National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2044a

White Diffuser for 6:di Spectral Reflectance Factor[1]

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 2044a consists of a Spectralon 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 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 until **01 October 2005**, within the uncertainties specified, provided it is handled and stored in accordance with the instructions given in this certificate (see *Instructions for Use*). This certification is nullified if this SRM is damaged, contaminated, or otherwise 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 Group by J.W.L. Thomas and B.S. MacDonald.

Albert C. Parr, Chief
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Certificate Issue Date: 02 April 2003

John Rumble, Jr., Chief
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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-99-020. The diffuser material is Spectralon, a sintered thermoplastic material, chosen for its high, nearly Lambertian reflectance.

INSTRUCTIONS FOR USE

Remove the protective cover from the container, 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 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 6º 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 the 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 800 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 ºC ± 3 ºC, and the relative humidity was 40 % ± 10 %.

Master diffusers, equivalent to the calibrated diffusers, with serial numbers 2044a-01-1, 2044a-01-2, and 2044a-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 SRM 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 400 nm to 2000 nm since the reflectance factor is nearly constant 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).

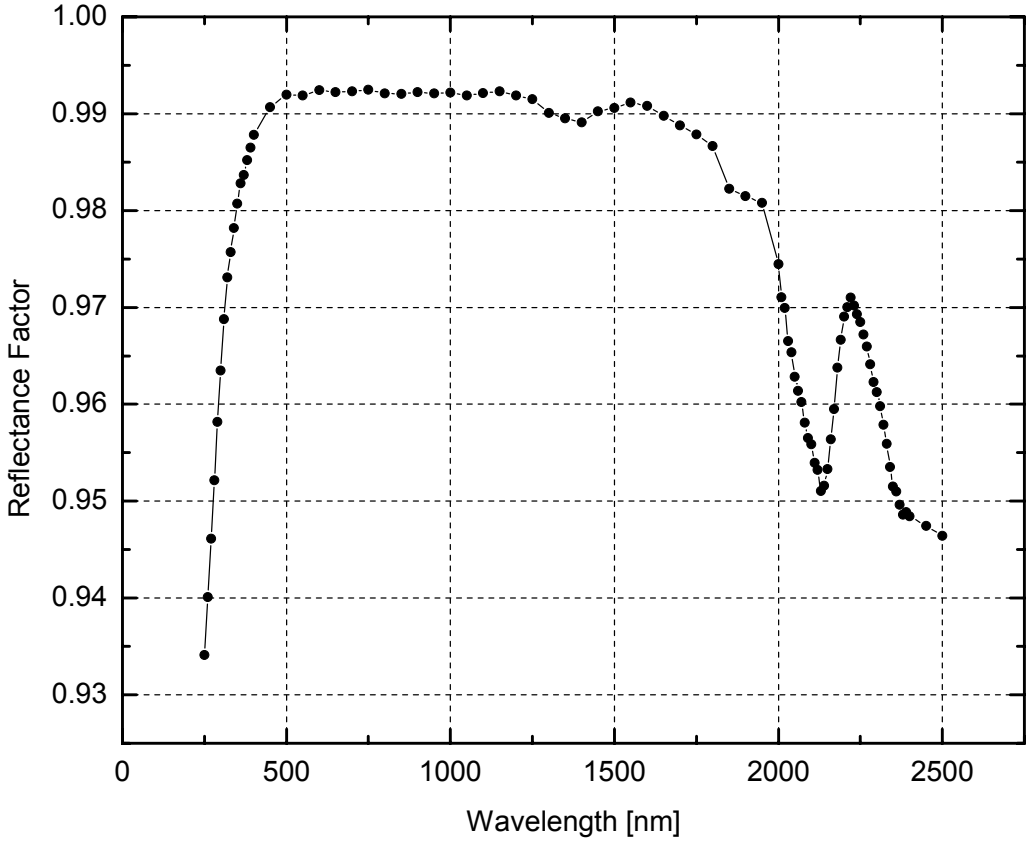

Figure 1. 6:di reflectance factor as a function of wavelength for a representative SRM 2044a white diffuser.

Table 1. 6:di Reflectance Factor *R* as a Function of Wavelength λ of SRM 2044a

Serial No.: 2044a-01-4 Calibration Date: 1 October 2002

λ (nm)	*R*	λ (nm)	*R*	λ (nm)	*R*
250	0.942	1150	0.993	2130	0.954
260	0.945	1200	0.992	2140	0.954
270	0.954	1250	0.992	2150	0.955
280	0.959	1300	0.991	2160	0.958
290	0.964	1350	0.990	2170	0.961
300	0.969	1400	0.990	2180	0.965
310	0.972	1450	0.991	2190	0.968
320	0.974	1500	0.991	2200	0.970
330	0.976	1550	0.991	2210	0.971
340	0.977	1600	0.991	2220	0.972
350	0.980	1650	0.990	2230	0.972
360	0.981	1700	0.989	2240	0.971
370	0.983	1750	0.988	2250	0.970
380	0.985	1800	0.987	2260	0.969
390	0.986	1850	0.983	2270	0.967
400	0.987	1900	0.982	2280	0.965
450	0.991	1950	0.982	2290	0.964
500	0.992	2000	0.975	2300	0.963
550	0.993	2010	0.972	2310	0.961
600	0.993	2020	0.971	2320	0.960
650	0.993	2030	0.969	2330	0.958
700	0.993	2040	0.967	2340	0.956
750	0.993	2050	0.965	2350	0.954
800	0.993	2060	0.963	2360	0.953
850	0.993	2070	0.961	2370	0.952
900	0.993	2080	0.960	2380	0.951
950	0.993	2090	0.958	2390	0.951
1000	0.993	2100	0.957	2400	0.950
1050	0.993	2110	0.956	2450	0.949
1100	0.993	2120	0.955	2500	0.948

Table 2. Standard Uncertainty from Components and Expanded Uncertainty, $k = 2$, as a Function of Wavelength λ for the 6:di Reflectance Factor of SRM 2044a

Uncertainty Component	Standard Uncertainty
Master Diffuser	
250 nm $\leq \lambda \leq$ 390 nm	0.003
400 nm $\leq \lambda \leq$ 1500 nm	0.001
1550 nm $\leq \lambda \leq$ 2500 nm	0.002
Uniformity	0.001
Repeatability	
250 nm $\leq \lambda \leq$ 390 nm	0.002
400 nm $\leq \lambda \leq$ 2500 nm	0.001
Wavelength	Expanded Uncertainty
250 nm $\leq \lambda \leq$ 390 nm	0.007
400 nm $\leq \lambda \leq$ 1500 nm	0.003
1550 nm $\leq \lambda \leq$ 2500 nm	0.005