National Institute of Standards & Technology

Certificate

Standard Reference Material® 2003

First Surface Aluminum Mirror for Specular Reflectance from 250 nm to 2500 nm

Series:

This Standard Reference Material (SRM) is intended for use in calibrating the radiometric scale of specular reflectometers. The SRM 2003 mirror consists of a glass substrate, 5.1 cm in diameter and 0.65 cm thick, onto which aluminum has been vacuum deposited. No protective coating is applied to the surface. SRM 2003 is shipped in an aluminum container fitted with Teflon® inserts constructed in such a way as not to impinge upon the front surface of the mirror. The SRM unit itself is placed face down into the second half or bottom of the container.

Certified Reflectance Values: This mirror was measured using the NIST High Accuracy Reference Reflectometer. This instrument measures specular reflectance using absolute techniques. The measurements are made as a function of wavelength, angle of incidence, and polarization. Each SRM series is independently certified for a wavelength range of 250 nm to 2500 nm. This SRM series was certified for specular reflectance using 6°/6° geometries. In this configuration, the incident beam was 6° from the normal of the mirror, and the measurement direction was in the plane of incidence, at the specular angle. The values listed in Table 1 of this certificate are valid for 6°/6° geometries only.

Expiration of Certification: This certification is valid within the uncertainties specified, for two years from the date of calibration specified in Table 1, provided the mirror has been maintained in accordance with the instructions given in this certificate. SRM 2003 may be recertified if the mirror surface has not been compromised; however, acceptance for recertification is contingent upon inspection by NIST. For acceptance inspection and recertification information, contact P.Y. Barnes of the NIST Optical Technology Division by phone (301) 975-2345, fax (301) 840-8551, or email yvonne.barnes@nist.gov.

Cautions to User: SRM 2003 is fragile and must be handled with extreme care so that nothing touches the bare aluminum surface. Airborne particulates, aromatics, and improper handling will adversely affect the surface conditions. Under the best of handling conditions, the delicate first surface may become contaminated and cannot be restored to its original reflectance by cleaning. The user should not attempt to clean the units as such action will adversely affect the aluminum coating.

The initial research and development of this SRM were conducted in the NIST Radiometric Physics Division (now the Optical Technology Division) by V.R. Weidner and J.J. Hsia [1].

The technical and support aspects involved in the certification and issuance of this SRM were coordinated through the Standard Reference Materials Program by J.C. Colbert. Revision of this certificate was coordinated through the Standard Reference Materials Program by R.J. Gettings and J.W.L. Thomas

Gaithersburg, MD 20899
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26 Mar 1996 (original certificate date)
*This editorial revision reports a stronger caution in handling of the SRM.

Thomas E. Gills, Chief
Standard Reference Materials Program

The technical measurements leading to certification were performed in the NIST Optical Technology Division by P.Y. Barnes. The overall direction and coordination of the technical measurement leading to certification were performed under the direction of R.D. Saunders of the NIST Optical Technology Division.

Handling Instructions: When not in use, the mirror should be properly stored in its container. A lint-free glove or finger cots (nylon or latex) should be used to prevent fingerprints on mirror surfaces. Extreme care must be exercised when removing dust from the mirror. Gently use a very clean air bulb so that no damage is done to the mirror's calibrated surface. It is strongly recommended that a face mask be also worn to prevent contaminating the SRM with vapors or particles from the mouth or nose.

Source and Preparation of Material: The mirrors for this SRM were produced by the Muffoletto Optical Company Inc. of Baltimore, MD. Each mirror consists of a low thermal expansion glass substrate, Cervit C-101[1], polished flat within 1/10 wavelength of 500 nm and smoothed to within 2.5 nm. The substrate coated by fast evaporation of aluminum, 3 s or less at 7 x 10^{-5} Pa vacuum [2]. To produce the mirrors, an aluminum element is prefired to coat the tungsten conductor. With a closed shutter between the tungsten conductor and the mirror substrate, the tungsten conductor is heated to a temperature at which aluminum will be deposited at a rate of approximately 30 nm/s. When the prescribed temperature is reached, the shutter is opened for 3 s and the mirrors are coated. The mirrors are arranged in a hemispherical pattern above the evaporating element so that all mirrors are approximately the same distance from this element.

NIST Determination of Specular Reflectance: Newly manufactured mirrors are aged under normal laboratory conditions in glass covered containers (Petri dishes) for at least one year before being tested. The reflectance measurements are made at an ambient temperature of 20 °C ± 3 °C and a relative humidity of 40 % ± 3 %.

The absolute specular reflectance measurements background signal are recorded in the following sequence: background signal, incident signal, background signal, reflected signal, background signal, incident signal. The sequence is performed for both vertically (s) and horizontally (p) polarized incident beams for a given wavelength and incidence angle. The background signal (B_1) is subtracted from the measured incident signal (S_1), the background signal (B_2) is subtracted from the reflected signal (S_2), and the background signal (B_3) is subtracted from the incident signal (S_3), so that the specular reflectance (R) can be calculated as $R = (S_2-B_2)/(((S_1-B_1)+(S_3-B_3))/2)$ for each polarization. The ratios are averaged and reported in Table 1.

A xenon arc source and a silicon photodiode detector are used over the spectral range 250 nm through 400 nm; a tungsten source and a silicon photodiode detector are used over the spectral range 450 nm to 1100 nm; and a tungsten source and an indium-arsenide detector are used over the spectral range 1100 nm through 2500 nm. An Oriel Multispec[1] (Model No. 257) monochromator was used to limit and select the spectral bandpass of the incident radiation. The collimated incident beam is 14 mm in diameter and the spectral bandpass is 10 nm.

Each mirror is calibrated at selected wavelength intervals: 50 nm intervals from 250 nm to 900 nm; 100 nm intervals from 900 nm to 1750 nm; 250 nm intervals from 1750 nm to 2500 nm; and at the helium-neon laser line at 632.8 nm. The measurement values are valid for the condition of illumination in which the incident sample beam is 6° from the normal to the plane of the test surface.

Uniformity: The reflectance uniformity of each mirror is established over an area 20 mm in diameter at a measurement wavelength of 250 nm.

[1]Certain commercial equipment, instruments, or materials are identified in this certificate to adequately describe 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 are the best available for the purpose.

Determination of Certified Uncertainties: The expanded uncertainties with a coverage factor, $k = 2$, of the measured values are as follows: 0.007 (0.7 %) for wavelengths below 350 nm; 0.006 (0.6 %) over the wavelength range 400 nm to 2050 nm; 0.009 (0.9 %) over the wavelength range 2050 nm through 2500 nm. The expanded uncertainty includes Type A uncertainties and Type B uncertainties. The contributors to Type A uncertainties are spatial uniformity over an area 20 mm in diameter, repetitive measurements at the same location, and the random noise contribution to the measurement. The Type A uncertainty (coverage factor, $k = 2$) for reflectance uniformity is 0.002. The contributors to the Type B uncertainties are the receiver system non-linearity and non-uniformity, scattered flux, angular setting, view factor uncertainties, and stability over the calibration interval [1,3,4]; the uncertainties are combined by the root sum of squares method. Type A uncertainties are evaluated statistically, Type B uncertainties are evaluated by other means [4,5].

REFERENCES

[1] Weidner, V.R. and Hsia, J.J., "NBS Measurement Services: Spectral Reflectance," NBS Special Publication 250-8, U.S. Department of Commerce, Washington DC, (1987).

[2] Taylor, B.N., "Guidelines for the Use of the International System of Units (SI)," NIST Special Publication 811, 1995 Ed., (April 1995).

[3] Barnes, P.Y., Early, E.A., and Parr, A.C., "NIST Measurement Services: Spectral Reflectance (In Progress)," NIST Special Publication 250-8 Revised, (1998).

[4] Weidner, V.R. and Hsia, J.J., "Standard Reference Materials: Preparation and Calibration of First-Surface Aluminum Mirror Specular Reflectance Standards," NIST Special Publication 260-75, (1982).

[5] *Guide to the Expression of Uncertainty in Measurement*, ISBN 92-67-10188-9, 1st Ed. ISO, Geneva, Switzerland, (1993): see also Taylor, B.N. and Kuyatt, C.E., "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," NIST Technical Note 1297, U.S. Government Printing Office, Washington DC, (1994).

It is the responsibility of users of this SRM to assure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: Phone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.