National Institute of Standards & Technology

Certificate

Standard Reference Material® 2074

Sinusoidal Roughness Specimen

Serial No.: Sample

Standard Reference Material (SRM) 2074 is a sinusoidal profile roughness specimen certified for roughness average *Ra*, and surface spatial wavelength *D.* The SRM is intended for use as a standard for the calibration of stylus instruments that are used to measure surface roughness. SRM 2074 is a steel block of nominal Knoop hardness (HK) 500 which has been coated by the electroless nickel deposition process. A sinusoidal roughness profile was machined onto the top surface of the specimen in a facing operation by a single-point diamond tool on a numerically controlled lathe.

The certified *Ra* and *D* values and their associated expanded uncertainties for this specimen are:

Roughness Average (*Ra*), µm	Sample ± 0.013 (individually certified)
Surface Wavelength (*D*), µm	39.998 $^{+0.048}_{-0.013}$

This SRM was originally calibrated and certified in May 1992, when the NIST uncertainty policy used a coverage factor of $k = 3$ for reporting NIST measurement uncertainties, and was recertified on November 24, 2009. From 1993 to 2008, this calibration result has been continually monitored by routinely measuring a NIST check-standard, SRM 2073-1104, 89 times. The NIST check-standard, SRM 2073-1104, is a sinusoidal profile roughness specimen with nominal values of $Ra = 3$ µm and $D = 100$ µm, which was made from the same material and manufactured by the same manufacturing process as the SRM 2074 sinusoidal profile roughness specimens. A dynamic control chart [1] with both dynamic and fixed control limits is used for monitoring the long-term variation from the certified *Ra* values for the SRM specimens. The check measurement results have demonstrated high measurement reproducibility within the uncertainty range, and do not reveal any significant variations or drift.

Expiration of Certification: The certification of **SRM 2074** is valid, within the measurement uncertainty specified, until **30 June 2024**, provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling, Storage and Use"). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

The technical direction and physical measurements leading to certification were provided by T.V. Vorburger, J.F. Song, C.F. Vezzetti, J.E. Potzick, T.B. Renegar, and A. Zheng of the NIST Precision Engineering Division.

Statistical analysis was provided by J.H. Yen of the NIST Statistical Engineering Division.

David G. Seiler, Chief
Semiconductor and Dimensional Metrology Division

Gaithersburg, MD 20899
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Certificate Revision History on Last Page

Robert L. Watters, Jr., Director
Office of Reference Materials

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

INSTRUCTIONS FOR HANDLING, STORAGE AND USE

Storage: SRM 2074 should be stored in its original wooden box in a clean dry environment at temperatures between 10 °C and 30 °C.

Handling and Use: Please note that every measurement included in the results for *D* was an average taken over at least 100 spatial periods. Therefore, users should include at least 100 periods in any calibrations they perform using the spatial wavelength *D*. For certification measurements, the stylus force was approximately 4×10^{-4} N. This force should cause negligible damage to the hard metal surface; however, faint stylus traces may be visible on the surface. Repeated use with stylus instruments can slowly degrade roughness specimens; however, the specimen is expected to maintain its calibration values provided these measurements are taken on clear, undamaged areas.

Source and Preparation[1]: The SRM 2074 specimens were machined by Pneumo Precision, Inc. of Keene, New Hampshire using a single-point diamond tool in a facing operation with a numerically controlled tool path. The surface profile is highly sinusoidal as shown in Figure 1.

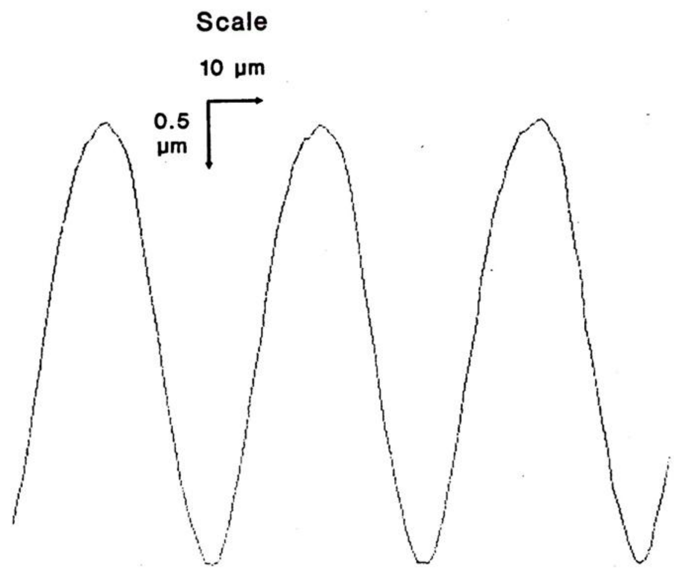

Figure 1: Representative Surface Profile Trace of SRM 2074. The dimensions are approximate.

NIST Certification Procedure: The roughness average, *Ra,* is the average absolute deviation of the surface peaks and valleys about the mean line, and is defined in the ASME B46.1-2009 standard entitled "*Surface Texture*" [2]. The surface wavelength, *D,* is the average period of the sinusoidal surface profile. This quantity is also equal to the mean spacing of profile irregularities, *RSm*, as described in ASME B46.1-2009 [2] and ISO 4287:1997(E/F) [3]. The procedure to calculate *D* here is slightly different from standard procedures to calculate *RSm*, but the result for a highly sinusoidal profile is robust against such differences.

The parameters *Ra* and *D* were calculated from surface roughness profiles of the SRM measured with a stylus instrument using procedures in ASME B46.1-2009 [2]. The sampling rate was 1 point per micrometer over the evaluation length of 4.0 mm. The stylus had a tip radius of 5 µm ± 1 µm as profiled by the razor blade method [4], and calculated in accordance with ASME B46.1-2009 [2]. The high-pass 2RC filter [2] cutoff length was 0.76 mm; however, the quoted *Ra* value also applies to calibrations of instruments using Gaussian filters with 0.8 mm cutoff because the 40 µm spatial wavelength is much smaller than the 0.8 mm cutoff.

[1] Certain commercial equipment, instruments, or materials are identified in this certificate in order to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

The stylus instrument was interfaced to a laboratory computer and a HeNe laser interferometer, and its vertical motion was calibrated using an interferometrically measured step height standard. The instrument was operated in the skidless mode with an external reference datum.

The results for *Ra* and *D* are based on profile traces in pairs at each of nine evenly distributed positions on the specimen surface as shown in Figure 2. The certification of both parameters is valid for any unflawed positions within the area defined by the extremes of the profile traces shown in Figure 2. However, both the *Ra* and *D* values are observed to vary systematically over the surface when data from all the specimens are examined collectively.

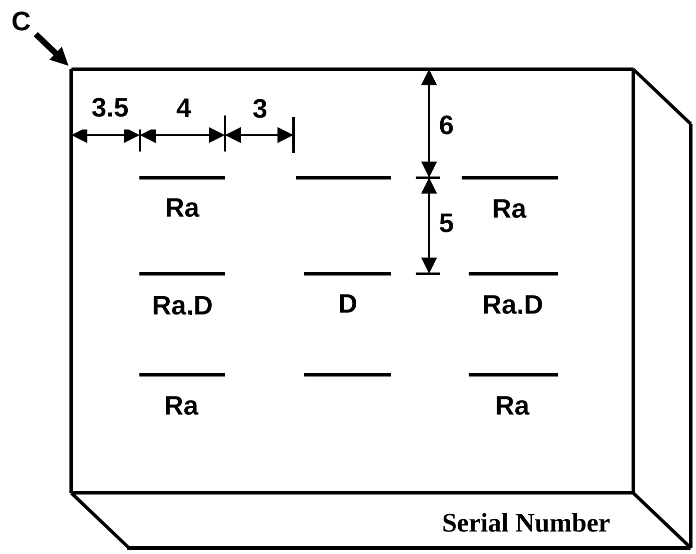

Figure 2: Measurements positions for SRM 2074. The positions of traces are shown in mm with respect to the upper left corner C of the roughness area.

Calibration Uncertainty: The *Ra* values on the left side differ systematically by 0.005 µm from those on the right side. Therefore, the quoted value for *Ra* is an average of the six positions indicated as "*Ra*" in Figure 2 rather than nine. The expanded calibration uncertainty *U* for both *Ra* and *D* is the combined standard uncertainty u_c multiplied by a coverage factor $k = 2$ [5,6]. The combined standard uncertainty u_c is the quadratic sum of the system standard uncertainty $u(I)$ and the statistical variation of the measurements *s*. The statistical variation of the measurements is a Type A uncertainty component [5,6], which is mainly derived from the geometrical nonuniformity of the specimen under test, but which also includes instrumental random variation during the measurement process. The statistical variation of the measurements *s* is calculated as one standard deviation (1σ) of the set of values measured at different positions on the measuring area, as shown in Figure 2. The system standard uncertainty $u(I)$ for *Ra* is the quadratic sum of seven uncertainty components. These are derived from [7]:

1. Geometrical nonuniformity and surface finish of the step-height used to calibrate the stylus instrument producing small variations in the *z*-scale calibration constant of the stylus instrument from day to day.
2. Noise in the instrument transducer, the sampling and digitizing processes in the controller, round-off in the software computations, and imperfections in the surface topography of the reference datum of the instrument also producing variations in the *z*-scale calibration constant from day to day.
3. Variations in the measured *Ra* values due to nonlinearity in the instrument transducer.
4. Uncertainty in the average height of the step-height master as determined from interferometric and other measurements of it.
5. Uncertainty in the horizontal resolution of the instrument due to the stylus radius [4] or to the frequency response of the electronics.
6. Nonuniformity of the surface giving rise to the systematic variation of the *Ra* value described above.
7. Potential long-term variation in the surface; the estimate is based on control charts of SRM check standards maintained over 15 years.

Components 1, 2, and 7 are Type A components estimated by statistical methods. The other components are Type B components, which are estimated by other means [5,6]. The combined standard uncertainty for *Ra* is calculated as $u_{c\ (Ra)} = 0.0067$ µm; the expanded uncertainty for *Ra* is calculated as $U_{(Ra)} = 0.013$ µm ($k = 2$).

Because the wavelength of this SRM is only 40 µm, the measured value for *Ra* depends somewhat on the resolution of the instrument used to measure the specimen. NIST estimates that the value of *Ra* may be as much as 0.05 µm smaller when measured with a stylus having a 10 µm radius than when measured with a stylus having a 2 µm radius. Therefore, the uncertainties quoted above should be used only for calibrations performed with a stylus having a tip radius 5 µm or smaller. Accordingly, for optical or other types of profiling instruments, the lateral resolution of the instrument should also be 5 µm or smaller.

The values for *D* are slightly smaller along the central row of profile traces than those along traces at the top and bottom rows, because of the slight curvature of the machining marks on the specimen. Therefore, the quoted value for *D* is an average of results for only the three central positions marked "*D*" in Figure 2. The combined standard uncertainty for *D* is the quadratic sum of several standard uncertainty components. These are:

1. A single component that represents the instrument variability combined with the nonuniformity of the specimen.
2. Uncertainty in the vacuum wavelength of the HeNe laser interferometer.
3. Uncertainty in the HeNe wavelength due to the uncertainty in the temperature, pressure, and humidity of the laboratory.
4. Uncertainty in the temperature of the SRM itself leading to dimensional uncertainty.
5. Possible variation in the interferometric path length due to possible variation in the air temperature, and the base plate temperature during a single measurement cycle.
6. Possible cosine errors in the specimen alignment.
7. Possible errors associated with Abbe offset.
8. Nonuniformity of the *D* parameters over the certified area due to the curvature of the machining marks. The value for *D* is quoted for the central axis of the specimen. Any misalignment would tend to increase the *D* value. Hence, the uncertainty interval for this component is only in the positive direction.
9. Potential long-term variation in the surface.

Components 1 and 9 are Type A uncertainty components; the other components are Type B [5,6]. The combined standard uncertainty for *D* is calculated as $u_{c\,(D)}$ = (+0.0239 µm, –0.0063 µm); the combined expanded uncertainty for *D* is calculated as $U_{(D)}$ = (+0.048 µm, –0.013µm) ($k = 2$).

Calibration Service: The NIST Semiconductor and Dimensional Metrology Division will verify the calibration of SRM specimens for a fee. To inquire about the service, call (301) 975-2200.

REFERENCES

[1] Song, J.F.; Vorburger, T.V.; *Verifying measurement uncertainty using a control chart with dynamic control limits,* NCSL International Measure, 2 (3), p. 76, (September 2007).

[2] ASME B46.1-2009, *Surface Texture*, American Society of Mechanical Engineers, New York, 2010.

[3] ISO Standard 4287:1997(E/F), *Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, Definitions and Surface Texture Parameters,* International Standards Organization (ISO), Geneva, (1997).

[4] Vorburger, T.V.; Teague E.C; Scire, F.E. and Rosberry, F.W.; "Measurement of Stylus Radii," Wear, Vol. 57, p. 39, (1979).

[5] Taylor, B.N. and Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note 1297 (National Institute of Standards and Technology, Gaithersburg, MD, 1993), available at http://physics.nist.gov/Pubs/. (accessed Dec 2012)

[6] JCGM 100:2008; *Evaluation of Measurement Data — Guide to the Expression of Uncertainty in Measurement* (ISO GUM 1995 with Minor Corrections); Joint Committee for Guides in Metrology (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Dec 2012)

[7] "Appendix A, *Measurement Conditions and Sources of Uncertainties for NIST Surface Roughness and Step Height Calibration Reports*", January 2008, http://www.nist.gov/pml/div683/grp02/upload/nistsurfcalib.pdf (accessed Dec 2012)

Certificate Revision History: 26 February 2013 (Editorial correction of the certified value for roughness average, *Ra*; editorial changes) 10 February 2011 (Re-certification resulting in updated expanded uncertainties for roughness average, *Ra,* and surface wavelength, *D*; editorial changes); 25 June 1992 (original certificate date).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.