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Application News

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Spectrophotometric Analysis

Evaluation of Functional Properties (Thermal Insulation and Lighting) of Fabric, Paper, Film, and Other Materials – Measuring Solar Transmittance/Reflectance Using ISR-1503 Integrating Sphere Attachment –

Interest in private power generation, energy-saving strategies, and other methods of caring for the environment is increasing alongside the global warming, energy disputes, and other environmental problems. A variety of functional materials and products are being developed with energy-saving characteristics not only in the electronics industry, but also in the construction and chemicals industry. These materials and products are often used in our immediate surroundings. Window glass and insulating film that transmits visible light but prevents transmission of near-infrared light are used to increase cooling and heating efficiencies in buildings. Items such as curtains and Japanese paper screen doors (shoji) have a variety of functions, such as thermal insulation and natural illumination. Parameters such as solar transmittance/reflectance are used to represent the optical properties of these materials and products and are described in Japanese Industrial Standards (JIS).
This article describes measuring the transmission and reflection spectra of four commercially available and common solar shields: curtains, shoji, roller blinds, and thermal insulation films. Measurements were made using a UV-3600 Plus UV-VIS-NIR spectrophotometer with ISR-1503 integrating sphere attachment, and solar transmittance software was used to calculate solar transmittance/reflectance.

Spectra Measurement

The UV-3600 Plus and ISR-1503 instruments are shown in Fig. 1. When using the ISR-1503 to take transmittance/zero-degree reflectance measurements, film samples, tapered samples, and powder samples can be analyzed without spillage by placing them in a horizontal orientation in the optical system as shown in Fig. 2.
Square, 5-cm samples of curtain, shoji (the paper that is normally mounted on a wooden frame), roller blind (a cloth curtain that is open and shut vertically), and thermal insulation film (applied to windows for a variety of functions) were cut out as shown in Fig. 3, and measurements were taken using the conditions shown in Table 1.

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

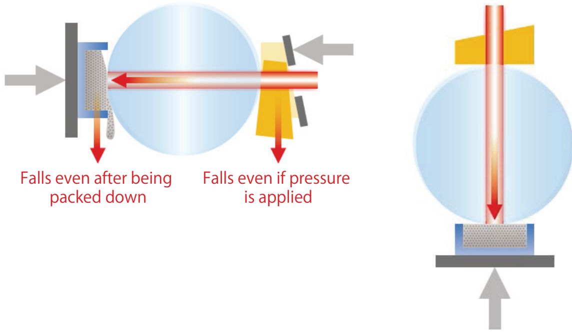

Fig. 2 Samples in Vertical and Horizontal Positions (Lateral View of Integrating Sphere)

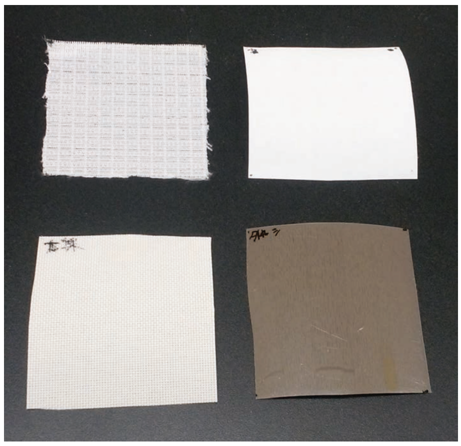

Fig. 3 Samples of Curtain, Shoji, Roller Blind, and Thermal Insulation Film

Table 1 Measurement Conditions

Instruments Used	: UV-3600 Plus, ISR-1503
Measured Wavelength Range	: 200 nm to 2500 nm
Scanning Speed	: Low speed
Sampling Interval	: 5.0 nm
Photometric Value	: Transmittance/Reflectance
Slit Width	: (32) nm
Light Source Switching Wavelength	: 310 nm
Detector Unit	: External (3 detectors)
Detector Switching Wavelength (s)	: 870 nm / 1650 nm
Grating Switching Wavelength	: 780 nm
S-beam/R-beam Switching	: Inversion
Step Correction	: Effective

The transmittance spectra of curtain materials are shown in Fig. 4, and the reflectance spectra are shown in Fig. 5. The curtain materials tested were normal curtain, curtain designed for natural illumination, and curtain designed for thermal insulation. The curtain designed for natural illumination generally has a higher transmittance but lower reflectance over the entire wavelength range compared to normal curtain. The curtain designed for thermal insulation generally has a lower transmittance but higher reflectance over the entire wavelength range compared to normal curtain. It can be presumed that increasing transmittance and lowering reflectance produce illuminating properties, while lowering transmittance and increasing reflectance produce thermal insulation properties.

The transmittance spectra of shoji materials are shown in Fig. 6, and the reflectance spectra are shown in Fig. 7. The shoji materials tested were plastic shoji, shoji designed for natural illumination, and shoji designed for thermal insulation. The shoji designed for natural illumination had a transmittance of around 45 % and reflectance of around 55 % over the entire wavelength range. The shoji designed for thermal insulation had a transmittance of around 20 % and reflectance of around 75 % over the entire wavelength range. The plastic shoji produced spectral shapes, transmittance results, and reflectance results similar to those obtained from the shoji designed for natural illumination.

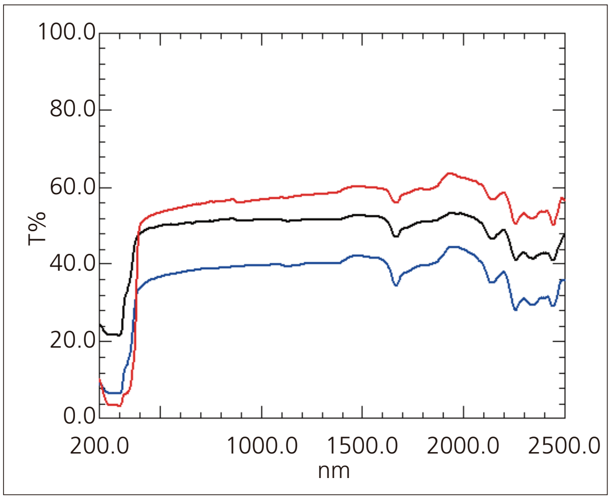

Fig. 4 Transmittance Spectra of Curtain Materials
Black: Normal, Red: Designed for Natural Illumination, Blue: Designed for Thermal Insulation

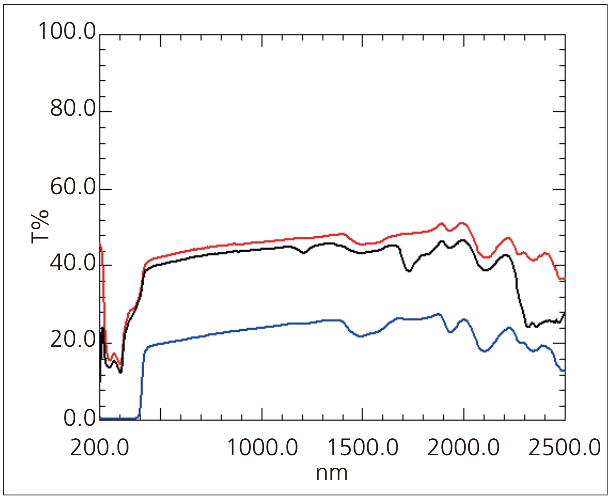

Fig. 6 Transmittance Spectra of Shoji Materials
Black: Plastic, Red: Designed for Natural Illumination, Blue: Designed for Thermal Insulation

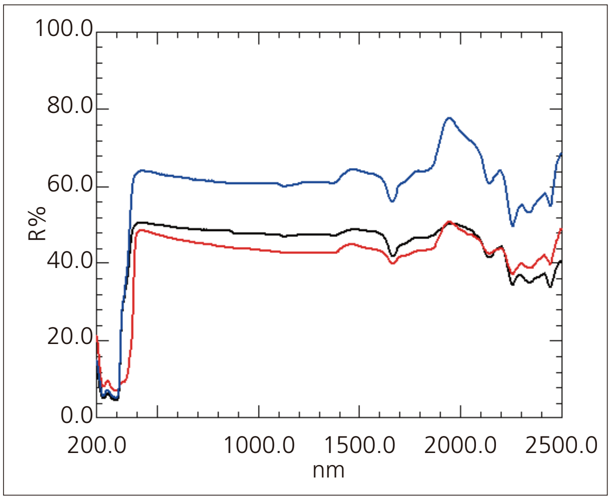

Fig. 5 Reflectance Spectra of Curtain Materials
Black: Normal, Red: Designed for Natural Illumination, Blue: Designed for Thermal Insulation

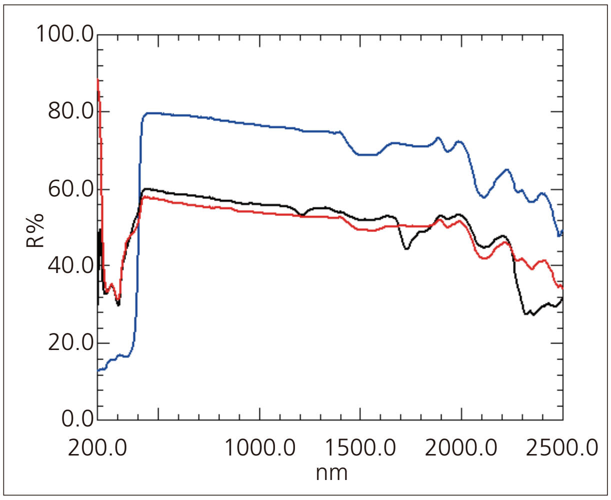

Fig. 7 Reflectance Spectra of Shoji Materials
Black: Plastic, Red: Designed for Natural Illumination, Blue: Designed for Thermal Insulation

The transmittance spectra of roller blind materials are shown in Fig. 8, and the reflectance spectra are shown in Fig. 9. The materials tested were roller blind designed for natural illumination, and roller blind designed for light shielding. The roller blind designed for natural illumination had a transmittance of around 35 % and reflectance of around 65 % over the entire wavelength range. The roller blind designed for light shielding had a transmittance of almost zero over the entire wavelength range, and a high reflectance in the visible region but low reflectance in the near-infrared region. It can be presumed that light shielding is produced by reflecting sunlight in the visible region while light in the near-infrared region is absorbed.

The transmittance spectra of thermal insulation films are shown in Fig. 10, and the reflectance spectra are shown in Fig. 11. The thermal insulation films tested were designed for 30 % and 80 % thermal insulation. The 30 % thermal insulation film had a lower transmittance in the near-infrared region compared to the visible region. Similarly, the 80 % thermal insulation film had a reduced transmittance in the near-infrared region, but allowed more transmission of 800 nm to 1000 nm light compared to near-infrared region light. It can be presumed the thermal insulation films tested produce a thermal insulation effect by absorbing sunlight, and not by reflecting sunlight.

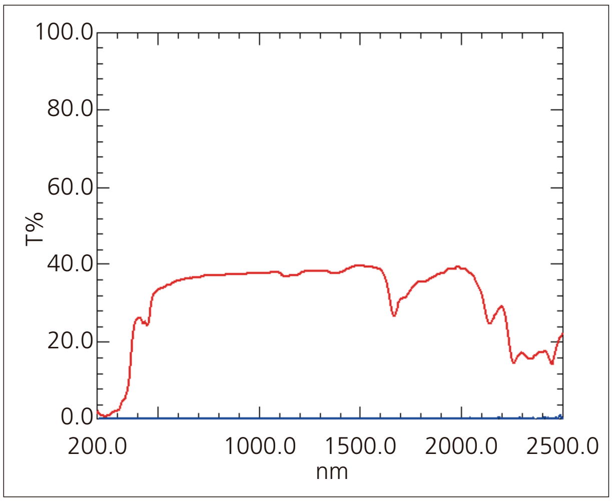

Fig. 8 Transmittance Spectra of Roller Blind Materials
Red: Designed for Natural Illumination,
Blue: Designed for Light Shielding

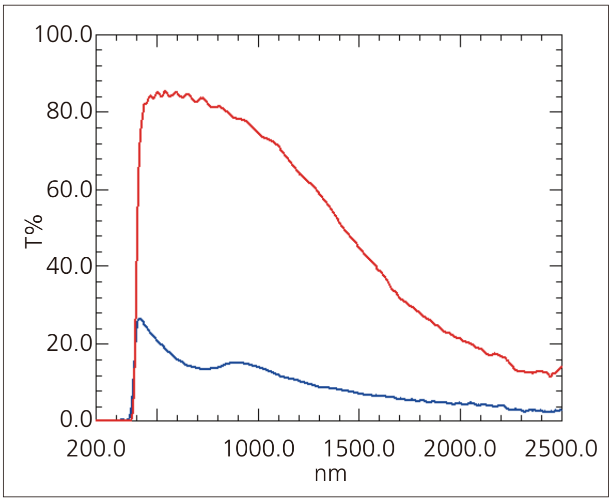

Fig. 10 Transmittance Spectra of Thermal Insulation Films
Red: 30 % Thermal Insulation,
Blue: 80 % Thermal Insulation

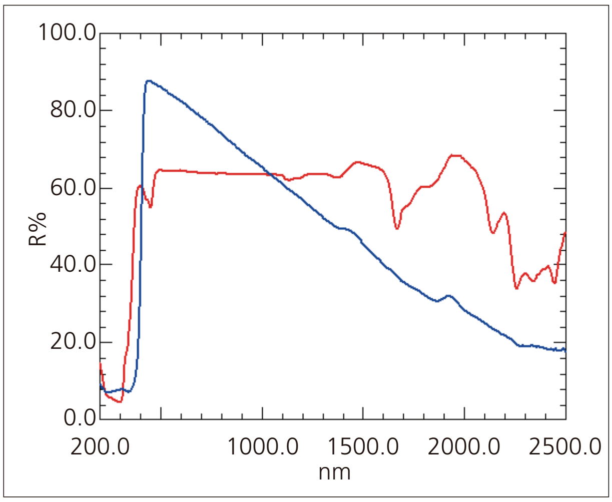

Fig. 9 Reflectance Spectra of Roller Blind Materials
Red: Designed for Natural Illumination,
Blue: Designed for Light Shielding

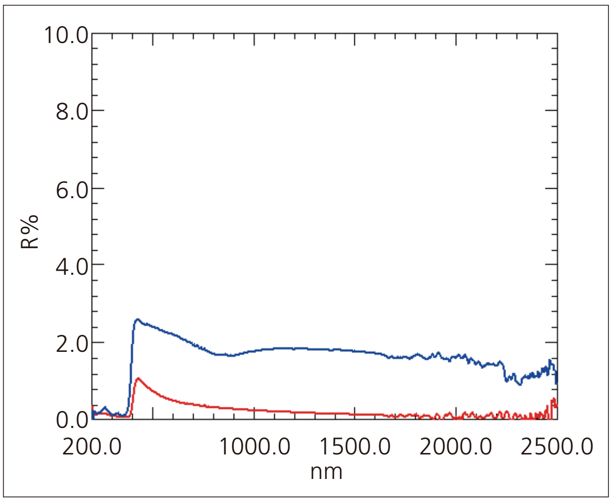

Fig. 11 Reflectance Spectra of Thermal Insulation Films
Red: 30 % Thermal Insulation,
Blue: 80 % Thermal Insulation

Table 2 Solar Transmittance/Reflectance and Visible Light Transmittance/Reflectance

Type	Properties	Solar Transmittance (%)	Visible Light Transmittance (%)	Solar Reflectance (%)	Visible Light Reflectance (%)
Curtain	Normal	50.66	50.34	48.44	49.64
	Designed for Natural Illumination	54.98	54.23	44.51	46.82
	Designed for Thermal Insulation	38.16	37.24	61.63	62.80
Shoji	Plastic	42.15	41.10	56.54	58.96
	Designed for Natural Illumination	44.28	43.03	54.50	56.76
	Designed for Thermal Insulation	21.30	20.15	75.14	79.02
Roller blind	Designed for Natural Illumination	34.92	34.52	62.52	64.23
	Designed for Light Shielding	0.01	0.00	69.10	83.97
Thermal Insulation Film	30 % Thermal Insulation	72.39	84.54	0.38	0.58
	80 % Thermal Insulation	14.31	18.02	1.91	2.27

The solar transmittance/reflectance and visual light transmittance/reflectance results calculated from spectra using solar transmittance software are shown in Table 2.* Comparing the samples, the transmittance of curtain is higher than shoji, but the reflectance of curtain is lower than shoji. The transmittance of roller blind is lower than both curtain and shoji, while the reflectance of roller blind is higher than both curtain and shoji. For the thermal insulation films, transmittance varies greatly depending on type, while reflectance is extremely low for all film types. There was no substantial difference between transmittance/reflectance in the visible light and near-infrared regions for curtains and shoji, but a difference between the visible light and near-infrared regions was observed in the reflectance of roller blinds designed for light shielding and the transmittance of thermal insulation film. Although these measurements are used as simple examples and do not produce defining characteristics for each sample material, they show that sample characteristics can be estimated based on spectral analysis and calculation of solar transmittance/reflectance.

Conclusion

Materials and products with energy-saving features are used all around us. The optical properties of these materials and products are described in JIS, and in this article we used a UV-3600 Plus with ISR-1503 attachment to measure the transmittance/reflectance spectra of commercially available curtains, shoji, roller blinds, and thermal insulation films. Using the ISR-1503 allowed us to obtain spectra with reduced steps between detectors. Using solar transmittance software also allowed us to calculate solar transmittance/reflectance based on the measurement results obtained. We anticipate that spectra and solar transmittance/reflectance data will be used to evaluate and check materials and products with improved functional features that will be developed in the future.

*: The solar transmittance software calculates solar transmittance/reflectance in the range of 300 nm to 2100 nm. Employing the user settings function in the software, it can also calculate solar transmittance/reflectance in the range of 300 nm to 2500 nm.

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