Spectralon® Diffuse Reflectance Material

Spectralon diffuse reflectance material is a thermoplastic resin that can be machined into a wide variety of shapes for the construction of optical components. The material has a hardness roughly equal to that of high-density polyethylene and is thermally stable to >350°C. It is chemically inert to all but the most powerful bases such as sodium amide and organo-sodium or lithium compounds. The material is extremely hydrophobic. Gross contamination of the material or marring of the optical surface can be remedied by sanding under a stream of running water. This surface refinishing both restores the original topography of the surface and returns the material to its original reflectance. Weathering tests on the material show no damage upon exposure to atmospheric UV flux. The material shows no sign of optical or physical degradation after long-term immersion testing in sea water.

Spectralon SRM-99 material gives the highest diffuse reflectance of any known material or coating over the UV-VIS-NIR region of the spectrum. The reflectance is generally >99% over a range from 400 to 1500 nm and >95% from 250 to 2500 nm. Surface or subsurface contamination may lower the reflectance at the extreme upper and lower ends of the spectral range. The material is also highly lambertian at wavelengths from 0.257 µm to 10.6 µm, although the material exhibits much lower reflectance at 10.6 µm due to absorbance by the material.

The surface and immediate subsurface structure of Spectralon exhibits highly lambertian behavior. The porous network of thermoplastic produces multiple reflections in the first few tenths of a millimeter of Spectralon. Although it is extremely hydrophobic, this “open structure” readily absorbs non-polar solvents, greases and oils. Impurities are difficult to remove from Spectralon; thus, the material should be kept free from contaminants to maintain its reflectance properties.

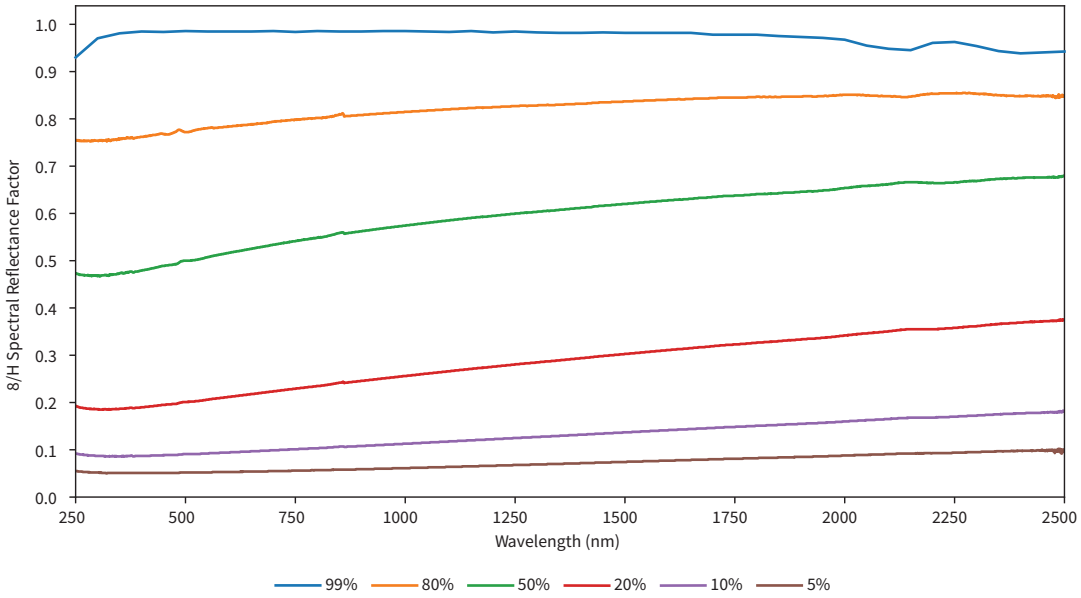
The use of Spectralon should be limited to the UV-VIS-NIR. Spectralon exhibits absorbances at 2800 nm, then absorbs strongly (<20% reflectance) from 5.4 to 8 µm. Plated metal surfaces, such as the Labsphere Infragold-IR standards, are recommended as diffuse reflectance standards for the MIR.

Three grades of Spectralon are available: optical-grade, extreme physics and vacuum (EPV), and space-grade. Optical-grade Spectralon is characterized by its Lambertian behavior over the UV-VIS-NIR wavelength region. The optical-grade materials include our highly reflective white, greyscale, color, and wavelength reference materials, and fluorescent pigment-doped materials. EPV Spectralon offers a purified output product for ground-based applications. Space-grade Spectralon combines high reflectance with an extremely Lambertian reflectance profile and is the material of choice for terrestrial remote sensing applications. EPV and space-grade Spectralon are only available in 99% white.

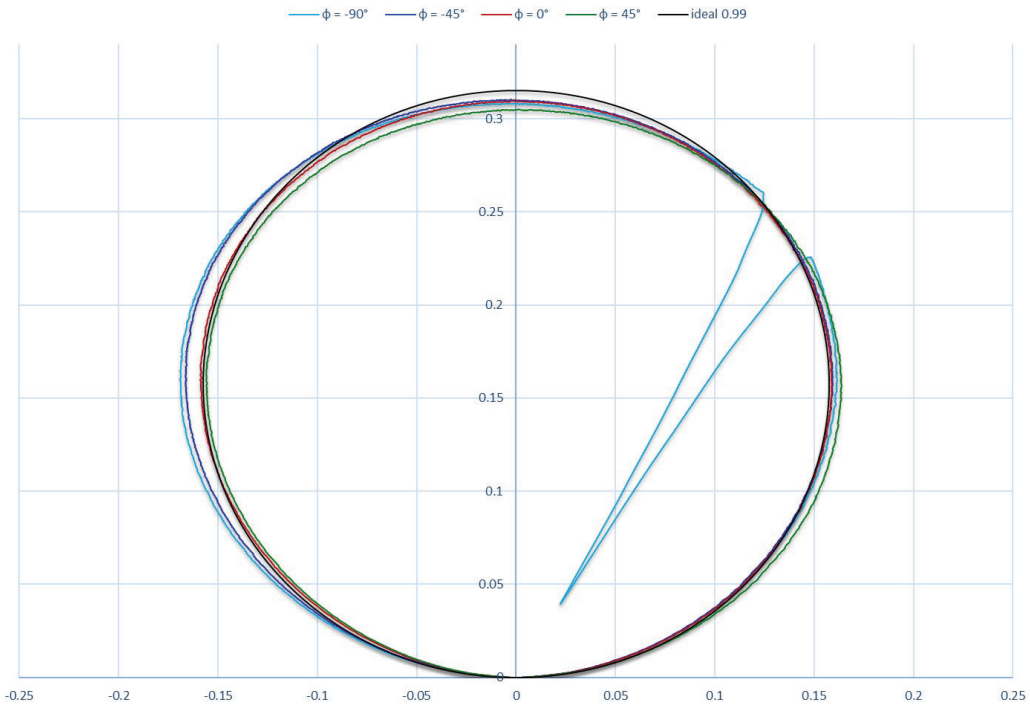
Reflectance Properties of Spectralon

Spectralon exhibits relatively flat spectral distribution over most of the UV-VIS-NIR. From 250 to 2500 nm, Spectralon SRM-99 exhibits a reflectance variance of <5% between 360 - 740 nm (VIS) the variance in reflectance is <0.5%. These spectral properties exceed those of most paints, which show strong absorbances in the UV due to absorbances by TiO2 or similar pigments. The hydrophobic nature of Spectralon also leads to exclusion of water overtone bands in the NIR which may occur in barium-sulfate-based materials. The open structure of Spectralon causes both reflectance and transmittance, but not absorbance of light.

Typical 8/H Reflectance Factors of Spectralon



99% Spectralon Polar Cosine Corrected BRDF with θ Lighting = 30°



2.4 Spectralon Gray Scale Material

Spectralon can be doped with black pigment to produce spectrally flat gray scale standards and targets. Spectralon gray materials have physical and spectral properties similar to Spectralon and are useful as standards for calibration of various optical instruments, including those used in blood analysis, CCD arrays and night vision devices.

Typical Reflectance Data of Spectralon Diffuse Reflectance Materials

Wavelength (nm)	Typical 8/H Reflectance Factor					
	99%	80%	50%	20%	10%	5%
250	0.91	0.75	0.47	0.19	0.09	0.05
300	0.96	0.75	0.46	0.18	0.08	0.05
350	0.98	0.75	0.47	0.18	0.08	0.05
400	0.98	0.76	0.47	0.19	0.08	0.05
450	0.99	0.76	0.48	0.19	0.08	0.05
500	0.99	0.77	0.50	0.20	0.09	0.05
550	0.99	0.78	0.50	0.20	0.09	0.05
600	0.99	0.78	0.51	0.21	0.09	0.05
650	0.99	0.78	0.52	0.21	0.09	0.05
700	0.99	0.79	0.53	0.22	0.09	0.05
750	0.99	0.79	0.54	0.22	0.10	0.05
800	0.99	0.80	0.54	0.23	0.10	0.05
850	0.99	0.81	0.55	0.24	0.10	0.05
900	0.99	0.80	0.56	0.24	0.10	0.05
950	0.99	0.81	0.56	0.25	0.11	0.06
1000	0.99	0.81	0.57	0.25	0.11	0.06
1050	0.99	0.81	0.58	0.26	0.11	0.06
1100	0.99	0.82	0.58	0.26	0.11	0.06
1150	0.99	0.82	0.59	0.27	0.12	0.06
1200	0.99	0.82	0.59	0.27	0.12	0.06
1250	0.99	0.82	0.60	0.28	0.12	0.06
1300	0.98	0.82	0.60	0.28	0.12	0.06
1350	0.98	0.83	0.60	0.28	0.12	0.07
1400	0.98	0.83	0.61	0.29	0.13	0.07
1450	0.98	0.83	0.61	0.29	0.13	0.07
1500	0.98	0.83	0.62	0.30	0.13	0.07
1550	0.98	0.83	0.62	0.30	0.13	0.07
1600	0.98	0.84	0.62	0.31	0.14	0.07
1650	0.98	0.84	0.63	0.31	0.14	0.07
1700	0.98	0.84	0.63	0.31	0.14	0.08
1750	0.98	0.84	0.63	0.32	0.14	0.08
1800	0.98	0.84	0.64	0.32	0.15	0.08
1850	0.98	0.84	0.64	0.33	0.15	0.08
1900	0.97	0.84	0.64	0.33	0.15	0.08
1950	0.97	0.84	0.64	0.33	0.15	0.08
2000	0.97	0.85	0.65	0.34	0.16	0.08
2050	0.95	0.84	0.65	0.34	0.16	0.08
2100	0.95	0.84	0.66	0.35	0.16	0.09
2150	0.94	0.84	0.66	0.35	0.16	0.09
2200	0.96	0.85	0.66	0.35	0.16	0.09
2250	0.96	0.85	0.66	0.35	0.17	0.09
2300	0.95	0.85	0.66	0.36	0.17	0.09
2350	0.94	0.85	0.67	0.36	0.17	0.09
2400	0.94	0.84	0.67	0.36	0.17	0.09
2450	0.94	0.84	0.67	0.37	0.17	0.10
2500	0.93	0.84	0.67	0.37	0.18	0.09

Physical, Thermo-Optical and Electronic Properties of Spectralon

Property	ASTM	Test Value
Water Permeability:	D-570	<0.001% (hydrophobic)
Hardness:	D-785	20 - 30 Shore D
Thermal Stability:	**	Decomposes at >400°C
Coefficient of Linear Expansion:	D-696	5.5 - 6.5 x 10-5 in/in -°F; 10-4°C-1
Vacuum Stability:	**	No outgassing except for entrained air
Flammability:	**	Non-flammable (UL rating V-O) Incompatible with non-polar solvents and greases
Yield Stress:	D-638	208 psi
Ultimate Stress:	D-638	891 psi
Young's Modulus:	**	35774 psi
Elongation in 2 in.:	D-638	42.8%
Elongation at Failure:	D-638	91.3%
Poisson's Ratio:	E-132	0.296
Deformation Under Load:	D-621	13.3 % @ 250 lbs.
	D-621	22.6% @ 500 lbs.
Absorbance (as):	**	0.07
Emittance (e):	**	0.88
Volume Resistivity:	**	>1018 ohm/cm
Dielectric Strength:	D-149	18 V/µm
Refractive Index:	D-542	1.35
Flammability Rating:	UL-94	V-O

Reflectance Properties of Thin Sections of Spectralon

The reflectance of Spectralon decreases with decreasing thickness over most of the spectrum.
The figures below illustrate the reflectance properties of thin sections of Spectralon.

Typical Reflectance Data of Thin Sections of Spectralon SRM-99

Thickness	Wavelength (nm)					
	325	450	555	720	850	1060
1.0	0.93	0.93	0.93	0.92	0.92	0.91
1.5	0.94	0.95	0.94	0.94	0.94	0.94
2.0	0.95	0.96	0.96	0.95	0.95	0.95
2.5	0.96	0.96	0.96	0.97	0.96	0.96
3.0	0.97	0.97	0.97	0.97	0.96	0.96
3.5	0.96	0.97	0.97	0.97	0.97	0.97
4.0	0.97	0.97	0.97	0.97	0.97	0.97
4.5	0.97	0.98	0.98	0.98	0.98	0.98
5.0	0.98	0.99	0.98	0.98	0.98	0.98
5.5	0.98	0.99	0.98	0.98	0.98	0.98
6.0	0.98	0.99	0.98	0.98	0.98	0.98
6.5	0.98	0.99	0.98	0.98	0.98	0.98
7.0	0.98	0.99	0.99	0.98	0.98	0.98

Environmental Testing of Spectralon Material

Spectralon was exposed to atomic oxygen from an ERC plasma stream, with a fluence of ≈5.3 x 10^{20} oxygen ions per square centimeter, with a vacuum in the range of 10-5 torr. Post-exposure measurements of the Spectralon showed no change in either the reflectance or the BRDF of the material.(1)

Spectralon was bombarded with low energy protons at a current density of 10^{12} protons cm^{-2} at 40 KeV in a vacuum of ≤10^{-6} torr. As with the atomic oxygen exposure, no change was seen in either the reflectance or BRDF of the material from pre-exposure measurements.(1)

Spectralon test samples were exposed to deep and mid-UV (unfiltered Hg arc lamp) at a vacuum of ≤10-6 torr with the equivalent of 2 suns for 500 equivalent sun hours. At 110 sun hours, a lowering of reflectance of between 5 - 10 % in the UV was noted; at 500 sun hours, a slight yellowing in the VIS was noted, along with a 20% total drop in the UV (250 nm). However, upon returning to atmospheric conditions, the material returned to near original values, presumably due to oxidation and loss of the surface contaminants that caused the discoloration. (1) Data from another source indicates that the loss of reflectance in the UV and subsequent yellowing does not occur if Spectralon is subjected to a vacuum bakeout procedure. Spectralon has undergone extensive testing for UV-VUV exposure, proton bombardment, atomic oxygen exposure an α-Lyman radiation. Please contact Labsphere for a list of published articles for results of this testing.

Spectralon plates were subjected to electron beam bombardment with a beam energy of 10 KeV at densities of 0.5, 1.0, and 5.0 nA cm-2. The Spectralon was uniformly charged to a potential of -6000 V. Investigation of the discharge phenomenon over extended periods showed no discharge at any current density or charging.(1)

Spectralon has undergone two types of weathering and environmental tests. After measuring the initial reflectance of several samples, they were exposed to the outside environment of central New Hampshire for up to two years. At three month intervals, the samples were cleaned and gently sanded under a stream of tap water to restore the original surface finish. Measurements taken at 50 nm intervals throughout the visible wavelength region revealed essentially no change in reflectance. The results of those tests are shown below.

Environmental Exposure

Wavelength (nm)	Original Reflectance	Reflectance after Exposure		
		1 Month	4 Months	1.5 Years
400	0.988	0.987	0.988	0.986
450	0.990	0.988	0.988	0.990
500	0.989	0.985	0.987	0.985
550	0.987	0.983	0.987	0.986
600	0.987	0.984	0.988	0.988
650	0.987	0.985	0.988	0.988
700	0.986	0.983	0.988	0.987

In a second test, samples of the same material were immersed in sea water. After six months, no change in reflectance was noted. No surface preparation or cleaning was necessary as the samples were not wetted by sea water, neither initially or after six months immersion.

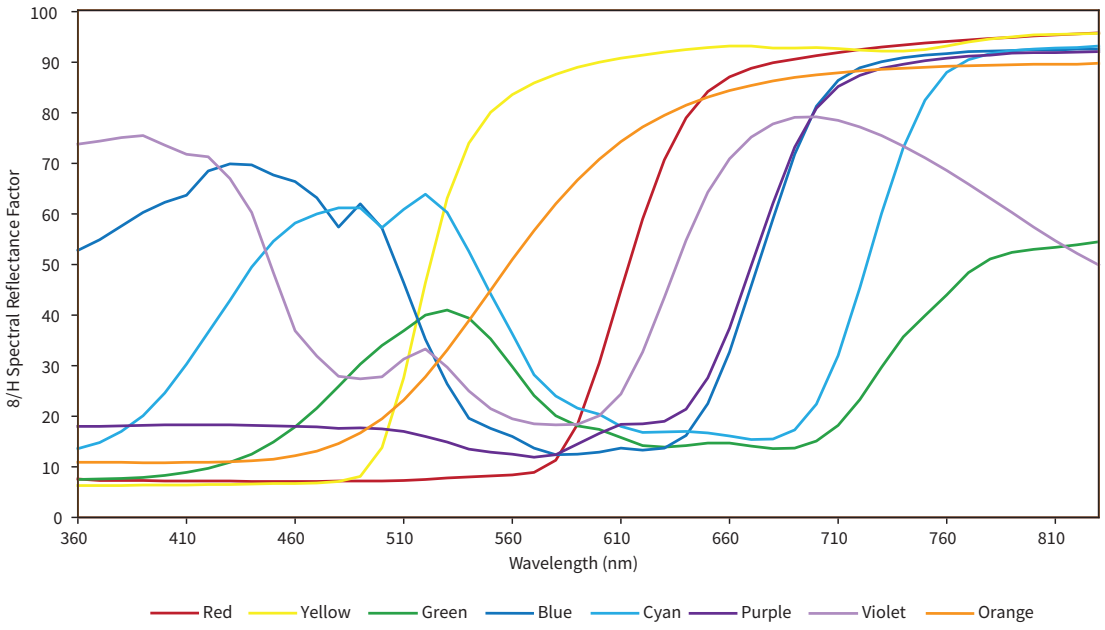
(1) MERIS Activities Report, Doc. No. PO.RP.LSP.ME.0008 10-28-93. This work was performed by Lockheed in conjunction with flight qualification of Spectralon Reflectance Material for use on the European Space Agency MERIS sensor, launched in 1997.

Spectralon Color Materials

Several colorimetric standards are available today, including Spectralon color materials, ceramic tiles, painted chips and Carrera glass. Spectralon color materials have the same physical properties as Spectralon. Therefore, they solve many of the problems associated with other standards. Available in an endless range of colors, Spectralon color materials offer the durability typically lacking in painted chips and ceramic tiles. Unlike ceramic tiles, Spectralon color materials are not subject to the restriction of a specific measurement geometry.

Slight translucency in supposedly opaque material can cause errors due to undetected light losses. Spectralon color standards exhibit significantly less translucency error than Carrera glass standards. Spectralon color standards are also less temperature sensitive than previously available standards and thus less subject to chromatic drift when warmed under intense illumination.

Reflectance Data of Spectralon Color Standards Red, Yellow, Green, Blue, Cyan, Purple, Violet, and Orange



Typical Reflectance Data of Spectralon Color Reflectance Standards

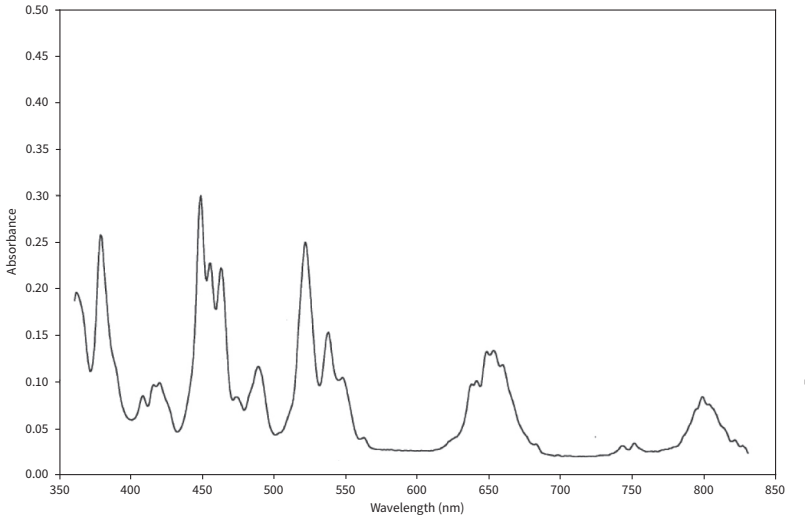
Wavelength	Red Corrected %R	Yellow Corrected %R	Green Corrected %R	Blue Corrected %R	Cyan Corrected %R	Purple Corrected %R	Violet Corrected %R	Orange Corrected %R
360	7.6	6.3	7.5	52.8	13.6	18.0	73.8	10.9
370	7.3	6.3	7.6	54.9	14.8	18.0	74.4	10.9
380	7.3	6.3	7.7	57.6	17.0	18.1	75.1	10.9
390	7.3	6.4	7.9	60.3	20.1	18.2	75.5	10.8
400	7.2	6.4	8.3	62.3	24.6	18.3	73.6	10.8
410	7.2	6.4	8.9	63.7	30.3	18.3	71.8	10.9
420	7.2	6.5	9.7	68.5	36.6	18.3	71.3	10.9
430	7.2	6.5	10.9	69.9	42.9	18.3	67.0	11.0
440	7.1	6.6	12.5	69.7	49.5	18.2	60.3	11.2
450	7.1	6.7	14.9	67.7	54.6	18.1	48.4	11.5
460	7.1	6.7	17.9	66.4	58.2	18.0	36.9	12.2
470	7.1	6.8	21.6	63.2	60.0	17.9	31.9	13.1
480	7.2	7.1	25.9	57.4	61.2	17.6	27.9	14.6
490	7.2	8.1	30.3	62.0	61.2	17.7	27.4	16.7
500	7.2	13.8	34.0	57.2	57.3	17.5	27.8	19.5
510	7.3	27.6	36.9	46.4	60.9	17.0	31.3	23.2
520	7.5	46.4	40.0	35.2	63.9	16.0	33.3	27.8
530	7.8	63.1	41.0	26.4	60.3	14.9	29.7	33.1
540	8.0	74.0	39.4	19.6	52.6	13.5	25.0	38.9
550	8.2	80.1	35.3	17.6	44.2	12.9	21.5	44.9
560	8.4	83.6	29.8	16.0	36.3	12.5	19.5	51.0
570	8.9	85.9	24.1	13.7	28.2	11.9	18.5	56.7
580	11.3	87.6	20.1	12.4	24.0	12.4	18.3	62.0
590	18.4	89.0	18.1	12.5	21.6	14.5	18.4	66.7
600	30.5	90.0	17.4	12.9	20.4	16.6	20.1	70.8
610	44.9	90.8	15.8	13.7	18.0	18.4	24.4	74.3
620	59.0	91.4	14.2	13.3	16.8	18.5	32.7	77.2
630	70.7	92.0	13.9	13.7	16.9	19.0	43.5	79.5
640	79.0	92.5	14.2	16.2	17.0	21.4	54.8	81.5
650	84.2	92.9	14.7	22.5	16.7	27.6	64.3	83.1
660	87.1	93.2	14.7	32.7	16.1	37.4	70.9	84.4
670	88.8	93.2	14.1	45.8	15.4	49.8	75.2	85.4
680	89.9	92.8	13.6	59.0	15.5	62.1	77.8	86.3
690	90.6	92.8	13.7	71.8	17.3	73.2	79.1	87.0
700	91.3	92.9	15.1	81.3	22.4	80.9	79.2	87.5
710	91.9	92.7	18.2	86.4	32.0	85.2	78.5	87.9
720	92.5	92.4	23.3	88.9	45.4	87.4	77.2	88.3
730	93.0	92.2	29.7	90.1	60.1	88.8	75.5	88.6
740	93.4	92.2	35.7	90.9	73.1	89.6	73.4	88.8
750	93.8	92.5	39.9	91.4	82.5	90.3	71.1	89.0
760	94.1	93.2	44.0	91.7	88.0	90.8	68.6	89.2
770	94.4	94.0	48.4	92.1	90.5	91.2	65.9	89.3
780	94.7	94.6	51.1	92.2	91.7	91.4	63.1	89.4
790	94.9	95.0	52.4	92.3	92.3	91.8	60.3	89.5
800	95.2	95.4	53.0	92.5	92.6	91.9	57.4	89.6
810	95.4	95.5	53.4	92.4	92.8	91.9	54.7	89.6
820	95.6	95.6	53.9	92.6	92.9	92.0	52.2	89.6
830	95.8	95.7	54.5	92.6	93.2	92.1	49.9	89.8

Spectralon Wavelength Standards

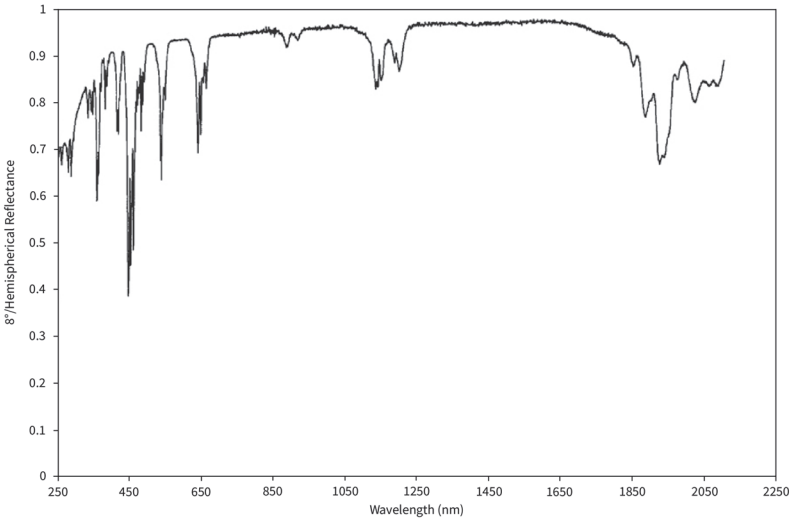
Spectralon wavelength calibration standards are formulated by impregnating a Spectralon substrate with the oxide of a rare earth element which displays sharp absorption spikes at specific wavelengths. Complete absorption spectral data is supplied with each standard. Durable, washable, and chemically inert without loss of surface texture, Spectralon wavelength calibration standards retain uniformity throughout making them ideal for calibration of spectrophotometers, reflectometers, and other spectral instruments. Calibration data for peak absorbance wavelengths relative to maximum absorbance across the UV-VIS-NIR is provided with each calibrated standard. Calibration is traceable to National Institute of Standards and Technology (NIST).

Spectralon wavelength calibration standards are available in either 1.25 or 2.00 inch diameters and are doped with one of the following: Holmium Oxide, Dysprosium Oxide, or Erbium Oxide. A multi-component wavelength calibration standard is also available and combines the three rare earth oxides.

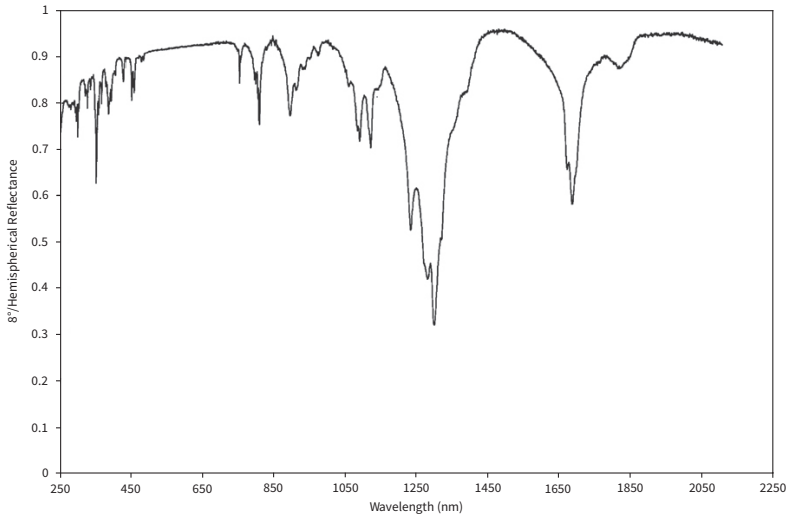
Absorbance Spectrum - Multi-Component Wavelength Calibration Standard



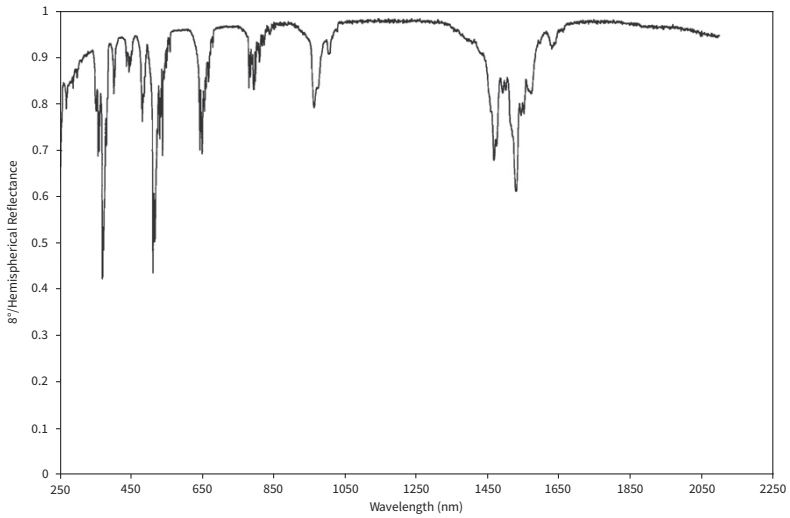
Holmium Oxide Wavelength Calibration Standard



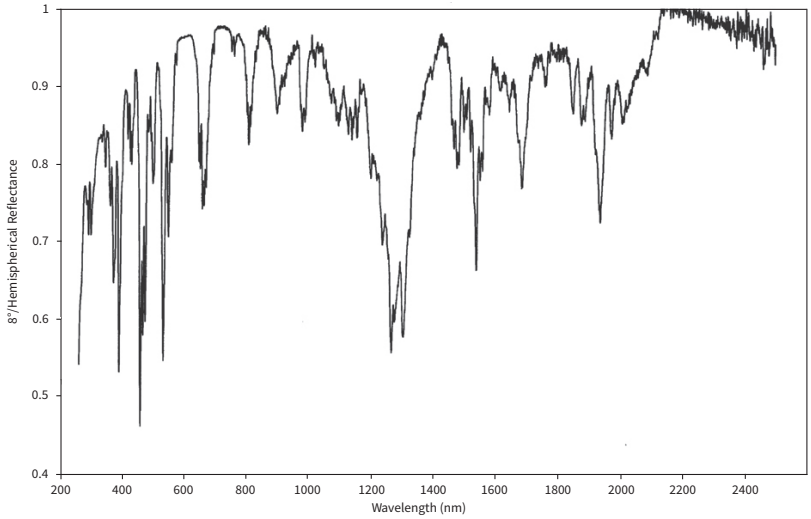
Dysprosium Oxide Wavelength Calibration Standard



Erbium Oxide Wavelength Calibration Standard



Multi-Component Wavelength Calibration Standard

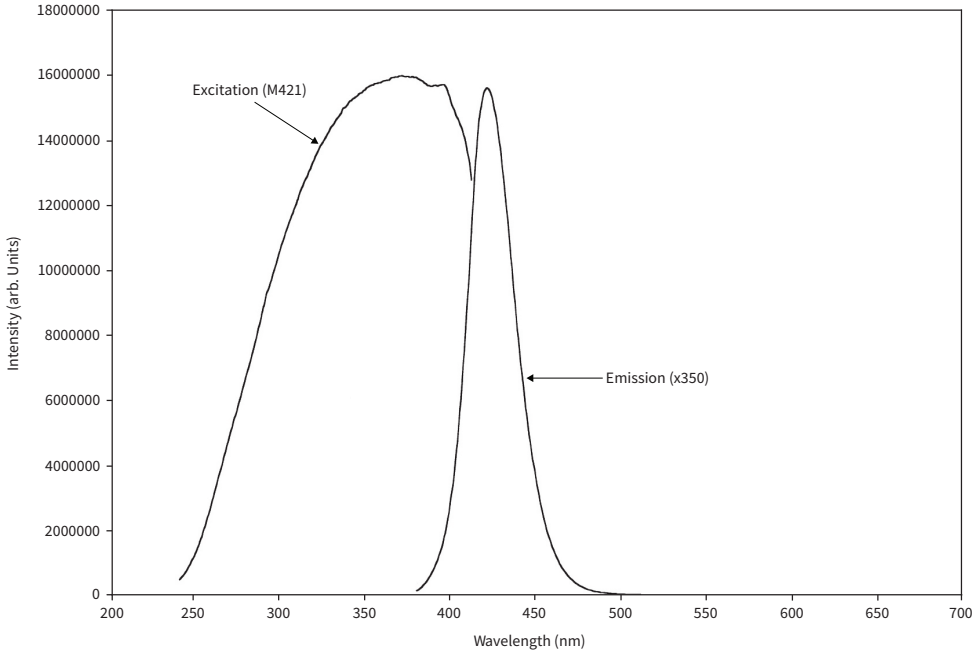


Spectralon Fluorescence Materials

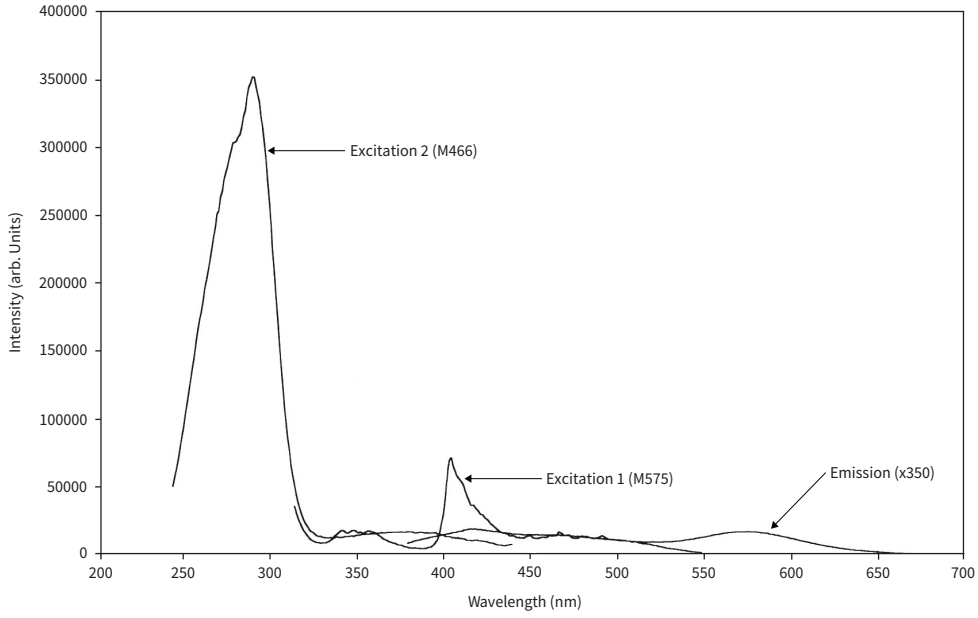
Spectralon fluorescence materials provide highly stable, reproducible fluorescence reflectance over long periods in varying conditions. Spectralon provides the ideal matrix for inorganic fluors which are photochemically stable compared to their organic counterparts. The stability of the inorganic fluors, when combined with the durability of Spectralon, results in rugged, long lasting fluorescence materials for both field and laboratory use.

The following charts show the Radiance Factor and Color Stimulus Function of Labsphere fluorescence materials.

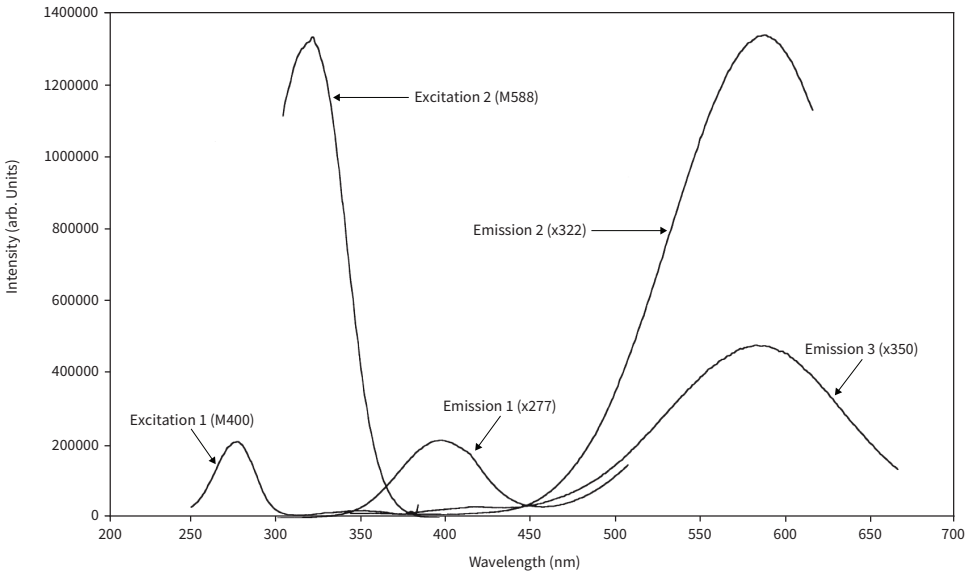
SFS-421 Blue-Violet Flourescence Excitation Maxima at 421 nm



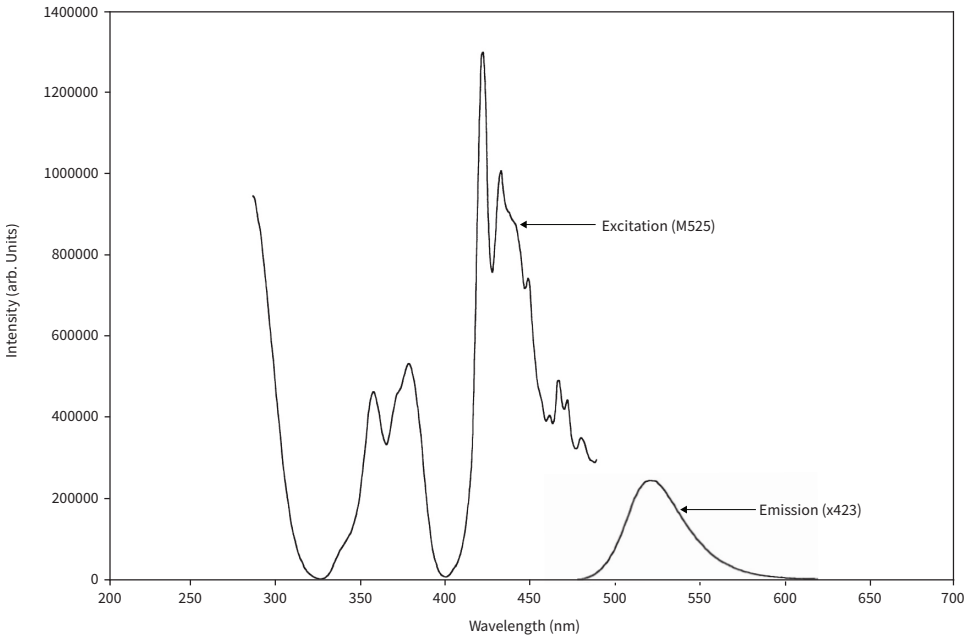
SFS-466 Bright Blue Flourescence Excitation Maxima at 466 nm and 575 nm



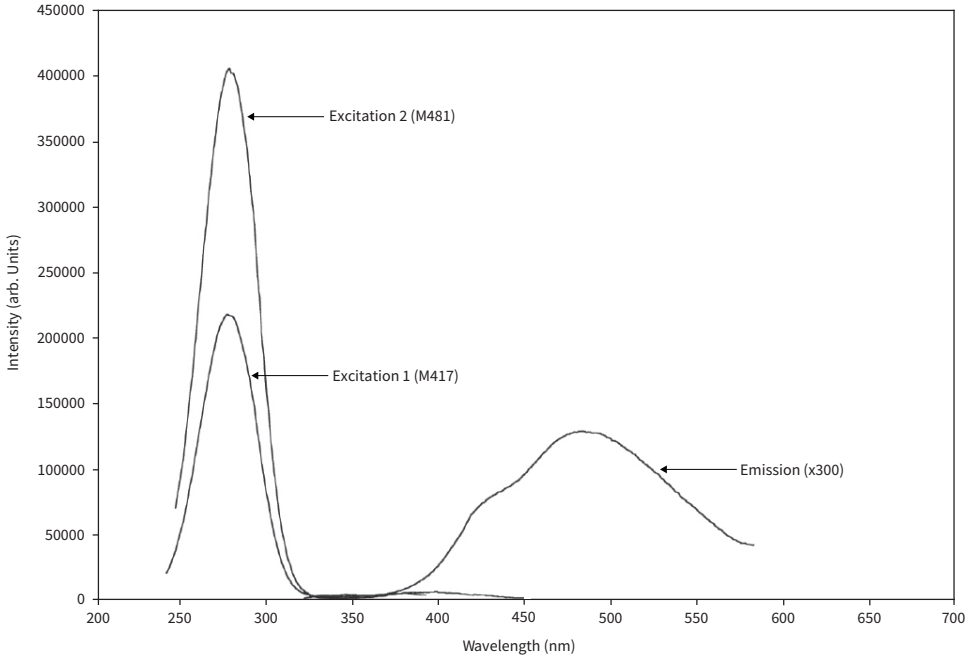
SFS400 Orange Fluorescence Excitation Maxima at 400 nm and 588 nm



SFS-525 Green Fluorescence Excitation Maxima at 525 nm



SFS-417 Broadband Blue/ White Fluorescence Excitation Maxima at 417 nm and 481 nm



SFS-425 Broadband Bright Blue/White Fluorescence Excitation Maxima at 425 nm and 564 nm