

Monitoring Radiation for Display of Objects – Do You Know the Whole Story Spectrum?

Introduction

A conservator's recent question regarding transmission properties of contemporary acrylic glazings prompted re-consideration of an earlier, informal study. The intent of the original test had been to assess qualitatively the dependence of light-induced appearance change in a set of inkjet inks on the extent of UV-blocking by different plastic glazings. It should be emphasized that the test was not designed to fully characterize color change in the inks used. The light stability of ink jet printing inks has been extensively studied (e.g., Glynn, 2001; Wilhelm, 2002; Rasmussen, et al., 2005; Venosa, et al., 2010). Rather, the inks were chosen for the test because they had a variety of sensitivities to radiation, and were likely to undergo significant appearance changes in a reasonable exposure time.

In several instances, the changes observed in the original test did not appear to depend on the presence of UV radiation. Because exposure to near UV is often regarded as the main cause of photo-induced appearance change in colorants, the reduction or removal of UV might have been expected to have a significant effect on the changes. The results indicated that this expectation might not be as widely applicable as generally assumed.

To clarify the situation, additional tests have been performed and the earlier data reevaluated. The results suggest that commonly used approaches to monitoring display lighting and predicting its damaging effects may benefit from modification. This endeavor is particularly timely due to renewed interest in risk assessment and in defining and applying the damage function concept to cultural heritage materials (Strlič, et al, 2013).

Materials and Methods

Sample preparation

The plastic glazings used were UF4 and UF5 from AtoHaas (now the Altuglas Division of Arkema), Cyro Acrylite OP-3 UV-blocking acrylic glazing (currently available from Evonik), and Polycast acrylic glazing without additional

UV blocking (referred to below as Polycast clear). Three glazings were used in each of the tests, to block near UV to very different extents. OP-3 and UF5 have very similar transmission properties and were used interchangeably.

Cyan, magenta, yellow, and black rectangles were printed on HP Multipurpose paper with HP Deskjet inks using a 772C desktop printer. For each test,

the printed papers were hinged to archival mat board. A window mat was cut asymmetrically to cover one end of each rectangle. Strips approximately 1" wide of the three glazings were secured over the samples in the mat board package with binder clips. The exposed end of each rectangle was unglazed (See Figure 1).

Procedures

The visible reflectance of the area of each color strip under each glazing was measured at three locations with an abridged spectrometer before light exposures were initiated. During light exposures, reflectance measurements were made at lengthening time intervals over the course of several weeks, until significant appearance changes could easily be detected by eye in some of the exposed areas. The software that accompanied the abridged spectrometer was used to obtain CIE L*a*b* values and Delta E's for each of the measurements on all areas of the printed rectangles and the unprinted support.

To simulate display in a space with natural lighting, a set of ink samples was placed in a North-facing window. The Polycast clear, UF4 and OP-3 glazings were used in this test. The samples were left in the window for 47 days, and the total hours of sunlight were recorded.

Another set of samples was hung in a box mounted on the laboratory wall, and illuminated by a PAR38 incandescent flood lamp in a ceiling track fixture to simulate gallery light exposures. Polycast Clear, UF4, and OP-3 glazings were again used. The door of the box was closed during the day when laboratory lighting was on, and opened at night when the room lighting was off.

In an additional test under similar gallery lighting conditions, some of the same HP DeskJet inks were exposed to gallery light using Polycast clear, UF4, and UF5 glazings. The lighting was two Philips PAR38 tungsten-halogen flood lamps. The samples were hung in the same gallery box and dark periods were less frequent.

Illumination and near UV levels were measured before and occasionally during exposures with an Elsec 764 meter. The percentages of near UV transmitted by the glazings were originally calculated from the Elsec UV measurements of the North window light with each of the glazings in front of the meter's detector. Percentage transmissions were subsequently determined by Elsec measurements of the PAR38 tungsten-halogen lamps with and without the glazings in front of the meter.

Transmission spectra of the glazings were also obtained in the near UV and the visible using a Varian Cary 50 spectrophotometer with air as the blank. Reflection spectra of unexposed ink samples were obtained with the Cary 50 spectrophotometer also, using an optical fiber and a Barreliino attachment, with the unprinted support serving as blank. To obtain absorbance information, Kubelka-Munk transforms of these spectra in the near UV and visible were calculated with Varian Win-UV Scan software.

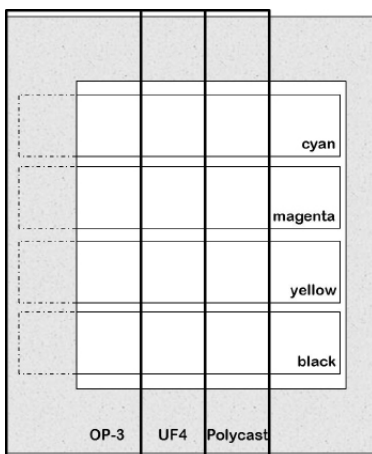


Figure 1. Diagram of mounted samples.

An Ocean Optics Jaz spectroradiometer was used to record the spectral irradiance of the PAR38 tungsten-halogen lamps and diffuse North window light in the visible and the near UV (325 – 400 nm), with and without the glazings in front of the instrument aperture. Radiometric and photometric quantities were calculated from these spectral data with Ocean Optics SpectraSuite software.

Results and Discussion

Some of the appearance changes observed during the exposures to PAR38 gallery lamps in the original and the repeated tests are shown in Figure 2. The standard deviations of the Delta E's were routinely less than 0.2 units for the black

and less than 0.5 units for the colored inks. The results were reproducible. The black ink is not altered by exposure to these lamps (Figure 2a). However, the appearances of all three colored inks – cyan, magenta, and yellow – were changed by the gallery light exposure.

Interestingly, the UV-blocking glazings did not appear to reduce the extent of the changes due to exposure to the PAR38 light (Figure 2). This result was independent of the amount of near UV removed by the different glazings (Table 1). The level of UV radiation was not high in these tests, but measurable with the Elsec meter. The observed behavior of the inks indicates that they were not sensitive to the UV radiation removed by the glazings, but they were sensitive to the longer wavelength visible light.

When the ink samples were exposed to diffuse daylight through a North facing window, the black ink was again observed to be stable (Figure 3). As expected due to the higher total light exposures, the colored inks underwent larger appearance changes than they did when exposed to gallery lighting. The UV-blocking glazings were somewhat effective in decreasing the extent of change in the cyan and magenta inks. The more near UV radiation blocked by the glazing, the lower the Delta E of these inks (Figure 3). The standard deviations of the measurements were typically less than 0.5 units.

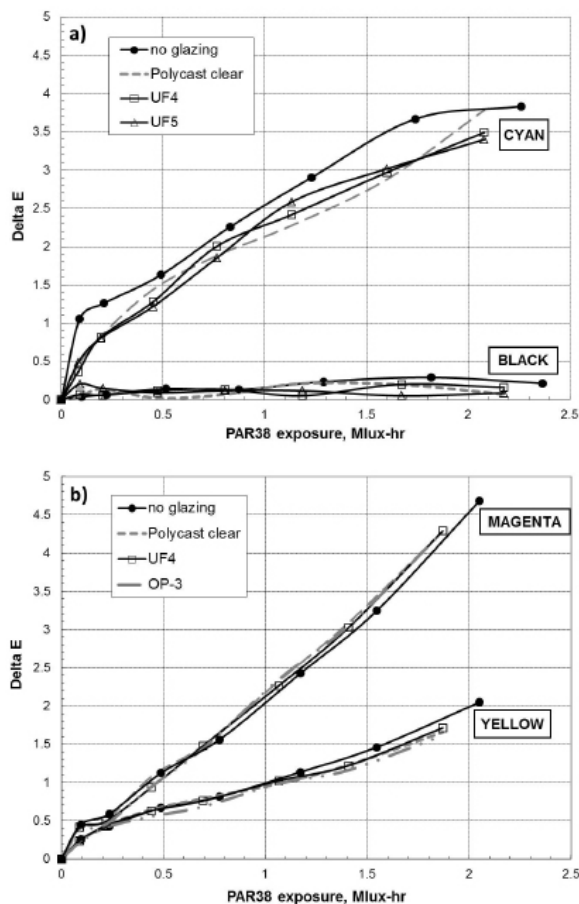


Figure 2. Change in appearance of inks exposed to PAR38 lamps directly or through glazings. SD's were ≤ 0.2 units for black and < 0.5 units for colored inks. a) Black and cyan, tungsten-halogen lamp; b) magenta and yellow, incandescent lamp.

Table 1. % Near UV radiation from different sources transmitted by glazings (Elsec 764 measurements).

Glazing	Tungsten-halogen PAR 38 lamp	Diffuse North window light
None	100	100
Polycast Clear	60	51
UF 4	4	6
OP-3	na	0.4
UF5	0.6	0.7

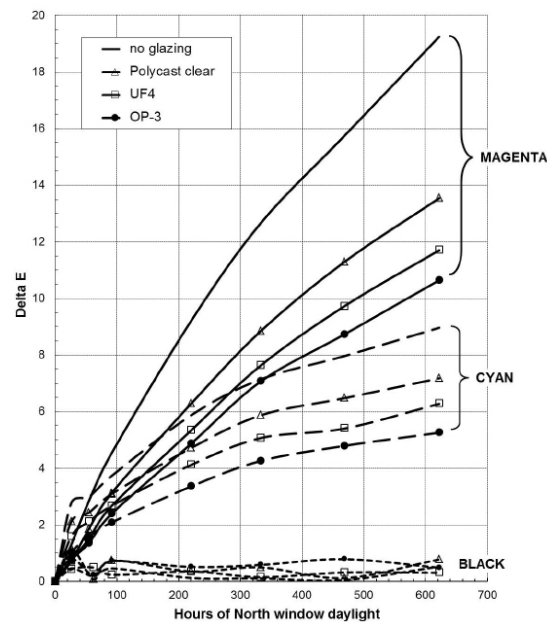


Figure 3. Change in appearance of black, cyan, and magenta inks exposed to North window light directly or through UV-blocking glazings. SD's were routinely ≤ 0.5 units.

Removal of UV radiation by the glazings did not appear to have a significant effect on the response of the yellow ink (data not shown). The standard deviations for some of these data were the order of one unit, probably due to uneven printing of the sample. However, the observed behavior of the yellow ink again suggested that it was more sensitive to the visible portion of North daylight than to the near UV.

Monitoring Radiation for Display of Objects – Do You Know the Whole Story Spectrum? continued

The Elsec measurements of near UV in the North daylight again indicated that the three glazings differed greatly in their UV blocking, by approximately order-of-magnitude steps in some cases (Table 1). Transmission spectra of the glazings obtained with the Cary 50 spectrophotometer confirmed these measurements, and showed that the shorter wavelength, i.e., the higher energy, UV radiation was blocked (Figure 4). The glazings differed in how far toward the longer wavelengths they began to transmit UV radiation – or blue light, in the case of UF5 and OP-3.

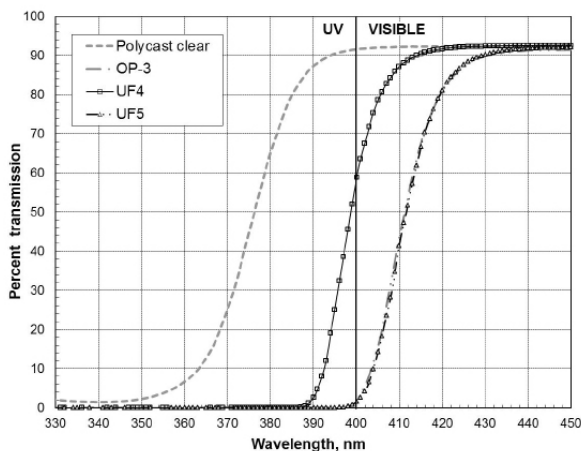


Figure 4. Transmission of glazings used in light exposure tests, measured with Cary 50 spectrophotometer using air as the blank.

Interestingly, although the UV blocking glazings did reduce appearance changes in the magenta and cyan inks caused by North window light, the measured amount of UV blocking did not correlate quantitatively with the observed decrease in appearance change. On the basis of the amount of UV blocked by the glazings, greater reduction in appearance change might have been expected. These results suggest instead that the photo-induced changes in the inks cannot be related directly to the near UV energy to which they were exposed.

Visible light (400 – 700 nm) caused major appearance changes in the colored inks in all the tests. The photometric measurements, in lux, indicated that all the glazings reduced the visible light in the PAR38 lamps and the North window to approximately the same extent. This observation was confirmed by the transmission spectra of the glazings, but only for wavelengths greater than 430 nm. The transmission measurements indicated that the different glazings had very different effects on blue light between 400 and 430 nm, a fact not revealed by the photometric measurements (in lux). In order to relate the observed changes in the inks to the radiation levels to which they were exposed additional, spectral, information on the inks and the light striking the samples is needed.

The normalized absorption spectra of the colored inks are shown in Figure 5. As expected, the cyan, magenta, and yellow ink absorbed broad bands of red, yellow and green, and blue light, respectively. However, the near UV

absorbances of the inks differ markedly: cyan absorbed relatively little, mostly at shorter wavelengths; the magenta absorbed strongly throughout the near UV, especially at shorter wavelengths, and some blue light; and the yellow absorbed the longer UV wavelengths very strongly. The lack of sensitivity of the yellow to changes in the near UV and blue radiation suggests that it has a very low probability of undergoing photo-induced change when it absorbs this radiation. The black ink is also highly absorbing in the near UV and throughout the visible (data not shown). The stability to light of the black ink suggests that it also has a very low probability of undergoing chemical reactions when it absorbs near UV and/or visible light.

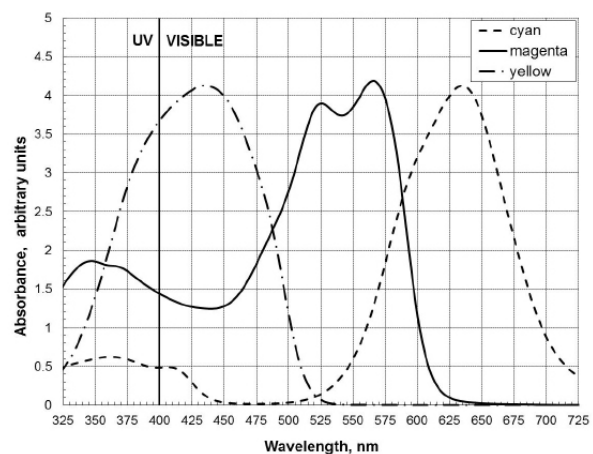


Figure 5. Normalized spectral absorbances of colored inks calculated from reflectance data using the Kubelka-Munk transform.

The near UV and visible spectral energy distributions of the PAR38 tungsten-halogen lamps and the diffuse North window daylight were measured with a Jaz spectroradiometer (Figures 6). The spectra are typical of

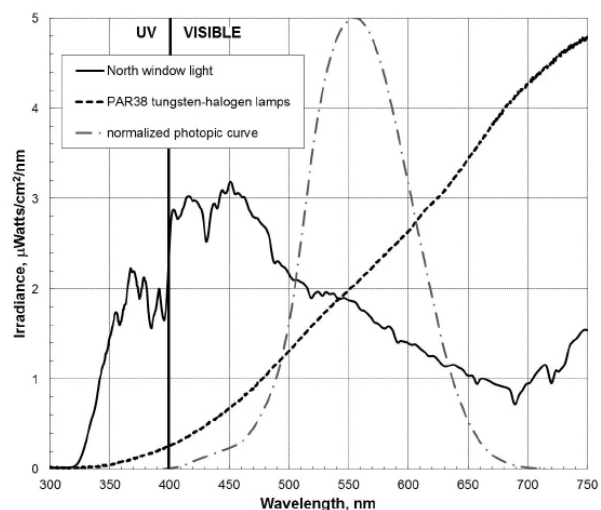


Figure 6. Spectral energy distribution of PAR38 tungsten-halogen gallery lamp light and North window daylight measured with Jaz spectroradiometer. The photopic curve, normalized to the scale of the graph, is shown for comparison.

Monitoring Radiation for Display of Objects – Do You Know the Whole Story Spectrum? continued

these types of lighting. Spectra of the light sources with each of the glazings directly in front of the aperture of the spectroradiometer were also measured. The results are shown in Figure 7a and 7b. All three glazings reduce the near UV radiation from both sources, as had been indicated by the Elsec meter. However, the spectral data show that the glazings differ in their effectiveness because they selectively block more of the shorter wavelength (that is, the higher energy) UV radiation.

Furthermore, the effects of the UF4 and, especially, UF5 glazings on the blue region of the spectrum between 400 and 430 nm are now clearly evident. The significant reductions in intensity of radiation in this wavelength range were not revealed by the photometric measurements recorded by the Elsec meter. Like all photometric instruments, its visible light detector is designed to respond to the part of the visible spectrum defined by the photopic curve, shown in Figure 6, i.e. only those wavelengths detected by the human eye (detector sensitivity information supplied by Littlemore Scientific, 2013). Also, the UV detector sensitivity falls significantly

above ca 380 nm (Littlemore Scientific), so it slightly underreports the longest wavelengths of near UV.

Comparison of the absorbance graphs for magenta and cyan ink in Figure 5 with the spectra of the light to which they were exposed (Figure 7) highlights the importance of having information on the spectral distribution in the near UV/blue region. The cyan ink absorbs very little blue light or the longest wavelength near UV radiation, but the magenta ink absorbs moderately strongly in both these wavelength bands.

Thus, the larger reduction in North daylight photo-induced fading of the magenta ink by the glazings could be due to the differences in the extent to which the blue and longest wavelengths of near UV (380 - 450 nm) were blocked. This is precisely the part of the spectrum not well characterized by meters designed for photometric measurements. Spectroradiometry was needed to provide the more detailed spectral information that led to a reasonable explanation of the behaviors observed.

Comments

The dictum: the shorter the wavelength of the light, the higher the probability of photo-induced appearance change, is not always applicable, as illustrated by the study described above. Removing UV radiation, although generally appropriate, need not be sufficient to significantly lengthen the display lifetime of light-sensitive materials. A much better understanding of suitable precautions to take can be achieved if more accurate damage functions for materials and the spectral energy distributions of light sources are available.

Investigators who have reported on damage functions for selected materials in the past have invariably emphasized that their data should not be over-generalized (e.g., Krochmann, 1988; Saunders and Kirby, 1996), but that message is not always heeded. This study has reinforced their message, while adding a few inkjet inks to the list of colorants previously investigated. Newer methods of assessing damage functions due to light exposure are now available (Whitmore, 2002); these techniques should be applied to many more materials.

To make better-informed decisions regarding light levels for exhibition, the spectral energy distributions of light sources should be obtained. For situations where the data are not available from the manufacturer, or the output of the source varies over time, (e.g., deterioration of the source (Rosenfeld, 2013); changes in daylight on a daily or seasonal basis), a spectroradiometer can be used for characterization and/or incorporated into a monitoring program. Contemporary radiometric instrumentation is becoming more compact, easier to use, and less expensive (ca \$6000). It is no longer out of the question to add spectroradiometry to the museum conservation toolbox.

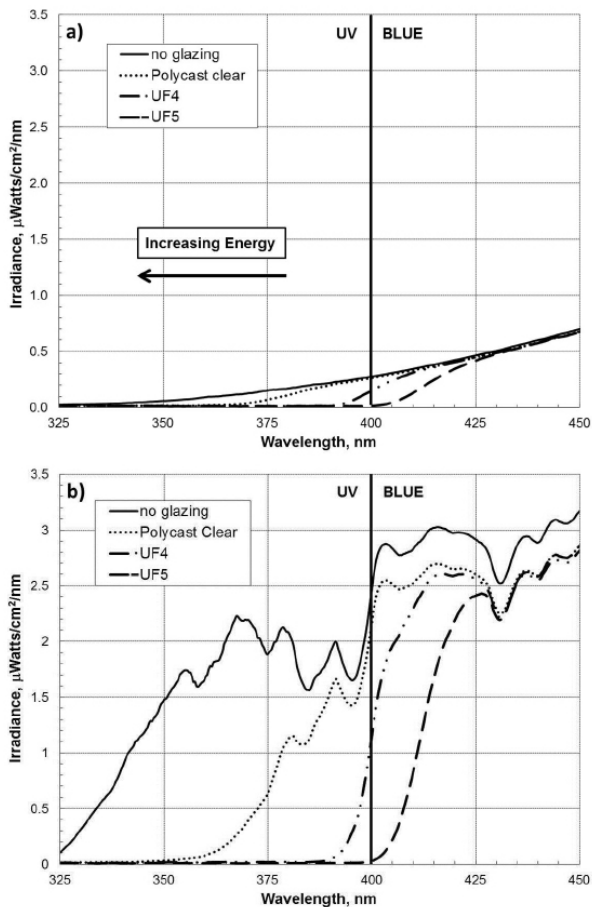


Figure 7. Effect of different glazings on: a) PAR38 tungsten-halogen lamp light, and b) diffuse North daylight through window glass. Averages of three measurements with Jaz spectroradiometer.

Monitoring Radiation for Display of Objects – Do You Know the Whole Story Spectrum? continued

Acknowledgements

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"Annenberg Foundation was Anonymous Bidder for Native American Artifacts," Los Angeles Times, 12/11/2013

The Annenberg Foundation has revealed that it was an anonymous bidder that paid \$530,000 for 24 Native American artifacts that were being sold at a controversial auction in Paris earlier this week.

The Los Angeles-based charitable organization headed by Wallis Annenberg said that it will return the artifacts to the Hopi Nation and to the San Carlos Apache tribe. Monday's auction in Paris drew international attention after U.S. officials attempted to postpone the sale of the 24 items, which included masks, dolls and other items.

A court in France had dismissed an effort by an attorney who represented the tribes to withdraw the items from the sale that was organized by Eve, a French auction house for antiques and art.

Smithsonian Asian Museums get \$1m to Fund Chinese Conservation," The Art Newspaper, 09/11/2013

The Smithsonian's museums of Asian art in Washington, DC, have received a \$1m conditional grant from the Mellon Foundation to endow the position of an assistant Chinese painting conservator. The grant will also help the Arthur M. Sackler Gallery and the Freer Gallery of Art continue a paid internship programme aimed at training the next generation of Chinese painting conservators.

The programme seeks to combat what Freer-Sackler officials see as a crisis in the field: only four senior Chinese painting conservators currently work at American museums and all of them are close to retirement, a museum spokeswoman says. The museums' conservation studio has trained 19 interns since its inception in 2000, some of whom went on to permanent positions at institutions including the Nelson-Atkins Museum in Kansas City and the National Palace Museum in Taipei. In its first year, the programme received more than 220 applicants from 22 countries for eight positions. Interns receive a stipend of \$45,000 for the year-long course.

"Saving Digital Art from an Early Death at the ZKM Museum," BBC News Technology, 10/21/2013

The ZKM Centre for Art and Media in Karlsruhe Germany has the world's largest collection of digital art, with over 500 pieces in its collection. It's also the global centre for digital art conservation.

It is a Herculean effort to keep their artworks running in their original form on computers often decades old. ZKM's staff try to find as much obsolete digital kit as possible. They trawl waste dumps and the auction site eBay in their quest for authenticity. As part of these efforts, they rent a warehouse outside the city where they store over 1,600 cathode ray TV sets, which are now out of production.

In an unlikely alliance, curators at ZKM foster connections with local dump managers who set aside old computers and audio visual machines in exchange for cigarettes. But keeping all of this obsolete equipment in storage is just a short-term solution. Bernhard Serexhe is the principal curator at ZKM's media museum and leader of a European Union funded