

SEMI MF1763-0706 (Reapproved 1111) TEST METHODS FOR MEASURING CONTRAST OF A LINEAR POLARIZER

This Standard was technically approved by the Silicon Wafer Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on September 12, 2011. Available at www.semiviews.org and www.semi.org in November 2011; originally published by ASTM International as ASTM F1763; previously published July 2006.

NOTICE: This Document was reapproved with minor editorial changes.

1 Purpose

1.1 Polarizer contrast is important in polarimetry systems, ellipsometers, optical modulators, shutters, and target signature discrimination based on polarized radiation.

1.2 These Test Methods cover measurement of polarizer contrast. A distinction is made between contrast, which is an intrinsic polarizer property, and extinction, which is a comparison between two polarizers. Use of contrast to characterize polarizers is encouraged because it is an intrinsic property of the polarizer. Use of extinction to characterize polarizers is discouraged because it is an average between two polarizers and not specific to either one.¹

1.3 These Test Methods are suitable for use in service evaluation, manufacturing control, or for research and development purposes. They are not recommended for use in acceptance testing until their precision has been evaluated by interlaboratory comparison unless the parties to the test conduct suitable correlation studies.

2 Scope

2.1 These Test Methods are applicable to polarizers that operate in a transmissive mode at near-normal incidence. Angular or translative offset of the transmitted beam is acceptable if the entire transmitted beam power can be measured.

2.2 The polarizer size or aperture is not limited by the test methods, but the operator must appreciate that the contrast is an average over the beam spot on the polarizer. Contrast measured at one location on the aperture does not necessarily apply to the entire aperture.

2.3 Three test methods are described. The first method is a direct contrast measurement that requires a linearly polarized light source with high contrast, C_L . The second method is a comparison with a linearly polarized light source with known C_L . The third method is an indirect contrast measurement that can use an unpolarized or polarized light source of unknown C_L .

2.3.1 *Direct Contrast Measurement* — This is the preferred method for measuring C of a single polarizer. This method can be used if $C_L \gg C$ for the polarizer to be tested. It is a simple, expedient, and accurate test method if a highly linear polarized light beam is available at the required wavelength. The source is normally a polarized laser beam in combination with a high-contrast prism polarizer. A tunable broadband source can also be used if a high-contrast polarizer is available for the wavelength of interest.

2.3.2 *Contrast Measurement with Comparison* — This method is used if C_L is approximately equal to C for the polarizer to be tested. The value of C_L must be known to obtain the correct C for the polarizer.

2.3.3 *Indirect Contrast Measurement* — This method requires three polarizers that have similar C . This test method can be used with any light beam regardless of the contrast of the light beam. It is the only method that can be used when the available $C_L \ll C$ for the polarizer to be tested.

2.4 The parties to the test shall agree upon the following items:

- Test method to be used,
- Light source properties including wavelength, power level, and degree of collimation, and

¹ Leonard, T. A. "Infrared Polarizer Selection." *Proceedings SPIE* **288**, 129 (1981).

- Measurement parameters at the polarizer, including beam size, location in the aperture, and angle-of-incidence.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 These Test Methods are limited to wavelengths for which the tester can provide a collimated beam, and correctly measure changes in the transmitted beam power. The contrast obtained at one wavelength does not necessarily apply at any other wavelength.

3.2 The maximum contrast obtained by these test methods is limited by the dynamic range of the source-detector combination.

4 Referenced Standards and Documents

4.1 ANSI Standard²

ANSI Z136.1 — American National Standard for Safe Use of Lasers

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Definitions

5.1.1 *contrast (of a light beam)*, C_L — a measure of the degree of linear polarization of a light beam given by the ratio of the linearly polarized light power in the maximum direction to that in the minimum direction.

5.1.1.1 *Discussion* — Contrast of a light beam is given by:

$$C_L = \frac{P_1}{P_2} \quad (1)$$

where:

P_1 = linearly polarized light power in the maximum direction.

P_2 = linearly polarized light power in the minimum direction.

For an unpolarized or circularly polarized light beam, $C_L = 1$. For a completely linearly polarized light beam, $C_L = \infty$.

5.1.2 *contrast (of a polarizer)*, C — ratio of maximum transmission through a polarizer to minimum transmission when the polarizer is rotated in a light beam of infinite contrast.

5.1.2.1 *Discussion* — Contrast is an intrinsic property of a polarizer. It is given by the expression:

$$C = \frac{t_1}{t_2} \quad (2)$$

where:

t_1 = maximum transmission through the polarizer.

t_2 = minimum transmission through the polarizer.

5.1.3 *extinction*, X — ratio of maximum to minimum transmission of light through a pair of polarizers that are rotated with respect to each other.³

² American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, <http://www.ansi.org>

³ Bennett, J. M., and Bennett, H. E. "Polarization." in the *Handbook of Optics*, W. G. Driscoll and W. Vaughan, Eds., McGraw-Hill, New York, 1978, § 10.

5.1.3.1 *Discussion* — X is an average between the two measured polarizers and is not necessarily applicable to either polarizer taken alone. If the two polarizers have the same contrast, $X = t_1/2t_2 = 1/2C$. Extinction can be measured with unpolarized or polarized light. The inverse of X is sometimes referred to as *extinction ratio*. The distinction is self-evident because X varies from 1 to ∞ and $1/x$ varies from 1 to zero.

5.1.4 *leakage transmission, t_2* — ratio of minimum transmitted light power for a polarizer rotated in a light beam of infinite contrast, to the total light beam power without the polarizer.

5.1.4.1 *Discussion* — This ratio is given by:

$$t_2 = \frac{P_{\min}}{P_{\text{tot}}} \quad (3)$$

where:

$P_{\min}$ = minimum transmitted light power for a polarizer rotated in a light beam of infinite contrast, and

P_{tot} = total light beam power without the polarizer.

Note that $P_{\text{tot}} = P_1 + P_2$.

5.1.5 *transmission, t_1* — the ratio of maximum transmitted light power for a polarizer rotated in a light beam of infinite contrast, to the total light beam power without the polarizer.

5.1.5.1 *Discussion* — This ratio is given by:

$$t_1 = \frac{P_{\max}}{P_{\text{tot}}} \quad (4)$$

where:

$P_{\max}$ = maximum transmitted light power for a polarizer rotated in a light beam of infinite contrast.

6 Summary of Test Methods

6.1 *Direct Contrast Measurement* — In this test method the polarizer being tested is rotated in the light beam and the maximum and minimum transmissions are used to calculate C .

6.2 *Contrast Measurement with Comparison* — In this test method the polarizer being tested is rotated in the light beam and the maximum and minimum transmissions are used with the known value of C_L to calculate C .

6.3 *Indirect Contrast Measurement* — The three polarizers are measured in pairs to obtain an X for each pair. The three X 's are then used to approximate C for each individual polarizer. In this test method one polarizer is aligned in the light beam in such a way as to cancel effects of the polarization state of the light beam on the measurement. The second polarizer is rotated in the beam and the maximum and minimum transmissions are used to calculate X for the pair.

7 Apparatus

7.1 *Contrast measurements* shall utilize some form of the three assemblies described in this section. These assemblies are described in a general manner in order not to exclude any particular type of measurement apparatus.

7.2 *Source Assembly* — Light source and associated optics to produce a collimated light beam of power P_{tot} , with specified size at the sample polarizer, and a high contrast (for direct contrast measurement). If a broad band light source is used, the wavelength selection technique and bandwidth shall be specified. If a laser source is used, it is usually sufficient to specify the center wavelength; however, it is sometimes necessary to be more specific such as the particular line in a CO_2 laser. Slightly converging or diverging source light can be used; however, it must be appreciated that this configuration compromises the angle of incidence (AOI). Polarizer C may be very sensitive to AOI (e.g., a Brewster angle polarizer) or insensitive to AOI (e.g., a metal grid polarizer). It is the user's responsibility to ensure that any spread in AOI does not compromise the measurement.

7.3 *Polarizer Holder(s)* — With provision for smoothly rotating the polarizer(s) in azimuth. One polarizer holder is needed for the direct and comparison test methods and two are needed for the indirect test method. It may also be necessary to have a means of adjusting the AOI on the polarizer and positioning the polarizer aperture in the beam.