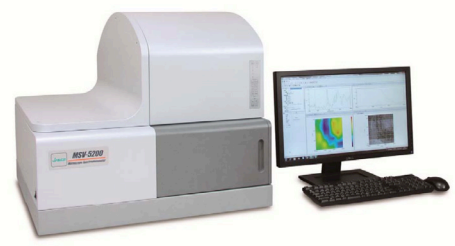
Application Note
UV-0025

Estimation of the Refractive Index of a Monocrystalline Sapphire via Polarization Measurement using the MSV-5000 Series Microscopic Spectrophotometer

Introduction

The MSV-5000 series microscopic spectrophotometer is for transmission and reflection measurements in a wide wavelength range from the ultraviolet to near infrared. The high resolution camera enables sample areas as small as 10 µm in diameter. The built-in Glan-Taylor polarizer allows optical constants such as refractive index and extinction coefficient to be obtained by measuring the reflectance spectrum of birefringent samples.

In this application note, a 50 µm monocrystalline sapphire, which has two types of crystal axes, was measured and the dispersion of the refractive index was calculated.



MSV-5200
UV-Visible/NIR Microscopic Spectrophotometer

Keywords

MSV-5200 UV-Vis/NIR microscopic spectrophotometer, VWML-791 Multi-layer Analysis program, Materials

Experimental

Measurement Conditions			
Bandwidth	5 nm	Scan speed	200 nm/min
Response	Slow	Data interval	0.1 nm
Accumulation	3	Cassegrain objective	16x
Incident Angle	23°	IN/OUT aperture	50 µmΦ
Polarizer Angle	0, 90°		

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Two baselines of an aluminum vapor-deposited mirror was measured with the polarizer angle at 0 and 90° as a reference. To determine the crystalline axis, the polarizer angle was set to 0° and the wavelength 550 nm. The sample was then rotated to find the angle where the sample displayed maximum reflectance. The c-axis was determined by this angle and the a-axis was taken orthogonal to it. The sample reflectance spectra were obtained with polarizer angles at 0 and 90° for the c- and a- axis, respectively. The sample absolute reflectance spectrum was calculated by multiplying the obtained relative reflectance by the absolute reflectance spectrum of the aluminum vapor-deposited mirror.

The refractive index can be calculated by either the *UV-Vis K-K Conversion* program or *Multi-Layer Analysis* program. Using the *UV-Vis K-K Conversion* program, the refractive index (*n*) is expressed by the specular reflectance spectrum (*R*) and phase change (Φ):

$$n = \frac{1}{1 + R - 2\sqrt{R}\cos\phi}$$

The phase change was calculated using the Kramers-Kronig conversion of the specular reflectance spectrum:

$$\phi(\omega) = \frac{2\omega}{\pi} P \int_0^\infty \frac{ln\sqrt{R(\omega)}}{\omega^2 - \omega^2} d\omega$$

and then the refractive index (*n*) was calculated.

Using the *Multi-Layer Analysis* program, the reflectance spectrum is expressed by the refractive index of air and the sample (n_1, n_2), the indicence angle (θ_1), and the reflection angle (θ_2):

$$R = \frac{1}{2}\left\{\left(\frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2}\right)^2 + \left(\frac{n_1 \cos\theta_2 - n_2 \cos\theta_1}{n_2 \cos\theta_1 + n_1 \cos\theta_2}\right)^2\right\}$$

By applying this equation, the wavelength dispersion of the refractive index is calculated using the *Multi-Layer Analysis* program by fitting the calculated reflectance spectrum to the measured.

Results

The absolute reflectance spectrum of monocrystalline sapphire is shown in Figure 1. The reflectance of the ordinary light (c-axis) is approximately 0.15% higher than that of the extraordinary light (a-axis).

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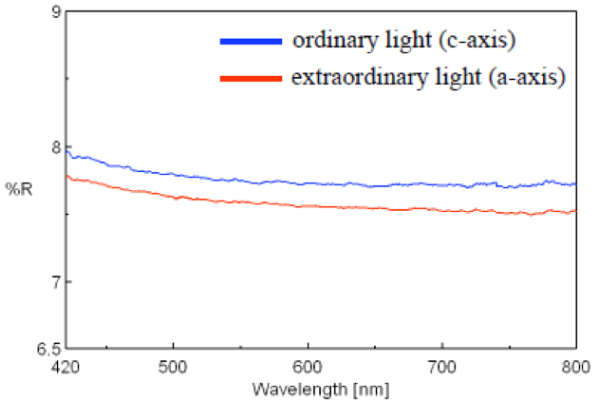

Figure 1. Absolute reflectance spectra of the monocrystalline sapphire.

Using the *UV-Vis K-K Conversion* and *Multi-Layer Analysis* program, the wavelength dispersion of the refractive index was obtained and shown in Figure 2. Tables 1 and 2 illustrate the results compared with literature values of the refractive index of ordinary and extraordinary light. The refractive index was determined within two decimal places in an area several tens of microns in diameter.

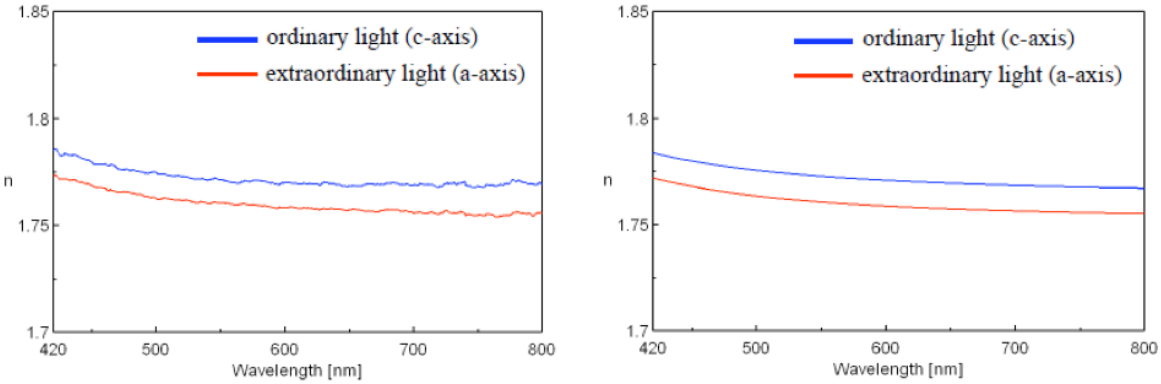

Figure 2. Wavelength dispersion of the refractive index calculated using the *UV-Vis K-K Conversion* program (left) and *Multi-Layer Analysis* program (right).

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Table 1. Comparison of the calculated refractive index values of ordinary light (c-axis) using the *UV-Vis K-K Conversion* program with the literature values.

Wavelength (nm)	Literature value	K-K Transform		Multilayer Analysis	
	Refractive Index	Refractive Index	Error	Refractive Index	Error
632.8	1.776	1.770	0.0037	1.769	0.0036
589.3	1.768	1.770	0.0016	1.771	0.0028
546.1	1.771	1.772	0.0012	1.773	0.0018
532.0	1,772	1.771	-0.0005	1.773	0.0015
514.5	1.773	1.773	-0.0005	1.774	0.0011
488.0	1.775	1.775	-0.0005	1.776	0.0007

Table 2. Comparison of the calculated refractive index values of unordinary light (c-axis) using the *UV-Vis K-K Conversion* program with the literature values.

Wavelength (nm)	Literature value	K-K Transform		Multilayer Analysis	
	Refractive Index	Refractive Index	Error	Refractive Index	Error
632.8	1.758	1.757	-0.0005	1.758	-0.0003
589.3	1.760	1.758	-0.0015	1.759	-0.0011
546.1	1.763	1.761	-0.0017	1.761	-0.0020
532.0	1,764	1.761	-0.0030	1.761	-0.0022
514.5	1.765	1.762	-0.0032	1.762	-0.0026
488.0	1.767	1.764	-0.0028	1.764	-0.0030

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