UV and Visible Light Filtering Window Films

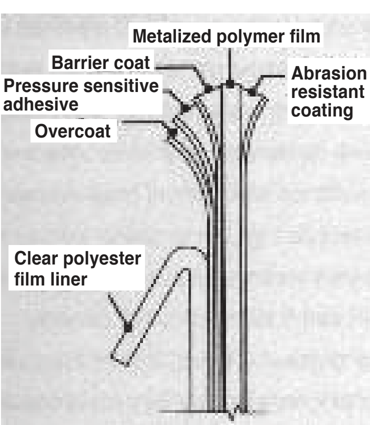
Introduction

UV-filtering window films are flexible films that adhere to glass and block ultraviolet and visible light to varying degrees. In the past decade there has been a great increase in the number of manufacturers producing these films and in the variety of films that are available. Films that filter mainly ultraviolet light are clear (usually with a slight yellowish cast when viewed on edge), while to filter visible light the film must be tinted or coated. The majority of films available now nearly eliminate ultraviolet radiation making the choice between suppliers more dependent on the options available and reputation of the supplier. Elimination of ultraviolet light is typically stated as 95-99% or better in the range of 200 to 380 nm. (The 380 to 400 nm range is often not included in the manufacturer's range and, therefore, not accounted for in their data.)

This report summarizes the evaluation of UV and visible light filtering films for possible use as part of the multi-tiered system for controlling natural light from the almost 250 windows and doors at the Winterthur Museum.

How UV-Filtering Window Films Work

Window films are typically laminated polyester film layers modified with material that absorbs, scatters, or reflects ultraviolet and visible light (see figs. 1 and 2). Most often films are impregnated with dyes or carbon particles or coated with a layer of magnetic sputter vapor deposited metal to accomplish the desired results. Metallic coatings, usually aluminum, reflect incident light, thereby reducing the transmission of UV and visible light. Metallic coatings also create a reflective mirror-like surface from the exterior that is usually deemed unacceptable for historic house museums.



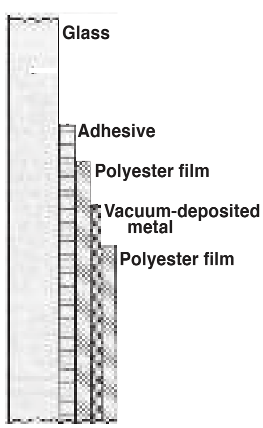


Figure 1 (left): Schematic diagram of a typical reflective solar control film. Films without vacuum-deposited metal layer often still have a lamellar structure. (Image from Horie.[1])

Figure 2 (right): Schematic diagram of the laminated structure of a 3MTM adhesive film. Image from 3MTM marketing information.

Non-metallic window films contain organic UV-absorbing compounds to prevent UV light from penetrating the window. Various organic molecules are capable of absorbing UV energy and converting it to heat, which is harmless to polymers. Although not harmful to the window film, the heat, when combined with the heat absorption of dark tinting, can be enough to stress glass and cause cracks and breakage.

The four most important groups of UV absorbing compounds (see fig. 3) include: hydroxyphenyl benzotriazoles; hydroxyphenyl-s-triazines; oxalanilides; and 2-hydroxybenzophenones. Of these compounds, the most widely used in polymers is 2-(2-hydroxyphenyl)-benzotriazole. Because the specific compound used is usually considered proprietary information, it is difficult to ascertain what compounds are present in contemporary products. The transmission curves for the known compounds (see fig. 4), however, explain why films often do not eliminate ultraviolet light in the 380-400 nm range.

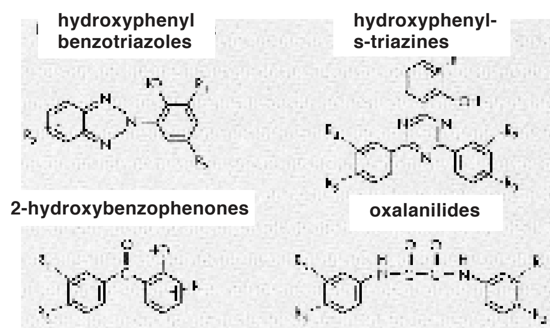


Figure 3: Structures of organic UV absorbing materials. (Image from Valet.[2])

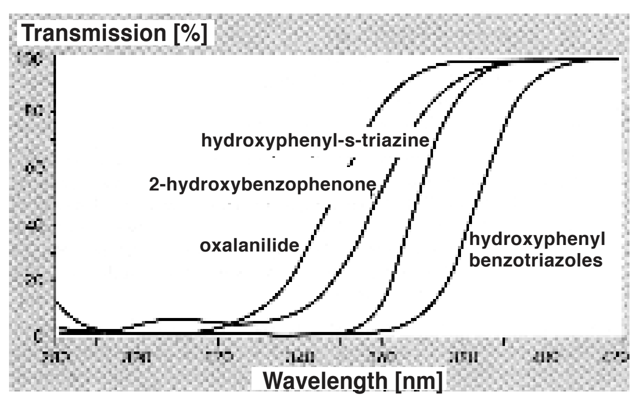


Figure 4: Transmission spectra of different UV-absorber groups. (Image from Valet.[2])

1. Horie, C. V. "Solar Control Films for Reducing Light Levels in Buildings with Daylight." in *Preprints of the Contributions to the Vienna Congress, 7-13 Sept. 1980: Conservation Within Historic Buildings*. Eds. N. S. Bromelle, Garry Thomson, and Perry Smith. 49-54. London: IIC, 1980.

2. Valet, Andreas. *Light Stabilizers for Paints*. Trans. M. S. Welling. Hannover: Vincentz Verlag, 1997.

by Samantha Springer

The base or film is most commonly polyester, or Mylar sheet, although acetate, and, less preferably, vinyl chloride have been used. The films come in different thicknesses, but the most common is 2 mils., with thicker films being used for security applications and as roller shades. As illustrated above, the films are often thinner layers laminated together to make the desired thickness. This type of construction adds to their strength. The UV absorbers can be built into the film base, coated on the film, or applied in the adhesive. The last two types of application are less desirable, because uniformity and quality is harder to control.

For the most part, window films are applied to the interior window surface. There are films made for exterior application, but they tend to be more expensive and guaranteed for about half the amount of time. This is because they are prone to peeling due to exposure to the elements. Interior films are generally guaranteed for 10-15 years. Some films are sold as do-it-yourself kits, but the majority of companies only offer a warranty with professional installation, because complete and even adhesion is so critical to their effectiveness.

The majority of films are installed by dissolving a water-soluble barrier over the adhesive with an aqueous solution (see fig. 2), applying the film to the glass, and then removing excess water and air bubbles with a squeegee. It can take from a week to a couple of months for the films to completely dry and harden. During this period the film bonds to the glass, becoming less reversible with time. Some 3M products are applied with a pressure sensitive adhesive, developed and made by the same company.

It is widely recommended that these types of films not be applied to old and historic glass, including crown glass, glass with a highly irregular surface, stained or dark colored glass, or glass with many air bubbles or inclusions. It can be difficult to achieve adequate adhesion to irregular surfaces, but even more significant is the issue of reversibility without damaging the glass.

Films can be removed with solvents, such as paint strippers, ammoniated solutions, or odorless thinners. The solvents required, however, have associated health hazards and can be damaging to historic paint or wood trim. Metal scrapers can also be used to remove the films; risk of scratching or breaking the glass, however, is usually high. In addition, tinted films can cause damage to the types of glass listed above, because of the heat gain.

To summarize, the pros and cons of window films are:

+ they come in a wide variety of options, increasing the probability of finding a suitable product to eliminate UV and a specific amount of visible light;

+ most films nearly eliminate ultraviolet light;

+ there are non-reflective/metallic options that can also reduce glare on the interior, making it easier for visitors to see inside;

+ they can be applied to interior windows, storm glass, or used as roller blinds;

+ they can be cut and fitted to each individual pane of glass, making them practically invisible from the interior and exterior;

+ the polyester film base is a stable and durable material;

+ they have the potential to last much longer than their guaranteed life of 10-15 years, however, no studies have been done on their aging properties;

+ there are a number of manufacturers and distributors to choose from;

+ most of the manufacturers have various local suppliers/installers;

+ in addition to limiting the transmission of visible and ultraviolet light, they provide safety features (e.g. reduced breakage in heavy storms) and reduce solar heat gain and heat loss, which can reduce energy costs.

- they are not easily removed;
- solubility of the adhesive decreases over time;
- they should not be applied to historic glass;
- they are only guaranteed for 10-15 years, which means replacement will be necessary, so these costs must be factored into the decision;
- due to the nature of the material, they often do not eliminate light in the 380-400 nm range of the ultraviolet spectrum, however, new evidence suggests that this is no longer the case;
- the long-term stability of the light absorbers in the films has not been tested extensively—it should be noted that the adhesive will likely fail before the UV absorbers—advances in adhesive technology, however, may change this in the future;
- heavily tinted films can cause irregular or excessive heat build-up, which may in turn cause cracks and breakage due to uneven expansion of the glass;
- windows with the films must be cleaned carefully to avoid scratching or causing cloudiness of the film—this could become problematic if they are only in a few areas and housekeeping crew are not reminded of their presence as they are different from the norm;
- manufacturers can change their product without warning, so it is always necessary to check that the product meets its specifications;
- manufacturers can go out of business, merge, or change their focus, making it necessary to reevaluate the products available, which can be time consuming and costly (this is particularly relevant with a product that only has a ten-year warrantee).

Evaluation of UV-Filtering Window Films

Two studies, Craft and Miller (2000) and National Park Service (NPS) (2001), have reported on the effectiveness of these types of films. Both studies measured the UV transmittance as a gauge of the film's efficacy. Craft and Miller measured the % transmittance and to which wavelength the filter was effective, while the NPS measured visible light in footcandles and ultraviolet in microwatts/lumen. These types of measurements can be taken with a handheld light meter by completely covering the sensor with the filtering material. This measurement can then be divided by the amount of light measured without the filter to obtain the % transmittance.

When evaluating the window films with this method several factors must be kept in mind. Fluorescent or tungsten light sources do not emit the same amount of energy throughout the spectrum as sunlight, which may affect the accuracy of the readings. In addition, light meters do not measure light evenly throughout the spectrum. For example, the UV meter used in this study has a high response to light around 310 nm and its response falls off below 380 nm (see fig. 5).

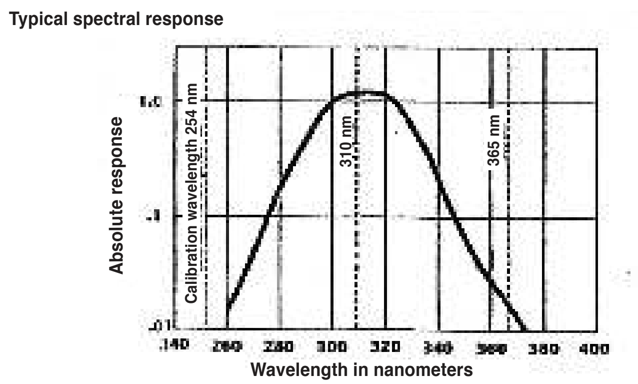


Figure 5: Spectral response curve of the UV-300 Ultraviolet Monitor meter. It has its greatest sensitivity at 310nm and does not measure in the infamous 380-400nm range. (Image from product literature.)

This indicates that readings are not comprehensive, because the meter is measuring mainly the wavelengths that the window films absorb. This is the most significant point of inaccuracy in this type of measurement.

Another method of measuring the absorbance, from which the transmittance can be calculated, is by using a UV/VIS spectrometer. The UV/VIS spectrometer provides data across the full spectrum of UV and visible light energy (200-800nm). Using this type of instrumentation would indicate regions of maximum and minimum absorption and how well the films absorb at each specific wavelength relative to one another. In addition, the spectra can be compared to roughly compare the films' effectiveness.

For this study, initial measurements were taken of the UV films to identify any egregious inconsistencies in the manufacturer's data. Afterwards, films that met the criteria for this project were evaluated with the UV/VIS spectrometer. Table 2 contains data collected from the window film samples obtained from various prospective suppliers. Visible light readings were taken with the Mannix DLM2000 Digital Light Meter in lux, and UV light readings were taken with the UV-300 Ultra Violet Monitor meter in mW/m2. All readings were taken in a room with overhead fluorescent and tungsten lights, and with some daylight through windows fitted with UV filters. The % transmittance and rejection were obtained by dividing the reading through the film by the control reading. The control was taken with the meter's sensor fully exposed to the ambient light.

The Vista, LLumar, and Madico films tested with the light meters were consistent with the manufacturer's specifications. Readings from the Global Window Films and 3M films indicated a discrepancy from the manufacturers ultraviolet light specs. The 3M films measured a % rejection of ultraviolet light between 30-99% for films that the manufacturer reported a 99% rejection. Some of the films from Global Window Films measured as low as 83% rejection for films that the manufacturer states a 98-99% rejection. Because of this amount of inconsistency these films were judged inadequate for the requirements of most museums.

The discrepancy could be due to the fact that the some of the ultraviolet absorbers are present in the adhesive, which was not on the film samples that were tested. However, even if there are additional UV absorbers in the adhesive, those films remain inadequate because that type of adhesive is undesirable. As was mentioned earlier, it is more desirable to have the UV absorbers dispersed through the film material. These results are also a reminder that the quality of any product should be tested periodically, for example, whenever a new order is placed.

Discrepancies also occurred in visible light % transmittance for all of the window films. This could be caused by a number of factors, such as: some manufacturers' specs are given for the film adhered to a pane of clear glass, while test readings were taken of the film alone; the manufacturer's specs could have been measured with a different type of meter; and a range of variation is accepted by manufactures of the films and the industry.

In actual use, the films are applied to a single pane of glass, so more accurate test readings could have been achieved by placing the film over glass. The sample films, however, were not received with any adhesive on them and testing them over glass without the adhesive would likely have produced greater inconsistency because of air trapped between the two materials.

The films that met the necessary criteria were then tested with the UV/VIS spectrometer for a more accurate evaluation. A representative sample of the resulting spectra are

Manufacturers Specifications versus Measured Readings

Manufacturer Film Name	Visible Light Manuf. Specs %T	 Measured Lux/ %T	UV Light Manuf. Specs % Rejected	 Measured mW/m2/ %Rejected	Notes
Clear Glass No Film	83	2330	N/A	30.0	
Control* No Film	100	2570	0	34.3	
Madico CLS-200-XSR Clear	77	2290/ 89	100 (<380 nm) 99 (380-400 nm)	0.02/ >99	Comes in a variety of thicknesses.
Madico Neutralux NG-20	13	270/ 11	99	0.05/ >99	
Madico Neutralux NG-35	36	910/ 35	99	0.32/ 99	
Madico Neutralux NG-50	43	1260/ 49	99	0.38/ 99	
Madico Neutralux NG-70	64	1864/ 73	99	0.55/ 98	
Madico Insulux SG-220	24	590/ 23	99	0.16/ >99	Possibly metallic appearance.
Madico Insulux SG-330	32	1063/ 41	99	0.33/ 99	
Madico Insulux SG-550	50	1480/ 58	99	0.32/ 99	
Madico Neutralite TSG-335	40	1513/ 59	99	0.32/ 99	
Madico Neutralite TSG-550	45	1260/ 49	99	0.03/ >99	
Madico Sunscape Designer Gray DG-35	38	966/ 38	>99	0.56/ 98	
Madico Sunscape Designer Gray DG-45	42	1219/ 47	>99	0.68/ 98	
Madico Sunscape Designer Gray DG-55	51	1340/ 52	>99	0.96/ 97	
LLumar UV CL-SR PS Clear	84	2280/ 91	99.9	0.02/ >99.9	
LLumar NUV SR PS4 Neutral	63	1850/ 72	99.9	0.00/>99.9	
LLumar N1065 SR CDF	71	1840/ 72	99	0.41/ 99	
LLumar N1050 SR CDF	50	1344/ 52	99	0.27/ 99	
LLumar N1040 SR CDF	41	1120/ 45	99	0.30/ 99	
LLumar N1020 SR CDF	24	640/ 25	99	0.10/ >99	
LLumar DR 35 SR CDF	36	1020/ 40	99	0.62/ 98	On double strength clear glass.
LLumar DR 25 SR CDF	22	743/ 29	99	0.56/ 98	On double strength clear glass.
LLumar DL-15 G SR CDF	16	414/ 16	99	0.06/ >99	
Vista Window Film Celeste (V-18 SR CDF)	18.0	534/ 21	99.9	0.01/ >99	
Vista Window Film Luminance (V-28 SR CDF)	27.0	788/ 31	99.9	0.03/ >99	Possibly metallic appearance.
Vista Window Film Soft Horizons (V-33 SR CDF)	33.0	880/ 34	99.9	0.01/ >99	
Vista Window Film Mirage (V-38 SR CDF)	37.0	970/ 38	99.9	0.03/ >99	
Vista Window Film Dayview (V-45 SR CDF)	45.0	1176/ 46	99.9	0.03/ >99	
Vista Window Film Crystal Elegance (V58 SR CDF)	58	N/A	99.9	N/A	

Manufacturers Specifications versus Measured Readings

Manufacturer Film Name	Visible Light Manuf. Specs %T	 Measured Lux/ %T	UV Light Manuf. Specs % Rejected	 Measured mW/m2/ %Rejected	Notes
3MScotchshield SCLARL400	86	2220/ 86	98	24.2/ 30	All films applied with pressure sensitive
3M Scotchshield S50NEAR400	51	1320/ 51	99	14.89/ 56	adhesive which may account for the
3M Scotchshield S35NEAR400	37	943/ 37	99	9.02/ 74	discrepancy in UV transmittance.
3M Scotchtint HP PNTHR50 Light	56	1400/ 54	99	0.33/ 99	
3M Scotchtint HP PNTHR35 Medium	37	958/ 37	99	0.30/ 99	These films had up to 68% difference
3M Scotchtint Sun Control RE70NEARL	66	1780/ 69	98	21.4/ 38	between the measured values and
3M Scotchtint Sun Control RE50NEARL	51	1401/ 54	98	17.4/ 49	manufacturer's specs.
3M Scotchtint Sun Control RE35NEARL Medium	37	986/ 38	99	12.5/ 64	
3M Scotchtint Sun Control RE20NEARL	16	430/ 17	99	4.3/ 87	
3M Scotchtint Sun Control NV-35	35	914/ 36	99	10.1/ 71	
3M Scotchtint Sun Control NV-25	24	670/ 26	99	7.2/ 79 .	Appears slightly metallic.
Control** No Film	100	2510	0	33.8	
Global Window Films UV Clear	89	2290/ 91	99	0.06/ 99.9	These films had up to 17% difference
Global Window Films Sungate Crystal 50	52	1480/ 59	99	1.21/ 96	between the measured values and
Global Window Films Sungate Crystal 35	42	1160/ 46	99	1.09/ 97	manufacturer's specs.
Global Window Films Sungate Crystal 20	21	580/ 23	99	5.05/ 85	
Global Window Films Sungate Alox 50	55	1440/ 57	99	1.24/ 96	
Global Window Films Sungate Alox 35	36	1147/ 46	99	0.90/ 97	
Global Window Films Sungate Alox 20	25	754/ 30	99	5.68/ 83	
Global Window Films Estate Neutral 65	63	1717/ 68	99	1.15/ 97	
Global Window Films Estate Neutral 50	50	1497/ 60	99	0.99/ 97	
Global Window Films Estate Neutral 35	37	1035/ 41	99	0.92/ 97	
Global Window Films Estate Neutral 20	21	675/ 27	99	0.53/ 98	
Global Window Films Estate Dual Reflective 40	40	1108/ 44	99	0.93/ 97	
Global Window Films Estate Dual Reflective 30	29	839/ 33	99	0.68/ 98	
Global Window Films Estate Dual Reflective 20	16	508/ 20	99	0.37/ 99	

* This control reading was used to calculate the % transmittance and rejection for all films, except those from Global Window Films. The measurements were all taken within a two hour period of the control.

** This control reading was used to calculate the % transmittance and rejection for the Global Window Films. The readings were all taken within one hour of the control.

given in Appendix B. (For the results of all tests, please contact the auhor.) These films were:

Madico CLS-200-XSR Clear,
Madico Neutralux NG-20,
Madico Neutralux NG-70,
Madico Neutralux NG-35,
Madico Insulux SG-330,
LLumar Clear UV CL-SR PS Clear,
LLumar N1065 SR CDF,
LLumar DL-15 G SR CDF,
LLumar DR 25 SR CDF,
LLumar N1020 SR CDF.

The Vista films were not tested, because they did not have enough options to meet the visible light transmittance criteria.

Most of the films had a similar absorbance pattern with an even absorbance through the visible region, a spike around 400 nm, and then a drop around 300 nm. This information indicates that previously reported problems with lack of absorption in the 380-400nm range have been remedied. In addition, it should be noted that clear glass absorbs UV in the 200-300 nm range, making it unnecessary for the films to absorb as intensely in this range as they do in the 300-400 nm range. Two of the LLumar films did absorb the light evenly through the visible region. This indicates that they are not truly a neutral grey color. In fact, they appeared slightly bronze to the author, although they are advertised as neutral.

Summary and Recommendations

The evaluation of the window films established that several of the manufacturers produce suitable films for application in a museum. The 3M and Global Window films were found to be below the acceptable standards; in both cases the measured % rejected ultraviolet was well below the manufacturers specifications and museum requirements of 99%. Looking at other criteria, the remaining manufacturers appear somewhat equal. Of the remaining, both Madico and LLumar make a broad enough variety of films to match the required tinting strengths necessary at Winterthur.

Conservators at the Freer and Sackler Galleries and the Colonial Williamsburg Foundation and the director of operations at the Delaware Art Museum were consulted about window films that were recently installed at each of their respective museums. In each case, the films were applied to modern glass and only one type of film was needed. A Madico product was used at the Freer and Sackler Gallery, a LLumar product at the Colonial Williamsburg Foundation, and a Vista product at the Delaware Art Museum. In each of these cases, the museums had different criteria to be met than those at Winterthur.

The films that matched the criteria for the needs at Winterthur were tested with the UV/VIS spectrometer. The results from these tests found all of the films to have adequate absorption in the UV range. Two of the LLumar films, DL-15 G SR CDF and DR 25 SR CDF, were found not to be truly neutral in color. On the comparison spectra the Madico films appear to slightly outperform the LLumar products. The testing carried out in this study has shown that there has been a significant improvement in the manufacturing of UV and visible light filtering window films. With the appropriate evaluation methods it is possible to choose the best product available and avoid the previous disadvantage of films not eliminating UV light from the 380-400 nm range. However, many of the previous pros and cons still exist for deciding whether or not window films are appropriate for use in a particular situation. The overall benefits and disadvantages to window films must always be taken into consideration before choosing them as the solution to mitigating the effects of natural light.

[The recommendations made in this report were made with the information available at the time. A study on the long-term aging properties of the adhesives and UV absorbers used with the films would improve these recommendations.]

Appendix A: Window Film Suppliers

Express Window Films
East coast supplier of Global Express Window Films
82 Mill Plain Road
Danbury, CT 06811
Phone: (800)345-6669
Fax: (203)798-2253
www.filmnow.com

3M™ Scotchtint™ and Scotchshield™ Window Films
Manufacturer of 3M product
Specified Construction Products Dept.
3M Center, Building 207-1W-08 or 225-4S-08
St. Paul, MN 55144-1000
www.3m.com
http://solutions.3m.com/wps/portal/3M/en_US/WF/3MWindowFilms?redirectName=www.3m.com/windowfilm

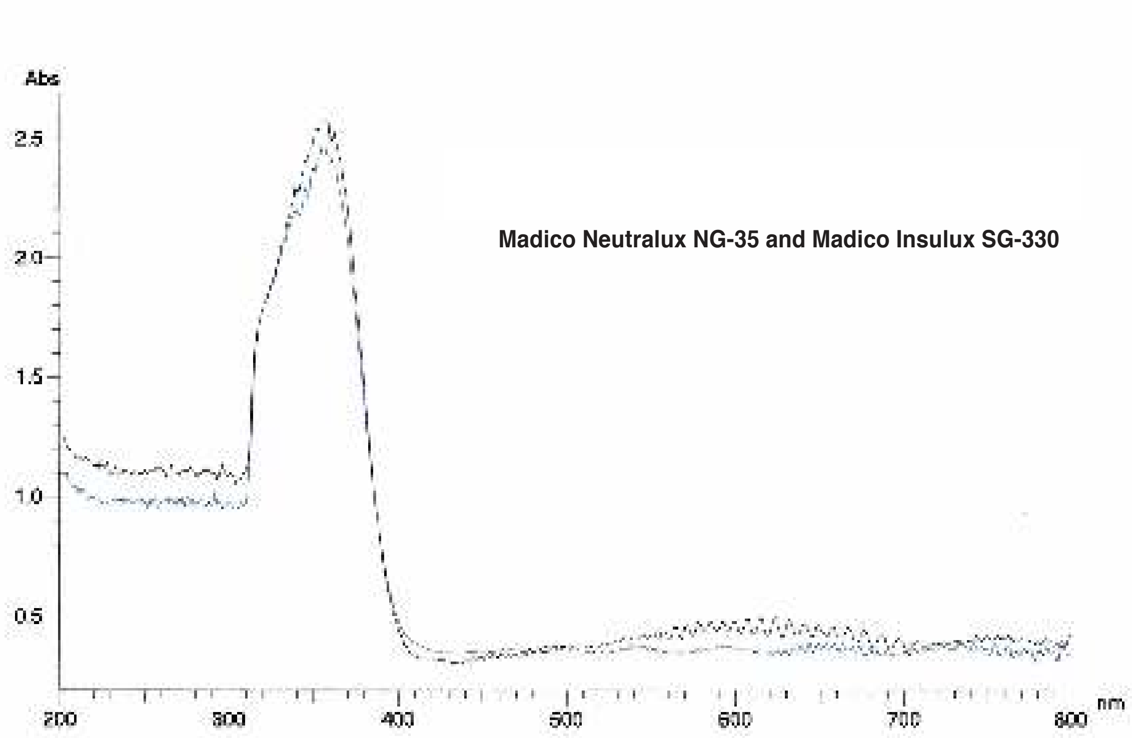
Madico Window Film
Manufacturer of Madico product
Madico, Inc.
64 Industrial Parkway
P.O.Box 4023
Woburn, MA 01801
Phone: (800)225-1926
Fax: (781)935-6841
www.madico.com

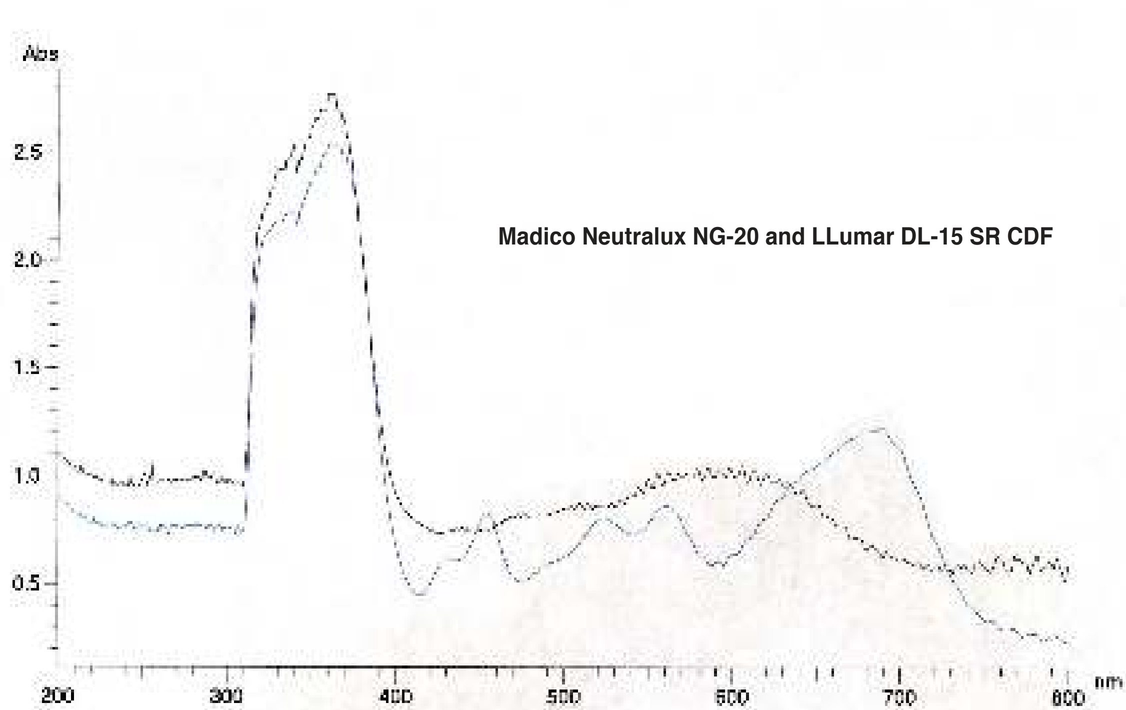
CPFilms Inc. (subsidiary of Solutia)
Manufacturer of LLumar, Gila, Vista Window Films (Gila is a self-installation product)
Corporate Headquarters:
CPFilms Inc.
PO Box 5068
Martinsville, VA 24115
Phone: (276)627-3000
Fax: (276)627-3032
www.cpfilms.com

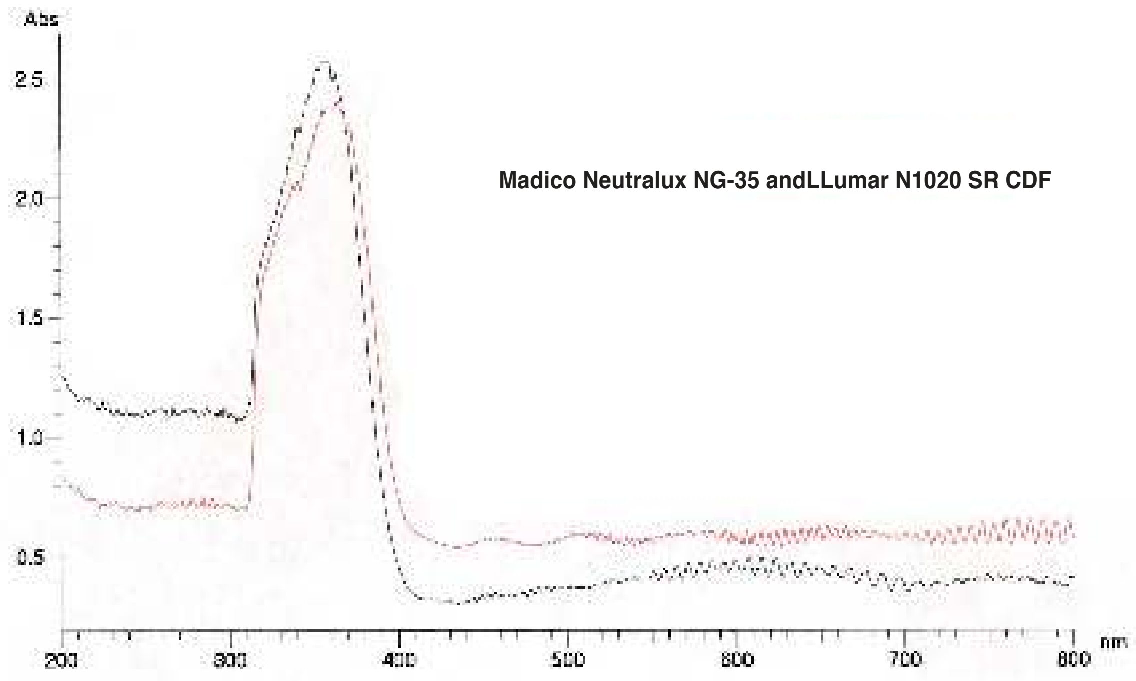
The spectra for all films tested with the UV/VIS spectrometer and an extensive annotated bibliography are available from the author at samkspringer@aol.com.

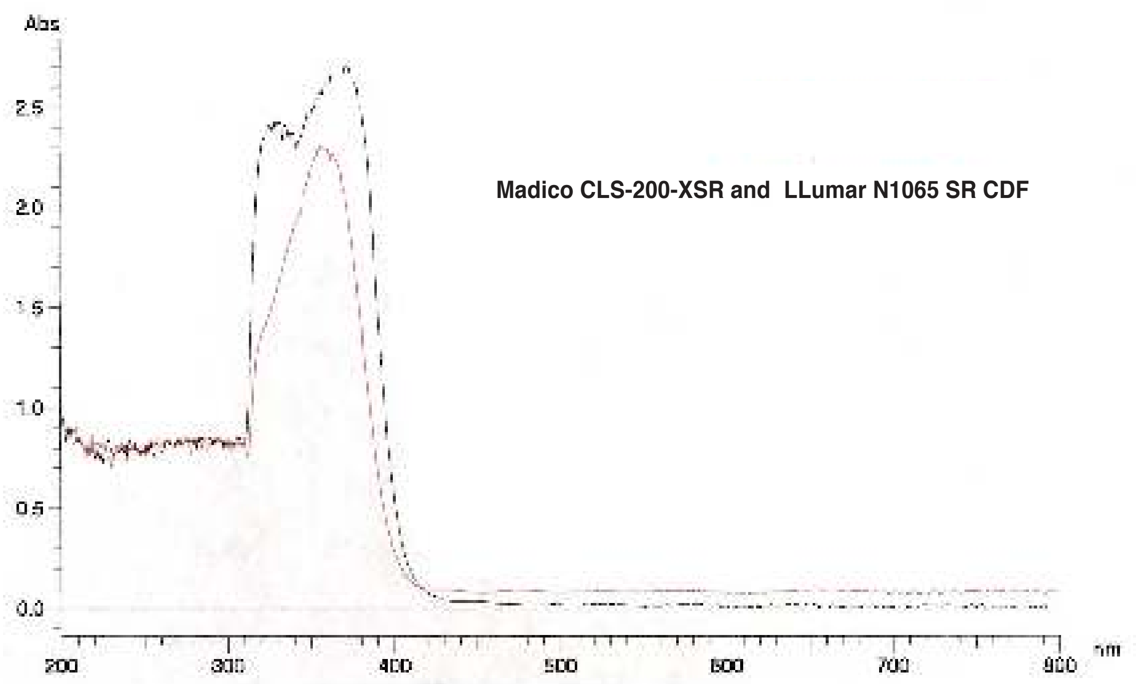
UV and Visible Light Filtering Window Films, continued

Appendix B: Results of Tests with UV/VIS Spectrometer






Abs
2.5
2.0
1.5
1.0
0.5
Madico Neutralux NG-35 andLLumar N1020 SR CDF
200
300
400
500
600
700
800
nm


Abs
2.5
2.0
1.5
1.0
0.5
0.0
Madico CLS-200-XSR and LLumar N1065 SR CDF
200
300
400
500
600
700
800
nm