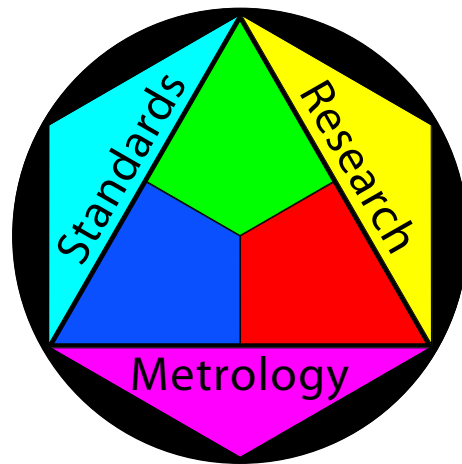


Mt. Baker Research LLC



Technical Report

OnColor Profiler® Tile Set

Instruction Manual

By

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Instruction Manual for the OnColor Profiler® Tile Set

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Introduction

In 1969 Ceram Technology Ltd. introduced the Series I transfer standards. Ceramic standards are preferred for testing the stability of spectrophotometers. CyberChrome introduced the OnColor Profiler® software in 2008. OnColor Profiler® and the OnColor Profiler® tile set were developed for testing and improving inter-instrument agreement in a multi-instrument or multi-laboratory environment.^{1,2}

The advantages of transfer standards made from ceramic tiles include durability, stability and ease of cleaning. Ceramic standards do not spontaneously change color or appearance, but proper procedures for storage, handling and maintenance are required to insure long-term stability.³

Photometric Range and Color Gamut

The OnColor Profiler® tile set contains 32 mounted, 2-inch ceramic transfer standards packaged in 2 re-sealable, permanent storage cases.⁴ The individual standards are listed in Appendix A, and typical spectral reflectance data are shown in Appendixes G and H. Although this tile set is optimized for profiling, it may also be used to test instruments and to assess inter-instrument agreement.

The standards included in the OnColor Profiler® tile set were selected to meet the following criteria:

- (1) Span the complete photometric range.

¹ For an introduction to color measurement, see: R.S. Berns, "Billmeyer and Saltzman's Principles of Color Technology," 3rd edition, Wiley-Interscience, New York, 2000. ISBN: 978-0-471-19459-0.

² This manual does not describe the features and use of OnColor Profiler® software. For an introduction to profiling see: "The Importance of Instrument Profiling," white paper, CyberChrome, Inc., Stone Ridge, New York, 2008.

³ J.W. Root, "Maintenance Manual for Glass & Ceramic Transfer Standards," technical report, release 2.1, Mt. Baker Research L.L.C., Bellingham, Washington, November 18, 2007.

⁴ The author's website posts descriptions of the transfer standards and examples of CIELAB color gamut diagrams. Ultra-white standards and profiling are described. The free downloads include the maintenance manual and sample certificates that detail the ASTM procedures on which testing and validation are based. (See: <<http://www.mtbakerresearch.com>> .)

(2) Span the widest possible gamut in CIELAB color space.⁴

(3) Include only high quality standards with minimal translucency.

To anchor the photometric scale, the set includes a low reflectance black and a high reflectance ultra-white standard. Nine grey standards are included to test photometric linearity.⁵ The 21 colored standards sample all the regions of CIELAB color space that can be reproduced using ceramic glazes.^{4,6}

The OnColor Profiler® tile set was developed at Mt. Baker Research in 2007. In the original product release the upper end of the photometric scale was anchored with a #T-11 grey 85% standard. This standard exhibits slight translucency, and its typical mid-range spectral reflectance measures $85.2\% \pm 1.0\%$.⁷

Beta-testing of OnColor Profiler® at PPG Industries showed that a more reflective white standard was needed. With a typical mid-range reflectance value of $89.5\% \pm 1.5\%$, Ceram white tiles are not sufficiently reflective. The mid-range reflectance of the new #T-1 ultra-white standard is $95.8\% \pm 1.5\%$.

As described below, additional criteria based on translucency were applied to the standards selected for the OnColor Profiler® tile set.

Introduction to Translucency

A translucent solid is not perfectly opaque. Part of the light incident on it penetrates the surface where it undergoes internal scattering and lateral diffusion away from the point of entry. Because these processes reduce the intensity of the reflected light, the Lambertian efficiency of the reflective surface is decreased.

As a result of lateral diffusion, the spectral reflectance of a translucent solid decreases as the size of the instrument's sample port is reduced. This loss of reflectance may lead to significant measurement errors. These errors vary from instrument to

⁵ J. Ladson, A.W. Springsteen, J. Sefl, H.S. Fairman, M.H. Brill, and J. Zwinkels, "Technical Report 2003-1: Guide to Material Standards and Their Use in Color Measurement," 2nd Revision 2003, Inter-Society Color Council, Inc., Reston, Virginia.

⁶ For a review of ceramic glazes, see: R.A. Eppler and M. Obstler, "Understanding Glazes," The American Ceramics Society, Westerville, Ohio, 2005. ISBN: 1-57498-222-2.

⁷ The cited spectral reflectance data were measured with an X-Rite ColorEye 7000A operated in the diffuse, specular-included geometry. The mid-range reflectance data correspond to a wavelength of 550 nm.

instrument depending on the optical geometry and the sizes of the illuminated and measured areas of a mounted test sample.^{8,9}

For each translucent material a complete description of the reflectance loss should include the following information:

(1) Magnitude: How large is the reflectance loss?

(2) Radial Dependence: What is the radial dependence of the reflectance loss that originates from an illuminated point on the optical surface?

(3) Thickness Dependence: Is the sample sufficiently thick to prevent loss from the rear surface as a result of transmission?

(4) Wavelength Dependence: How and why does the wavelength dependence of the spectral reflectance vary with the physical state and the chemical composition?

Translucency in Transfer Standards

Because many of the ceramic materials available on the market today exhibit moderate to severe translucency, the standards selected for the diagnostic tile set were subjected to rigorous testing. The other available transfer standards and tile sets have not been screened for translucency.

During 2008 and 2009 the author investigated the reflectance behavior of translucent ceramic tiles, optical glasses and plastics.¹⁰ Mathematical models were developed that describe the magnitude of spectral reflectance factor ("SRF") losses in these materials, as well as the radial and the sample thickness dependencies of these losses.¹¹

⁸ J.J. Hsia, "Optical Radiation Measurements: The Translucent Blurring Effect—Method of Evaluation and Estimation," NBS Technical Note 594-12, U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., 1976. NTIS No. PB259639.

⁹ D.L. Spooner, "Stray Darkness: A New Error or a Previously Known Error Recast?," in G.B. Beretta and R. Eschbach, editors. "Device-Independent Color, Color Hardcopy, and Graphic Arts IV." SPIE Conference Proceedings 3648, 242(7), January, 1999. ISBN: 9780819431196.

¹⁰ J.W. Root, "Ultra-White Color Standards: Tests for Translucency and Standoff Behavior," technical report, release 1.5, Mt. Baker Research L.L.C., Bellingham, Washington, October 13, 2008. J.W. Root, "Translucency Tests: 14 Ceramic Tiles, 8 Carrera Glasses, White Vitrolite Glass & M-20 Russian White Opal Glass," technical report, release 1.0, Mt. Baker Research L.L.C., Bellingham, Washington, March 9, 2009.

¹¹ J.W. Root, "Ultra-White Color Standards: Tests & Models for Translucency," technical report, release 2.5, Mt. Baker Research L.L.C., Bellingham, Washington, January 6, 2009.

Although the corresponding wavelength dependencies are not understood, the magnitudes of the reflectance losses were measured in 15 plastics, 29 Ceram tiles and 125 other ceramic and vitreous materials. To date the radial dependencies have been characterized for 20 materials, including several Ceram tiles.¹²

Many translucent materials are used as transfer standards. The following examples are listed in order of decreasing reflectance loss: white Vitrolite glass, Teflon®, Fluorilon® and Spectralon®, M-20 Russian white opal glass ("RWOOG"), many white and high-chroma ceramic tiles, and Japanese EverWhite ceramic.¹³

Spectrophotometric Measurement of Reflectance Loss

For a translucent material, the reflectance loss that results from lateral diffusion increases as the size of the instrument's sample port is decreased.⁸ This loss of reflectance may be measured using experiments in which over-illumination is systematically varied. As the over-illumination is decreased, the reflectance loss becomes detectable and measurable.

In a commercial instrument, over-illumination is accomplished by making the area viewed by the detector smaller than the illuminated area of the test sample. In instruments that support diffuse illumination, the entire exposed surface of the sample is illuminated, and an optical system controls the size of the area viewed by the detector.

With the X-Rite ColorEye 7000A ("CE 7000A"), over-illumination may be varied over an exceptionally large range. This is accomplished using the 10 supported combinations of sample port with detector viewed area. Maximum over-illumination is achieved when the LAV sample port is combined with the VSAV viewed area. Because the reflectance loss is minimized, the LAV/VSAV configuration yields the best possible measurement accuracy for translucent materials that exhibit uniform surface quality. Minimum over-illumination results when the VSAV sample port is combined with the VSAV viewed area. With the VSAV/VSAV configuration, lateral diffusion causes the largest reflectance loss that can be measured with the CE 7000A.^{14,15}

¹² J.W. Root, unpublished results.

¹³ Fluorilon® and Spectralon® are made by sintering spectroscopic grade Teflon® powder. Teflon® contains polymerized tetrafluoroethylene.

¹⁴ The acronyms LAV, MAV, SAV and VSAV denote large, medium, small and very small area of view. In this manual typical port sizes are defined by the CE 7000A. The following port sizes are published by X-Rite: LAV = 25.4 mm d. MAV = 15.0 mm d. SAV = 10.0 x 7.5 mm. VSAV = 8.0 x 3.0 mm. The port sizes of the X-Rite ColorEye 7 ("CE 7") are as follows: LAV = 25.4 mm d. #2 = 17.0 mm d. MAV = 10.0 mm d. SAV = 6.0 mm d. Those of the Konica-Minolta CM-3700d are as follows: LAV = 25.4 mm d. MAV

For each test material, replicate measurements are performed using the LAV/VSAV and VSAV/VSAV configurations of the CE 7000A. For each configuration the total reflectance is the sum over the measured SRF values. The fractional reflectance loss is calculated from the difference in total reflectance between the LAV/VSAV and VSAV/VSAV configurations. In graphical terms, the fractional reflectance loss represents the magnitude of the integrated area, which is enclosed between the LAV/VSAV and VSAV/VSAV SRF plots, divided by the magnitude of the integrated area enclosed beneath the LAV/VSAV plot.^{10,11}

Although RWOG exhibits moderate translucency, accurate reflectance measurements are achieved for it with the CE 7000A operated in the specular-included ("SCI") geometry and the LAV/VSAV configuration. RWOG provides a convenient reference standard for defining the relative reflectance loss ("RRL") values of other translucent materials. To calculate the RRL value, the measured fractional reflectance loss is multiplied by 100 and divided by the value for RWOG.¹⁶

Selection of the OnColor Profiler® Tile Set

The following limits are recommended for transfer standards that are used for profiling and testing instruments in the diffuse SCI geometry. For target instruments that support a LAV, MAV or SAV sample port, with RWOG as the reference the RRL values should not exceed 100%. For target instruments that support a VSAV sample port the RRL values should not exceed 30%.^{12,14,16}

After 125 ceramic materials were screened for translucency, standards were assigned to the OnColor Profiler® tile set based on the limits and the other criteria described above together with the following requirements:

- (1) All spectrophotometers: Minimize the errors that result from translucency.

= 11.0 mm d. SAV = 7.0 x 5.0 mm. In each configuration of these instruments, the area viewed by the detector is 2 mm smaller in each dimension.

¹⁵ The CE 7000A supports 4 sample ports and 4 lens settings. The lens setting determines the size of the detector viewed area. In this manual LAV/VSAV denotes the LAV sample port combined with the VSAV lens setting. The 10 combinations supported by the CE 7000A restrict measurements to over-illumination.

¹⁶ The following RRL values were measured in the diffuse SCI geometry with RWOG as the reference standard: (a) 825%; white Vitrolite glass. (b) 740%; Teflon®. (c) 95% & 115%; 2 Avian Technologies Fluorilon® white reflectance standards. (d) 100%; #T-46A deep orange standard and Ceram BCRA series II orange and red tiles. (e) 80%; Ceram BCRA series II yellow tile. (f) 50%; Ceram series II white calibration standard supplied with CE 7000A instrument S/N 37116190602. (g) 30%; #T-1 ultra-white standard and Konica-Minolta CM-A103 white calibration standard S/N 18776042. (h) 6%; #T-11A grey 85% standard.

(2) Diode-array instruments that feature over-illumination and typical LAV, MAV or SAV sample ports: Reduce these errors to statistical insignificance.

(3) Diode-array instruments that feature over-illumination and typical VSAV sample ports: Minimize and characterize these errors.

The 32 standards included in the OnColor Profiler® tile set exhibit RRL values ranging from 0% to 30%.¹⁷ Because translucency does not cause significant measurement errors, these standards are optimized for use with instruments that support over-illumination and typical LAV, MAV or SAV sample ports. In addition, the standards are reliable for use with instruments that support VSAV sample ports.

Translucency of Ceram Tiles

Ceram BCRA series II tiles are commonly used to monitor the stability of spectrophotometers.¹⁸ At Mt. Baker Research, 29 calibrated Ceram series II tiles are available for testing. With RWOOG as the reference standard, the RRL values range from 10% to 100% for BCRA series II tiles measured in the diffuse SCI geometry. For the other 17 series II tiles, the RRL values range from 0% to 300%.¹⁷ Spectral reflectance data measured for the more translucent BCRA tiles are not portable between instruments that support large vs. very small sample ports.^{9,12,16}

At reference laboratories, including the National Research Council of Canada and the U.S. National Institute of Standards and Technology, large-aperture, dual-beam scanning instruments are used during metrological calibrations of spectral reflectance. Because the VSAV sample port and viewed area are not supported, BCRA series II tiles calibrated in this way cannot be used to evaluate the absolute accuracy of an instrument that is operated with a small sample port. Ceram series II tiles are not recommended for profiling or for validating small-aperture instruments.^{9,12}

Profiling Procedure

Scenario: The user purchases a complete OnColor Profiler® tile set. The 32 transfer standards are measured with each test instrument, and the data are used for profiling analysis.

CyberChrome's OnColor Profiler® software may be used to improve inter-instrument agreement in a multi-instrument environment. This is accomplished by

¹⁷ For a black transfer standard RRL = 0. If the spectral reflectance is very small, changes in over-illumination do not lead to measurable changes in reflectance.

¹⁸ CIELAB colorimetric data are used to certify spectrophotometers. A master set of Ceram BCRA series II tiles is measured on the test instrument. The CIELAB parameters are calculated, and the average ΔE^*_{ab} difference from the master data set is reported. This test does not constitute validation. (See ref. 1.)

profiling each test instrument against a designated master instrument. Both the OnColor Profiler® tile set and the complete diagnostic tile set are supported.^{4,19,20}

The recommended procedures for measuring data sets for profiling are described in Appendixes C and D.²

Instrument Tests

In addition to profiling, the OnColor Profiler® tile set may be used to perform the diagnostic tests that are described below. The transfer standards listed in Appendix E are used in these tests. Although pre-calibrated transfer standards are not needed for profiling, many of the following tests require calibrated standards and data analysis performed at Mt. Baker Research.^{21,22}

1. Instrument Validation Test

Scenario: The user purchases a pre-calibrated OnColor Profiler® tile set. A test instrument is used to re-calibrate the 16 standards listed in Appendix E, and the data are submitted for analysis.

Prior to delivery, each OnColor Profiler® tile set is calibrated in the geometry (or geometries) specified by the user. To validate the performance of a spectrophotometer, the user should carefully follow the procedures described in Appendixes B, C and F. These procedures were developed for use with OnColor QC® control software and instruments that support diffuse or bi-directional flash illumination, variable over-illumination and diode-array detection.²³

¹⁹ OnColor Profiler® exclusively supports OnColor QC® control software. Because 3rd-party profiling support is not available, each client organization must purchase a license for OnColor Profiler® from CyberChrome, Inc. (See: <<http://www.cyberchromeusa.com>> .)

²⁰ J.W. Root, "Instruction Manual for the Diagnostic Tile Set," technical report, release 2.0, Mt. Baker Research L.L.C., Bellingham, Washington, October 1, 2009.

²¹ The certified calibrations offered by Mt. Baker Research are traceable to the National Research Council of Canada and the U.S. National Institute of Standards and Technology. Calibrations are offered in the diffuse SCI, the diffuse SCE and the (45°/0°) bi-directional geometries. The available reference quality spectrophotometers support flash illumination and diode-array detection. Because of Helmholtz reciprocity, the (0°/45°) and (45°/0°) geometries are optically equivalent.

²² The original purchase price of the OnColor Profiler® tile set does not include the #T-46A standard or these additional services. The prices for certified calibration and testing services are based on the data format, the requested scheduling, and the requested numbers of standards, test instruments, and geometries. Transfer standards are priced separately.

²³ The calibration and testing procedures described in this manual support CyberChrome's OnColor QC® software. Although the user may adapt the validation procedure for use with other control software, at this time Mt. Baker Research exclusively supports OnColor QC®. Users of other control software, who

The repeatability and accuracy of the test instrument are measured using procedures approved by ASTM, which are implemented in algorithms developed by the author.⁴ After the instrument is calibrated, repeated measurements of a calibrated white standard are alternated with measurements of 16 of the standards in the OnColor Profiler® tile set. Although frequent calibration reduces the significance of instrument drift, the data analysis includes a correction for this source of error.

The user creates one OnColor® disk file that contains the SRF data for each tested instrument configuration. After the measurements are completed, these OnColor® files are submitted for analysis. One certificate of traceable instrument performance is issued for each file.^{21,22}

2. Inter-laboratory Agreement Test

Scenario: The calibrated white standard used in the instrument validation test is traceable to an unsupported metrology laboratory. The results from the data analysis reflect the differences between the laboratories on which traceability is based.

During the instrument validation test, repeated measurements of a calibrated white standard are alternated with measurements of 16 of the standards in the OnColor Profiler® tile set. During the analysis the measured data are converted to absolute SRF values. If the calibrated white standard used in these measurements is traceable to an unsupported metrology laboratory, the calculated results will reflect any systematic differences that exist between these laboratories. This problem may be diagnosed using the inter-laboratory agreement test.^{21,22,24}

3. Multiple Geometries Test

Scenario: The user needs to validate an instrument in more than one geometry.

The OnColor Profiler® tile set must be pre-calibrated in each geometry in which the user needs to validate instruments. The instruments employed in these calibrations should be similar to those that will be validated. If the user's instruments employ flash illumination and diode-array detection, the pre-calibrations should be based on similar reference quality instruments.^{21,22,24}

4. Multiple Instruments Test

Scenario: The user needs to validate more than one instrument.

purchase standards and acquire validation data as described in Appendixes B, C and F, may submit Excel®-readable text files for analysis.

²⁴ Licensed users of the OnColor Profiler® tile set may request instructions for performing this test using OnColor QC® control software. Send an email to <jackroot@mtbakerresearch.com> .

Licensed users of the OnColor Profiler® tile set are permitted to validate more than one instrument. These validation results may demonstrate the benefits of profiling.²²

5. Annual Revalidation Tests

Scenario: The user repeats the instrument validation procedure on an annual basis.

Yearly re-measurement of the standards listed in Appendix E provides a basis for revalidating instruments, for tracking performance (see below), and for testing the long-term stability of the standards. Ceramic standards are inherently stable, so annual revalidation of a master instrument provides an important check of the user's procedures for storing, handling and maintaining the standards. In addition, the need for service and the benefits of profiling may be demonstrated by annual revalidation tests.²²

6. Absolute Accuracy Test

Scenario: The user needs to determine the absolute accuracy of spectral reflectance measurements.

To characterize the absolute spectrophotometric accuracy, the results from validation tests may be compared with SRF data measured for similar transfer standards at the National Research Council of Canada.^{22,25}

7. White Calibration Tile Test

Scenario: The user needs to test the possible translucency of the white calibration tile supplied with the test instrument.

Every spectrophotometer is supplied with a white tile that is used during calibration. These transfer standards are not screened for translucency, although many of the materials from which they are made are subject to translucency.^{10,11,16} A translucent calibration tile may lead to significant measurement errors. Provided that a VSAV sample port is available for the test instrument, this problem may be diagnosed using the white calibration tile test.^{22,24,26}

8. Translucency Sensitivity Test

Scenario: The user needs to determine whether significant measurement errors occur for translucent test samples.

²⁵ This test is supported for the (0°/45°) bi-directional geometry. (See note 21.)

²⁶ The #T-11A grey 85% tile is needed for this test. (See Appendixes A and E.)

Because the #T-46A deep orange standard is translucent, it may be used to test the sensitivity of the instrument to errors in spectral reflectance that result from lateral diffusion. This test requires 2 sample ports, which must include a SAV or VSAV port in addition to a LAV or MAV port.^{22,24,27}

9. Translucency Accuracy Test

Scenario: The user needs to confirm the accuracy of translucency measurements that are performed in-house.

The procedures described here for characterizing translucent materials employ reference quality instruments that support flash illumination, variable over-illumination and diode-array detection. The #T-46A deep orange standard may be used to test the accuracy of similar translucency measurements performed by the user. As a basis for this test, the absolute translucency of the #T-46A standard must be calibrated.²⁸

10. Tracking Instrument Performance

Scenario: The user needs to monitor the performance of one or more instruments on a routine basis.

Instrument performance may be monitored using CyberChrome's OnColor Profiler® software or the validation procedure described in this manual. Because OnColor Profiler® monitors 32 standards, an OnColor Profiler® tile set or a complete diagnostic tile set is required.¹⁹

To reduce statistical noise during SRF measurements, the procedure recommended in Appendix D averages over several lamp flashes. Based on the procedures described in Appendix F, if the time is included for instrument initialization and for averaging over 3 lamp flashes per measurement, one hour is needed to acquire an OnColor Profiler® data set for one instrument configuration. For a portable instrument the number of lamp flashes per measurement is increased to 5, and the required time increases to 1.3 hours.

The validation procedure requires more instrument time than profiling. Based on the procedures described in Appendixes C and F, 2 hours are needed to validate a benchtop instrument in one configuration. For a portable instrument the required time increases to 3 hours.

²⁷ The LAV and VSAV sample ports are preferred. See note 14 for definitions of port sizes.

²⁸ The calibrated translucency standards offered by Mt. Baker Research sample all the regions of CIELAB color space that can be reproduced using high-chroma ceramic glazes. (See notes 4, 6 and 21.)

The instrument time needed to acquire one data set for use with OnColor Profiler® is about 50% of that, which is required to execute the validation procedure for one test instrument. However, this is not an apples-to-apples comparison. The validation procedure provides a detailed statistical analysis of instrument performance, but it is not optimized for routine monitoring. If several instruments are being monitored, the OnColor Profiler® procedure may offer a more cost effective solution for tracking performance.

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The author thanks the individuals listed below for their support. During the past 3 years Elaine Becker (CyberChrome, Inc.) offered frequent guidance, including the original suggestion that translucency may be important in profiling. Elaine helped develop the OnColor Profiler® tile set, and she beta-tested it on several instruments. She helped with this manual, and beta-tested the diagnostic tile set on a Konica-Minolta CM-3700d instrument.

Tom Sawyer and Tim Ragan (Quarry Tile Co.) participated in a beta test of the diagnostic tile set. Since 2007 Tom has shared his extensive knowledge about commercial tile making. He offered many helpful suggestions and provided critical assistance with quality control.

Dr. Art Springsteen (Avian Technologies L.L.C.) loaned samples of Fluorilon®, white Vitrolite glass and several Carrera glasses for translucency measurements. During 2005 – 2007 he participated in the development of 3 tile sets.⁴

Appendix A. OnColor Profiler® Tile Set Contents

The standards assigned to the OnColor Profiler® tile set are listed in Table 1. Typical SRF data are shown in Appendixes G and H for the diffuse SCI geometry and the diffuse SCE geometry. This set includes either a #T-11 or #T-11A grey 85% standard. The #T-11A standard is used in the white calibration tile test. The #T-46A deep orange standard, which is available for separate purchase, is required for the translucency sensitivity and accuracy tests.²²

The diagnostic tile set was introduced in 2009 to support users who need to evaluate inter-instrument agreement in a multi-instrument environment. Either the OnColor Profiler® tile set or the diagnostic tile set may be used for profiling.²⁰

Tile Number	Color Name
T-01	Ultra-White
T-02	Black
T-03	Deep Grey 10%
T-04	Grey 20%
T-05	Mid-Grey 27%
T-06	Grey 33%
T-07	Grey 40%
T-08	Grey 50%
T-09	Light Grey 60%
T-10	Grey 80%
T-11	Grey 85%
T-11A	Grey 85%
T-12	Deep Red
T-13	Yellow
T-14	Deep Green
T-15	Mid-Blue
T-16	Deep Orange-Red
T-17	Greenish-Blue
T-18	Deep Blue
T-19	Light Orange
T-20	Rose Pink
T-21	Light Yellow
T-22	Light Blue

Table 3. OnColor Profiler® Tile Set Continued	
Tile Number	Color Name
T-23	Light Cyan
T-24	Deep Violet
T-25	Light Blue-Green
T-26	Yellow-Green
T-27	Purple
T-28	Yellow-Orange
T-29	Light Green
T-30	Mid-Brown
T-31	Dark Blue
T-32	Mid-Green
T-46A	Deep Orange

Appendix B. General Procedures

Clean the Sample Stage and Transfer Standards

Before beginning measurements, follow the manufacturer's instructions to clean the sample stage of the test instrument. Check the integrating sphere for accumulated dust. If necessary, carefully clean the sphere using compressed tetrafluoroethane.²⁹

Each set of transfer standards is shipped in a re-sealable foam-lined plastic case. The optical surface of each standard is protected with a soft pad made from white polyester felt. Store the standards in the original case when they are not in use. The storage environment should exclude chemical vapors and large variations in temperature and humidity.

Always wear clean, lint-free cotton gloves when handling or measuring standards. Observe the cleaning practices described in the maintenance manual, and never expose the optical surfaces to harsh chemicals or abrasives. Use a soft, static-free brush to remove dust before mounting each standard for measurement.^{3,4}

Sample Placement

Consistent sample placement underlies the achievement of good measurement precision. The positioning foot located on the sample arm of the CE 7000A provides adequate control.³⁰ Because the sample arm of the CE 7 is less rigid, extra care is needed to achieve consistent placement.

A custom optical bench was developed to control sample placement with portable instruments that are similar in size to the Konica-Minolta CM-2500c.³¹ Since the instrument is inverted, the sample stage is accessed from above. In the horizontal x- and y-directions, the optical bench insures consistent placement with an estimated precision of ± 0.05 mm. In the vertical direction effective optical contact is achieved with the aid of a 240 gram weight, which is placed in the positioning well located on the back of each standard.

²⁹ Avoid propellants that are flammable or that contain residue-forming additives.

³⁰ Use a rubber band to increase the tension and maintain effective optical contact between the standard and the sample stage.

³¹ The optical bench may be special ordered. Send email inquiries to <jackroot@mtbakerresearch.com> .

Temperature Measurement

Measure and record the temperature at the beginning of each series of measurements. For in-house measurements, the author records the temperature with a precision of ± 0.1 °C using the averaged readings from 3 fluid-filled, NIST-traceable thermometers. A Control Company model 4000 NIST-traceable digital thermometer is used for off-site measurements. This device is accurate to ± 0.05 °C.

OnColor Disk File Names

Use consistent, readily identifiable names for each disk file that contains OnColor® data. The author uses the naming conventions described below.

(1) OnColor QC® disk filenames: Data_MBR_CE7000A#2_090901_#01.wsv and Data_MBR_CM2500c_090901_#02_copy.wsv

Here, "Data_MBR" identifies this file as OnColor® measurements performed at Mt. Baker Research. "CE7000A#2" and "CM2500c" show that CE 7000A (S/N 37132651108) and Konica-Minolta CM-2500c (S/N D4001408) instruments were used. "090901" identifies the date. "#01" and "#02" show that these were the 1st and 2nd OnColor® disk files saved on that date.

Individual Measurement Names

The individual sets of SRF data contained in an OnColor® disk file are so similar that they are difficult to identify unless easily recognizable names are used. Some examples follow below:

(1) Initial measurement in a series: CRM Wh #5 09/01 (CRIILL,CAL,23.0)

Here, "CRM Wh #5" identifies the white calibration tile, which also serves to identify the CE 7000A (S/N 37132651108) instrument. "09/01" specifies the date. "CRIILL" specifies the instrument configuration using OnColor® syntax. "CAL" shows that this measurement was preceded by calibration of the instrument. "23.0" specifies the temperature of the sample stage in °C.

(2) Subsequent measurement of the white calibration tile: CRM Wh #5 0 (CRIILL,23.0)

Here, "0" denotes 0° orientation for the fiducial mark on the mounted standard. The other syntax is described above.

(3) On-site measurement of another standard: MBR #D01#3 0 (CRIILL,23.0)

Here, "MBR" shows that the measurement was made in house. "#D01#3" references standard #D-1 from diagnostic tile set #3.

(4) Off-site measurement of a standard: QTC #D01#3 0 (CRIILL,23.0)

Here, "QTC" shows that the measurement was performed at Quarry Tile Co.

The practices described above do not represent overkill. On a typical day the author may access several hundred OnColor® data sets from disk files created since 2005.

Appendix C. Instrument Initialization Procedure

If the instrument is functioning properly and careful procedures are used for sample placement, flash lamp instability is the main source of statistical noise in the measured SRF data. Use the procedures described below to reduce noise.

- (1) Instrument configuration.
- (2) Instrument initialization.
- (3) Consistent time delay between lamp flashes.
- (4) Multiple lamp flashes, if supported.

Instrument Configuration

Many commercial spectrophotometers support only one lamp flash per SRF measurement. With such instruments configure OnColor® to average over a series of flashes separated by a constant time delay. With the CE 7000A configure OnColor® to average over 3 lamp flashes spaced at 10-second intervals.

In contrast, the CE 7 employs a series of rapid flashes during each firing of the lamp. If the test instrument supports this option, configure OnColor® to execute bursts of 10 flashes during each lamp firing, and average over 3 successive bursts spaced at 10-second intervals.

Instrument Initialization

At the beginning of each work session, use the following sequence to initialize the instrument:

$C \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \dots$

Here, C denotes calibration of the instrument; \rightarrow , the next sequential SRF measurement; and T_r , individual trial measurements of the white calibration tile supplied with the instrument. Configure OnColor® to execute at least 75 lamp flashes using the fastest available repetition rate, and then discard the averaged trial data.³²

³² Setup instructions: Launch OnColor® and access the Options \rightarrow Measurement Averaging control panel. Set the minimum allowed number of flashes = 1, the maximum allowed number = 75, and the time between measurements = 1 second. Select the Always Copy to Notes option.

Appendix D. Profiling Procedure

Configure OnColor® Software

Configure OnColor® to record the date, sensor and time indices in each data set.³³ After the warm-up procedure, each standard or trial measurement should average the data from at least 3 lamp flashes separated by a constant time delay. With instruments that are similar to the CE 7000A, configure OnColor® to average over 3 lamp flashes spaced at 10-second intervals.³⁴

Normal Profiling Procedure

To create a data set for profiling, measure the transfer standards in the OnColor Profiler® tile set or the diagnostic tile set in sequence.³⁵ Each data set may contain only the 32 SRF measurements that are used by OnColor Profiler® to create a profile for the test instrument.

At the beginning of each profiling session, initialize the instrument and configure OnColor® as described above.³⁶ Create a new OnColor® data set and a new working OnColor® disk file. These will only be used to document one profiling session.

Next, calibrate the instrument and perform the following sequence of 32 averaged measurements:

$$C \rightarrow S_1 \rightarrow T_2 \rightarrow T_3 \rightarrow \dots T_{30} \rightarrow T_{31} \rightarrow T_{32}$$

Here C denotes calibration of the instrument; \rightarrow , the next measurement of a trial or standard; S_1 , an averaged standard measurement of ultra-white standard #T-1; and T_2 , T_3 and T_{32} , averaged trial measurements of standards #T-2, #T-3 and #T-32.

To begin this data series, measure S_1 with ultra-white standard #T-1. When the Delete all Trials for this new Standard? dialog box appears, choose Yes. Next, the Naming dialog box appears. Use simple, consistent names for the standard and 31 trials.

³³ Setup instructions: Launch OnColor® and access the Options \rightarrow Select Indices control panel. Activate the date, sensor and time indices.

³⁴ Setup instructions: Launch OnColor® and access the Options \rightarrow Measurement Averaging control panel. Set the minimum allowed number of flashes = 1, the maximum allowed number = 3, and the time between measurements = 7 seconds. Select the Always Copy to Notes option. With the CE 7000A and CM-2500c instruments, these settings correspond to a 10-second delay between lamp flashes.

³⁵ Always use the same sequence for profiling.

³⁶ The initialization procedure is described in Appendix C. Do not replace the white calibration tile between the T_r measurements.

Following each measurement of a standard, the OnColor® software automatically replaces the existing standard in the working data set. After each averaged trial measurement, the Averaging Complete dialog box appears. To append the new data to the working data set, choose Copy to Notes followed by Done. After the standard and the 31 trials have been measured, save the data set in the active OnColor® disk file.

Repeat the above procedure for each configuration of each test instrument. Use easily recognizable names for the OnColor® disk files (see Appendix B).

Appendix E. Standards Used for Instrument Tests

The standards listed in Table 2 are used in instrument tests 1 - 10. The 16 standards included in part A of the diagnostic tile set also may be used. Each OnColor Profiler® tile set includes either a #T-11 or #T-11A grey 85% standard. The #T-11A standard is required for the white calibration tile test. The #T-46A deep orange standard, which may be purchased separately, is required for the translucency sensitivity and accuracy tests.²²

Table 2. Standards Used for Instrument Tests	
Tile Number	Color Name
T-01	Ultra-White
T-02	Black
T-03	Deep Grey 10%
T-06	Grey 33%
T-09	Light Grey 60%
T-11	Grey 85%
T-11A	Grey 85%
T-12	Deep Red
T-13	Yellow
T-14	Deep Green
T-16	Deep Orange-Red
T-17	Greenish-Blue
T-18	Deep Blue
T-20	Rose Pink
T-21	Light Yellow
T-31	Dark Blue
T-32	Mid-Green
T-46A	Deep Orange

Appendix F. Validation Procedures

Configure OnColor® Software

Configure OnColor® to record the date, sensor and time indices in each data set.³³ After the warm-up procedure, each standard or trial measurement should average the data from at least 3 lamp flashes separated by a constant time delay. With instruments that are similar to the CE 7000A, configure OnColor® to average over 3 lamp flashes spaced at 10-second intervals.³⁴

Preliminary Repeatability Test

At the beginning of each work session, create a new OnColor® data set or import the working data set by loading the active OnColor® disk file. Next, initialize the instrument and perform a repeatability test using the sequence shown below:³⁶

$$C \rightarrow S_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r \rightarrow T_r$$

Here C denotes calibration of the instrument; \rightarrow , the next measurement of a trial or standard; S_r , an averaged standard measurement of the white calibration tile supplied with the instrument; and T_r , an averaged trial measurement of the white calibration tile.

Following each measurement of a standard, the OnColor® software automatically replaces the existing standard in the working data set. After each averaged trial measurement, the Averaging Complete dialog box appears. To append the new data to the working data set, choose Copy to Notes followed by Done. Verify that 10 T_r measurements were performed, and save the data set in the active OnColor® disk file.

Normal Validation Procedure

Each data set contains 12 trials in which measurements of a calibrated white transfer standard are alternated with measurements of 2 of the standards listed in Appendix E. A complete validation series consists of 8 data sets, and includes SRF measurements for 16 standards.

To create the 1st data set in a validation series, configure OnColor® and perform a repeatability test as described above. Calibrate the instrument and perform the following sequence of 12 averaged trials:

$$C \rightarrow T_r \rightarrow T_r \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_r \rightarrow T_r \rightarrow T_2 \rightarrow T_2 \rightarrow T_2 \rightarrow T_r \rightarrow T_r$$

Here C denotes calibration of the instrument; \rightarrow , the next trial; T_r , an averaged trial measurement of the calibrated white tile supplied with the instrument; and T_1 and T_2 , averaged trial measurements of standards #T-1 and #T-2.

After each trial measurement, the Averaging Complete dialog box appears. To append the newly acquired data to the working data set, choose Copy to Notes

followed by Done. After the 12 trials are completed, save the data set in the active OnColor® disk file.

Repeat the above procedure to create the 2nd data set in the series.³⁷

$C \rightarrow T_r \rightarrow T_r \rightarrow T_3 \rightarrow T_3 \rightarrow T_3 \rightarrow T_r \rightarrow T_r \rightarrow T_6 \rightarrow T_6 \rightarrow T_6 \rightarrow T_r \rightarrow T_r$

Here, C, T_r and \rightarrow are as defined above, and T_3 and T_6 denote averaged trial measurements of standards #T-3 and #T-6. After the 12 trials are measured, save the working data set in the active OnColor® disk file, and repeat the above sequence with the next pair of standards listed in Appendix E.

Alternate Validation Procedure

Use the procedure described above provided that accurate, traceable SRF data are available for the calibrated white tile supplied with the instrument. If reliable data are not available, replace T_r with T_1 , averaged trial measurements of the #T-1 ultra-white standard. The #T-1 standard provided with each calibrated OnColor Profiler® tile set has been accurately pre-calibrated.

Exercise careful judgment in making this decision. If T_1 is substituted for T_r , acquire the 1st data set by performing the sequence shown below:

$C \rightarrow S_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_1 \rightarrow T_2 \rightarrow T_2 \rightarrow T_2 \rightarrow T_1 \rightarrow T_1$

Here S_1 denotes an averaged standard measurement of ultra-white standard #T-1; T_1 , an averaged trial measurement of standard #T-1; and T_2 , an averaged trial measurement of standard #T-2.

Next, acquire the 2nd data set using the sequence shown below:

$C \rightarrow T_1 \rightarrow T_1 \rightarrow T_3 \rightarrow T_3 \rightarrow T_3 \rightarrow T_1 \rightarrow T_1 \rightarrow T_6 \rightarrow T_6 \rightarrow T_6 \rightarrow T_1 \rightarrow T_1$

After the 12 trials are measured, save the working data set in the active OnColor® disk file, and repeat the above sequence with the next pair of standards.

Avoid Time Delays

In order to minimize variations in the output of the flash lamp, complete each series of measurements without interruption. If the measurements between consecutive data sets are interrupted for more than 1 or 2 minutes, delay the calibration until the beginning of the next data set and discard 2 or 3 successive T_r or T_1 measurements before saving new data. If the instrument is powered down before a series of 8 data sets

³⁷ Provided that the measurements have not been interrupted, it is not necessary to perform the repeatability test again.

is completed, repeat the initialization procedure and the repeatability test before acquiring new data.

Typical Measurement Times

Powerful flash lamps are incorporated in instruments such as the CE 7, CE 7000A and Konica-Minolta CM-3700d. With these instruments average the data from 3 lamp flashes during each measurement. Based on this setup, about 12 minutes are needed to acquire one data set that contains 12 trial measurements.

The Konica-Minolta CM-2500c is a small portable ($45^\circ/0^\circ$) bi-directional instrument provided with a less powerful flash lamp. To reduce statistical noise, the number of lamp flashes is increased to 5 per measurement, and the average time needed to acquire a data set increases to 20 minutes.

To measure 16 standards, the estimated instrument times increase to 96 minutes for the CE 7000A and 160 minutes for the CM-2500c. If the time needed for instrument initialization is included, these totals increase to 120 and 180 minutes, respectively.

Three or 4 complete validation series are required to perform one high-precision, traceable metrological calibration of 16 standards. This requires 6 – 8 hours of instrument time on the CE 7000A and 9 – 12 hours on the CM-2500c. The data analysis requires another 4 – 6 hours.

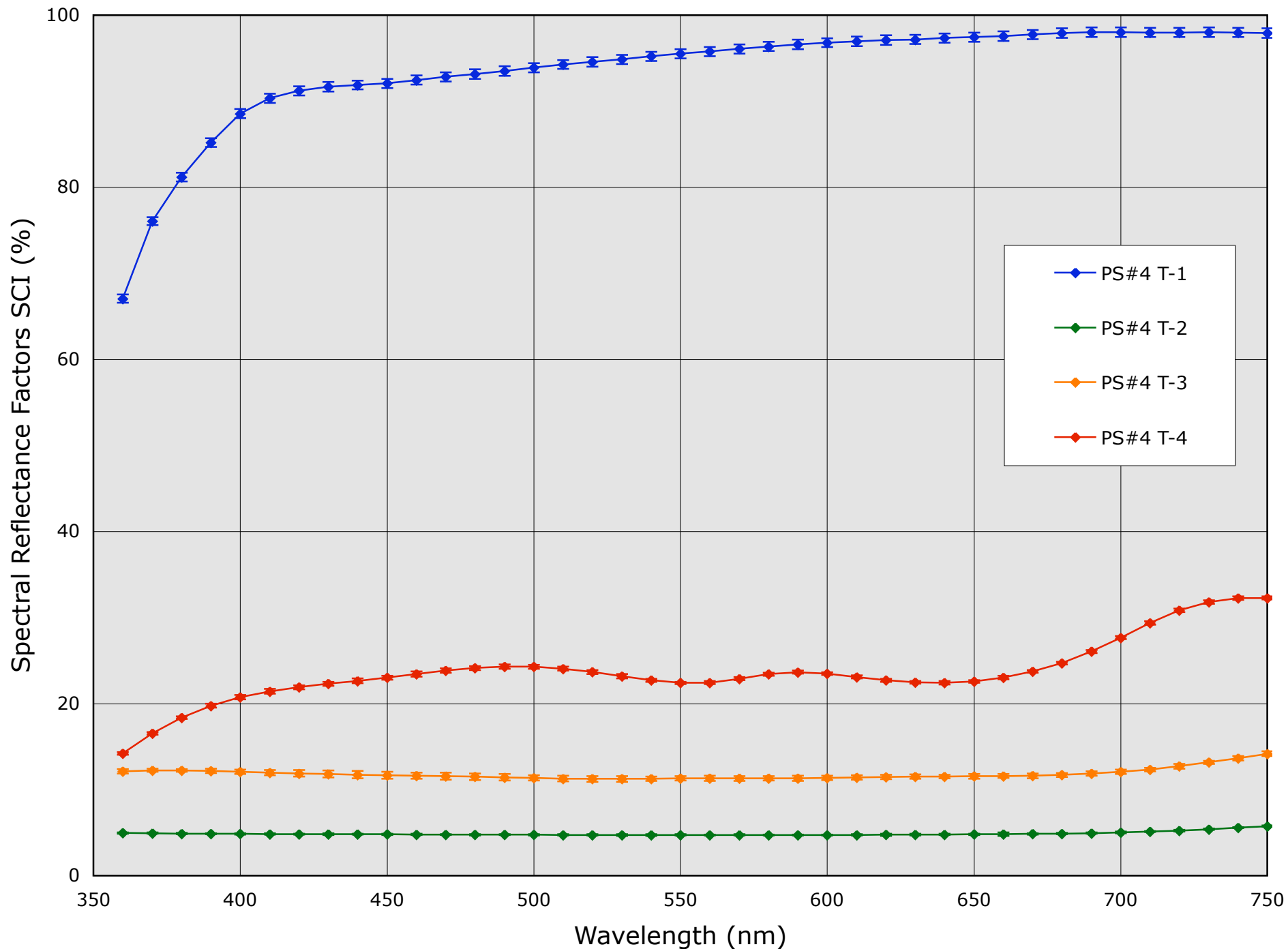
Appendix G. Typical SRF Data for the OnColor Profiler® Tile Set in the Diffuse SCI Geometry

Procedure

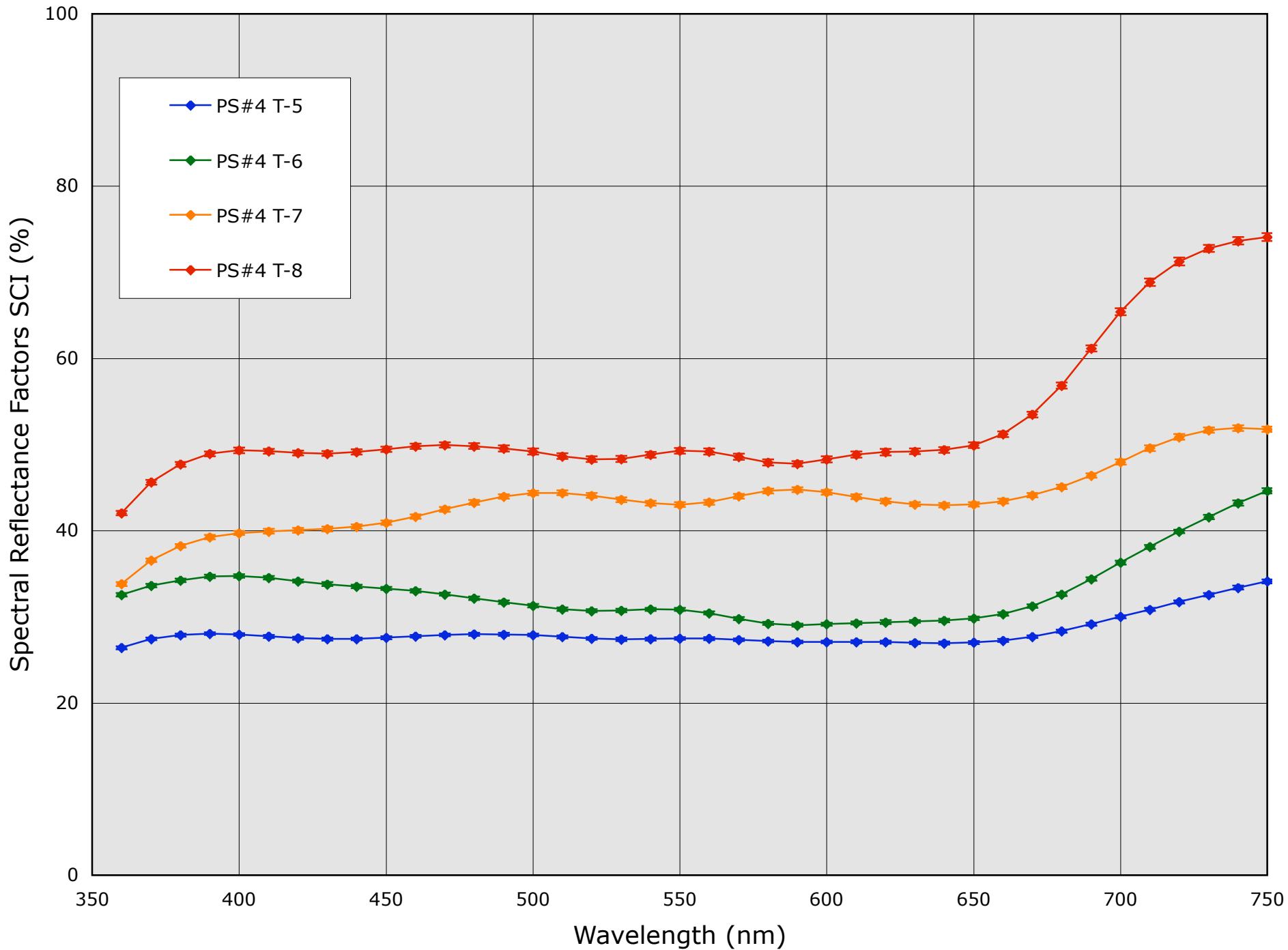
Spectral reflectance factors were measured at ambient temperature and humidity with CE 7000A S/N 37132651108 operated in the (t/8°) diffuse specular-included geometry. CyberChrome OnColor QC Premium® software was used to operate the spectrophotometer, to average the replicate spectra obtained during each measurement series, and to perform the colorimetric analysis. As described in Appendix F, SRF values were measured relative to the calibrated, NIST traceable white reference tile supplied with the instrument.

The statistical uncertainties shown on the charts represent average 2σ standard errors of estimate (95% confidence level).

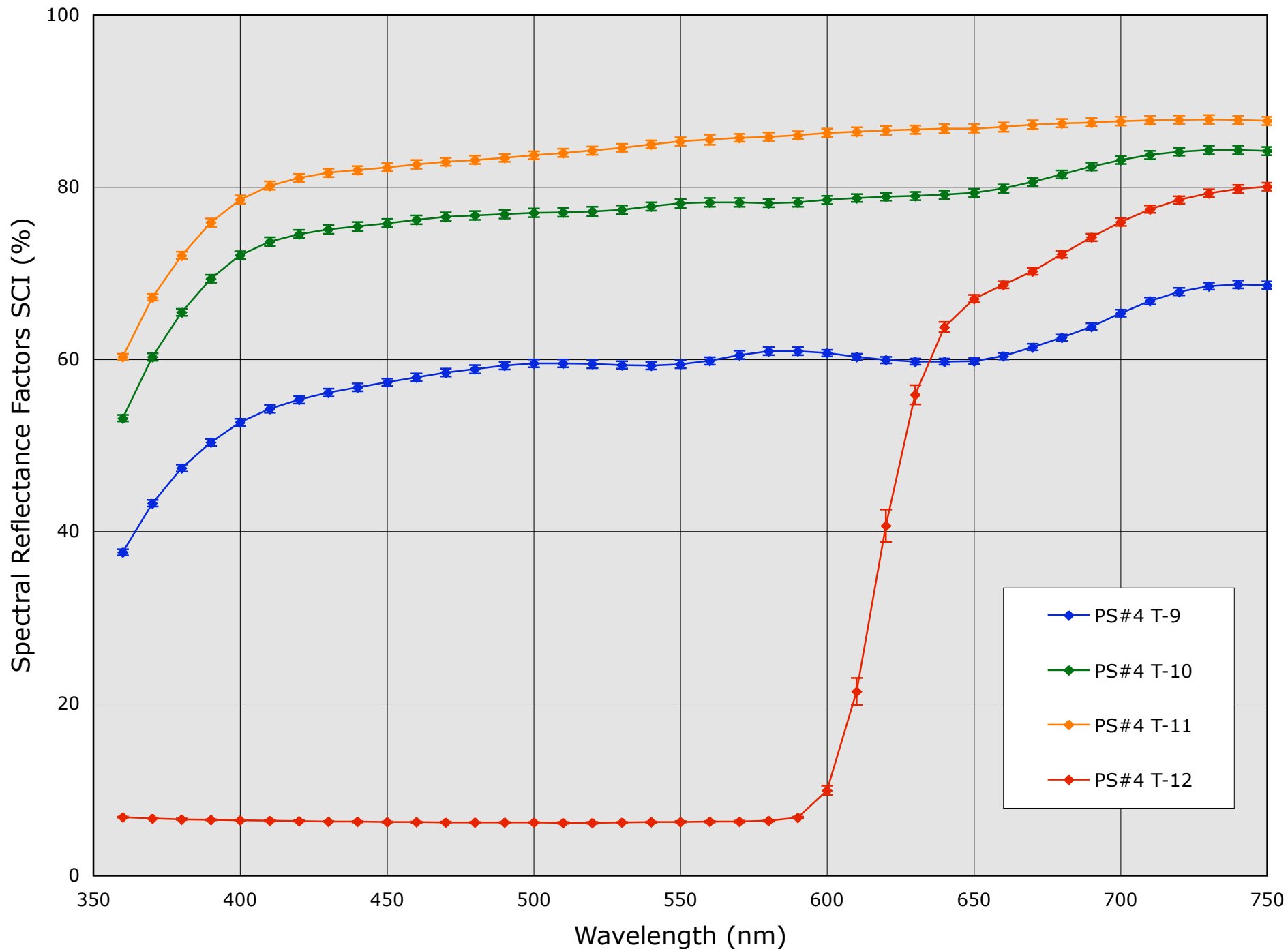
Traceable SCI Spectral Reflectance Factors Measured for Profiling Tile Set #4



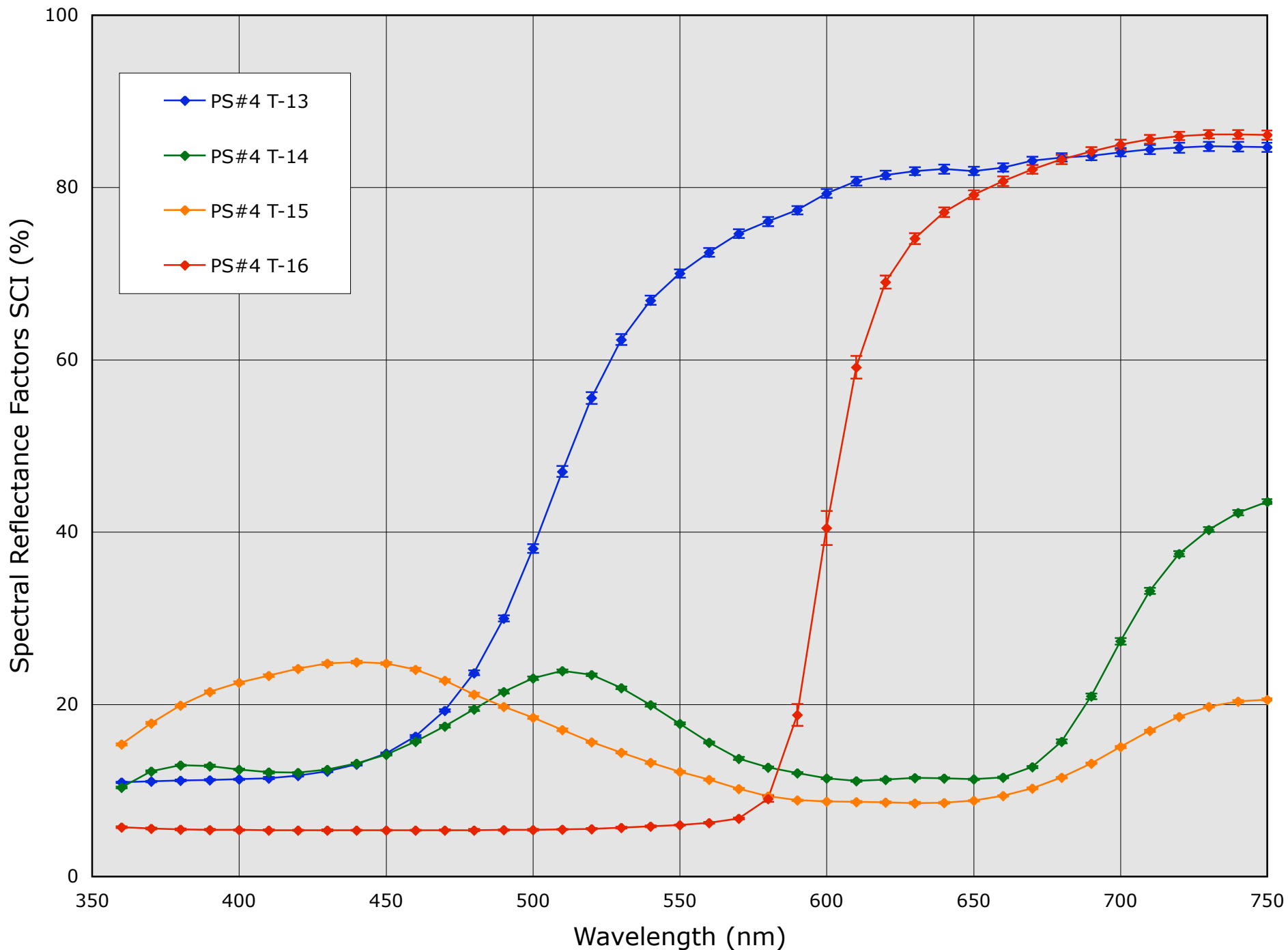
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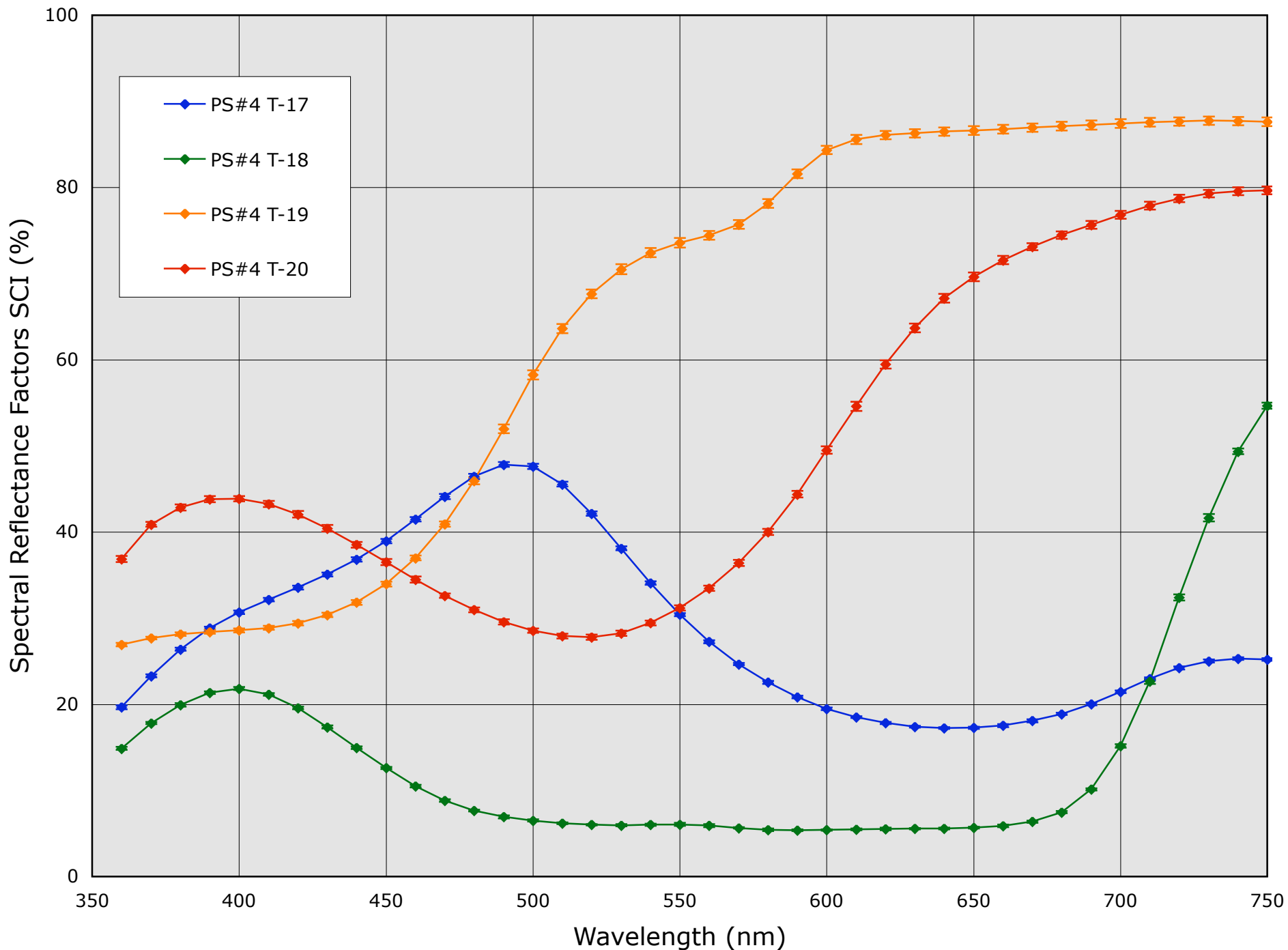
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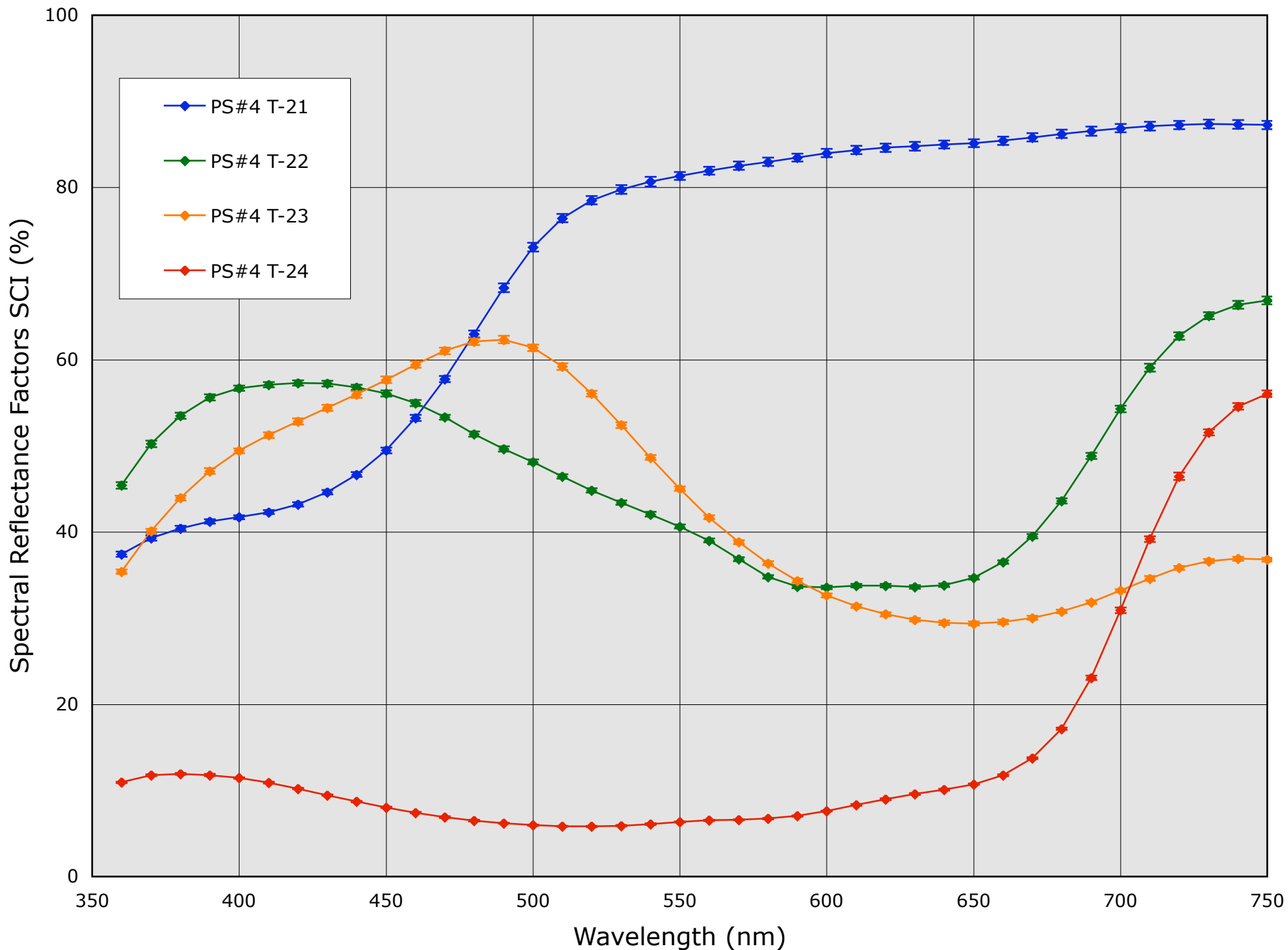
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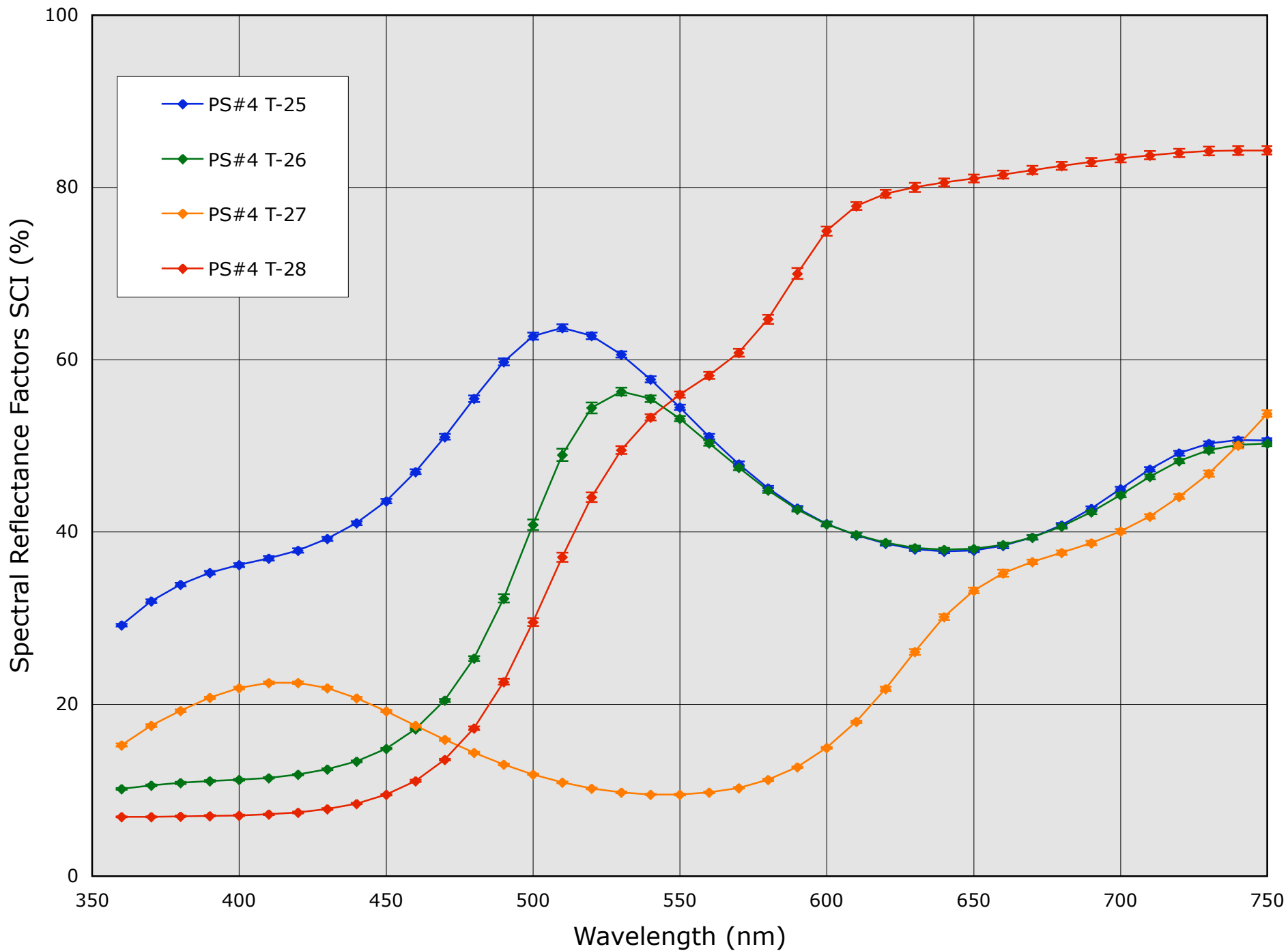
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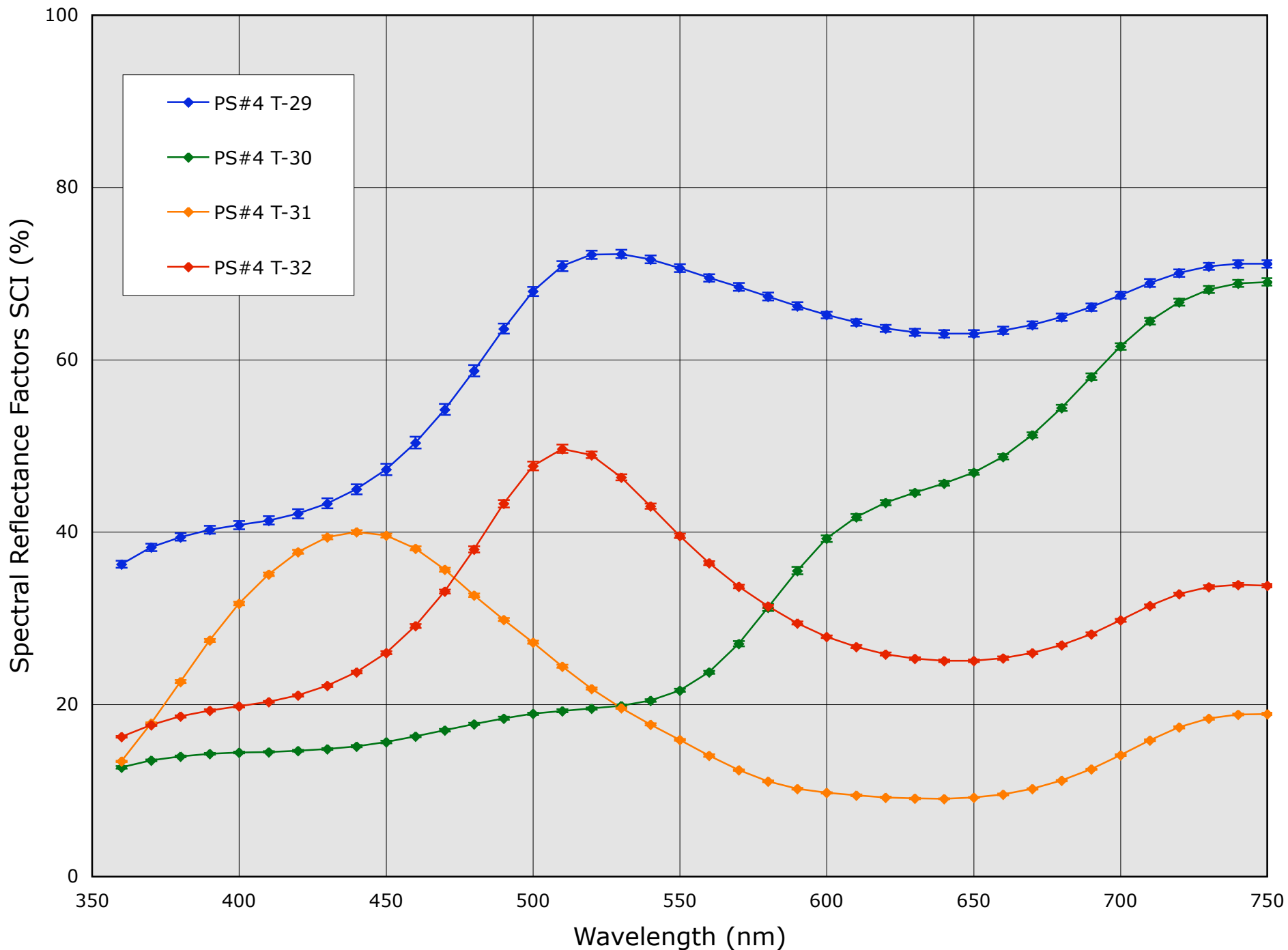
Traceable SCI Spectral Reflectance Factors Measured for Profiling Tile Set #4



Traceable SCI Spectral Reflectance Factors Measured for Profiling Tile Set #4



Traceable SCI Spectral Reflectance Factors Measured for Profiling Tile Set #4



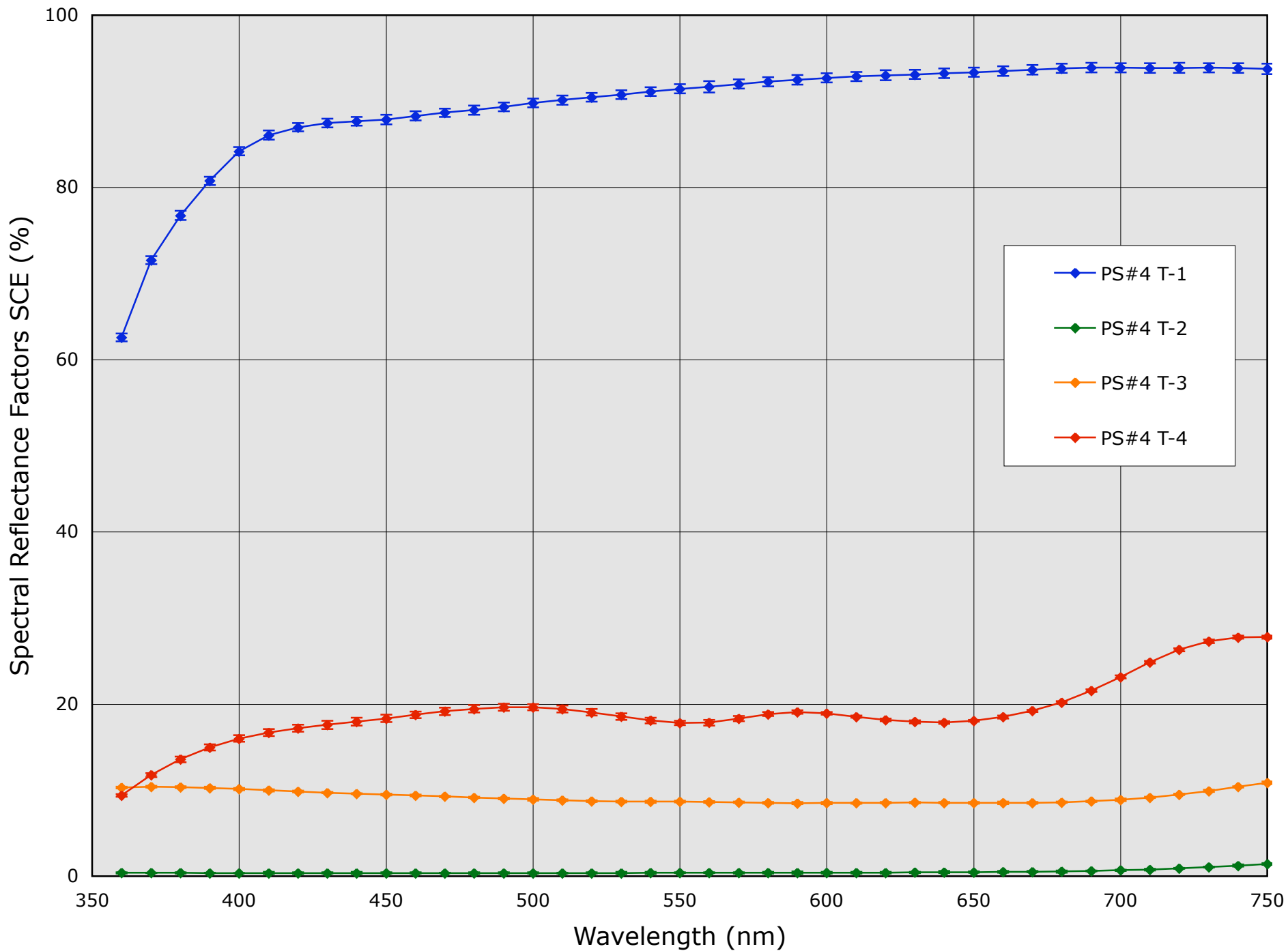
Appendix H. Typical SRF Data for the OnColor Profiler® Tile Set in the Diffuse SCE Geometry

Procedure

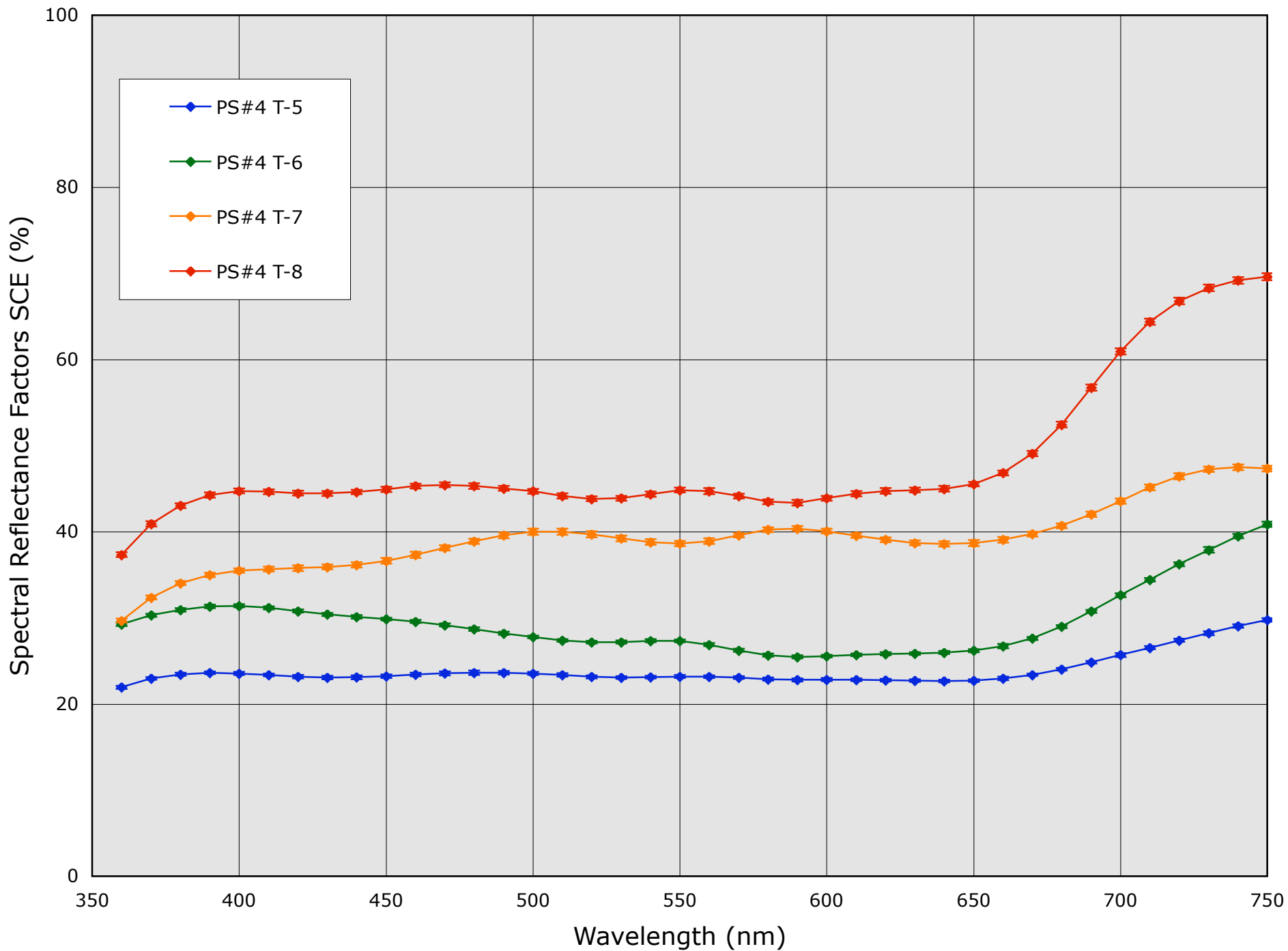
Spectral reflectance factors were measured at ambient temperature and humidity with CE 7000A S/N 37132651108 operated in the (d/8°) diffuse specular-excluded geometry. CyberChrome OnColor QC Premium® software was used to operate the spectrophotometer, to average the replicate spectra obtained during each measurement series, and to perform the colorimetric analysis. As described in Appendix F, SRF values were measured relative to the calibrated, NIST traceable white reference tile supplied with the instrument.

The statistical uncertainties shown on the charts represent average 2σ standard errors of estimate (95% confidence level).

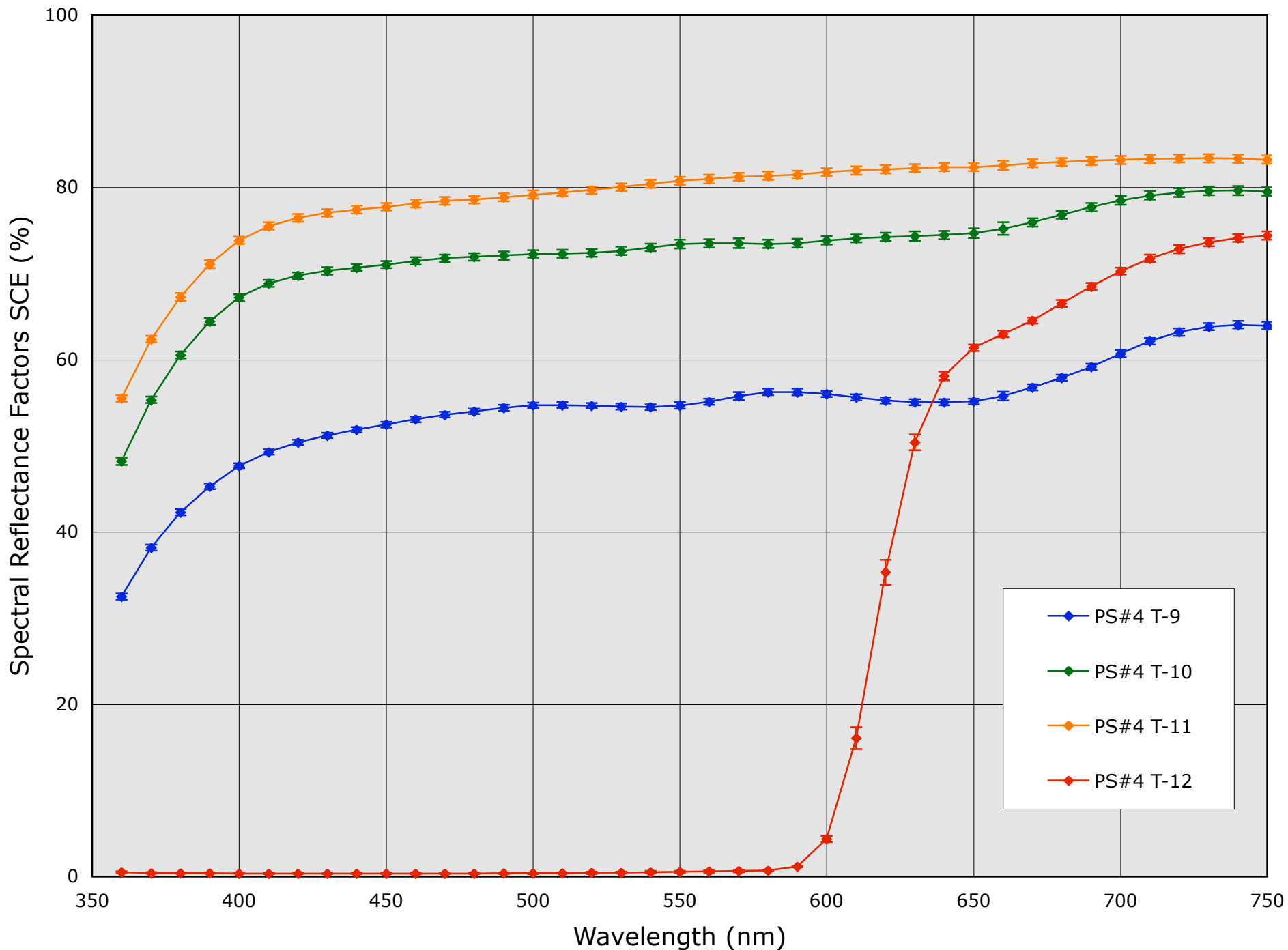
Traceable SCE Spectral Reflectance Factors Measured for Profiling Tile Set #4



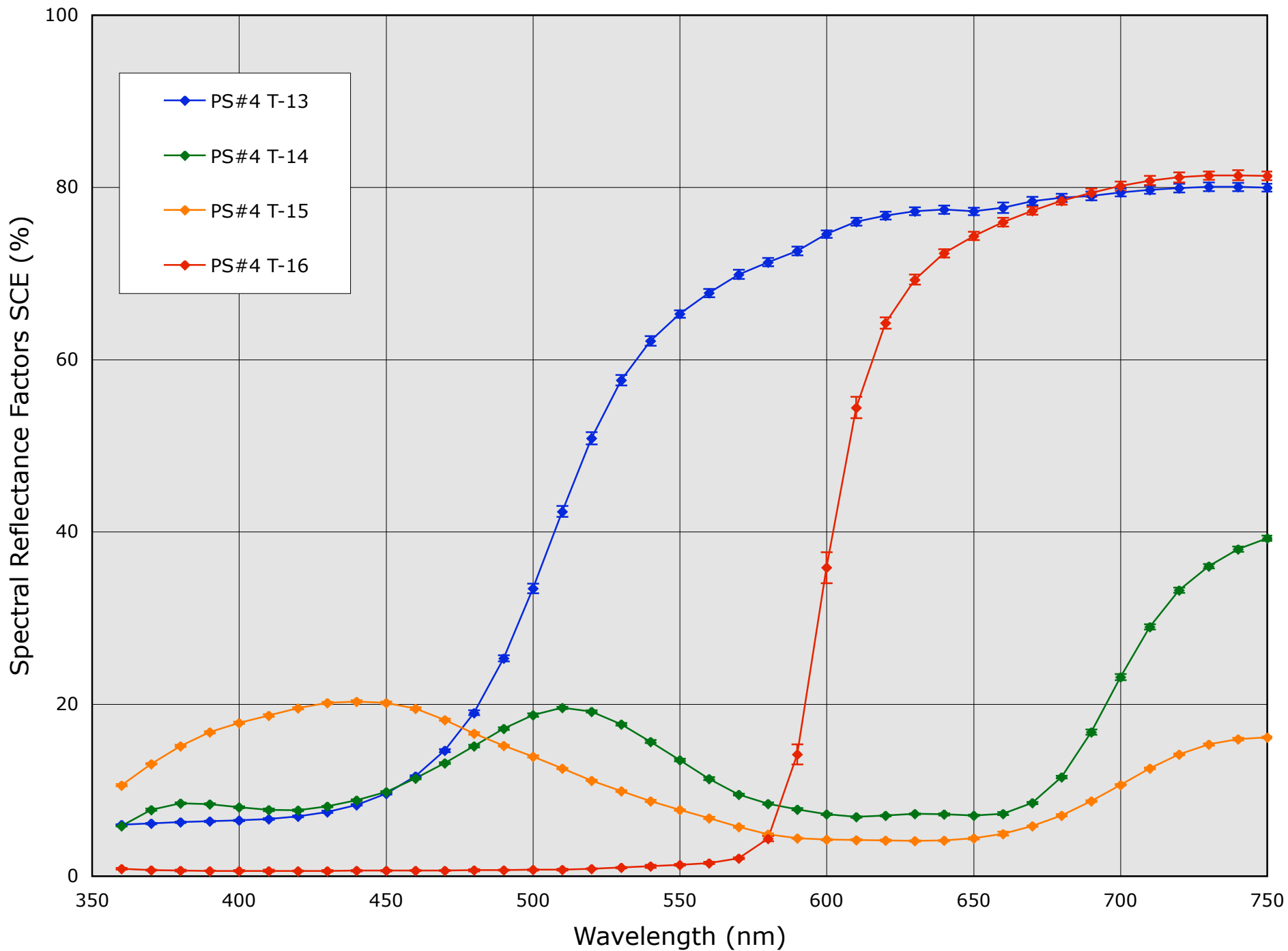
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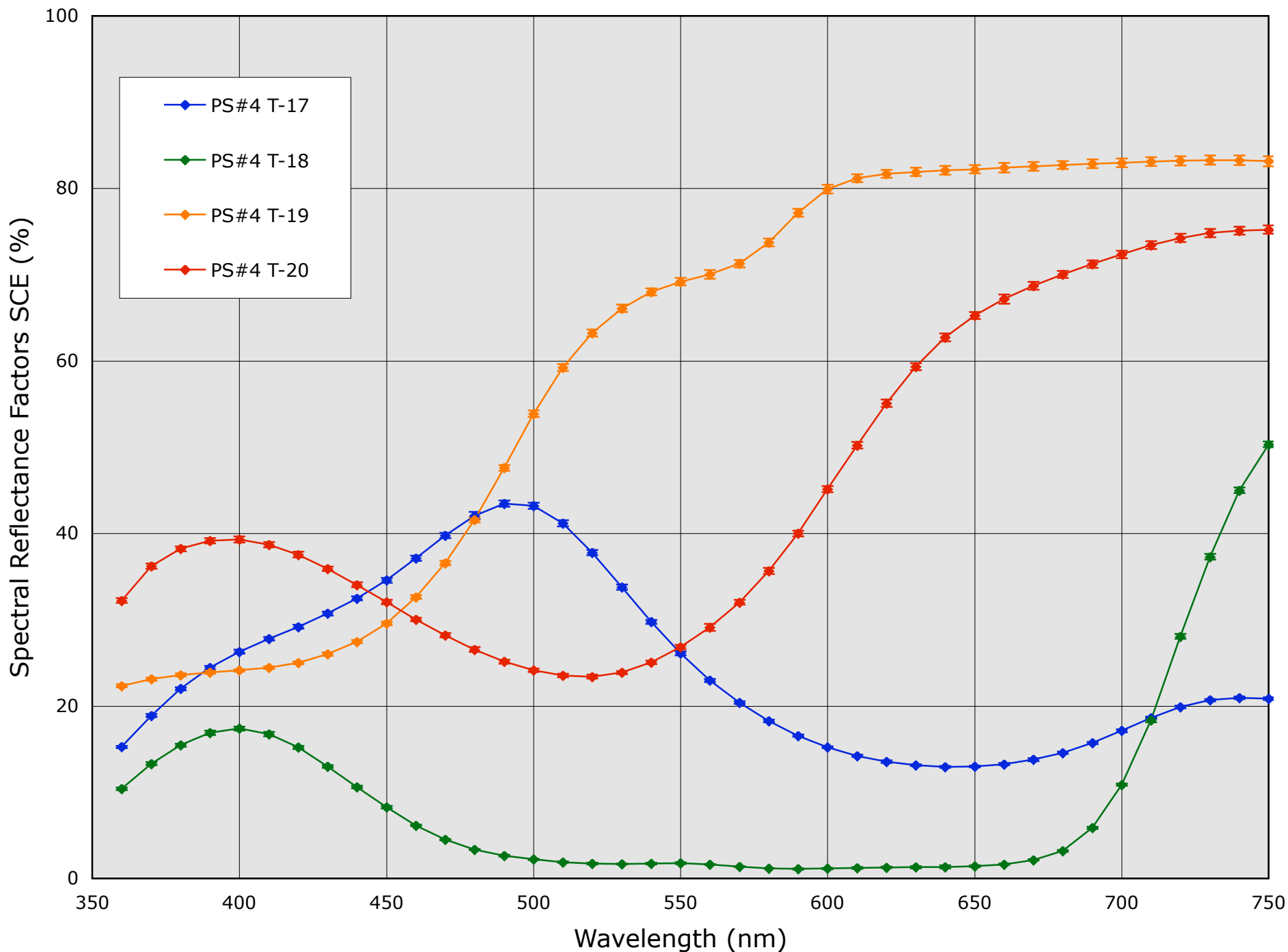
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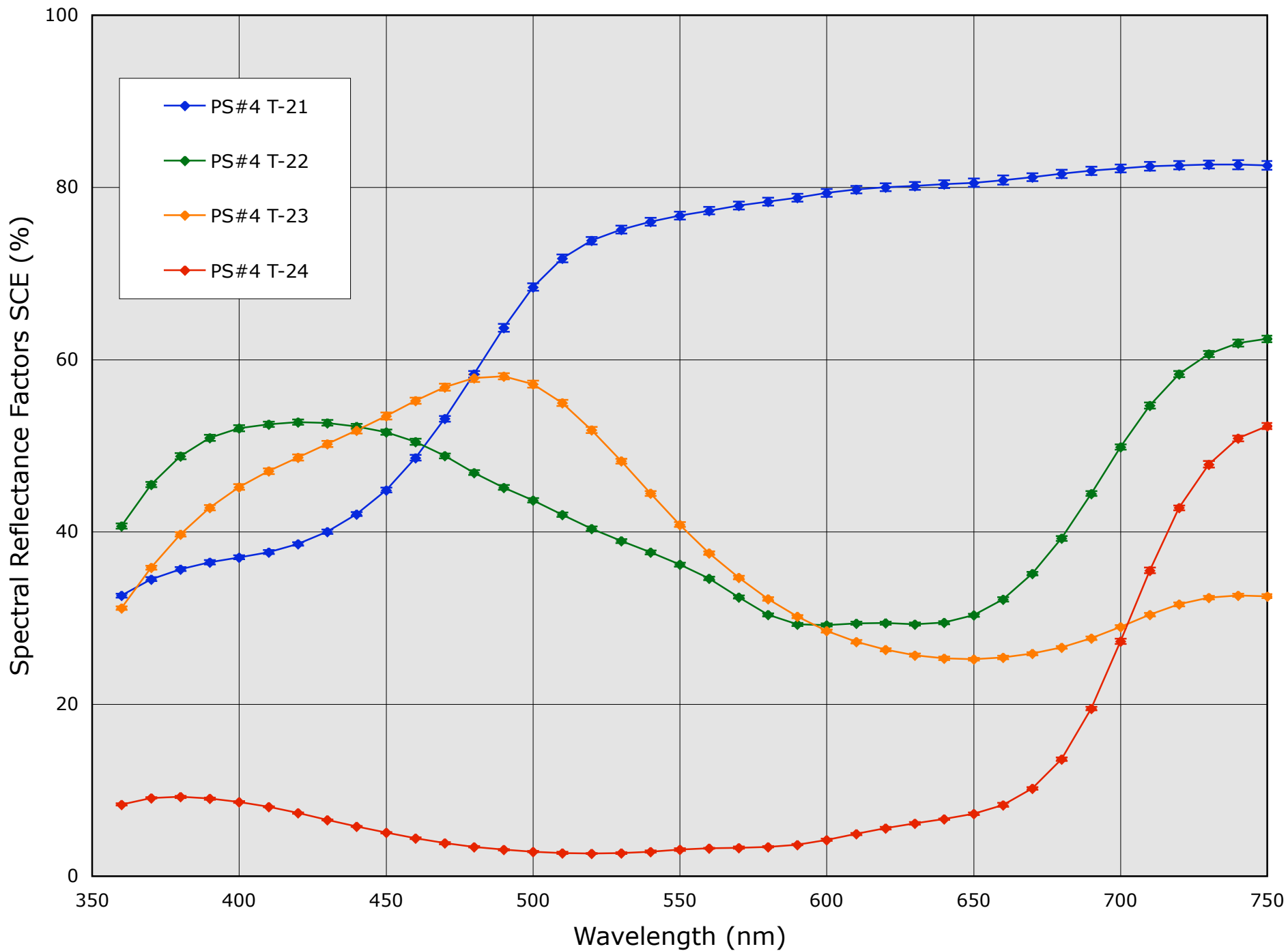
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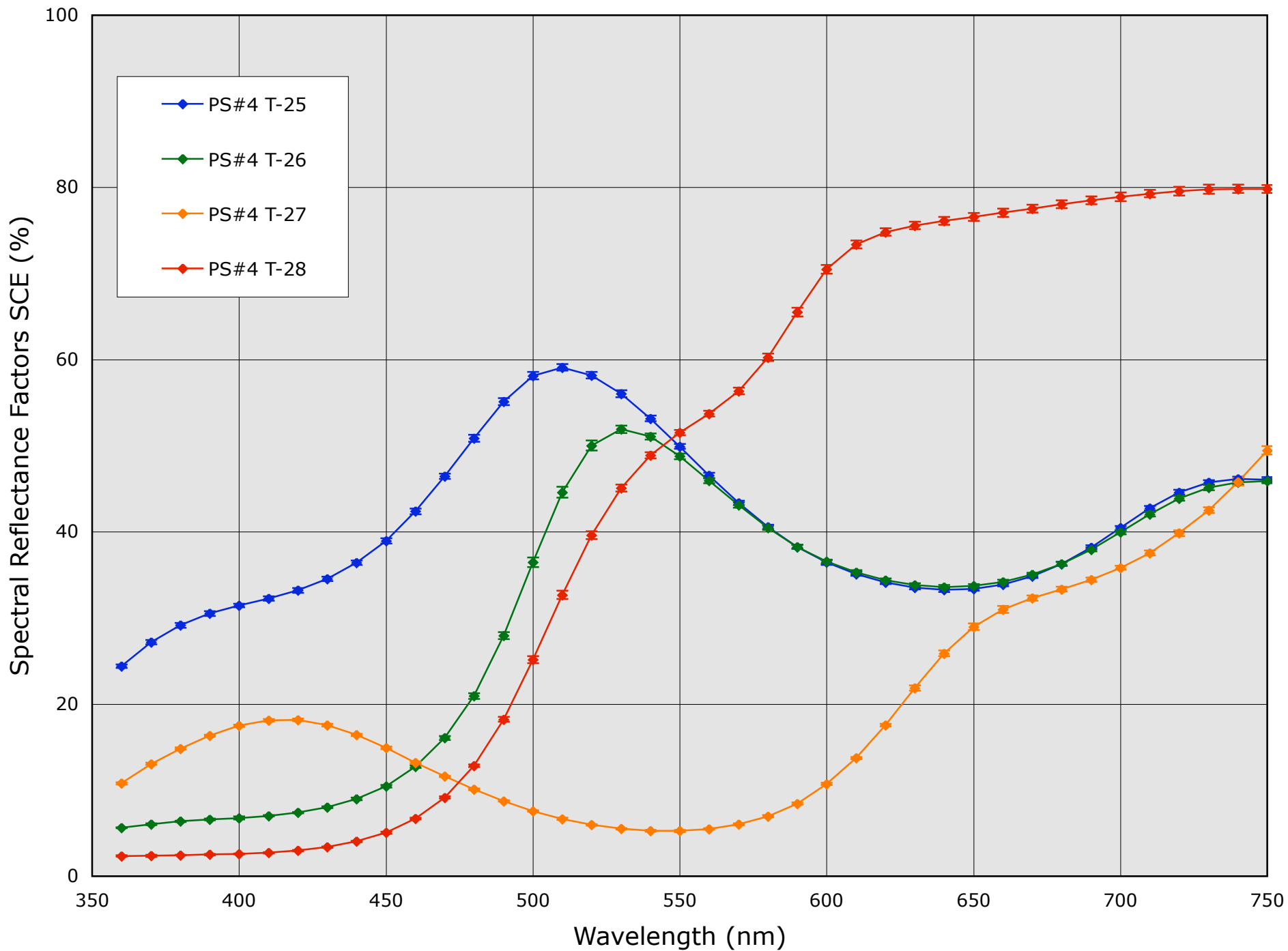
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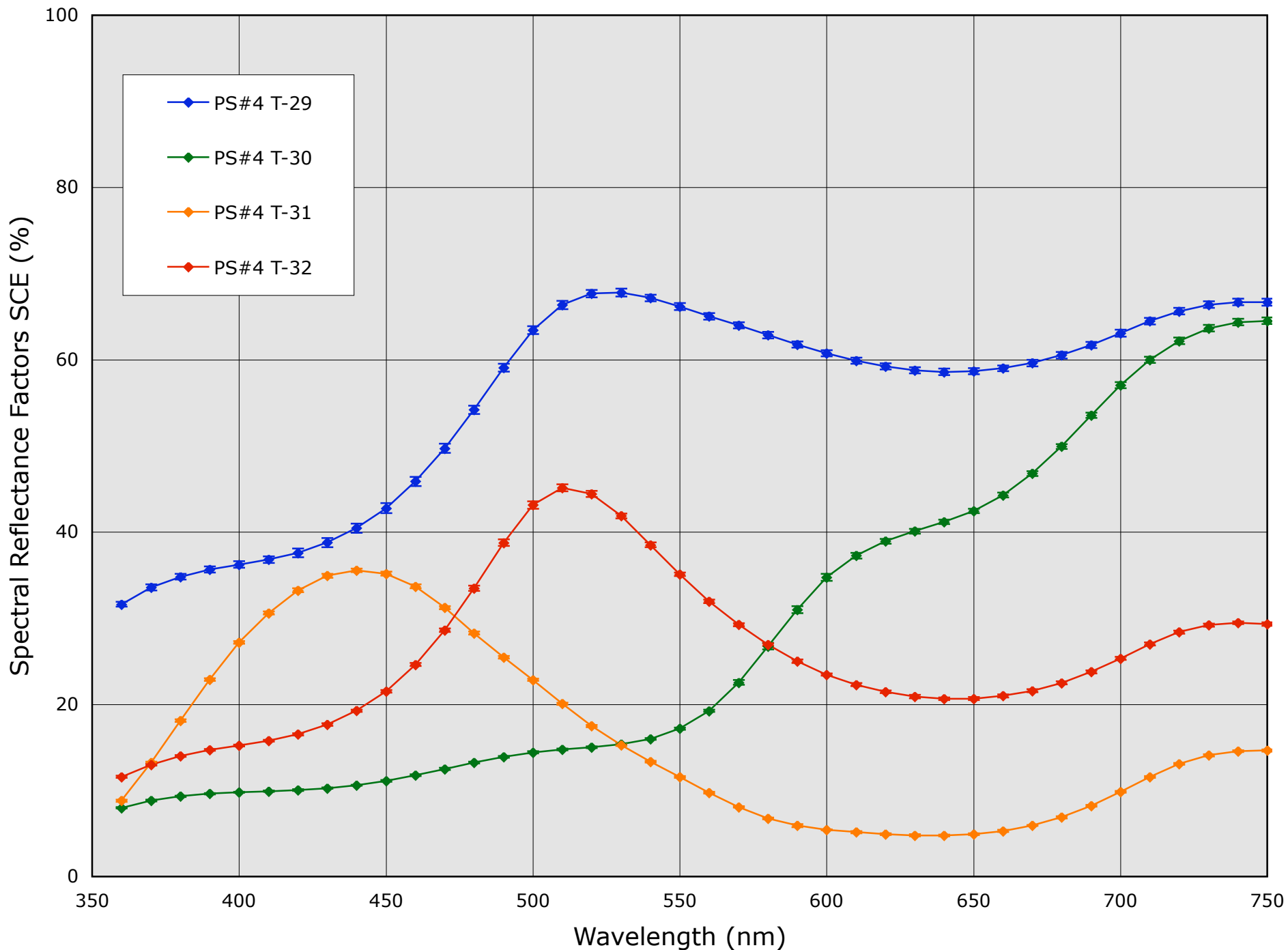
Traceable SCE Spectral Reflectance Factors Measured for Profiling Tile Set #4

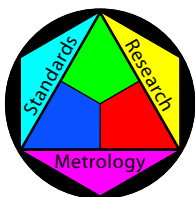


Traceable SCE Spectral Reflectance Factors Measured for Profiling Tile Set #4



Traceable SCE Spectral Reflectance Factors Measured for Profiling Tile Set #4





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