S. Department of Commerce
Malcolm Baldrige
Secretary

National Bureau of Standards
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National Bureau of Standards

Certificate

Standard Reference Material 474

Optical Microscope Linewidth Measurement Standard

This Standard Reference Material (SRM) is intended for calibrating optical microscopes used to measure linewidths from 0.5 to 12.0 µm and is specifically designed for the measurement of opaque lines and clear lines on integrated-circuit (IC) photomasks in transmitted illumination.

This SRM is certified for linewidths (both clear and opaque) and line spacings (both center-to-center and edge-to-edge) for one of eight basic patterns. These certified values are given in the attached tables. (The last digit of the serial number ______________ identifies which basic pattern is certified.) Each certified value is an average of nine measurements.

All of the certified values have an uncertainty (systematic and random errors) of ± 0.05 µm. The dominant contribution to the uncertainty is the estimated maximum linewidth error resulting from the finite material edge slope; further details are given on the following page. In addition, the linewidth uncertainty includes a small contribution from the measurement precision which is ______________ (95% confidence limits) on rows A through D and row F. The precision uncertainty for the edge locations in row G is ______________. The line-spacing uncertainty (precision only) for row E is ______________ .

The method for using SRM 474 to calibrate optical linewidth measurement systems is described in the attached documents. These procedures have successfully been used in an interlaboratory study with photomasks nearly identical to SRM 474. This study showed that the SRM can be used to calibrate optical linewidth measurement systems and, in most cases, leads to an improvement in the accuracy of the measurements.

SRM 474 is made from an anti-reflective chromium photoplate by conventional photolithographic techniques. The substrate is a borosilicate glass plate nominally 6.35 x 6.35 x 0.15 cm (2.5 x 2.5 x 0.060 in). The nominal thickness of the two-part anti-reflective chromium layer is 150 nm.

The technical measurements and characterization of this Standard Reference Material were performed in the Semiconductor Materials and Processes Division by M. J. Dodge, W. R. Smallwood and C. Vezzetti. J. M. Jerke assisted in the preparation of the recommended procedures for its use. Technical measurement coordination and overall direction of the technical activities were performed by D. Nyyssonen.

The technical and support aspects involved in the preparation, certification, and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by R. K. Kirby.

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George A. Uriano, Chief
Office of Standard Reference Materials

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Figure 1 shows the overall pattern of SRM 474. The cross-shaped clear area contains a series of horizontal and vertical lines that are used to help locate the basic measurement pattern on the gold-colored surface. The basic pattern is repeated at eight locations around the center of the standard as shown in figure 2, which is a magnified view of the central area of SRM 474. As seen in this figure, each basic pattern is located near the terminal of a horizontal or vertical line, or both. An underlined number (1 through 8) is located next to each basic pattern. These numbers, which are shown in figure 2, are used to identify which one of the eight basic patterns has been certified by NBS.

Figure 3 shows the basic measurement pattern on SRM 474. Letters A through G designate the row locations, and numbers 0 through 9 designate the column location for each line, line pair, or other pattern element; for example, C-5 refers to the opaque line in row C and column 5. Rows A and C consist of opaque lines on a clear background, and rows B and D consist of clear lines on an opaque background. These opaque and clear lines are used for calibrating the optical microscope to measure linewidths of both polarities (opaque and clear). Row E consists of opaque line pairs (two interior lines of equal length) for calibrating the optical microscope to measure the distances between line centers. Row F consists of adjacent lines and spaces (two interior lines of equal length and intervening space) of approximately equal widths for setting the line-to-space ratio on video image-scanning micrometer attachments. The widths of the left interior line and central space are certified. Row G consists of two patterns with a series of 10 opaque lines in each pattern for detecting certain types of mechanical and optical errors in the measurement system. The position of each edge, both left and right, is certified sequentially as measured from the left-most line edge. Each row contains a broken horizontal fiducial line which is used to define the measurement area of each pattern.

All measurements were made with the NBS optical linewidth measurement system [1,2]. This system is an optical image-scanning microscope with an interferometric stage. Linewidths are determined from the image profile using coherent optical edge detection. The effective scanning slit corresponds to a measurement area of 0.13 x 1.3 μm which, during measurement, is centered top to bottom on the fiducial line.

Based on measurements with a scanning electron microscope (SEM), the line-edge slope is approximately 70 degrees. As shown in figure 4, this value of line-edge slope gives a line-edge width of approximately 0.05 μm for a 150-nm thick layer of chromium/chromium oxide. Although preliminary analysis indicates that the optical linewidth corresponds to the material width measured approximately 75 nm above the glass surface as indicated in figure 4, the effects of the material edge profile on the optical measurement are as yet unknown.

All measurements are performed in a laboratory with temperature controlled at 22 ± 1 °C (72 ° ± 2 °F). Since the maximum dimension measured is less than 40 μm, the effects of temperature variation on the SRM in a normal laboratory environment are expected to be negligible.

CAUTION

Contamination or damage can change the measured linewidths. The user should prevent the accumulation of airborne and other contaminants on the SRM. If cleaning becomes necessary, use only noncorrosive wetting solutions at room temperature. *Never use ultrasonic cleaning* which may cause the chromium-oxide coating to detach. The user should not bring the microscope objective, or any other object, into contact with the top surface (gold-colored side with the chromium/chromium oxide) of the SRM. (The chromium-oxide coating will detach under impact and the glass substrate may break.)

SRM 474 is specifically designed for use only with optical microscopes and *should not* be used in a scanning electron microscope (SEM). The material profile of the lines and spaces could change as a result of (1) coating the SRM with an evaporated film to reduce electrical charging in the SEM, (2) contamination deposition during operation of the SEM, and (3) subsequent cleaning to remove any contaminants. These changes in the material profile would invalidate the NBS certification.

References

1. Nyyssonen, D., "Linewidth Measurement with an Optical Microscope: The Effect of Operating Conditions on the Image Profile," *Appl. Opt. 16*, 2223-2230 (Aug. 1977).

2. Nyyssonen, D., "Spatial Coherence: The Key to Accurate Optical Micrometrology," Application of Optical Coherence Vol. 194 (Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 1979) pp. 34-44.