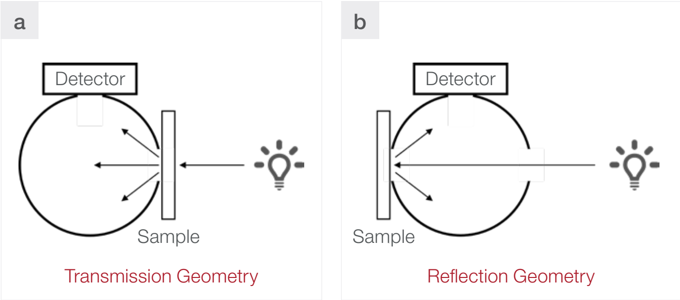

Figure 2. General diagram of an integrating sphere used in (a) transmission and (b) reflection geometry.

Due to the angle at which the detector is held, either reflectance or transmission measurements can be collected as shown in Figure 2. Through use of an integrating sphere, all light can theoretically be directed toward the detector, effectively eliminating issues posed by curved objects, diffuse reflectors or scattering substances. Owing to its ability to collect light directed off the beam axis and the versatility of the possible measurement geometries (reflection vs transmission), an integrating sphere is particularly useful for analysis of solid-state samples.

Blue light reduction glasses, a curved solid material, claim to reduce the amount of UV, violet and/or blue light which reaches the eye. The material in the lenses is intended to block the transmission of short wavelengths (UV: <400 nm, Violet: 400 – 440 nm, Blue: 440 – 500 nm) and transmit the remainder of the visible spectrum.[1,2] It is important that these lenses only block/reduce transmission at shorter wavelengths, allowing transmission at longer wavelengths. As a result, the measurement of the transmission spectrum is important for quality purposes. To demonstrate the ability to measure a curved surface, the transmission and reflectance spectra of a lens from a pair of violet/blue light reduction eyeglasses were measured using the Thermo Scientific™ Evolution™ One Plus spectrophotometer equipped with the Thermo Scientific ISA-220 integrating sphere (ISA-220). Through experiments described herein, the blocked UV-Visible range for a pair of violet/blue light reduction eyeglass lenses was found to be below 430 nm, indicating violet and UV light is blocked by the lens. However, these results indicate blue light can be transmitted through these lenses. Additionally, the absorptance spectrum of the lens was determined using the transmission and reflectance data. The absorptance spectrum was found to have a peak at 600 nm, matching the absorbance spectrum of the lens calculated from the measured transmission spectrum.

Experimental

A lens from a pair of violet/blue light reduction glasses was used as received. The material was measured using the Evolution One Plus UV-Visible spectrophotometer and ISA-220. Both % transmission (*%T*) and % reflectance (*%R*) spectra were collected, with the latter acquired using an 8˚ wedge to position the sample such that both diffuse and specular reflections were collected. A white Spectralon™ reference standard was used to establish the 100% reflectance baseline for the total reflectance measurements. This reference standard was also held at 8˚ with respect to the incident beam as well. The data was integrated for 0.1 s for each measurement.

Results/Discussion

Figure 3 includes both the transmission and total reflection spectrum of the eyeglass lens. The transmission spectrum starts to cut off at 430 nm and reaches 0% transmittance at 410 nm, indicating this lens is able to reduce violet light and below, however it does transmit blue light and above. At wavelengths longer than 430 nm, the transmission spectrum plateaus at ~90%, implying ~10 % of the light is unable to pass through the material. The remaining light can either be a result of absorption from the sample or from reflections. To better ascertain the origin of the unaccounted light, total reflectance measurements were acquired for the lens (Figure 3, red curve). Here, at wavelengths greater than 430 nm, ~10% of the incident light is reflected, accounting for the loss of transmitted light in this region.

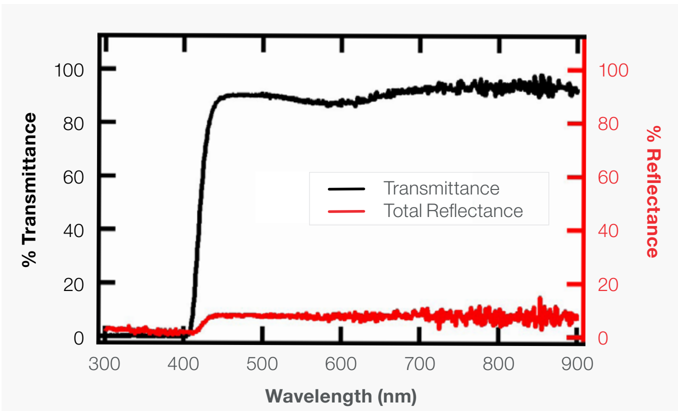

Figure 3. Transmittance (black) and Reflectance (red) spectra for a blue light reduction lens.

Additionally, in the transmission spectrum, a dip at 600 nm can also be observed. This dip is not present in the reflection spectrum, implying the lens or lens coating contains a material which absorbs in this region. As these lenses were commercially available, the source of this absorbance may either be intentionally included or is an unavoidable result due to the material used in the lens. However, it may be important to identify if an absorbing species is present and to what extent this species affects the optical transmission of the lens in the spectral region of interest.

By subtracting the transmittance and reflectance spectra from an assumed 100% light collection, the % absorptance of the material can be determined. Absorptance should not be confused with the more commonly referenced "absorbance" of a sample. While these terms are similar, the former includes the loss of light through reflections and transmission while the latter only accounts for the transmissive losses through Beer's law. Absorptance is typically reported using the same symbol as absorbance, A, but for the purposes of this note it shall be denoted as *%A*.

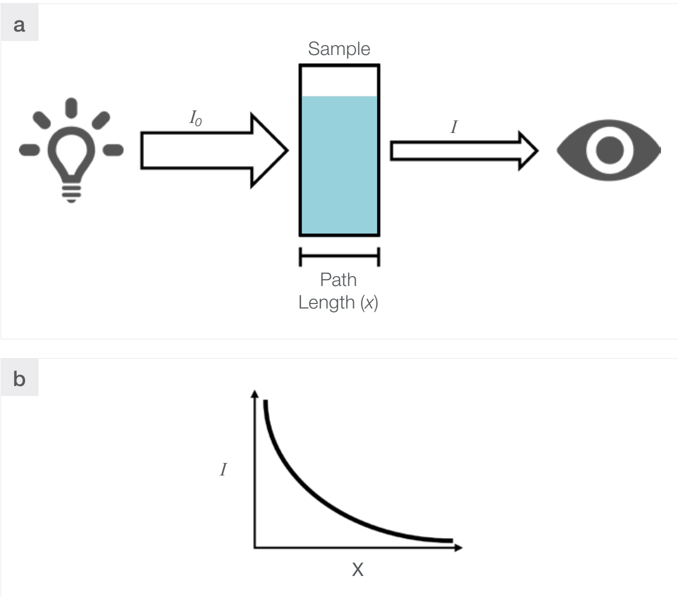

Figure 4. (a) Diagram depicting how incident light (I_0) is absorbed within a material, resulting in a lower intensity of remaining light (I) observed by the detector. (b) A depiction of the exponential relationship between the intensity of the light exiting the sample (I) and the path length (x).

Absorbance is calculated using equation 1, and is typically applied for liquid samples, where reflections are negligible, implying only transmissive losses exist.

$$A = log\left(\frac{I_0}{I}\right) = log\left(\frac{100}{\%T}\right)$$

Equation 1.

Here, I_0 is the intensity of the light before it interacts with the sample, and I is the intensity of the light that exits the sample through some given path length and *%T* is the percent transmission at a given wavelength. This is the form of Beer's law used by the spectrophotometer to determine the absorbance of a sample, and is visually represented through Figure 4, where I decays exponentially as a function of path length.

As absorbance is linear with respect to analyte concentration in solution, a linear function can be fit against a set of standards of known concentration. This technique makes quantification of an unknown concentration easy. From equation 1, it is shown that only the transmission of the material is accounted for, indicating any reflections or scattered light are, in effect, considered a part of the calculated absorbance term. For clear, non-turbid solutions, as has been discussed previously, these reflections and scattering events are considered negligible, allowing for this correlation between transmittance and absorbance to be accurate for solution phase samples.

Absorptance however, does not follow Beer's law and is not linear with changes to the concentration of the absorptive analyte. *%A* is related to the transmission and reflection spectra through the following equation,

$$100 = \%A + \%T + \%R$$

Equation 2.

where *%T* is the percent transmittance and *%R* is the percent total reflectance at a given wavelength. For solid-state materials, where reflections are non-negligible, this method is commonly reported.

Additionally, reporting *%A* can be helpful in applications in which the ratio of light absorbed by the sample is more important than quantifying the amount of a given analyte present in the sample matrix, such as solar energy applications.[3,4] For these applications, if the intensity of the light source is known, the absorptance can be used to determine the true intensity of incident light which is absorbed by the material. However, it is important to note that this is often an estimate as the *%R* spectrum is measured against a reference material (typically a mirror or diffuse reflectance standard). If the reference standard does not reflect 100% of the light, those losses will contribute to the calculated *%A* spectrum, though these differences are often negligible.

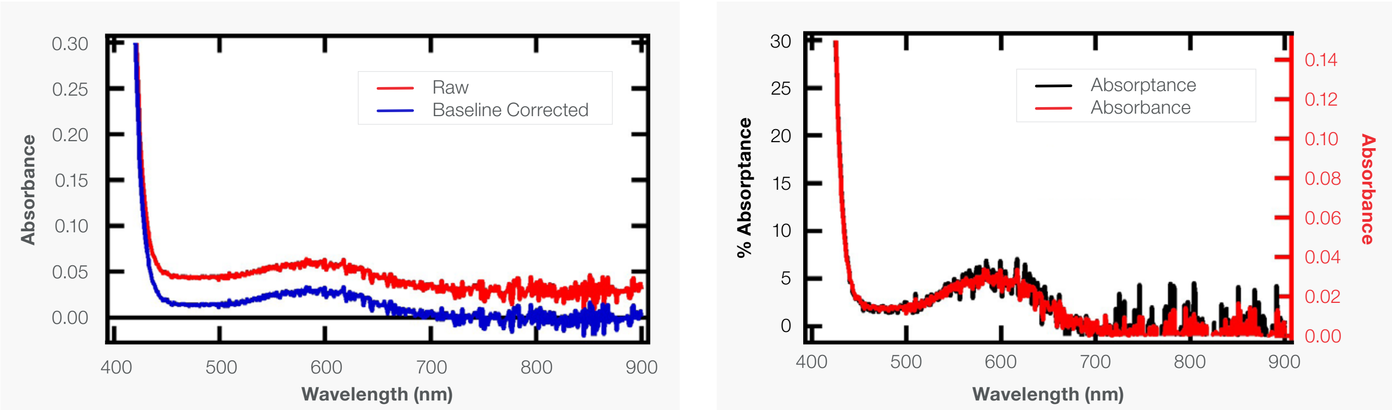

Figure 5. (a) Absorbance spectra (red - raw spectrum, blue - baselined corrected spectrum) of a blue light reduction lens. (b) Overlayed absorbance (red) and absorptance (black) spectra.

Absorbance and absorptance are very similar to one another, as is shown in Figure 5. Here, the calculated absorption spectrum (Figure 5a), taken by converting the percent transmission spectrum as shown in equation 1, can be shown to include a wide band with an absorption maximum centered at ~580 nm. The reflection spectrum for this material is significant, leading to an offset in the measured absorption spectrum. The contributions from reflections can be removed for this example by taking the average of the baseline (700 nm – 900 nm) and subtracting that value from the entire absorption spectrum.

Comparatively, the absorptance spectrum takes into account contributions from reflections. The resulting spectrum has a feature centered at ~580 nm as well. When scaled to match the maximum absorbance and absorptance, the spectra closely match one another (Figure 5b). While the value of the y-axis cannot be compared, the absorptance spectrum can be used to identify the spectral features present and compare to established absorption spectra of a given analyte.

Conclusions

Through the use of an integrating sphere, the experiments described herein demonstrate the ability to analyze the UV-Visible spectra of curved samples like lenses. The transmittance and reflectance spectra collected indicate the violet/blue light reduction glasses measured in this study prevent only violet and UV light from being transmitted. Additionally, the measurements included herein indicate a chromophore is present in the sample which absorbs at 600 nm, highlighting the ability to also calculate *%A* for solid materials in the UV-Visible range—a technique useful when analyzing samples when the fraction of light absorbed is more important to ascertain than the concentration of a given analyte.

References

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