National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 473

Optical Microscope Linewidth Measurement Standard

Serial No.

This Standard Reference Material (SRM) is intended primarily for use in calibrating optical microscopes used to make dimensional measurements on antireflecting chromium integrated circuit photomasks. SRM 473 consists of patterns of clear and opaque lines with nominal dimensions ranging from 0.5 µm to 30.0 µm and line-spacing (pitch) patterns ranging from 2 µm to 70 µm (see figures 1 to 3). These patterns are on a nominal 127 mm x 127 mm x 2.3 mm (5.0 in x 5.0 in x 0.09 in) quartz substrate. Certified values are given for linewidths (both clear and opaque) and line-spacings (center-to-center) for one of the eight repeated patterns on the SRM as indicated by the pattern number given with the serial number. All measurements were made within 3 µm of the center of each line feature (at the fiducial line) and the certification applies only to that portion of the feature. The certified values and uncertainties are given in Table 1. A copy of SP 260-129 [1] is included with each unit for further reference.

Note: Use of this SRM in a scanning electron microscope is not recommended; the SRM may become contaminated, the material profile may be altered, and charging and edge effects may invalidate the measurement.

Certification Technique: All measurements for certification were made with the NIST optical linewidth measurement system [2], which is a photometric transmission microscope with a scanning stage and displacement measuring interferometer. Except for the set up and removal of the photomasks, the entire calibration process is automated. The performance of the system is assessed before and after each calibration by measuring features on a control photomask. These control measurements include center-to-center spacing of line pairs which have been independently calibrated on the NIST Line Scale Interferometer.

Linewidths are determined from the image profile (image intensity vs. position across a feature). The algorithm for locating the position on the image profile of the feature edge is derived from a mathematical model of the optical microscope and is based on the theory of partial coherence [3-5]. Because the relative brightness of an image profile at this edge position is a function of the physical and optical properties of the imaged object (the line), the calibration of a measurement system by using this SRM is valid only for measuring artifacts with physical and optical properties similar to the specific SRM used.

The underlying theory and the optical equipment used in the certification of the NIST photomask SRMs were developed and initially constructed by D. Nyyssonen of the NIST Precision Engineering Division.

The equipment for automation of the measurement process was subsequently designed, constructed, and programmed by J.E. Potzick of the NIST Precision Engineering Division.

Measurement and statistical analysis for this SRM were performed using the NIST optical linewidth measurement system by C.F. Vezzetti and P.A. Snoots of the NIST Precision Engineering Division.

Statistical support was provided by R.N. Varner of the NIST Statistical Engineering Division.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by R.J. Gettings.

Gaithersburg, MD 20899
Certificate Issue Date: January 30, 1997

Thomas E. Gills, Chief
Standard Reference Materials Program

Expiration of Certification: The certification of SRM 473 is valid indefinitely, within the measurement uncertainty specified, provided the SRM is handled and stored in accordance with the instructions given in this certificate (see Instructions for Use). Periodic recertification is not required; however, this certification will be nullified if the SRM is damaged, contaminated, or modified.

Instructions for Use: Care must be exercised when handling this SRM. Avoid touching the surface with the microscope objective lens while setting up or focusing. The procedures for using this SRM to calibrate optical linewidth systems are described in the documents accompanying this certificate. These procedures were used successfully in an interlaboratory study [6] with prototype antireflecting chromium SRM photomasks. This study showed that, in most cases, using an SRM to calibrate optical linewidth measurement systems leads to improved measurement accuracy.

Note: This SRM is one of a suite of three SRMs (473, 475, and 476) intended for calibrating systems for measuring linewidths on artifacts consisting of transparent substrates with thin, opaque patterned coatings. SRM 476 is patterned with bright chromium and is intended for calibrating systems for measuring artifacts with high reflectance. SRM 473 and SRM 475 are patterned with antireflecting chromium and are intended for calibrating systems for measuring artifacts with low reflectance. SRM 475 and SRM 476 are patterned on nominal 63.5 mm x 63.5 mm substrates and have certified linewidths ranging from 0.9 µm to 10.8 µm. SRM 473 is patterned on a nominal 127 mm x 127 mm substrate and has certified linewidths ranging from 0.5 µm to 30 µm nominal.

REFERENCES

[1] Potzick, J.E., "Antireflecting-Chromium Linewidth Standard, SRM 473, for Calibration of Optical Microscope Linewidth Measuring Systems," NIST Special Publication 260-129, (1996).

[2] Potzick, J.E., "Automated Calibration of Optical Photomask Linewidth Standards at the National Institute of Standards and Technology," SPIE Vol. 1087, Integrated Circuit Metrology, Inspection, and Process Control, Session 34, (Feb. 1989).

[3] Nyyssonen, D., "Linewidth Measurement with an Optical Microscope: The Effect of Operating Conditions on the Image Profile," App. Opt. 16, pp. 2223-2230, (Aug. 1977).

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

[5] Nyyssonen, D., Larrabee, R.D., "Submicrometer Linewidth Metrology in the Optical Microscope," NBS J. Res. (May-June issue) 92 (3), pp. 184-204, (1987).

[6] Jerke, J.M., Croarkin, M.C., and Varner, R.N., "Interlaboratory Study on Linewidth Measurement for Antireflective Chromium Photomasks," NBS Special Publication 400-74, (1982).

Certified Measurements and Uncertainties: All certified values given in Table I are mean values of 9 or more repeated optical linewidth measurements. The certified linewidth values have a maximum expanded combined uncertainty of 36 mm at the 95% confidence level. The dominant components are the estimated Type B linewidth uncertainties from the finite material edge geometry of the pattern features and from the unknown phase of light transmitted through the chrome, as well as the Type A random uncertainty of 9 nm.

The certified line spacing values have a maximum expanded uncertainty (from random and systematic effects) of 10 nm at the 95% confidence level.

Table 1. Certified Values. The following are the certified values, given in micrometers for SRM 473 Serial Number 473-BO38, pattern 1, calibrated 8 June 1995.

Linewidth:

1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	1K	1L
0.50	0.59	0.73	0.82	0.90	1.01	1.51	2.01	5.01	10.02	20.01	29.99

Spacewidth:

2A	2B	2C	2D	2E	2F	2G	2H	2I	2J	2K	2L
0.45	0.57	0.65	0.76	0.86	0.95	1.46	1.97	4.97	9.99	19.99	30.00

Center-to-center pitch:

3A	3B	3C	3D	3E
1.990	3.022	4.006	4.802	6.213

Relative line center positions:

4A	4B	4C	4D	4E	4F
0.000	4.990	14.995	19.995	39.990	69.993

Left inner linewidth/center spacewidth:

5A		5B		5C		5D	
1.02	0.98	2.02	1.99	3.02	2.99	5.01	4.98

Relative line center positions:

6A

0.000	1.997	3.995	5.987	8.001	9.998	12.007	14.008	15.994	17.987
20.010	22.002	23.996	25.998	28.002	29.985	31.991	33.991	36.000	37.997
40.011	42.001	44.000	45.989	48.001	49.995	52.001	53.991	55.993	58.001
59.996									

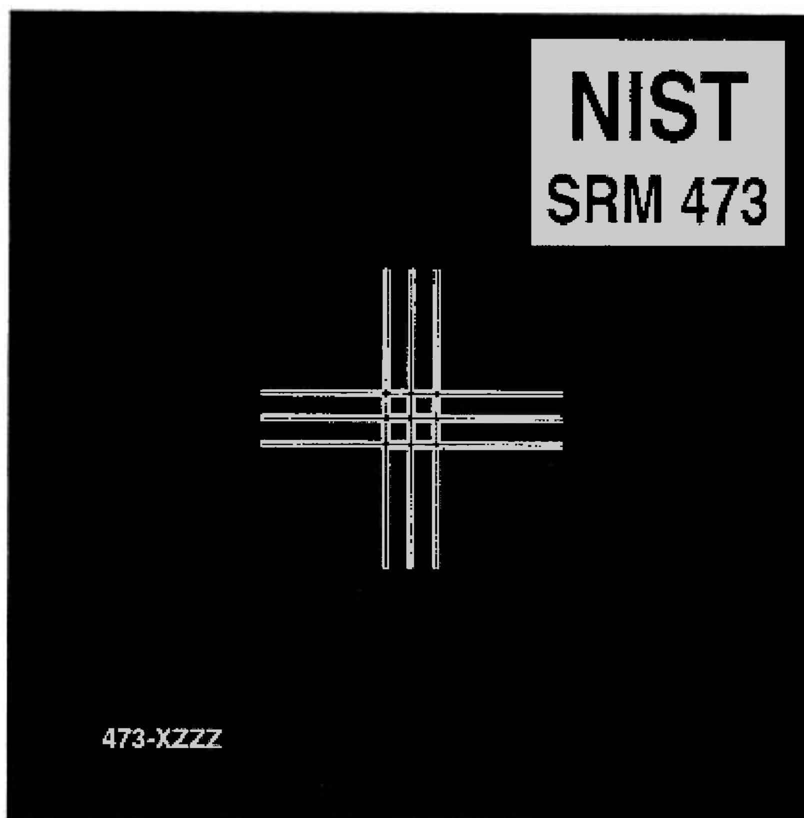

Figure 1. A view of the overall pattern on SRM 473. The basic measurement pattern is repeated eight times about the center. The horizontal and vertical lines help locate the patterns.

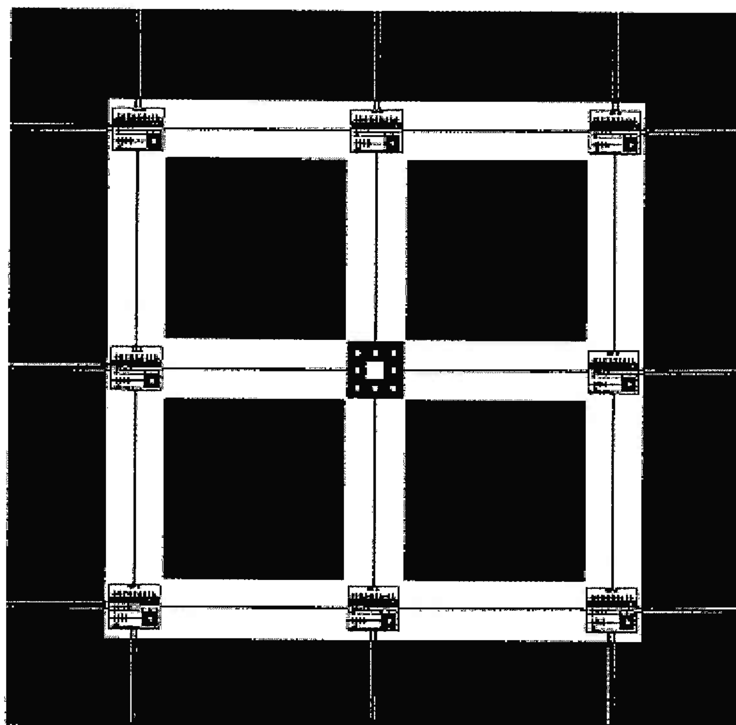

Figure 2. A view of the center of the SRM. The pattern number given with the serial number identifies which pattern has been measured by NIST. Pattern number 1 is in the upper left, pattern number 8 is in the lower right.

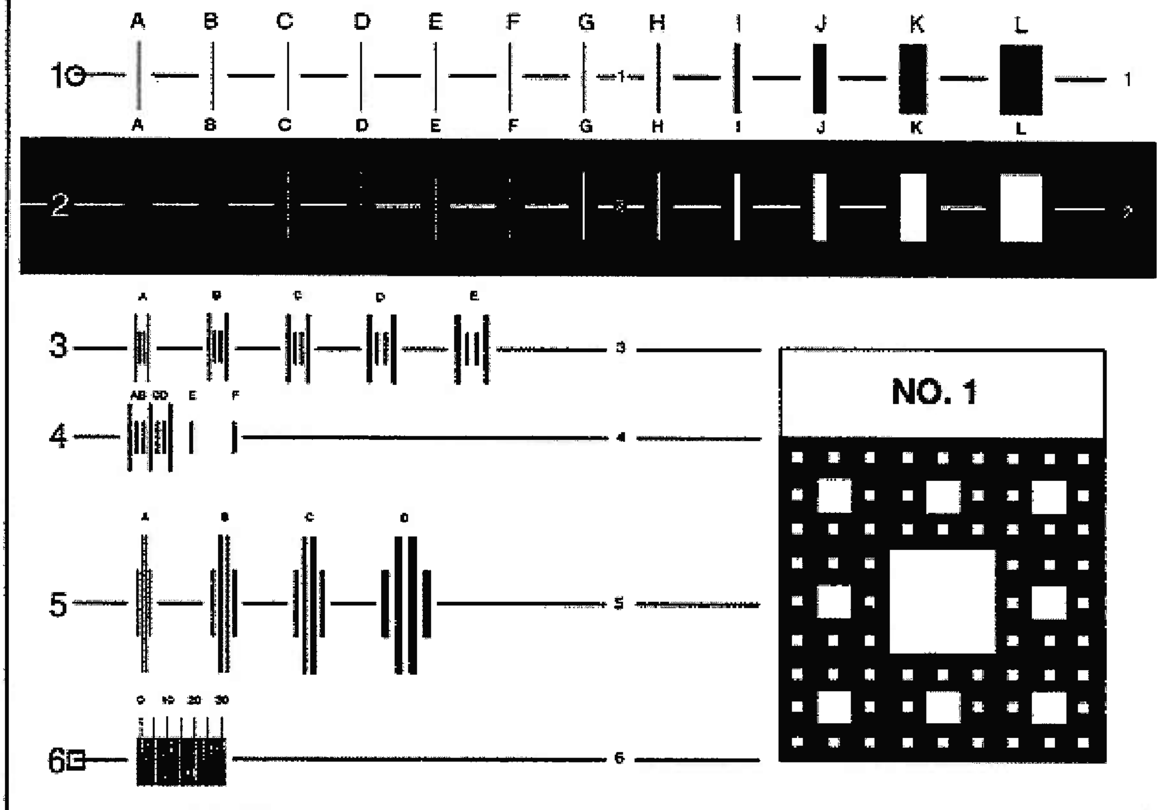

Figure 3. A view of one basic measurement pattern on the SRM. The calibrated features are arranged in six rows. The location of individual features in rows 1 through 6 are identified by reference to an alphanumeric code with numbers indicating the row and letters indicating the position within that row. Row 6 contains a single multi-line feature with every tenth line numbered. The box surrounding the overall pattern is used to align the pattern on the measurement system. The broken horizontal lines mark the central calibrated area of the features. The pattern identification number can be seen in the box above the carpet design in the lower right quadrant.

Calibration values are given for the following:

- widths of opaque lines in row 1 and clear lines in row 2;
- center-to-center spacing of the two inner (short) lines of each line pattern in row 3;
- center-to-center spacings from line 4A to lines 4B through 4F in row 4;
- widths of the left inner (long) line and the space to its right of each line pattern in row 5; and
- center-to-center spacings from line 0 to lines 1 through 30 in row 6.