National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2052

Black Diffuser for 6:di Spectral Reflectance Factor

Serial No.:

This Standard Reference Material (SRM) is intended for use in calibrating the photometric scale of diffuse reflectometers for the 6:di geometry at wavelengths from 250 nm to 2500 nm. SRM 2052 consists of a black Spectralon[1] disk with a diameter of 5.1 cm press fitted into a round delrin container with a diameter of 6 cm and a thickness of 1.5 cm. A plot of the 6:di spectral reflectance factor of this SRM is shown in Figure 1 for a representative diffuser.

Certified Values of 6:di Spectral Reflectance Factor: This SRM was individually certified. The 6:di spectral reflectance factor of each diffuser was measured using a Varian Cary5E spectrophotometer with an integrating sphere attachment [1] by comparison to master standards of the same material. These master standards were calibrated previously on the NIST High Accuracy Reference Reflectometer [1,2]. The certified 6:di spectral reflectance factor for unpolarized incident light for this diffuser is given in Table 1 for wavelengths from 250 nm to 2500 nm.

Discussion of Uncertainties: Uncertainties were calculated according to the procedures outlined in Reference 3. Uncertainty components due to random effects include source stability and detector noise. The uncertainty contributions caused by these effects were evaluated as the standard deviation for repeated measurements of each diffuser. Uncertainty components due to systematic effects include the reflectance factor of the master standards and the uniformity of the diffusers. The expanded uncertainty, $k = 2$, of the 6:di spectral reflectance factor is given in Table 2.

Expiration of Certification: The certification of this SRM is valid for **two years** from the date of certification shown in Table 1, within the uncertainties specified, provided it is handled and stored in accordance with the instructions given in this certificate (see *Instructions for Use*). However, the certification is invalid if this SRM is damaged, contaminated, or modified.

The overall direction and coordination of the technical measurements leading to certification were performed under the direction of R.D. Saunders of the NIST Optical Technology Division.

The initial research and development for this SRM was conducted by P.Y. Barnes and J.J. Hsia of the NIST Optical Technology Division.

The technical measurements leading to certification were performed by E.A. Early and M.E. Nadal of the NIST Optical Technology Division.

The support aspects involved in preparation, certification, and issuance of this SRM were coordinated through the NIST Standard Reference Materials Program by J.W.L. Thomas and B.S. MacDonald.

Albert C. Parr, Chief
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Certificate Issue Date: 07 March 2003

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[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.

Source and Preparation of Material: This SRM was produced by Labsphere, Inc., of North Sutton, NH, part number SRS-02-020. The diffuser material is Spectralon, a sintered thermoplastic material, chosen for its high, nearly Lambertian reflectance, with an additive to reduce the reflectance.

INSTRUCTIONS FOR USE

Remove the protective cover from the container with the diffuser, then carefully center the diffuser surface at the sample or reference port of the integrating sphere of the reflectometer to be calibrated.

Handling Instructions: This SRM consists of a black Spectralon diffuser in a round delrin container. The diffuser is press fitted in the container with the certified surface facing outward. A protective delrin cover screws on to the container. When not in use, the cover should be on the container and the SRM stored in a clean and safe location. Airborne particles, aromatics, and improper handling will adversely affect the diffuser surface. Lint-free gloves should be used when handling the diffuser to prevent fingerprints on the surface. The diffuser cannot be cleaned without adversely affecting the certified surface, except by using a clean air bulb to gently remove dust from the diffuser surface.

Determination of 6:di Spectral Reflectance Factor: The diffusers were measured using a Varian Cary5E spectrophotometer with an integrating sphere attachment [1]. Each diffuser was mounted at the sample port of the integrating sphere attachment. The diffusers were measured at wavelengths from 250 nm to 2500 nm every 10 nm for unpolarized incident light. The angle of incidence was 6° from the normal of the surface of each diffuser, and the specular component of reflection was included. This geometry is denoted as 6:di. The converging incident beam, with a spectral bandwidth of 5 nm for wavelengths less than 900 nm and up to 20 nm for longer wavelengths, was centered on the front of each diffuser. The source was a deuterium arc lamp for wavelengths shorter than 350 nm and a quartz-tungsten-halogen incandescent lamp for longer wavelengths, while the detector was a photomultiplier tube for wavelengths shorter than 900 nm and a lead sulfide detector for longer wavelengths. The integrating sphere had a diameter of 110 mm, was lined with pressed PTFE powder, and had a sample port with a diameter of 22.5 mm. During the measurements, the ambient temperature was 20 °C ± 3 °C, and the relative humidity was 40 % ± 10 %.

Master diffusers, equivalent to the calibrated diffusers, with serial numbers 2052-01-1, 2052-01-2, and 2052-01-3, were also measured under the same conditions. The spectral reflectance factor of the master diffusers, at the 6:di geometry, was determined using the High Accuracy Reference Reflectometer [1,2] and primary standards of polytetrafluoroethylene (PTFE) [4]. Each diffuser was measured four separate times. Dark signals were obtained by performing measurements with no diffuser at the sample port of the integrating sphere. Net signals were obtained by subtracting the dark signal. The 6:di spectral reflectance factor of each diffuser was calculated by dividing the net signal for the diffuser by the net signal for the master diffuser and multiplying by the reflectance factor of the master. The results from all four measurements of each diffuser were averaged to obtain the final values. The wavelengths, at which values are given were reduced to every 50 nm from 300 nm to 2500 nm since the reflectance factor varies smoothly over this wavelength range.

REFERENCES

[1] Barnes, P.Y.; Early, E.A.; Parr, A.C.; *NIST Measurement Services: Spectral Reflectance*; NIST Special Publication 250-48 (1998).

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

[3] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297 (1994).

[4] Weidner, V.R.; Hsia, J.J.; *Reflection Properties of Pressed Polytetrafluoroethylene Powder*; J. Opt. Soc. Am. Vol. 71, p. 856 (1981).

Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: telephone (301) 975-6776; fax (301) 926-4751; e-mail srminfo@nist.gov; or via the Internet http://www.nist.gov/srm.

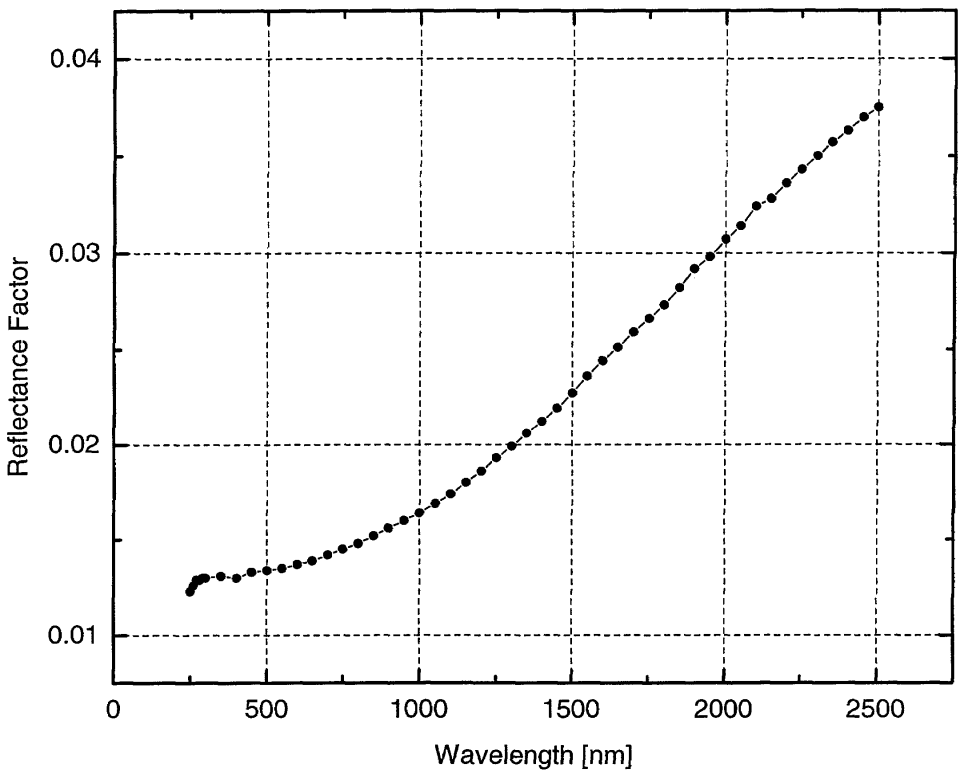

Figure 1. 6:di reflectance factor as a function of wavelength for a representative SRM 2052 black diffuser.

Table 1. 6:di Reflectance Factor R as a Function of Wavelength λ

Serial No.: 2052-01-4 Calibration Date: 1 October 2002

λ (nm)	R	λ (nm)	R
250	0.0117	1300	0.0182
260	0.0120	1350	0.0187
270	0.0122	1400	0.0196
280	0.0122	1450	0.0201
290	0.0122	1500	0.0209
300	0.0123	1550	0.0217
350	0.0123	1600	0.0222
400	0.0122	1650	0.0230
450	0.0123	1700	0.0240
500	0.0124	1750	0.0246
550	0.0125	1800	0.0252
600	0.0126	1850	0.0262
650	0.0128	1900	0.0272
700	0.0130	1950	0.0277
750	0.0132	2000	0.0288
800	0.0135	2050	0.0294
850	0.0138	2100	0.0304
900	0.0141	2150	0.0310
950	0.0144	2200	0.0317
1000	0.0151	2250	0.0322
1050	0.0153	2300	0.0330
1100	0.0159	2350	0.0335
1150	0.0164	2400	0.0345
1200	0.0169	2450	0.0351
1250	0.0177	2500	0.0357

Table 2. Standard Uncertainty from Components and Expanded Uncertainty, $k = 2$, as a Function of Wavelength λ for the 6:di Reflectance Factor

Uncertainty Component	Standard Uncertainty
Master Diffuser	
250 nm ≤ λ ≤ 390 nm	0.0022
400 nm ≤ λ ≤ 1500 nm	0.0011
1550 nm ≤ λ ≤ 2500 nm	0.0013
Uniformity	0.0001
Repeatability	
250 nm ≤ λ ≤ 850 nm	0.0002
900 nm ≤ λ ≤ 2500 nm	0.0004
Wavelength	Expanded Uncertainty
250 nm ≤ λ ≤ 390 nm	0.0044
400 nm ≤ λ ≤ 850 nm	0.0022
900 nm ≤ λ ≤ 1500 nm	0.0023
1550 nm ≤ λ ≤ 2500 nm	0.0027