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Application News

No.A502

Spectrophotometric Analysis

Color Evaluation of Structurally Colored Films by Angle of Incidence

Biomimetics is a new field of technology that incorporates to mimic the functions or structures of biological organisms into technology development and manufacturing.
The wings of the morpho butterfly shown in Fig. 1 contain no pigment, and yet appear a brilliant blue due to their structure[1, 2]. This is called structural coloration, which for the morpho butterfly arises from light interference caused by the complex structure of scales that cover the wings. Some familiar examples of structural coloration is the thin-film interference that occurs on the surface of soap bubbles, the multilayer interference that occurs on jewel beetles and inside shells, and the structural coloration seen on CD-ROMs. Characteristics of structural coloration are that coloration varies according to the angle of view, and colors do not fade like a pigment since they are produced by a structure.
With the cooperation of Teijin DuPont Films Japan Limited, we performed measurements of a new optical film called multilayer film (MLF). In this article, we report the results of our observations of coloration changes at different angles of incident light, a characteristic property of structurally colored materials.

Fig. 1 Morpho Butterfly[1)]

Color Evaluation of MLF Film at Angles of Incidence

Three different MLF films were measured: MLF-13.0, MLF-16.5, and MLF-19.0. MLF films have a multilayered structure, consisting of several hundred layers of polyester resins several tens of nanometers thick with different refractive indices[3)]. The MLF films are shown when viewed from above in Fig. 2, and in Fig. 3 the MLF films are shown when viewed at an angle. The images show the different colors that appear due to the light interference caused by structural coloration.

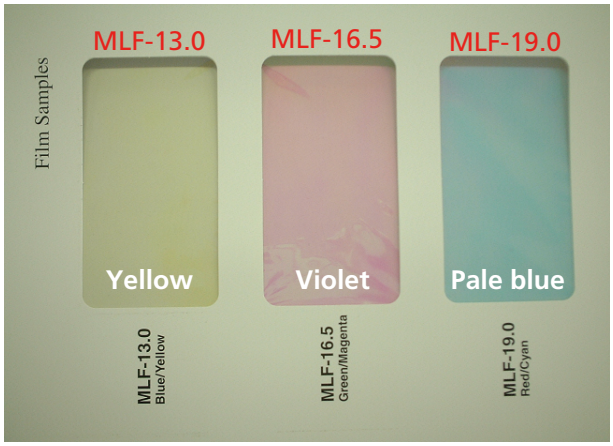

Fig. 2 MLF Films Viewed from Above

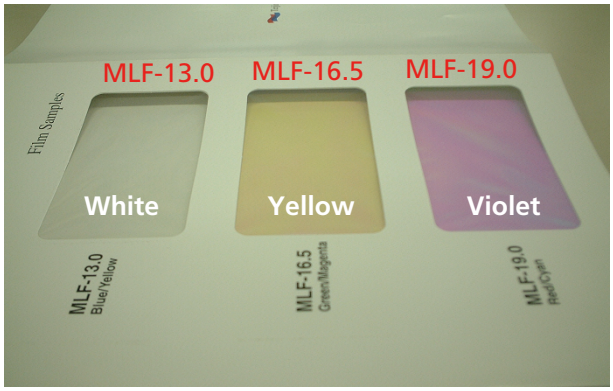

Fig. 3 MLF Films Viewed from an Angle

The SolidSpec-3700DUV and variable angle absolute reflectance attachment shown in Fig. 4 were used to measure transmission of changing the angle of incident light. The variable angle absolute reflectance attachment allowed measurements to be performed at different angles of light incident on the samples. For detailed information on the variable angle absolute reflectance attachment, please refer to Application News No. A390 and A394.

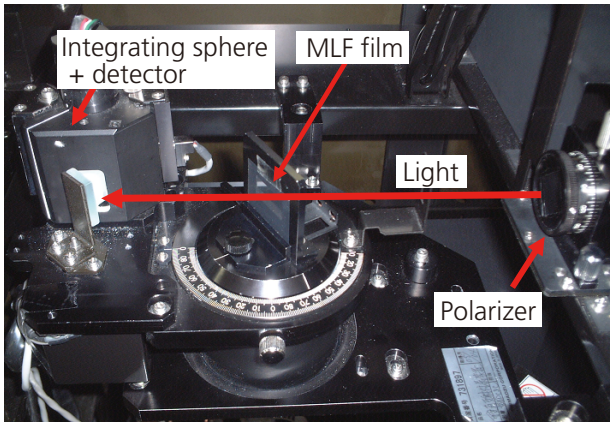

Fig. 4 Inside the Sample Compartment of SolidSpec-3700DUV with Variable Angle Absolute Reflectance Attachment

The conditions used during measurements are shown in Table 1. The transmission spectra obtained from light incident at 0°, 15°, 30°, 45°, and 60° on the MLF-13.0 film are shown in Fig. 5. The results of using color measurement software to display transmission in terms of an L*a*b* color space are shown in Fig. 6. Fig. 5 shows that at an angle of incidence of 0°, the MLF-13.0 film absorbed blue light in the region of 400 to 500 nm. Accordingly, the observed light appears yellow, which is the complementary color to blue. As the angle of incidence increases, light of shorter wavelengths is absorbed, less visible light is absorbed, and the color of the observed light appears white (colorless).

Table 1 Measurement Conditions

Instruments used	: SolidSpec-3700DUV Variable angle absolute reflectance attachment Large polarizer assembly
Measured wavelength range	: 300 to 800 nm
Scanning speed	: Medium speed
Sampling pitch	: 1.0 nm
Photometric value	: Transmission
Slit width	: (20) nm
Angle of incidence	: 0°, 15°, 30°, 45°, 60°
Polarizer angle	: 45° (equivalent to unpolarized light)

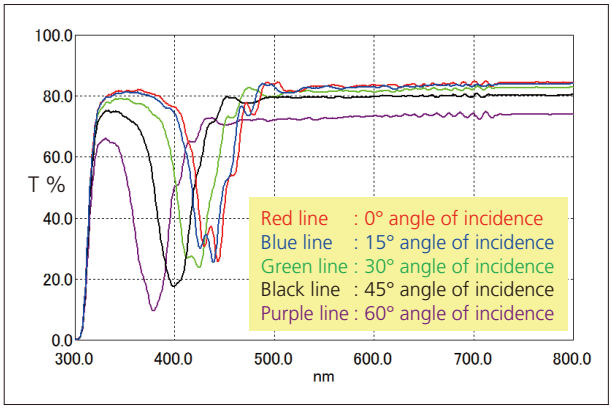

Fig. 5 MLF-13.0 Film Transmission Spectra

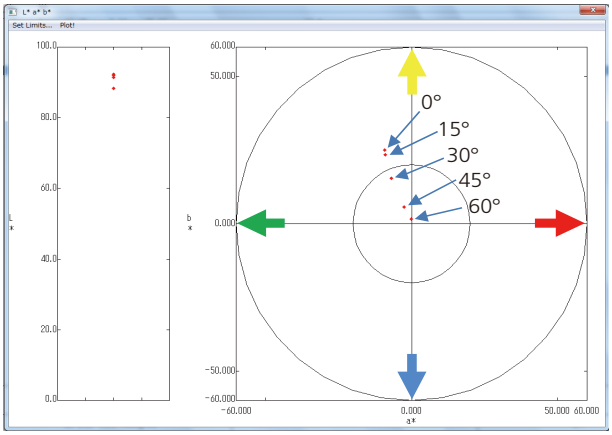

Fig. 6 MLF-13.0 Film L*a*b* Color Space

An L*a*b* color space is shown in Fig. 7. The L*a*b* color coordinate system is used to represent the color of a body, where L* represents lightness, and a* and b* together represent hue and chroma (saturation)[4]. According to the results shown in Fig. 6, the MLF-13.0 film is close to yellow at a 0° angle of incidence. As the angle of incidence increases, the film loses color and L* remains high, which shows the film becomes transparent. For detailed information on the color measurement software used please refer to Application News No. A438 and A477.

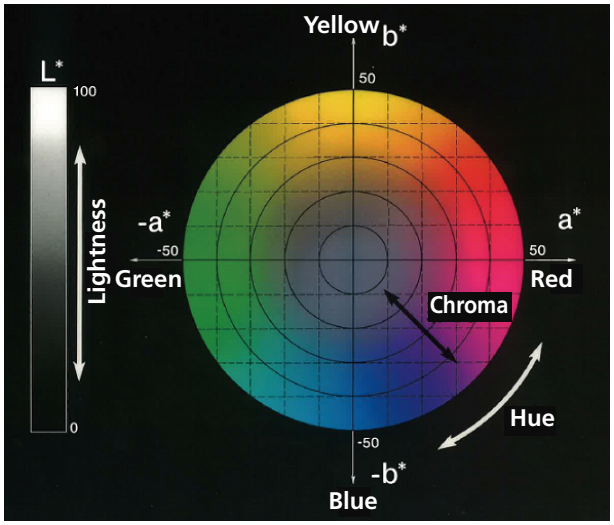

Fig. 7 L*a*b* Color Space

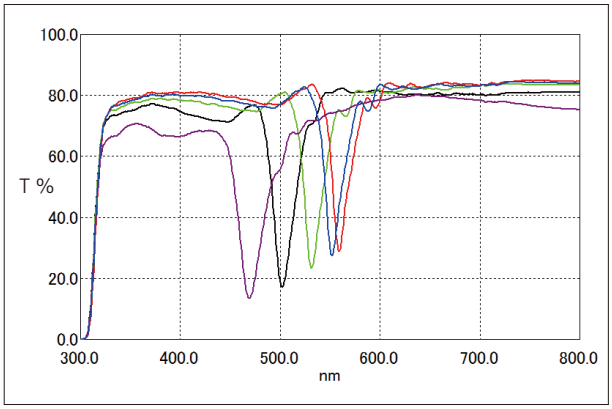

Fig. 8 MLF-16.5 Film Transmission Spectra

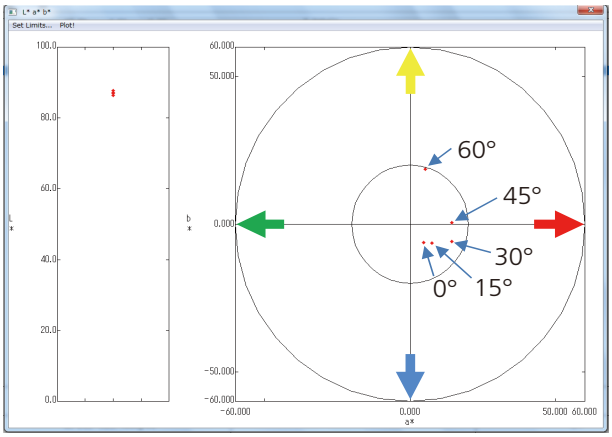

Fig. 9 MLF-16.5 Film L*a*b* Color Space

Results obtained from measuring the MLF-16.5 film under the same conditions are shown in Fig. 8 and Fig. 9. At a 0° angle of incidence, the MLF-16.5 film absorbs green light in the region of 500 to 600 nm and violet light is observed, the complementary color to green. As the angle of incidence increases, light of shorter wavelengths is absorbed. At a 60° angle of incidence, the MLF-16.5 film absorbs blue light in the region of 400 to 500 nm and yellow light is observed, the complementary color to blue. The same phenomena can be confirmed on an L*a*b* color space.

Results obtained from measuring the MLF-19 film under the same conditions are shown in Fig. 10 and Fig. 11. At a 0° angle of incidence, the MLF-19 film absorbs red light in the region of 600 to 700 nm and pale blue light is observed. As the angle of incidence increases, light of shorter wavelengths is absorbed. At a 60° angle of incidence, the MLF-19 film absorbs green light in the region of 500 to 600 nm and appears violet. The same phenomena can be confirmed on an L*a*b* color space.

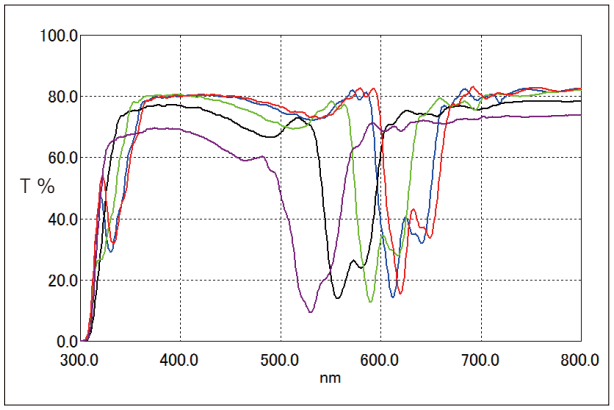

Fig. 10 MLF-19 Film Transmission Spectra

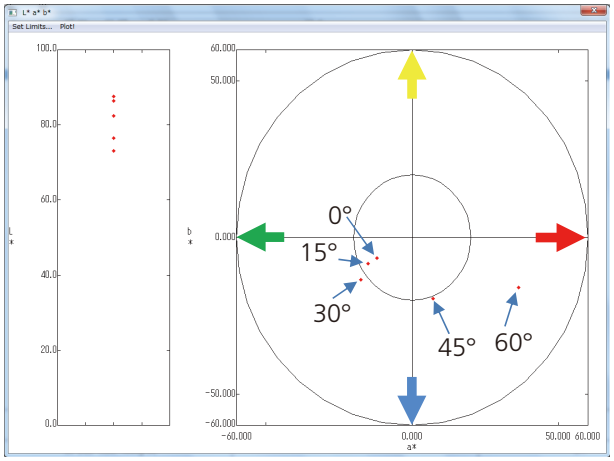

Fig. 11 MLF-19.0 Film L*a*b* Color Space

Conclusion

The field of biomimetics creates a variety of materials. Shimadzu Corporation's analytical instruments are used for observation of biological mimicry and for evaluation of materials created in the field of biomimetics. Using the SolidSpec-3700DUV and variable angle absolute reflectance attachment, we were able to successfully confirm coloration changes at different angles of incident light, which is a characteristic property of structural coloration.

<Acknowledgments>
The samples and technical information using in this analysis were provided by Tomoka Yoshimura of Teijin DuPont Films Japan Limited and Haruko Hirose at the Structural Analysis Research Laboratories of Teijin Limited. We are sincerely grateful for their help.

[References]

1) Teijin Laboratories
"Morphotex" structurally colored fibers created with advanced nanotechnology.
2) H. Hirose; Polymers 60 (5), 298-301 (2011).
3) Teijin DuPont Films Japan Limited PET Film MLF Product Overview
4) Konica Minolta, IROIROZATSUGAKU

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SolidSpec-3700i/3700i DUV

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