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SHIMADZU

Application News

No.A438

Spectrophotometric Analysis

Evaluation of Anti-Reflective Film on Solar Cell Using UV-2600 -Reflectance and Color Measurement-

Due to heightened concern over problems related to the environment and energy, attention is being focused on clean energy produced by solar cells. A variety of components are used to enhance the performance of solar cells, one of which is anti-reflective film. Anti-reflective film that is formed on the surface of a solar cell acts to prevent the loss of energy from incident light by suppressing its reflection. Therefore, investigation of the reflective characteristics of this film is important.

Here, we report on our investigation of the reflectance characteristics and color values of anti-reflective film using the UV-2600 with an integrating sphere mounted to allow measurement over a wider wavelength range, including the near infrared region.

Sample and Instrument

Fig. 1 shows a photograph of an anti-reflective film (155 × 155 mm) formed on a polycrystalline silicon wafer. Here, the sample was prepared with uneven color to elucidate the differences in color and reflectance. Fragments of the sample with obvious differences in color, in the regions of A, B and C, respectively, were cut out into suitable shapes for use as measurement specimens.

Measurement was conducted using the Shimadzu UV-2600 ultraviolet-visible spectrophotometer. The UV-2600 is applicable for measurement in the wavelength range of 185 – 900 nm, but with the ISR-2600 Plus integrating sphere attachment mounted, the measurement range is extended to include the near infrared region (measurement wavelength range: 220 – 1400 nm). The UV-2600 and ISR-2600 Plus are shown in the photographs of Fig. 2 and Fig. 3, respectively. The ISR-2600 Plus incorporates two detectors, a photomultiplier tube and the InGaAs photodiode detector, with the former permitting measurement in the ultraviolet and visible regions, and the latter in the near infrared region up to 1400 nm. Thus, use of the ISR-2600 Plus makes possible measurement over a wide wavelength range, from ultraviolet to the near infrared.

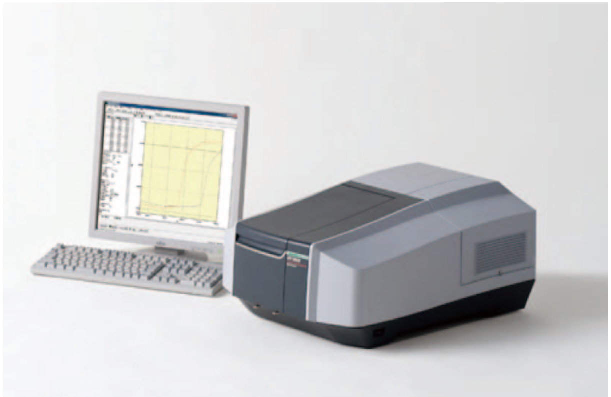

Fig. 2 UV-2600 UV-Visible Spectrophotometer

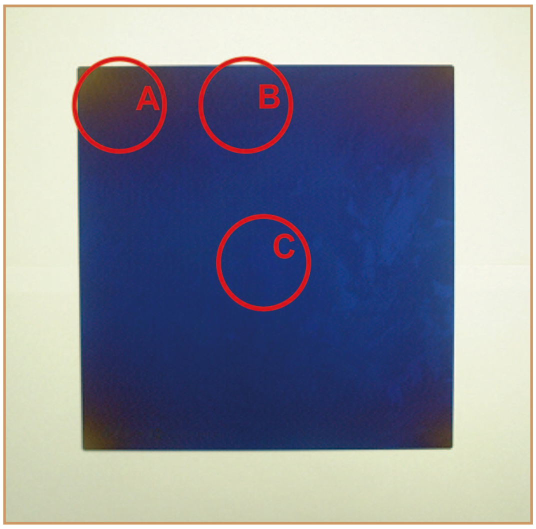

Fig. 1 Anti-Reflective Film on Polycrystalline Silicon Wafer

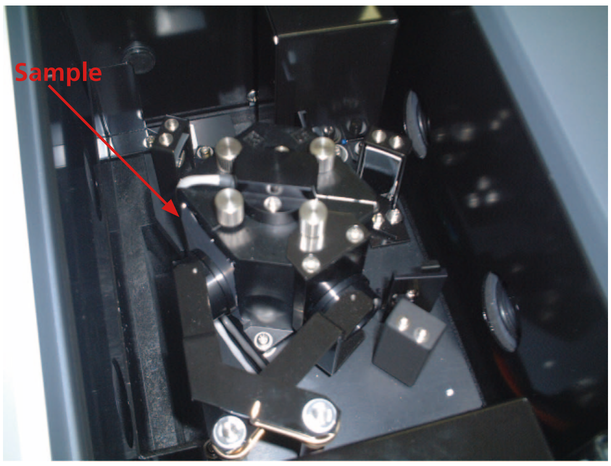

Fig. 3 ISR-2600 Plus Integrating Sphere Attachment

Measurement Results

The diffuse reflectance (relative reflectance) was measured at the 3 sites, regions A, B and C of the sample shown in Fig. 1, using barium sulfate as a standard. The results are shown in Fig. 4, and the analytical conditions are shown in Table 1. In each of A, B and C sites, the reflectance was high in the ultraviolet and near infrared regions, but was greatly diminished in the visible region. It is noteworthy that when comparing the 3 spectra, the high/low order of reflectance is reversed depending on the wavelength range. Furthermore, although all of spectra exhibit greatly reduced reflectance in the vicinity of 550 nm, the wavelength at which reflectance is lowest is slightly different in each of A, B and C. Fig. 5 shows an expanded view of the visible region (400 – 700 nm) of Fig. 4. It is clear that blue region light (400 – 500 nm) is greatly reflected in the case of site C, while red region light (600 – 700 nm) is greatly reflected in site A. It appears evident that there is a correlative tendency between the apparent colors of A, B and C and their respective spectra.

The reflectance (380 – 780 nm reflectance spectrum) of the sample can easily be converted to a color value using color measurement software. The measured reflectance spectrum was converted to one of the color indices, L*a*b*, as well as its color differential ΔE*ab(*). Those results are shown in Table 2. The calculation was made based on the use of a D65 lamp and a 10° field of view. Here, L* expresses "degree of lightness,"and the pair of a* and b* represent "hue"and"chroma."ΔE*ab expresses the difference in color (color difference) between the standard sample and an actual sample. Using sample A as the standard, we calculated ΔE*ab. From Table 2, the color difference between A and C is greatest, but even with respect to B and C, the difference is greater than 6, indicating that the colors vary widely among A, B and C.

The L*a*b* values are plotted in the color space, as shown in Fig. 6. The L* values are plotted on the column diagram on the left, and the a* and b* values are plotted in the graph on the right. The higher the position in the L* graph that a sample is plotted, the "brighter" the sample is. From Fig. 6 and Table 2, it is evident that C is the brightest, and B is the darkest. In the a*b* graph on the right (horizontal axis: a* value, vertical axis: b* value), the closer the sample is to the center of the circle, the "duller" the color is, and the further the sample is from the center, the more vivid the color. The radial direction of the a*b* graph expresses hue, in which the direction toward the right in the circle expresses the red system, toward the top, the yellow system, toward the left, the green system, and toward the bottom, the blue system. The shift of hue from the red to the blue system colors is evident as the order of samples moves from A→B→C. From this, it is clear that C is of bright hue in the blue system, and A is a dull color in the red system.

From the above results, it was observed that the color of A was quite different from those of B and C, and that there was even a difference in color between B and C.

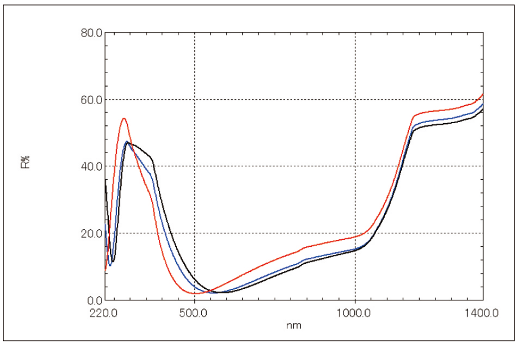

Fig. 4 Reflectance Spectra (Red: A, Blue: B, Black: C)

(*) The calculations were conducted according to JIS Z 8729 and JIS Z 8730.

Table 1 Analytical Conditions

Instrument	: Shimadzu UV-2600 Ultraviolet-Visible Spectrophotometer Integrating Sphere ISR-2600 Plus
Measurement wavelength range	: 220 nm – 1400 nm
Scan speed	: Medium
Sampling pitch	: 1.0 nm
Photometric value	: Reflectance
Slit width	: 5 nm
Detector switching wavelength	: 830 nm

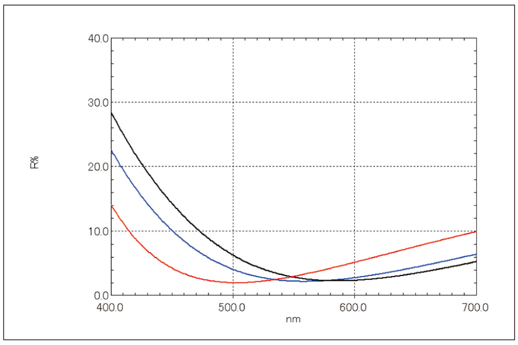

Fig. 5 Expanded Spectra of Fig. 4 (Red: A, Blue: B, Black: C)

Table 2 Value of L*a*b* (D65 lamp, 10° field of view) Data Name

Data Name	L*	a*	b*	ΔE*ab
A	21.96	18.33	-6.51	0
B	20.67	18.01	-30.45	23.98
C	23.58	14.36	-36.43	30.22

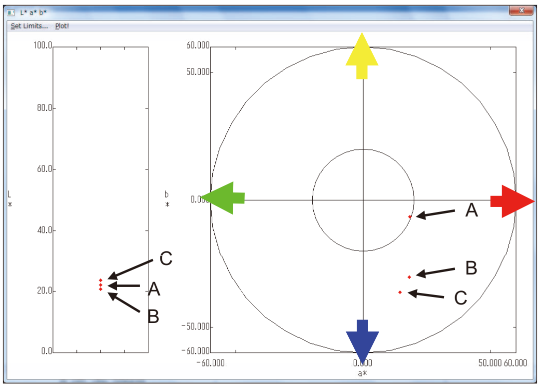

Fig. 6 L*a*b* Color Space

Summary

Here, using the UV-2600 with an integrating sphere attachment which allowed measurement up to the near infrared region, in addition to color measurement software, we evaluated the reflectance characteristics and color values of several samples. Using the UV-2600 and color measurement software in this way, the reflectance characteristics of the sample surfaces in addition to their color values and differences could be investigated quantitatively.

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