Calibration of an Optical Compensator by Ellipsometry

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Received 30 June 1965.

The literature on ellipsometry[1–4] emphasizes the measurement of optical constants of surfaces and thickness of thin films. We have found that the formulation of Winterbottom[1] and the zone representation of McCrackin *et al.*[3] can also be used to provide a convenient and accurate method for determining the retardation of an optical compensator. Furthermore, in contrast to a similar method described by Jerrard,[5] this technique does not require the use of a second compensator.

Ellipsometry is the measurement of the effect of reflection on the state of polarized light. As shown in Fig. 1, an ellipsometer is essentially a spectrometer fitted with a polarizer and an analyzer, a reflecting surface, and provision for mounting various compensators.

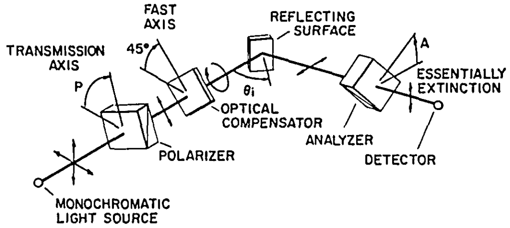

Fig. 1. Schematic diagram of ellipsometer.

Winterbottom[1] has shown that the Poincaré representation of polarized light permits the retardation of a compensator to be expressed in the form

$$\delta(\lambda) = \cos^{-1}\left[\frac{\sin(a_p - a_s)}{\sin(a_p + a_s)\cos 2p}\right], \qquad (1)$$

where p, a_p, and a_s (in the notation of refs. 1 and 3) are related to the polarizer and analyzer angles P and A required for extinction. The zonal classification introduced by McCrackin *et al.*,[3] outlined in Table I, provides a systematic procedure for determining the parameters of Eq. (1).

The locations of the fast and slow axes of the compensator can be found with an undeflected beam by crossing the polarizer and analyzer. Under these conditions, with the compensator removed, complete extinction exists. When the compensator is placed into its mount, extinction is no longer complete. The compensator is then rotated until extinction is restored.

To distinguish between the fast and slow axes, rotate the compensator so that its axes are at $\pm\pi/4$ to the plane of incidence, and locate the metallic reflecting surface near its principal angle of incidence. By rotating alternately the polarizer and analyzer, attempt to obtain an extinction subject to the condition that the polarizer angle P must lie between 0 and $\pi/4$ (Zone 1 of Table I). If extinction can be obtained in this range, the fast axis is at $-\pi/4$; otherwise it is at $+\pi/4$.

With the location of the fast axis known, p, a_p, and a_s can be found as follows: for each zone, set the compensator's fast axis to the angle indicated in column two of Table I, and then rotate the polarizer and analyzer to obtain complete extinction, subject to the requirement that P be in the angular range indicated in column three of Table I. The retardation $\delta(\lambda)$ can then be found from Eq. (1) using the average values of p, a_p, and a_s.

This method has been used to measure the retardation of several birefringent plates. A plot of δ vs λ for a typical plate is shown in Fig. 2. Measurements for this plate using steel, Au, Al, and Al_2O_3 on Al reflecting surfaces gave δ(5460 Å) of 87.88 ± 0.42°. $\Delta\delta$ falls within our estimated experimental error.

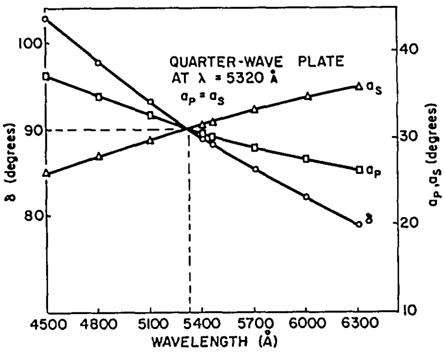

Fig. 2. Retardation of mica plate.

Table I. Zone Representation of the Ellipsometer

Zone	Angle of compensator fast axis	Range of P	P^a	$a_p{}^a$	$a_s{}^a$
1	$-\pi/4$	0–$\pi/4$	P_1	A_1	^{b}
2	$\pi/4$	$\pi/4$–$\pi/2$	$\pi/2-P_2$	^{b}	A_2
3	$-\pi/4$	$\pi/2$–$3\pi/4$	$P_3-\pi/2$	^{b}	$\pi-A_3$
4	$\pi/4$	$3/4\pi$–π	$\pi-P_4$	$\pi-A_4$	^{b}

[a] a_p and a_s are undetermined in this zone.

[b] The values of p, a_p, and a_s are averaged over the four zones.

References

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Further Remarks on "A Numerical Method for Determining the Relative Spectral Response of the Vidicons in a Nimbus Satellite System"

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Received 26 October 1965.

It has been brought to our attention that our recent paper[1] on the application of filters to the determination of the spectral sensitivity of various photometric devices has, in part, a close resemblance to the methods reported earlier by Wyszecki[2] and by Mori.[3] The purpose of this letter is to indicate that, when using a photometer whose signal-to-noise ratio is small (e.g., in ref. 1 the noise was about 5% of the maximum output), one cannot use a combination of filters which will lead to a well-conditioned matrix, and one, therefore, cannot apply the method of Wyszecki and Mori.