National Institute of Standards & Technology

Certificate

Standard Reference Material® 2011

First Surface Gold Mirror for Specular Reflectance from 600 nm to 2500 nm

Series:

This Standard Reference Material (SRM) is intended for use in calibrating the reflectance scales of specular reflectometers. The SRM 2011 mirror consists of a glass substrate, 5.1 cm in diameter and 1.5 cm thick, onto which gold has been vacuum deposited. No protective coating is applied to the surface. SRM 2011 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 is placed with the front surface 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 unit of SRM 2011 is independently certified for a wavelength range of 600 nm to 2500 nm. This SRM 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 2011 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 telephone (301) 975-2345, fax (301) 840-8551, or e-mail yvonne.barnes@nist.gov.

Cautions to User: SRM 2011 is fragile and must be handled with **extreme care** so that nothing touches the bare gold 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 unit as such action will adversely affect the gold coating.

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.

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

Albert C. Parr, Chief
Optical Technology Division

Gaithersburg, MD 20899
Certificate Issue Date: 30 June 1999
See Certificate Revision History on Last Page

Thomas E. Gills, Director
Office of Measurement Services

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.

Handling Instructions: When not in use, the mirror should be properly stored in its original container. Lint-free gloves or finger cots (nylon or latex) should be used to prevent fingerprints on mirror surfaces. Do not breathe on the mirror. It is strongly recommended that a facemask be worn to prevent contaminating the SRM with vapors or particles from the mouth or nose. 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.

Source and Preparation of Material: The mirrors were produced by the Epner Technology Incorporated of Brooklyn, NY. First surface gold mirrors are prepared by using a propriety nickel coated substrate and electroplating technique.

NIST Determination of Specular Reflectance: Newly manufactured mirrors are aged under normal laboratory conditions in specially designed covered containers for at least one year before being tested. The reflectance measurements are made at an ambient temperature of 21 °C ± 0.6 °C and a relative humidity of 34 % ± 0.6 %.

The absolute specular reflectance measurements and 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 tungsten source and a silicon photodiode detector are used over the spectral range 600 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 600 nm to 1000 nm; 100 nm intervals from 1000 nm to 2500 nm and at the helium-neon laser line at 632.8 nm as well as 1060 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 by measuring an area 14 mm away from the center in four directions at a measurement wavelength of 600 nm. Any scratches that may appear are in the substrate and do not affect the certified values.

Determination of Certified Uncertainties: The expanded uncertainties with a coverage factor, $k = 2$, of the measured values are 0.003 over the wavelength range 600 nm to 2050 nm and 0.005 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 [1,2]. 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 [3,4].

[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 is the best available for the purpose.

REFERENCES

[1] Proctor, J.E. and Barnes, P.Y., "NIST High Accuracy Reference Reflectometer-Spectrophotometer," *J. Res. Natl. Inst. Stand. Technol.* **101**, p. 619, (1996).

[2] Barnes, P.Y., Early, E.A., and Parr, A.C., *Spectral Reflectance*, Natl. Inst. Stand. Technol. Special Publication 250-48, (1998).

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

[4] G*uide 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).

Certificate Revision History: 29 Jun 99 (editorial revision); 5 May 92 (editorial revision); 19 Mar 84 (original certificate date).

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: Telephone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.