Ultraviolet Filters – Canadian Conservation Institute (CCI) Notes 2/1

Damage from Ultraviolet (UV) Radiation

UV radiation is highly energetic and tends to affect the stability of materials that make up an object. Prolonged exposure can result in the weakening of organic materials like textiles, paper, paint binders and plastics, with degradation often evident by increased brittleness, cracking or chalking (as can happen with paint films). Exposure to UV also causes varnishes and several plastics to yellow, and many dyes and pigments to fade. It is important to note, however, that both UV and visible energy (i.e. light) are responsible for fading, and it is incorrect to assume that avoiding UV exposure will stop this form of damage. Highly light-sensitive colourants are generally faded more by light with a minor contribution from UV, whereas the reverse is usually true for less sensitive colourants (McLaren 1956). Minimizing UV exposure to sensitive materials will reduce damage and, since UV is not required for viewing objects in most museum situations, reducing UV levels will not affect the display quality. Information on the relative sensitivity of materials to UV exposure is given by Michalski (1987 and 2011).

There are two main approaches for reducing the effects of UV on displayed objects. The first one is to lower the magnitude of UV received by the object when illuminated. This can be done by selecting a light source that emits the least UV, by reducing the light intensity and/or by filtering the UV from the light source. The second approach is to reduce the amount of time that the object is exposed. If the degree of UV exposure cannot be reduced to an acceptable level, the exposure time can be limited to minimize damage. This CCI Note focuses on the filtration of UV; however, all approaches should be considered in practice.

UV Filter Performance

A well-known UV filter specification for general museum applications was defined in 1978 (Thomson). In this approach, specific reductions were targeted at different wavelengths: a minimum 50% reduction in transmittance at 400 nm compared to the transmittance at 550 nm (the middle of the visible range), and at least 99% of the transmittance reduced at wavelengths of 380 nm and 320 nm. These criteria are rather difficult to achieve (especially the specification at 400 nm), as was shown by the testing of 17 glass and plastic UV filters at the Canadian Conservation Institute (CCI) in 2012. Only 35% fulfilled these requirements.

A disadvantage with the 1978 specification is that filtration around 380–400 nm causes slight yellowing of the light due to the reduction of violet radiation at the edge of the visible range. This effect is fortunately less noticeable without direct comparison. In a different approach, the International Organization for Standardization (ISO 2007) has developed a less stringent standard for the protection of photographs by recommending an overall 97% reduction of the transmittance in the UV range 300–380 nm. The standard excludes the challenging 380–400 nm range, and it does not consider the reactivity of different wavelengths. Of all UV filters included in the CCI study, 88% fulfilled these requirements.

Standards also exist for specific materials such as acrylic sheets with UV absorbers. The ASTM Standard D4802-10, *Standard Specifications for Poly(Methyl Methacrylate) Acrylic Plastic Sheet*, requires that UV radiation is cut by at least 95% in the 200–390 nm range. UV filtering (UVF) acrylics that fulfill this standard seem acceptable for conservation. Some manufacturers refer to a reduction of UV transmittance of their products based on the standard test method ASTM E903-12, *Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres*, or ASTM D1003-13, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*. The results of those tests will be rather meaningless if the manufacturer does not specify which UV range the test is covering. The window industry often refers to the test method NFRC 300-2010$_{E1A0}$, *Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems*, from the National Fenestration Rating Council Incorporated (2010) for reporting product performance. This test evaluates the performance of glazing systems (films and windows) in the UV and visible range (300–700 nm). Tinted or darker windows score highly; they reduce the UV but also the visible wavelengths, which may affect the quality of light. To avoid misinterpretation, it is useful to compare the performance of glazing materials among products having the same visible transmittance (e.g. compare all clear systems as one group and those with the same reduction in visible transmittance in another).

Since evaluating the performance of UV filters requires a spectrophotometer to determine the reduction in transmittance of specific wavelengths, many people will simply measure the UV using a portable monitor that targets a specific UV band. Based on the actual performance of UV filters on the market, filters that reduce more than 90% of the relative or absolute UV should be considered. Consult CCI Notes 2/2 *Measurement of Ultraviolet Radiation*, for details on measuring relative or absolute UV values.

UV Filter Types

UV filters can be glass, rigid plastic or thin flexible plastic. Glass is used for windows and spotlights as well as for enclosures, such as in picture frames (glazing) and display cases. Plastic panels are used for enclosures, while thin films are used primarily on windows.

The UV reduction measurements reported below were made with an Elsec 764 using the UV content (mW/m^2) of clear blue sky[1] (Ottawa, early afternoon, September 2012) with and without filter panels.

Glass

Transmittance measurements of regular glass performed with an Elsec UV meter showed a UV reduction of approximately 26% ± 11%, while glass UV filters targeted for museum applications offered an average reduction of 83% ± 14%. Note that the organic UV absorbing compounds on or within the glass will degrade over time, especially if exposed to high levels. The inorganic compounds are expected to remain stable.

Rigid plastic panel

Clear plastic panels are typically made of acrylic, polycarbonate or polystyrene polymers. Most of them offer some UV protection, mainly for the protection of the plastic itself. UV filters promoted in the conservation market cut 99% ± 1% of the UV, while acrylics with UVF that meet the ASTM D4802-10 standard will cut the UV by at least 95%. Plastic diffusion panels used for lighting, in addition to blocking some UV, disperse the radiation, which also reduces the amount of light and UV on a surface (UV reduction of 17–99% according to Public Health England [2008]). As with filters applied to glass products, the organic UV absorbing compounds will degrade over time.

Thin plastic film

Traditionally in museums, thin plastic UV films were used in the form of flexible tubes that were installed over linear fluorescent bulbs. These UV tubes remain useful when there is no plastic diffusion panel present underneath.

There is also an important market for solar protection film (i.e. solar screen). These materials are usually glued against the interior surface of a window. Many of the available products are tinted; however, it is preferable to use clear films or those called neutral (also called neutral density or gray) for museum applications. Neutral means that the film reduces the light transmittance without changing its colour (or quality). They can reduce the light transmittance up to 90%. Neutral density UV films can be quite useful when there is a need to block UV and also reduce the light levels on objects. Boye et al. (2010) reported that these films offer a reduction of 96% ± 2% in the range of 300–400 nm. Useful life of UV films is expected to be 10–15 years when they are applied indoors. The plastic film, adhesive and the organic UV absorber will degrade over time at a rate that depends on conditions such as heat, light and humidity (Vavrova et al. 2004). Some UV films exposed to midday sun tend to degrade much faster (Gordon 2014). In cold climates, greater thermal changes and condensation on the windows can cause delamination of the film edges and affect the aesthetic.

There are some other concerns related to the installation and longevity of UV films applied on windows. Historical glass windows are more fragile than modern ones, and many conservators will point out the higher risk of scratches or breakage during the installation or removal of the film. A high level of skill is needed to ensure proper adherence, avoid wrinkles and bubbles, and ensure proper trimming. Other options could include installing a rigid plastic UV filter against the windows or installing an interior suspended UV shade.

While considering UV film for windows, security films may provide an interesting alternative. Security films are designed to hold glass fragments together, thereby discouraging or delaying forced entry. Many of them will also provide adequate UV reduction.

Evaluation and Testing

Prior to purchasing a large quantity of UV filters, inspect the technical literature and examine the transmission spectrum of the filter. Look for UV reduction based on recognized standards such as ISO 18902:2007, *Imaging Materials – Processed Imaging Materials – Albums, Framing and Storage Materials*, and ASTM D4802-10. Otherwise, look for the reduction of UV for a specific UV range such as 300–380 nm.

Data from Boye et al. (2010) shows that UV filter films were generally up to 5% less efficient when compared to performance claims. Manufacturers seem slightly optimistic about their UV filter performance. One filter was 15% less efficient than claimed and one UV filter tube was simply regular plastic and only reduced the UV by 32%.

Use UV filter samples to check how much actual UV reaches the objects from your lighting installation. Since the UV filter may degrade over time, do some monitoring of the UV every few years, especially for those films exposed to significant levels of heat and light.

Conclusion

As general practice for UV filtration, first filter daylight (direct sunlight and even blue sky[1]) that can reach the collection(s) or architectural components of the building that could be sensitive to UV radiation. Daylight contains significant UV radiation and it can be 10–13 times more reactive than light from a tungsten lamp of the same intensity. Next, consider filtering light from indoor sources and limiting the light that sensitive objects receive.

For information on recommended UV levels, measurements, quantification of UV filter performance and the impact of UV on objects, consult CCI Notes 2/2 *Measurement of Ultraviolet Radiation*.

Light and UV meters can be borrowed from CCI through Environmental Monitoring Equipment Loans.

End Note

[1] The term "blue sky" refers to midday clear sky opposite to the sun. In the northern hemisphere, this will be on the north side when the sun is on the south side. Alternatively, for the southern hemisphere, the blue sky would be on the south side of the sky when the sun is on the north side.

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