SEMI MF728-1106 (Reapproved 0622)
PRACTICE FOR PREPARING AN OPTICAL MICROSCOPE FOR DIMENSIONAL MEASUREMENTS

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1 Purpose

1.1 Dimensional measurements made with an optical microscope are made on the optical image of the specimen and not directly on the specimen itself. The method of illuminating the specimen affects the image content, including the appearance of edges which are used in defining the size of the specimen.

1.2 This Practice includes adjusting the microscope for Kohler illumination, which provides uniform illumination of the specimen, reduces stray light, and results in bright images with good contrast.

1.3 This Practice provides an image with steep edge gradients by setting the ratio of condenser numerical aperture to objective numerical aperture equal to approximately two thirds. As a result, the repeatability of edge settings used in measurement eyepieces and photometer line profiles is improved.

1.4 Many different types of microscopes and micrometer attachments are used for dimensional measurements. This Practice reduces the effects of image-contrast variation on measurements with these different systems.

1.5 This Practice is particularly useful for preparing the microscope to measure the width of lines on hard-surface photomasks and processed silicon wafers. These linewidths are used for comparison with design values and to help determine the quality control of the processes used to fabricate the photomasks and wafers. These linewidths are useful for materials acceptance purposes or for other matters relating to the sale or purchase of materials.

1.6 This Practice is intended primarily as a guide in preparing an optical microscope for dimensional measurements and is used in conjunction with the instruction manual provided by the manufacturer.

2 Scope

2.1 This Practice covers the preparation of an optical microscope for dimensional measurements. It is intended for preparing an optical microscope to measure the width of lines, in the range from 0.5 µm to 12 µm, inclusive, on hard surface photomasks and processed silicon wafers.

2.2 This Practice is applicable for a microscope equipped with a micrometer attachment, such as an optical filar, video filar, optical image-shearing with optical or video display, optical image-scanning, or video image-scanning micrometer. Adjustment and calibration of the micrometer attachment is not included in this practice.

2.3 This Practice is intended for observing optically transparent specimens in bright-field transmitted illumination or optically opaque specimens in bright-field reflected illumination. It is not intended for dark-field illumination.

2.4 This Practice is limited to an optical microscope with an illumination system that is an integral part of the microscope body and includes a condenser lens.

2.5 No useful figure capable of showing the arrangement of components for all microscope designs is available; therefore, this Practice does not contain illustrations and procedures that would suggest a specific microscope.

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3 Limitations

3.1 Most microscopes have lenses and mirrors that are either inaccessible for adjustment or permanently fixed in position. If these components were not properly pre-aligned by the manufacturer, adjusting the microscope for Kohler illumination may not be possible. If the microscope cannot be adjusted for Kohler illumination, the image of the specimen may exhibit poor contrast, the field of view may be illuminated nonuniformly, and the optical resolution may be reduced. Consequently, the repeatability of edge settings used in measurement systems would be adversely affected.

3.2 A microscope objective is designed for use with a specified mechanical tube length. Using an objective with the specified mechanical tube length that is different from the actual tube length of the microscope results in a degraded image and measurement errors.

3.3 For transmitted illumination, the use of a specimen with a thickness greater than about 2 mm may make it difficult to adjust for Kohler illumination, particularly for a condenser with a numerical aperture as high as 0.6. The specimen introduces spherical aberration and defocus in the image of the diaphragm that is focused on the top surface of the specimen (specimen plane), and the sharpness of this image is reduced as the specimen thickness increases.

4 Referenced Standards and Documents

4.1 *ASTM Standards*[1]

ASTM E175 — Standard Terminology of Microscopy

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

5 Terminology

5.1 Many of the terms used in this Practice are defined in ASTM E175.

5.2 *Definitions*

5.2.1 *coherence — in optics*, a measure of the ability of light to interfere.

5.2.1.1 *Discussion* — Coherence arising from the finite extent of the light source is spatial coherence. Coherence arising from the finite spectral width of the light source is temporal coherence.

5.2.2 *coherence parameter — in microscopy*, the ratio of the condenser numerical aperture to the objective numerical aperture for wide-field, bright-field, Kohler illumination.

5.2.3 *condenser aperture diaphragm — in microscopy*, a fixed or variable opening that controls the light passing through the condenser and determines the value of the condenser numerical aperture.

5.2.4 *condenser lens or substage condenser — in microscopy*, a lens that collects light for the purpose of illuminating the specimen.

5.2.5 *condenser numerical aperture — in microscopy*, the product of the index of refraction in object space multiplied by the sine of half the angular aperture of the condenser.

5.2.6 *condenser system — in microscopy*, lenses and mirrors that collect light for the purpose of illuminating the specimen.

5.2.6.1 *Discussion* — A condenser system usually consists of mirrors, a lamp collector, relay lenses, and a condenser lens.

5.2.7 *contrast — in microscopy*, the ratio of the transmittance or reflectance of two different areas on the specimen.

5.2.8 *cover glass — in microscopy*, a thin glass plate that is placed over the specimen.

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5.2.8.1 *Discussion* — Some microscope objectives are designed for use with a cover glass of a specified thickness, and use of these objectives without a cover glass or with a cover glass of a different thickness from the specified thickness introduces spherical aberration in the observed image.

5.2.9 *epi-objective — in microscopy* , an objective with an annular mirror that acts as a lens to illuminate the specimen.

5.2.9.1 *Discussion* — An epi-objective is commonly used in dark-field reflected illumination, but it is also useful in bright-field illumination.

5.2.10 *field diaphragm — in optics*, a usually variable opening that controls the field of view.

5.2.11 *field of view — in microscopy*, the area or solid angle viewed through the microscope.

5.2.11.1 *Discussion* — Field of view is often expressed as the diameter of the largest image which the eyepiece can cover.

5.2.12 *filar micrometer, optical* — for the purposes of this practice, a micrometer equipped with a movable fiducial line imaged in the eyepiece.

5.2.13 *filar micrometer, video* — for the purposes of this practice, a micrometer equipped with movable, electronically generated fiducial lines that appear, along with an image of the specimen, on a television monitor.

5.2.14 *illumination, bright-field — in microscopy*, a method of illumination in which the image appears against a bright background generally produced by uniformly illuminating a circular and unobstructed condenser aperture diaphragm.

5.2.15 *illumination, dark-field — in microscopy*, a method of illumination in which the image appears as self-luminous against a dark background generally produced by illuminating the specimen with an annular cone of light so that only scattered light enters the objective.

5.2.15.1 *Discussion* — In dark-field transmitted illumination, the condenser has an opaque center stop. In dark-field reflected illumination, the objective has a reflective annular surface that surrounds the lenses and serves as a condenser.

5.2.16 *illumination, Kohler — in microscopy*, a method of illumination in which an image of the light source is focused on the condenser aperture diaphragm located at or near the back focal plane of the condenser lens and an image of the lamp collector is focused on the specimen plane.

5.2.17 *image-scanning micrometer, optical* — for the purposes of this Practice, a micrometer that uses a phototube and scanning slit to generate an optical image profile from which the specimen dimension is determined by means of an optical threshold.

5.2.18 *image-scanning micrometer, video* — for the purposes of this Practice, a micrometer that uses a television camera to generate an electronic image profile from which the specimen dimension is determined by means of an electronic threshold.

5.2.18.1 *Discussion* — In semiautomatic image-scanning micrometers, the operator sets an electronic window in the vicinity of the boundaries of the specimen image, and the edge locations are determined automatically by electronic thresholding techniques.

5.2.19 *image-shearing micrometer, optical* — for the purposes of this Practice, a micrometer that optically shears, or splits, the image of the specimen into two identical images whose separation can be continuously adjusted while being viewed in the eyepiece.

5.2.20 *image-shearing micrometer, video* — for the purposes of this Practice, a micrometer that optically shears, or splits, the image of the specimen into two identical images whose separation can be continuously adjusted while being viewed on a television monitor.

5.2.21 *lamp collector or lamp condenser — in microscopy*, a lens that collects light from the lamp and usually focuses the light either on the specimen or on the condenser aperture diaphragm.

5.2.22 *lamp diffuser — in microscopy*, a ground-glass plate or other light-diffusing material used to improve the uniformity of the illumination.

5.2.23 *mechanical tube length — in microscopy*, the distance between the shoulder or flange of the objective and the eyepiece seating face.

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