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Application News

No.A525A

Spectrophotometric Analysis

Haze Evaluation of Plastic Sheets and Films – Haze Measurement Using ISR-1503 Integrating Sphere Attachment –

Plastics are broadly grouped into thermosetting plastics and thermoplastics, and thermoplastics are further grouped based on properties such as heat resistance and mechanical strength. Apart from these mechanical and thermal properties are the optical properties of plastics that include transmittance, reflectance, and haze. Haze refers to the proportion of diffuse transmittance to total transmittance, and is used to evaluate material surface treatment (roughness and matte). Materials used for solar cells may also have a periodic structure (textured structure) on their surface to increase dispersion and contain light. Measuring the haze of plastic materials is defined by international standard ISO 14782, while the same content is reproduced in Japanese Industrial Standard (JIS) K 7136.[1), 2)] This article describes analyzing plastics of different properties using Shimadzu UV-3600 Plus UV-VIS-NIR spectrophotometer with ISR-1503 integrating sphere attachment to calculate their haze and solar transmittance.

ISR-1503 Optical System and Haze Measurement

Fig. 1 shows the UV-3600 Plus and ISR-1503. Fig. 2 shows the ISR-1503 optical system. The optical system of the ISR-1503 is designed to enable horizontal sample placement when measuring transmittance/0 degree reflectance to allow measurement of film and tapered samples without special immobilization. Fig. 3 shows the method used to measure total transmittance and diffuse transmittance, which are properties used to calculate haze. Total transmittance is determined by measuring both light transmitted straight through the sample and light diffused inside the sample. Diffuse transmittance is determined by measuring only diffuse light after removing the standard white board from the integrating sphere, as shown by the bottom image in Fig. 3. τ_1 and τ_2 in JIS K 7136 correspond to measured total transmittance[Note 1] (τ_1 being 100 % transmittance without sample placement). τ_3 and τ_4 correspond to measured diffuse transmittance[Note 1] (τ_3 being almost 0 % transmittance without sample placement). Haze is defined as the ratio of diffuse transmittance to total transmittance, and can be calculated with the following equation. Haze (%) = [(τ_4/ τ_2) - (τ_3 / τ_1)] × 100

Fig. 1 UV-3600 Plus with ISR-1503 Installed

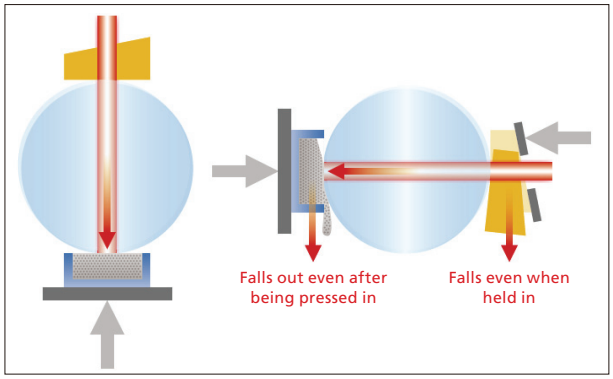

Fig. 2 Left: Optical System of ISR-1503, Right: Optical System of Conventional Integrating Sphere (Lateral View of Integrating Sphere)

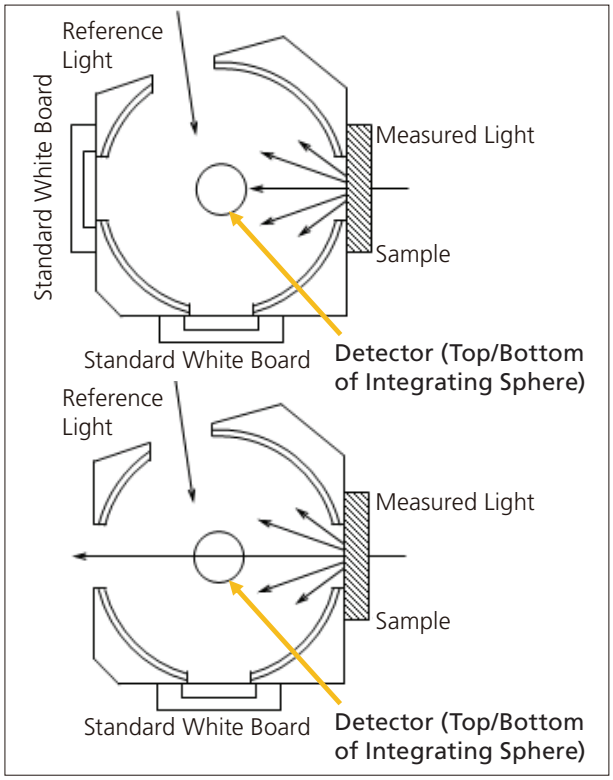

Fig. 3 Top: Total Transmittance Measurement (Corresponds to τ_2 Measurement Method from JIS K 7136) Bottom: Diffuse Transmittance Measurement (Corresponds to τ_4 Measurement Method from JIS K 7136)

Sample Spectra Measurement

Fig. 4 shows the plastics of different materials with different surface treatments that were analyzed. Samples No. 1 to 5 are sheets of approximately 2 to 3 mm thickness. Samples No. 1 to 3 are made of polymethyl methacrylate (PMMA), No. 2 has a matte treatment, and No. 3 has a textured structure in a striped pattern. No. 4 is made from polyethylene terephthalate (PET), and No. 5 is made from polyvinyl chloride (PVC). No. 6 and 7 are films of approximately 0.3 mm thickness and made from PVC with a plasticizing agent additive (phthalate ester). No. 7 has been given a surface treatment. No. 8 and 9 are films of approximately 0.03 mm thickness. No. 8 is made from polypropylene (PP) and No. 9 is made from polyethylene (PE). Samples were cut to sizes allowing their analysis with the ISR-1503 (maximum dimensions of W176 × D168 × T20 mm), and analyzed using the conditions shown in Table 1.

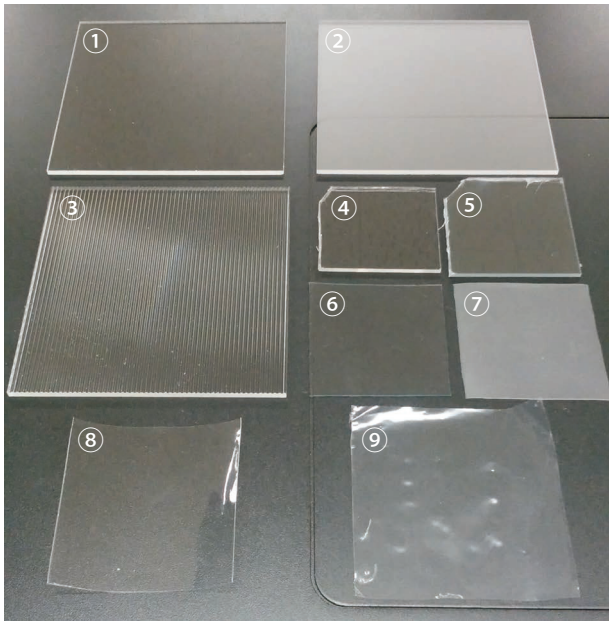

Fig. 4 Plastics of Different Materials and Surface Treatments
1: PMMA (Clear), 2: PMMA (Matte), 3: PMMA (Textured), 4: PET, 5: PVC, 6: PVC (Clear), 7: PVC (Surface Treated), 8: PP, 9: PE

Table 1 Measurement Conditions

Instruments Used	: UV-3600 Plus and ISR-1503
Measurement Wavelength Range	: 200 nm to 2500 nm
Scanning Speed	: Intermediate
Sampling Pitch	: 1.0 nm
Photometric Value	: Transmittance
Slit Width	: (20) nm
Light Source Switching Wavelength	: 290 nm
Detector Unit	: External (3 Detectors)
Detector Switching Wavelength	: 870 nm/1650 nm
Grating Switching Wavelength	: 850 nm
S/R Changeover	: Reverse
Stair Correction	: Effective

Fig. 5 shows the total transmittance spectra and diffuse transmittance spectra of samples No. 1 to 3. Samples No. 1 to 3 are all made of PMMA. The total transmittance spectra show all samples with around 90 % transmittance at long wavelengths above 400 nm. The diffuse transmittance spectra show around 40 % transmittance for the matte treatment sample (No. 2) and around 70 % transmittance for the textured structure sample (No. 3). This shows the surface treatment of samples results in light diffusion.
Fig. 6 shows total transmittance spectra in the range 200 to 2500 nm. The results show that PMMA absorbed light at long wavelengths above 1000 nm. Samples No. 1 to 3 show absorption at almost the same wavelengths since they are made of the same material.

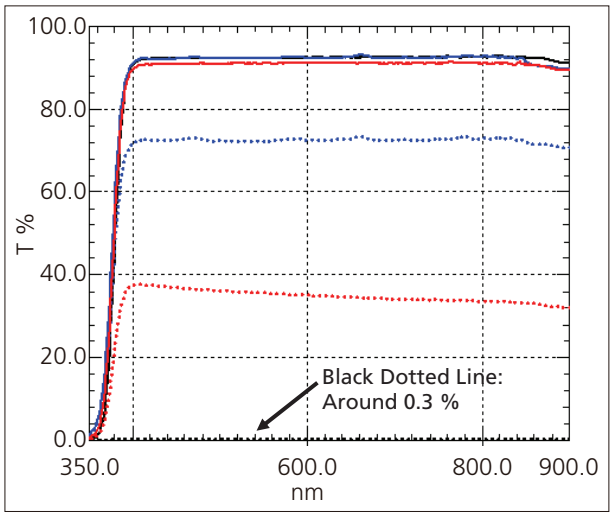

Fig. 5 Solid Lines: Total Transmittance, Dotted Lines: Diffuse Transmittance (PMMA) Black: No. 1 Clear, Red: No. 2 Matte, Blue: No. 3 Textured

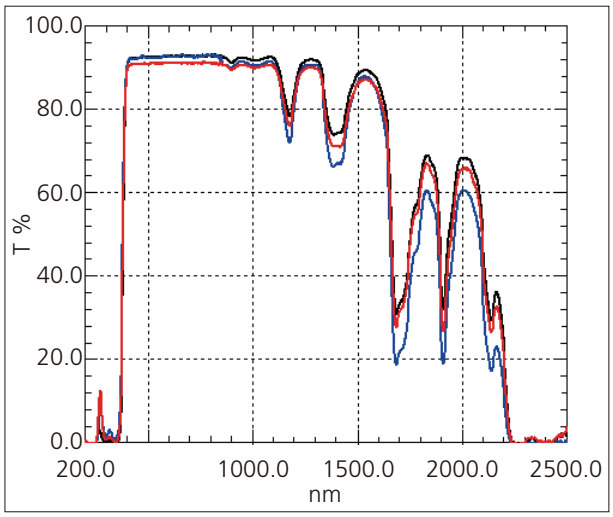

Fig. 6 Total Transmittance Spectra (PMMA) Black: No. 1 Clear, Red: No. 2 Matte, Blue: No. 3 Textured

Fig. 7 shows the total transmittance spectra and diffuse transmittance spectra of samples No. 5 to 7. The main material used in samples No. 5 to 7 is PVC. The total transmittance spectra show film samples with around 90 % transmittance at long wavelengths larger than 400 nm. The sheet samples were shown to absorb light at around 600 nm. The diffuse transmittance spectra show evidence of light diffusion for surface treated sample No. 7, with around 40 % transmittance.
Fig. 8 shows total transmittance spectra in the range 200 to 2500 nm. The results show samples of the same material absorbed light at almost identical wavelengths, and the degree of absorption differed depending on sample thickness.

Fig. 9 shows total transmittance spectra and diffuse transmittance spectra for samples No. 4, 8, and 9. The total transmittance spectra show all samples with around 90 % transmittance at long wavelengths larger than 400 nm. The spectra also show around 90 % transmittance for thin film samples (No. 8 and 9) at wavelengths of 350 to 400 nm. The spectra also show low diffuse transmittance for all samples.
Fig. 10 shows total transmittance spectra in the range 200 to 2500 nm. The results show the material in sample No. 4 absorbed light at long wavelengths above 1000 nm. This shows the thin film samples displayed high transmittance at almost all wavelengths.

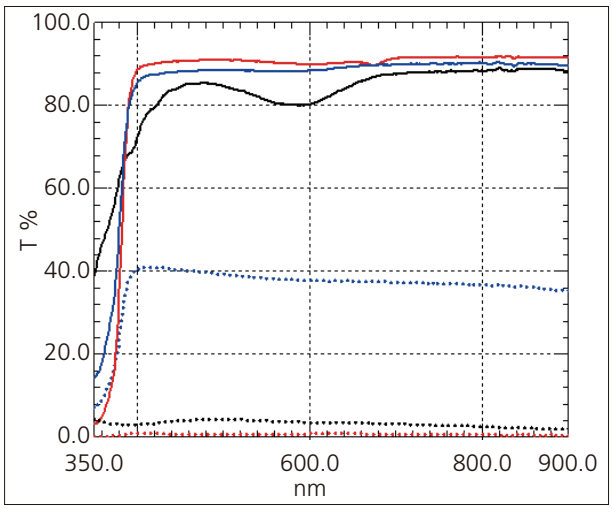

Fig. 7 Solid Line: Total Transmittance, Dotted Line: Diffuse Transmittance (PVC) Black: No. 5 Sheet, Red: No. 6 Film (Clear), Blue: No. 7 Film (Surface Treated)

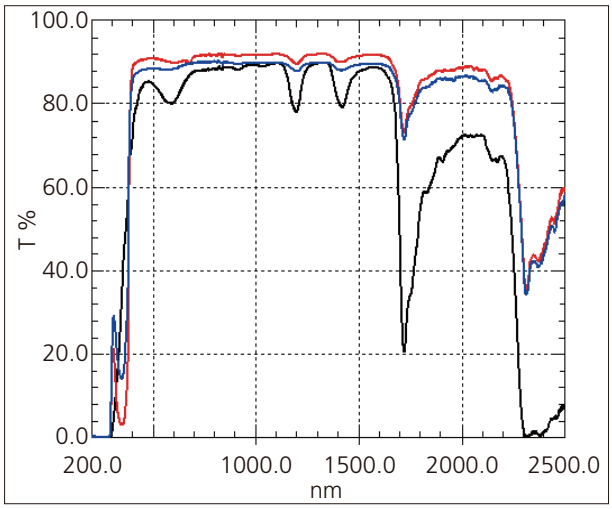

Fig. 8 Total Transmittance (PVC) Black: No. 5 Sheet, Red: No. 6 Film (Clear), Blue: No. 7 Film (Processing)

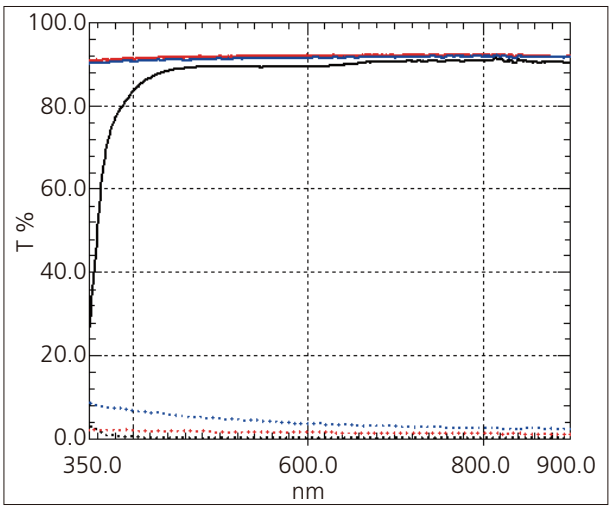

Fig. 9 Solid Line: Total Transmittance, Broken Line: Diffuse Transmittance Black: No. 4 PET Sheet, Red: No. 8 PP Film, Blue: No. 9 PE Film

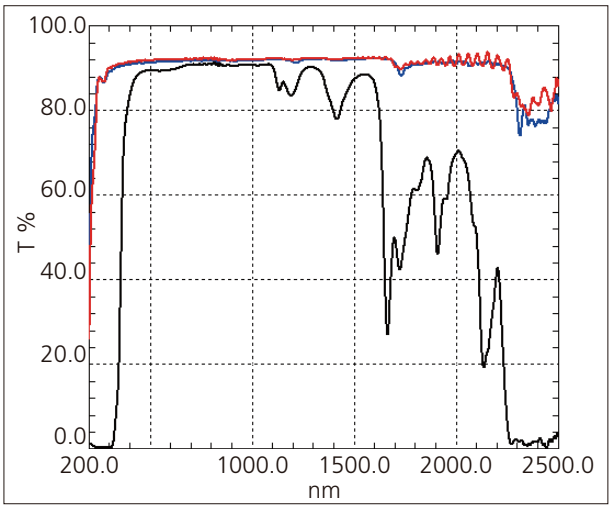

Fig. 10 Total Transmittance Black: No. 4 PET Sheet, Red: No. 8 PP Film, Blue: No. 9 PE Film

Table 2 Haze and Visible Light/Solar Transmittance

Sample Type	No.	Material	Thickness (mm)	Haze (%)	Visible Light Transmittance (%)	Solar Transmittance (%)
Plate	1	PMMA (Clear)	2.08	0.17	92.49	87.92
	2	PMMA (Matt)	2.16	38.74	91.06	86.32
	3	PMMA (Textured)	3.15	78.26 *3	92.36	86.85
	4	PET	1.99	0.11	89.38	86.53
	5	PVC *1	2.15	4.42	81.93	83.63
Film	6	PVC (Clear) *2	0.303	0.48	90.35	89.04
	7	PVC (Processing) *2	0.303	43.09 *3	88.46	87.58
	8	PP	0.031	1.52	91.92	91.95
	9	PE	0.035	4.36	91.41	91.55

*1: Carboxylated, *2: Phthalic ester, *3: Values for reference only; JIS K 7136 applicable for measurement of samples with 40 % or lower haze

Color analysis software was used to calculate τ_1, τ_2, τ_3, and τ_4 based on total/diffuse transmittance spectra. Color analysis software can output results in a variety of formats, including the L*a*b* color system, Munsell color system, and XYZ color system. τ_1, τ_2, τ_3, and τ_4 correspond to the Y value (color value) in the XYZ color system calculated based on a D_{65} standard illuminant. Haze results calculated based on each τ value are shown in Table 2. The results show surface treated samples No. 2 and 7 with a haze of around 40 %. They also show a high haze for sample No. 3 with its textured structure. Some haze was also measured in sheet sample No. 5 PVC, and thin film samples No. 8 and 9.

Visible light/solar transmittance results calculated using solar transmittance software are also shown in Table 2[Note 2]. All samples, including those with surface treatment, showed visible light/solar transmittance of around 80 to 90 %. We can predict that degree of light diffusion changes without almost no change in sample luminosity.

Conclusion

Total transmittance and diffuse transmittance of different plastics were measured using Shimadzu UV-3600 Plus with ISR-1503 attachment. Haze and visible light/solar transmittance of each sample were also calculated with software and analytical results.

Spectral, haze, and visual light/solar transmittance measurement is expected to be applied to evaluate and confirm the properties of ever more sophisticated materials and products in the future.

Note 1: JIS K 7136 assumes use of a single beam and for this reason requires a compensation port in the integrating sphere. The method used in this article is not entirely compliant with JIS K 7136, as the UV-3600 Plus uses a double beam and the ISR-1503 has no compensation port. The assumption was made that these factors did not affect haze results. Please refer to the erratum prepared on June 1, 2010 for the formula for calculating haze.

Note 2: The solar transmittance software calculates solar transmittance in the range of 300 to 2100 nm. A user defined function allows solar transmittance to be calculated in the range of 300 to 2500 nm.

References

1) ISO 14782 Plastics — Determination of haze for transparent materials
2) JIS K 7136 Plastics — Determination of haze for transparent materials

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