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Application News

No. A614

Spectrophotometric Analysis

Measurement of Film Thickness Using LabSolutions™ UV-Vis: Film Thickness Calculation by Interference Interval Method

Various measurement methods and instruments are available for film thickness measurements. However, simple, noncontact, nondestructive measurement is possible by using an ultraviolet-visible (UV-Vis) spectrophotometer. This article introduces the possible range of film thickness measurements in the ultraviolet-visible light wavelength region was investigated using an UV-Vis spectrophotometer.

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Calculation of Film Thickness

When measuring a thin film with a uniform thickness with a spectrophotometer, mutual interference occurs between the light reflected from the front surface and back surface, and an undulating interference spectrum with a wavelike pattern can be obtained. The thickness of the film can be calculated from this interference spectrum. A method in which the film thickness is calculated from the peak wavelength (or valley wavelength) of the interference spectrum (interference interval method) is provided in the film thickness calculation software (option) of the Shimadzu LabSolutions UV-Vis ultraviolet-visible spectrophotometer control software.

Fig. 1 shows the equation for calculating the film thickness from the peak wavelength (or valley wavelength) in the interference interval method. As shown in the equation, the refractive index of the material comprising the film is necessary in calculations of the film thickness. The film thickness is obtained from the number of wave peaks and valleys in the calculation wavelength range of the interference spectrum.

$$d = \frac{\Delta m}{2\sqrt{n^2 - \sin^2\Theta}} \times \frac{1}{\frac{1}{\lambda_2} - \frac{1}{\lambda_1}}$$

n : refractive index of film, Θ : angle of incidence with respect to the sample
d : thickness of film, Δm : number of peaks in calculation wavelength range
λ_1 : peak or valley wavelength on long wavelength side
λ_2 : peak or valley wavelength on short wavelength side

Fig. 1 Equation for Calculation of Film Thickness by Interference Interval Method

Film Thickness Measurement

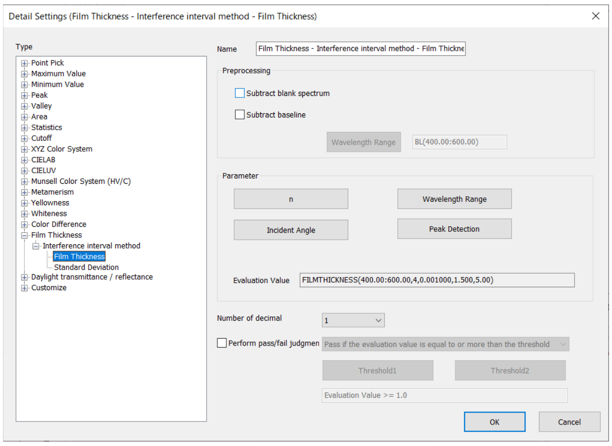
Fig. 2 shows an UV-1900i UV-Vis spectrophotometer. A film thickness measurement was carried out using the UV-1900i UV-Vis spectrophotometer, a mirror-surface reflecting measurement device (angle of incidence: 5°), and the above-mentioned Shimadzu film thickness calculation software. Table 1 shows the measurement conditions.

Fig. 3 shows the software “Settings” screen for film thickness calculations. Film thickness calculation is possible as one evaluation function.

Fig. 2 UV-1900i

Table 1 Measurement Conditions

Instrument	:	UV-1900i
Software	:	LabSolutions UV-Vis
Wavelength range	:	190 nm - 900 nm
Scan speed	:	Medium
Sampling pitch	:	0.5 nm
Slit width	:	1 nm (fixed)



Detail Settings (Film Thickness - Interference interval method - Film Thickness)

Name: Film Thickness - Interference interval method - Film Thickne

Preprocessing

☐ Subtract blank spectrum

☐ Subtract baseline

Wavelength Range: BL(400.00:600.00)

Evaluation Value: FILMTHICKNESS(400.00:600.00,4,0.001000,1.500,5.00)

Number of decimal: 1

☐ Perform pass/fail judgmen: Pass if the evaluation value is equal to or more than the threshold

Evaluation Value >= 1.0

Fig. 3 Settings Screen of Film Thickness Calculation Software

Measurable Film Thickness for Thin Films

First, photoresist films with different thicknesses on silicon wafers were measured to confirm the possible measurement range for thin films. Three films with thicknesses of approximately 3.0 µm, 1.1 µm, and 0.4 µm were prepared.

Fig. 4 to Fig. 6 show the spectra obtained by these measurements. The number of waves (interference fringes) decreases as the thickness of the films becomes thinner. The number of waves for the 0.4 µm film shown in Fig. 6 is 3. Based on this, it appears that a thickness of around 0.4 µm is the measurable limit for thin films. Theoretically, calculation is possible with one peak and valley each, but because a pattern caused by interference of that peak and valley cannot be observed, calculation with multiple waves is recommended. Fig. 7 shows the results of the film thickness calculations of the resist films. The calculations for these resists were based on a refractive index of 1.65.

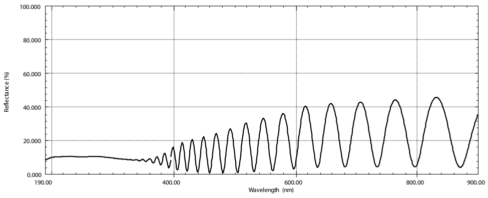


Fig. 4 Spectrum of 3.0 µm Resist Film

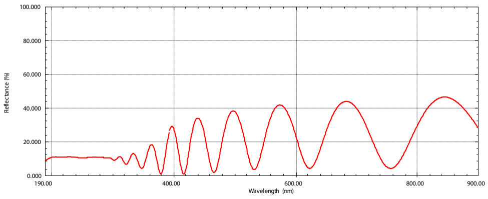


Fig. 5 Spectrum of 1.1 µm Resist Film

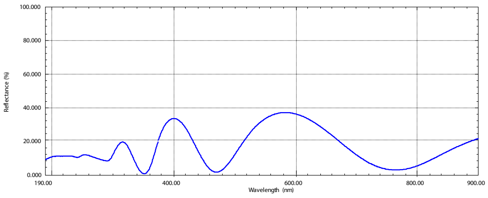
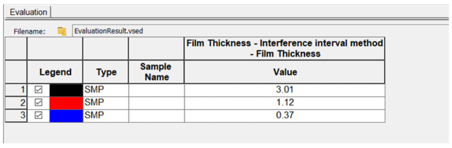


Fig. 6 Spectrum of 0.4 µm Resist Film



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				Film Thickness - Interference interval method - Film Thickness
	Legend	Type	Sample Name	Value
1	☑ ⬛	SMP		3.01
2	☑ 🟥	SMP		1.12
3	☑ 🟦	SMP		0.37

Fig. 7 Results of Film Thickness Calculations

Measurable Film Thickness for Thick Films

Next, the measurable thickness range for thick samples was studied. Three types of samples with thicknesses of approximately 10 µm, 40 µm, and 100 µm were prepared. Fig. 8 to Fig. 10 show the spectra obtained by these measurements. The number of waves (interference fringes) increases as the thickness of the films becomes larger.

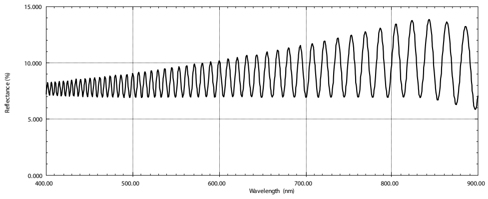


Fig. 8 Spectrum of 10 µm Film

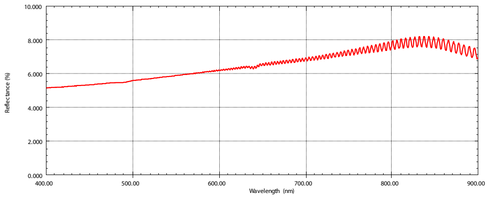


Fig. 9 Spectrum of 40 µm Film

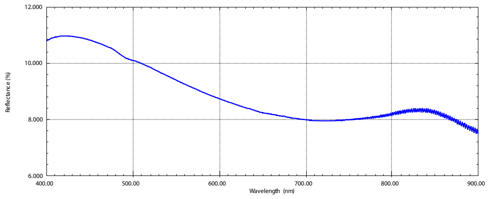
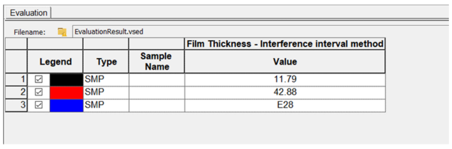


Fig. 10 Spectrum of 100 µm Film

Fig. 11 shows the results of the film thickness calculations of the thick films. Although calculation values are shown for the films up to the thickness of 40 µm, an "E28" error is shown for the 100 µm film. This occurs because the sampling pitch is wide, irrespective of the narrow interval of the waves (interference fringes), and as a result, peak detection is not possible.

Therefore, the film thickness was calculated after measuring the spectrum again with the sampling pitch set to 0.1 nm. Fig. 12 shows the calculation result. A result of 110 µm was obtained.



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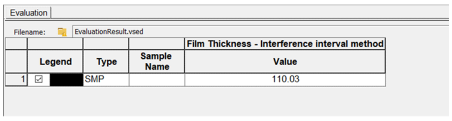
				Film Thickness - Interference interval method
	Legend	Type	Sample Name	Value
1	☑ ⬛	SMP		11.79
2	☑ 🟥	SMP		42.88
3	☑ 🟦	SMP		E28

Fig. 11 Results of Film Thickness Calculations



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				Film Thickness - Interference interval method
	Legend	Type	Sample Name	Value
1	☑ ⬛	SMP		110.03

Fig. 12 Result of Film Thickness Calculation (Sampling Pitch: 0.1 nm)

Conclusion

In this experiment, the thicknesses of films with various thicknesses were measured using the film thickness calculation function of LabSolutions UV-Vis software. As a condition for measurement, it must be possible to observe interference fringes. However, it is possible to measure film thicknesses from around 0.4 µm to 100 µm by film thickness measurement by using a UV-Vis spectrophotometer. Care is necessary in case of thick films, as calculation may not be possible if the sampling pitch is not sufficiently smaller than the wavelength (distance between interference fringes).

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First Edition: Mar. 2020

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