

SEMI P29-1111

SPECIFICATION FOR CHARACTERISTICS SPECIFIC TO ATTENUATED PHASE SHIFT MASKS AND MASK BLANKS

This Standard was technically approved by the Micropatterning 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 September 1997; previously published November 2005.

NOTICE: This Standard or Safety Guideline has an Inactive Status because the conditions to maintain Current Status have not been met. Inactive Standards or Safety Guidelines are available from SEMI and continue to be valid for use.

1 Purpose

1.1 This Specification covers the characteristics specific to attenuated phase shift masks and mask blanks.

2 Scope

2.1 This Standard details the attenuated phase shift masks and mask blanks for g-line, i-line, KrF, ArF and/or F2 lithography.

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 Referenced Standards and Documents

3.1 SEMI Standards and Safety Guidelines

SEMI P1 — Specification for Hard Surface Photomask Substrates

SEMI P2 — Specification for Chrome Thin Films for Hard Surface Photomasks

SEMI P22 — Guideline for Photomask Defect Classification and Size Definition

SEMI P28 — Specification for Overlay-Metrology Test Patterns for Integrated-Circuit Manufacture

3.2 ANSI Standard¹

ANSI/ASQ Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

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

4 Terminology

4.1 Definitions

4.1.1 Terms for General Description

4.1.1.1 *attenuated phase shift mask* — a photomask designed to increase resolution and DOF through the control of light transmittance and phase angle. This is done against a transparent part by replacing a conventional opaque pattern with a partially transmitted film (attenuated shifter film) that controls light phase angle and transmittance. Also referred to as “half-tone phase shift masks” and also referred to as “attPSM” for short.

4.1.1.2 *attenuated phase shift mask blanks* — mask blanks for making attenuated phase shift masks.

4.1.1.3 *opaque frame* — an area of a certain width, adjacent to the periphery of the desired exposure area on a reticle. It is located in the non-exposure area of the reticle to prevent exposure outside the desired printed field on the wafer.

4.1.1.4 *phase shift mask* — a photomask designed to increase resolution and DOF through the control of the phase angle. Also referred to as “PSM” for short.

¹ 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>

4.1.2 Terms for Structural Description

4.1.2.1 *additional film type attenuated phase shift mask* — an attenuated phase shift mask having an additional film for light shielding and/or improving a resolution enhancement.

4.1.2.2 *additional film type opaque frame* — an opaque frame composed of light shield materials other than the shifter. An opaque frame constructed with an additional stacked film on a shifter film.

4.1.2.3 *embedded attenuated phase shift mask* — an attenuated phase shift mask having an attenuated shifter film, to give a certain phase angle and transmittance. Also referred to as “EAPSM” for short.

4.1.2.4 *full tri-tone phase shift mask* — a tri-tone phase shift mask employing opaque patterns to improve lithographic performance of the primary features. Also referred to as “ternary type phase shift mask.”

4.1.2.5 *multi-layer attenuated phase shift mask* — an attenuated phase shift mask having multiple thin films of different material compositions to give a certain phase angle and transmittance. The layer that adjoins the substrate shall be called the first layer.

4.1.2.6 *phase shift overlay error* — a placement error between phase shift layer and opaque film layer, for additional film type attenuated phase shift masks.

4.1.2.7 *quartz etched attenuated phase shift mask* — an attenuated phase shift mask having a quartz etched portion for phase angle control.

4.1.2.8 *single-layer attenuated phase shift mask* — an attenuated phase shift mask having a thin film of the same material composition, to give a certain phase angle and transmittance. An attenuated shifter film whose components gradually change is classified as a single layer.

4.1.2.9 *sub-resolution type opaque frame* — an opaque frame composed of small rectangles or line/space patterns in a shifter.

4.1.2.10 *tri-tone phase shift mask* — an attenuated phase shift mask including an opaque area inside the exposure area. An opaque area consists of opaque film stacked on top of a phase shifter film.

4.1.3 *Terms for Description of Optical Characteristics* — The measurements of optical characteristics defined in this subsection should be performed at a uniform area where any edge in the pattern is sufficiently away from the measurement area so that diffraction effects are avoided.

4.1.3.1 *glass side reflectivity* — a ratio of the intensity of reflected light to the intensity of incident light into the glass side, which is the side of the mask or blank without the shifter films. The reflectivity depends on the incident angle, the wavelength of the light, and the extent of polarization of the incident light. The difference between the glass side reflectivity of an area with and without opaque film should be recognized. The intensity of the incident light is usually calculated by the intensity of the reflected light measured using a reference mirror. (Figure 1 illustrates the glass side reflectivity without opaque film.)

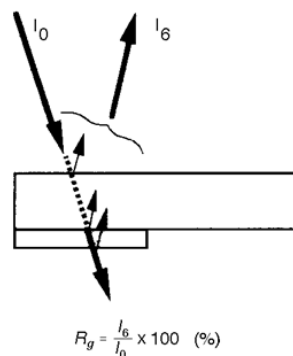
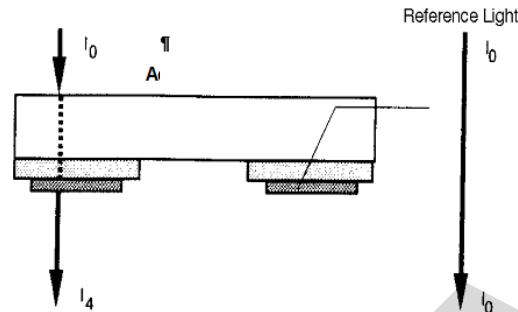


Figure 1
Glass Side Reflectivity

4.1.3.2 *opaque frame transmittance* — a ratio of the intensity of light transmitted through the additional film type opaque frame area to the intensity of incident light measured with air reference. (Figure 2 illustrates the opaque frame transmittance.)

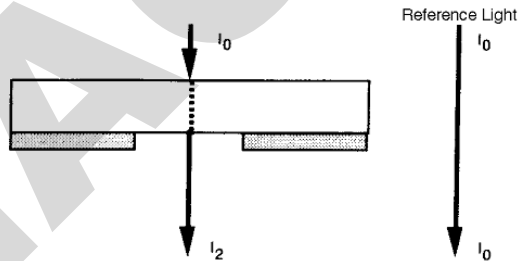
NOTE 1: For an attenuated phase shift mask with sub-resolution type opaque frame, transmittance of the opaque frame area is not defined in this Specification because it depends heavily on the characteristics of the optical systems used.



$$T_4 = \frac{I_4}{I_0} \times 100 \quad (\%)$$

Figure 2
Opaque Frame Transmittance

4.1.3.3 *opening area transmittance* — a ratio of the intensity of light transmitted through an opening area of a patterned attenuated phase shift mask to the intensity of vertical incident light measured with air reference. (Figure 3 illustrates the opening area transmittance.)



$$T_2 = \frac{I_2}{I_0} \times 100 \quad (\%)$$

Figure 3
Opening Area Transmittance

4.1.3.4 *phase angle* — a difference in the phase of light generated by vertical transmission through a shifter area and that through an opening area, with an optical path through air equivalent to the shifter film in thickness. Also referred to as “phase difference” or “phase shift” or “phase shift angle.” Unless otherwise defined, the reference point of the phase angle shall be the unetched Quartz surface. Direction of phase sign shall be the direction of vertical incident light. (Figure 4 illustrates the phase angle definition.)