Transmission Characteristics of Sunglasses and Tinted Windows

Evaluating Coatings that Filter UV and Vis-NIR Radiation

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Application Note

KEYWORDS

- UV radiation
- Eyewear protection
- UVA, UVB and UVC wavelengths

TECHNIQUES

- Transmission spectroscopy
- UV-Vis and NIR spectroscopy

APPLICATIONS

- Optical filter transmission
- Optical coating evaluation

Although the rise of modern sunglasses dates to the 1920s, there's evidence that even early man experimented with glasses designed to protect the eyes from the sun. Window tinting in automobiles, homes and buildings is a more recent development, with most sources suggesting its first use in the late 1960s.

With sunglasses, UV protection can be manufactured into the lens, with reflective coatings added later. However, those coatings are not nearly as effective in blocking UV radiation. On the other hand, window tinting in buildings and automobiles (which is what we measured for our experiment) is typically applied as a film or, as in the case of some automobiles, is added as a dye during the manufacturing process.

Transmission of UV and Vis-NIR wavelengths in sunglasses and car windows is regulated in many countries. With sunglasses, the focus is on the capacity of the lenses to absorb UV radiation, which can harm the eyes.

Since most UVC radiation (100-280 nm) is blocked by the Earth's ozone layer, the emphasis is on UVA (315-400 nm) and UVB (280-315 nm) wavelengths.

Also, window tinting in cars is regulated in different parts of the world, although the rules are less about UV protection than they are about the reduction in visible light transmission, which can reduce heat inside the vehicle but also decrease visibility at night. Nonetheless, as our experiments revealed, even window tinting that's been degraded over time and with prolonged exposure to sunlight provided some UV blocking capability.

Experimental Conditions

We used the same Ocean Insight spectrometer and accessories for both the eyewear and window tinting experiments:

- **FLAME-S-XR1** extended-range spectrometer to characterize transmission over the UV-Vis-NIR (200-1000 nm) range
- **DH-2000-BAL** deuterium tungsten halogen light source with balancing filter to provide illumination over a wide range (~230-2500 nm)
- **QP-450-XSR** extreme solarization-resistant, 450 μm diameter optical fibers
- **FOIS-1** integrating sphere to measure transmission through the curved, irregular surfaces of the samples
- **74-ACH** adjustable lens holder, to ensure alignment between two optics
- Ring stand and black cloth

In both experiments, the integrating sphere was screwed in to one of the openings on the 74-ACH holder. An optical fiber was then used to couple the integrating sphere to the spectrometer for the detection of light transmitted through the samples.

Another fiber was used to connect the DH-2000-BAL light source to a collimating lens screwed in to one of the openings on the 74-ACH. This helped to align the collimating lens with the integrating sphere. Light was delivered via the collimating lens through the sample and into the integrating sphere, which was coupled to the spectrometer.

The samples were placed in the path between the integrating sphere and the collimating lens, with the sample surface in contact with the port of the integrating sphere. Each sample was measured in three different locations with the average of the three samples shown in the graphs posted in this article.

An integrating sphere was used for the detection of transmission through the samples to ensure repeatable and accurate results with the curved surfaces of the eyewear and car windows. An integrating sphere is a good option if the reflectivity of the sample changes at different viewing angles. In fact, our measurements were very repeatable regardless of the curvature of the lenses.

Transmission of Sunglasses

To evaluate a range of eyewear options, we tested six samples ranging from discount store sunglasses to luxury brand eyewear:

Table I - Sample Eyewear

Eyewear Type	Estimated Price in USD
Inexpensive sunglasses with black lenses	$1
Plastic lab safety glasses (standard lab eyewear protection against chemicals or projectiles)	<$10
Plastic UV blocking eyewear (designed for use with UV sources)	$30
Progressive lens prescription eyewear with Transitions® coating that darkens with exposure to UV light	$300
Luxury brand polarized sunglasses with blue glass lenses	$350
Luxury brand polarized sunglasses with gray plastic lenses	$125

The glasses were oriented with the outside of the eyewear lens touching the integrating sphere. We observed that the eyewear orientation, proximity to the integrating sphere, and measurement location had little or no effect on the consistency of the measurements.

The ring stand held the 74-ACH with the integrating sphere port pointing up to facilitate placement and measurement of the different shaped eyewear lenses. A black cloth was used to prevent overhead lighting from entering the sphere.

Regardless of the composition of the lenses (glass or plastic, with or without different coatings to provide color and remove polarization), the eyewear had similar blocking efficiency of light in the UVB region with very low (~0.5%) transmission across the entire UVB range **(Figure 1)**. This level of blocking extended throughout the UVA region up to ~380 nm, where the lab safety glasses began transmitting light **(Figure 2)**. This was not unexpected as these glasses were not designed to block UV but to protect the wearer from chemical splashes, breaking glass or other projectiles.

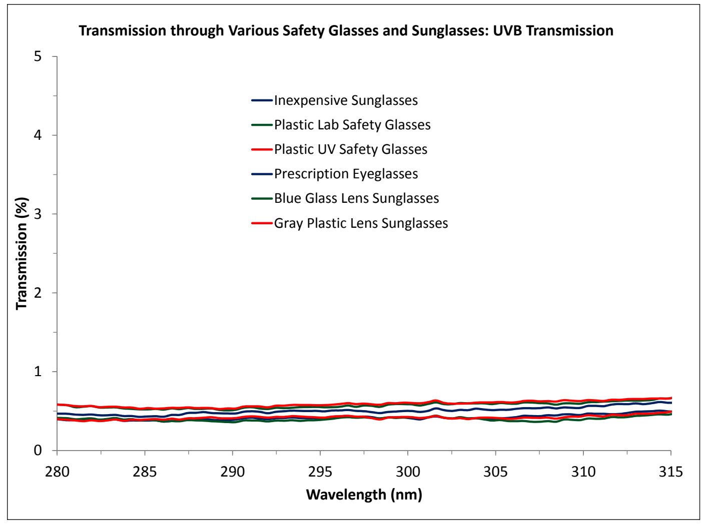

Figure 1. Regardless of lens composition, the glasses were effective in blocking UVB radiation (280-315 nm).

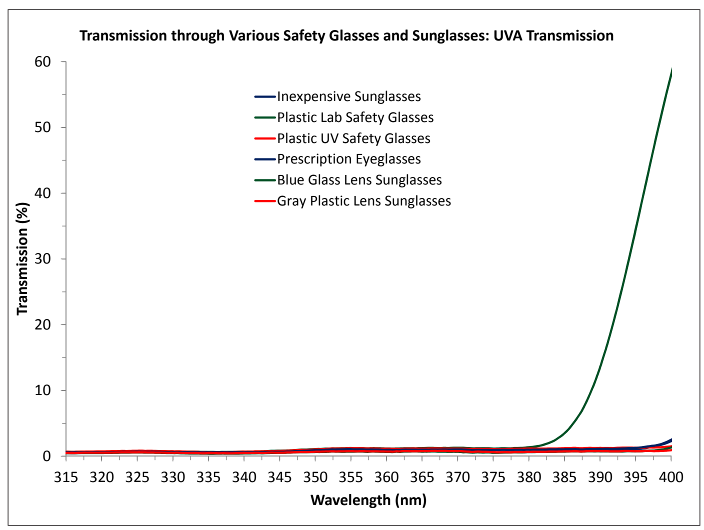

Figure 2. All eyewear samples tested demonstrated effective blocking of UVA wavelengths (315-400 nm) up to 380 nm.

All of the other eyewear had increased transmission of light starting at ~400 nm with varying degrees of blocking through the Vis-NIR range **(Figure 3)**. Interestingly, blocking across the Vis-NIR range had a similar profile for all the sunglasses measured with the best blocking (lowest transmission) across the visible range by the more expensive sunglasses. This suggests that the sunglasses share similar coatings or materials to provide better blocking in the visible region.

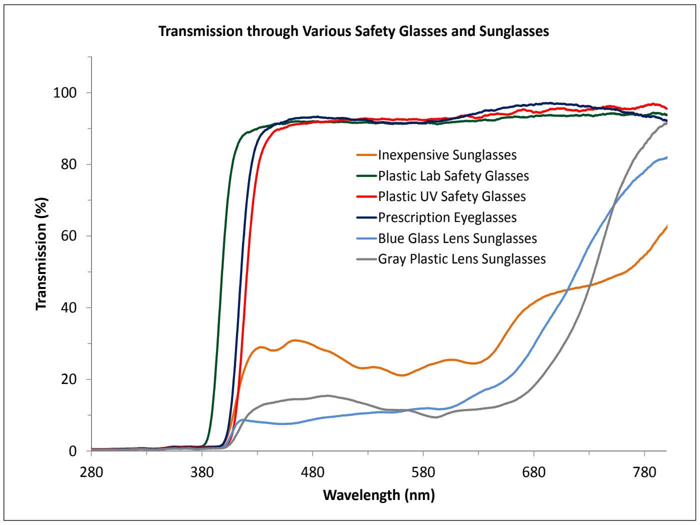

Figure 3. The Vis-NIR blocking efficiency of the more expensive eyewear options was very high, but even the least expensive glasses performed reasonably well.

Based on our observations, and in agreement with similar transmission experiments we performed earlier, all of the eyewear designed to absorb UVA and UVB radiation did so effectively, regardless of price. Also, aesthetics aside, because the more expensive sunglasses were the most effective in filtering visible wavelengths, the additional cost might be worth it for folks who require polarization and spend a lot of time in bright sunshine. Nonetheless, even the inexpensive sunglasses performed reasonably well in blocking visible light.

Transmission of Car Window Tinting

To evaluate a range of window tinting options, we tested three types of tinting from the same car and an untinted window from a different car:

Table II – Sample Car Window Tints

Car Window Tinting	Description
Factory tinted at time of purchase	Typically, added as a dye in the window manufacturing process
Tinted with window film	Thin film applied to the car's windows
Tinted with window film that has degraded	Thin film applied to the car's windows (tint lifetimes vary considerably)
Untinted window	Clear automotive glass

To evaluate the window tinting, the car window was opened halfway and the 74-ACH holder was placed over the open window with the integrating sphere on the outside of the car window. The integrating sphere was placed flush against the outside of the car window. A black cloth was used to prevent ambient light from entering the sphere.

Unlike eyewear, which is designed primarily to protect the eyes and improve vision in bright sunlight, car window tinting has many purposes. We tint our car windows to provide privacy, keep the interior of the car cooler and protect our skin and upholstery from damaging UV rays. Window tinting will reduce visible light transmission (VLT) in daylight and nighttime, which is one reason for regulation of VLT standards in some countries.

The effectiveness of the various window tinting materials at blocking light across the entire UV-Vis-NIR region is very clear when the spectra for all the samples are compared **(Figure 4)**. The untinted windows only block UV light to ~325 nm and have the highest transmission of all the samples across the entire region above 325 nm. The factory window tinting had the least transmission (best blocking) across the entire wavelength range with the film tinting providing good blocking at UV wavelengths <350 nm.

As observed with the eyewear, both the untinted and tinted windows provided excellent blocking of light in the UVA and UVB regions, with very low transmission across both ranges.

Since one purpose of tinting car windows is to keep the interior of the car cooler, we also looked at transmission characteristics in the NIR region above 780 nm. The factory tinting has the best blocking in this region with approximately half the transmission of the untinted window **(Figure 5)**.

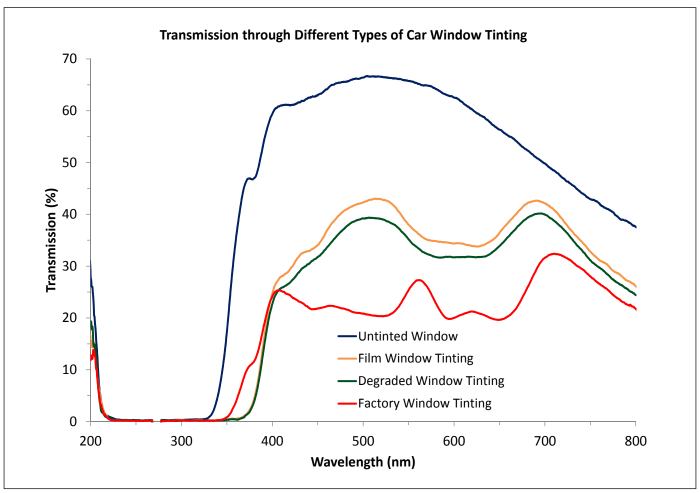

Figure 4. Factory tinting in car windows was most effective in filtering UV-Vis-NIR wavelengths when compared with other tinting options.

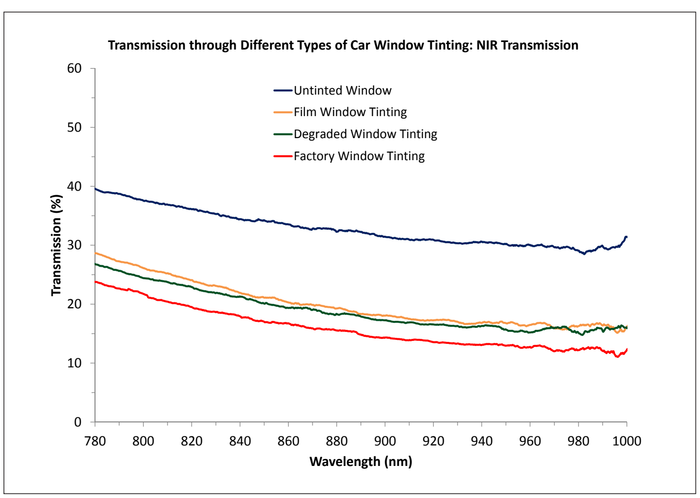

Figure 5. Effective blocking of heat-generating Vis-NIR radiation is one of the key functions of tinting in car windows.

Interestingly, the film window with tinting that appeared to be degraded or damaged had similar transmission properties to the undamaged film window tinting. The damage in this tinting is observed through a purplish tint to objects viewed through the window. Even though images appear to be a different color through the damaged window tinting, the transmission spectra were very similar across the entire wavelength range. Additional study would be necessary to determine the reasons for this result.

Conclusions

In most cases, all sunglasses offer some degree of protection against harmful UV radiation, with even the least expensive eyewear a viable option for folks spending time in the sun. Also, while window tinting affords some degree of protection against UV light, its primary function is to decrease light transmission at Vis-NIR wavelengths, which even the most degraded of our samples accomplished with reasonable efficiency.

The modular spectrometers and accessories used for these in situ measurements can be applied easily to similar types of transmission measurements, with tools like the 74-ACH collimating lens holder allowing users to mount lenses at multiple positions in setups. Additional spectrometers and accessories could be substituted for the items described here and achieve comparable results.

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