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UV-Vis Spectrophotometer UV-2600i Plus

Application News

Using UV-2600i Plus to Evaluate Ultraviolet-Degraded Plastics Based on the Hazen Color Scale

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User Benefits

- The yellowing of plastics due to UV-light degradation can be quantified based on the Hazen color scale.
- The spectral assessment feature in LabSolutions™ UV-Vis Color gives users a simple method for evaluating samples based on the Hazen color scale.

■ Introduction

Because of their excellent workability and lightweight, plastics are used in many industrial products, such as automobile components and packaging materials. However, aging and exposure to UV light, rain, and heat can degrade plastics, reducing their strength and affecting their appearance.

This Application News describes using a UV-Vis spectrophotometer to measure the color of plastics degraded by UV light and evaluate the color changes based on the Hazen color scale. Two highly transparent plastics were used for this analysis: polycarbonate (PC) and polyethylene terephthalate (PET). The Hazen color scale, also called the APHA scale and the platinum-cobalt scale, is used to evaluate materials based on their colors, from colorless or transparent to yellowish.

■ Samples

Samples were prepared by irradiating flat blocks of PC and PET with UV light for up to 30 hours (equivalent to approximately 7 months of UV light exposure) in an accelerated weathering testing machine (Iwasaki Electric Co., Ltd.). The samples used are shown in Fig. 1 and Fig. 2. The samples became increasingly yellow with longer exposure to UV light, with PET turning a more intense shade than PC.

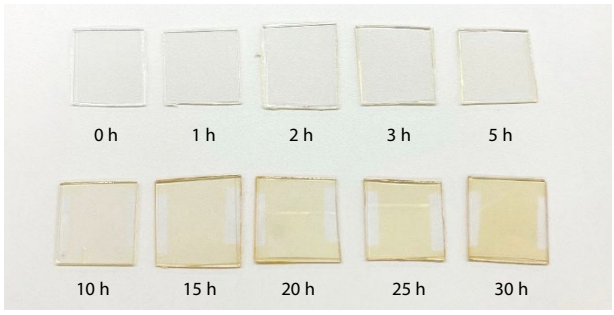

Fig. 1 Polycarbonate (PC) Irradiated with UV Light
(Numbers in image show duration of UV irradiation.)

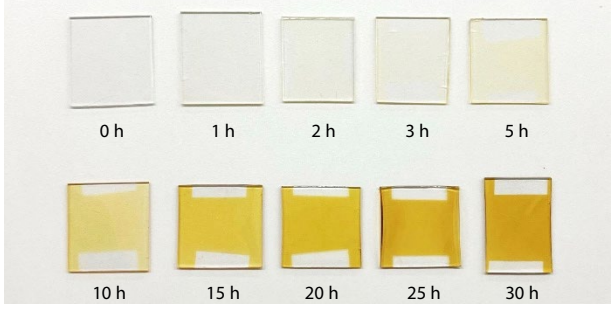

Fig. 2 Polyethylene Terephthalate (PET) Irradiated with UV Light
(Numbers in image show duration of UV irradiation.)

■ Measuring Total UV Transmittance of UV-Degraded PC and PET

Because the yellowing of the PC and PET samples caused by UV irradiation also caused some clouding of the samples, total UV transmittance was measured with an integrating sphere. If a sample creates a large amount of scattering, its total transmittance spectrum can be measured by attaching the ISR-2600Plus integrating sphere to the UV-2600i Plus (Fig. 3) and installing the samples at the entrance to the integrating sphere. After obtaining baseline measurements with no sample, the samples were installed and measurements were taken under the conditions shown in Table 1. The measurements taken are shown in Figs. 4 and 5.

Fig. 3 UV-2600i Plus

Table 1 Total Transmission Spectrum Measurement Conditions

Equipment:	UV-2600i Plus ISR-2600Plus
Measured Wavelength Range:	380 to 780 nm
Sampling Interval:	1.0 nm
Scanning Speed:	Medium
Slit Width:	5.0 nm

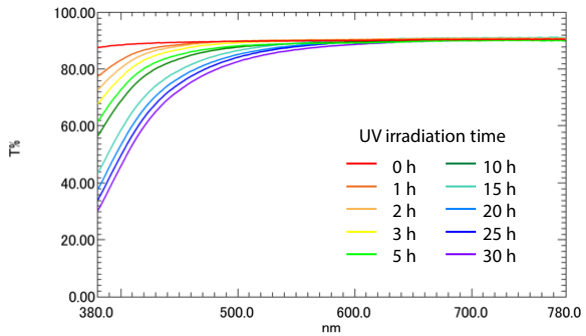

Fig. 4 Total Transmittance Spectra of UV-Degraded PC

The transmittance of unirradiated PC (0 h) was almost constant across all wavelengths (Fig. 4). Irradiating PC with UV light reduced transmittance at shorter wavelengths below 600 nm, and 30 hours of UV irradiation reduced transmittance at 380 nm to around 30 % of its original value.

The transmittance spectra measurements also show the longer the duration of UV irradiation the more yellow the PC sample becomes.

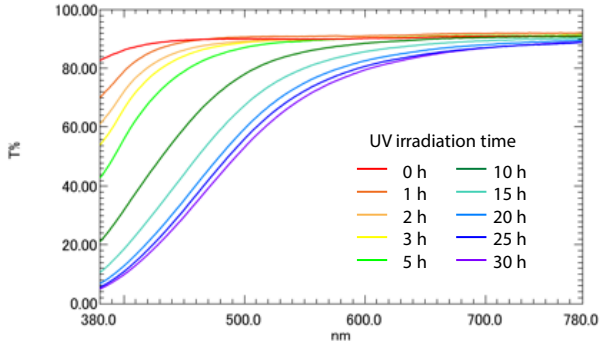

Fig. 5 Total Transmittance Spectra of UV-Degraded PET

Similar to PC, Fig. 5 shows the longer PET is irradiated with UV light the greater the loss of transmittance.

Fig. 6 shows an overlay of the total transmittance spectra of the PC and PET samples after 0, 10, 15, and 30 hours of UV irradiation. Comparing unirradiated (0 h) PC (solid red line) and unirradiated (0 h) PET (dashed red line) reveals that at wavelengths below 450 nm, PC transmittance was higher than PET transmittance, indicating that PC is a more transparent material. Also, while unirradiated PC and PET transmittance was almost identical at wavelengths above 450 nm, PET transmittance was lower than PC transmittance after an equivalent length of UV irradiation, and the irradiation had a greater yellowing effect on PET than PC.

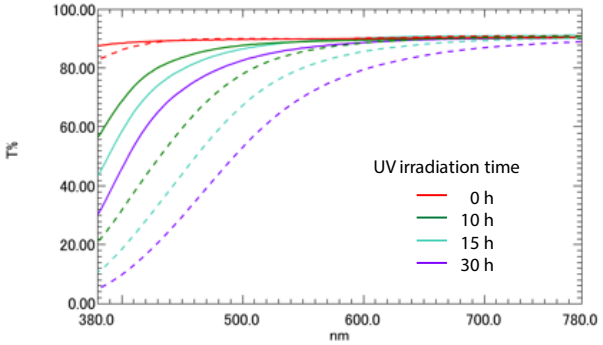

Fig. 6 Comparing Total Transmittance Spectra of UV-Degraded PC and PET
Solid Lines: PC, Dashed Lines: PET

■ Hazen Scale-Based Evaluation of UV-Degraded Plastics

LabSolutions UV-Vis Color, an optional software product for LabSolutions UV-Vis, can calculate Hazen unit values. Information on configuring advanced settings in the software to calculate Hazen unit values can be found in Application News No. 01-00834-EN.

The total transmittance spectra of the PC and PET samples were used to calculate Hazen unit values and the samples were evaluated based on these values. The Hazen unit values calculated from the spectra are shown in Tables 2 and 3.

Table 2 Hazen Unit Values Calculated for UV-Degraded PC

File Name	Hazen scale Value
PC_0h.vspd	2.038
PC_1h.vspd	6.387
PC_2h.vspd	9.334
PC_3h.vspd	13.033
PC_5h.vspd	17.075
PC_10h.vspd	24.192
PC_15h.vspd	43.611
PC_20h.vspd	52.944
PC_25h.vspd	61.264
PC_30h.vspd	68.562

Table 3 Hazen Unit Values Calculated for UV-Degraded PET

File Name	Hazen scale Value
PET_0h.vspd	2.305
PET_1h.vspd	9.002
PET_2h.vspd	16.694
PET_3h.vspd	25.220
PET_5h.vspd	46.237
PET_10h.vspd	127.591
PET_15h.vspd	210.888
PET_20h.vspd	270.964
PET_25h.vspd	295.726
PET_30h.vspd	317.631

Fig. 9 shows the relationship between the Hazen unit values in Tables 2 and 3 and the UV irradiation time.

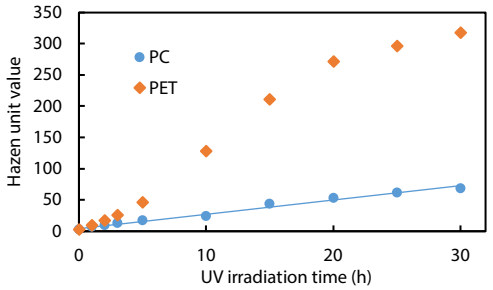

Fig. 9 Hazen Scale-Based Evaluation of UV-Degraded PC and PET

The Hazen unit values for PET increased faster with UV irradiation time than for PC, indicating that PET is more susceptible to UV degradation. Also, while the increase in Hazen unit values with UV irradiation time was almost entirely linear for PC, for PET the increase in Hazen unit values slowed from 20 hours onward.

■ Conclusion

Hazen unit values were calculated for the yellowing caused by UV irradiation of two highly transparent plastics (PC and PET). The relationship between these Hazen unit values and the duration of UV irradiation showed that PET was degraded by UV light more quickly than PC.

LabSolutions UV-Vis Color includes a calibration curve for calculating Hazen unit values, allowing the user to calculate Hazen unit values simply by measuring sample transmittance and without needing to measure the transmittance of numerous standard samples.

Finally, while standards such as ISO 6271:2015[1], ASTM D1209-05(2019)[2], and JIS K0071-1:2017[3] include criteria related to the Hazen scale, when evaluating a material based on any of these or similar standards, verifying that these standards are the latest versions of those standards is recommended.

<References>

1. ISO 6271:2015 Clear liquids — Estimation of colour by the platinum-cobalt colour scale
2. JIS K0071-1:2017 Test methods for colour of chemical products—Part 1: Estimation of colour in Hazen units (platinum-cobalt colour scale)
3. ASTM D1209-05(2019) Standard Test Method for Color of Clear Liquids (Platinum-Cobalt Scale)

<Related Application News Articles>

1. Using UV-1900i Plus to Evaluate Raw Materials for Chemical Products Based on the Hazen Color Scale
   Application News No. 01-00834-EN
2. Analysis of Ultraviolet-Degraded Plastic by Plastic Analyzer
   Application News No. A647

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