Characterization of the Reflectivity of Various Black Materials II

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ABSTRACT

We report on an expanded catalog of total and specular reflectance measurements of various common (and uncommon) materials used in the construction and/or baffling of optical systems. Total reflectance is measured over a broad wavelength range (250 nm < λ < 2500 nm) that is applicable to ultraviolet, visible, and near-infrared instrumentation. Characterization of each sample's specular reflection was measured using a Helium-Neon laser in two degree steps from near normal to grazing angles of incidence. The total and specular reflection measurements were then used to derive the specular fraction of each material.

Code	Sample	Specular Fraction [%]
ABH	Bead-Blasted 6061 Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.17 ± 0.02
AMH	Machined 6061 Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.11 ± 0.02
APH	Polished 6061 Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.59 ± 0.02
ARH	Raw 6061 Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.07 ± 0.02
CBB	Bead-Blasted Cast Aluminum, Anodized (MIL-A-8625, Type II, Class 2, Black)	0.07 ± 0.02
CBH	Bead-Blasted Cast Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.23 ± 0.02
CMB	Machined Cast Aluminum, Anodized (MIL-A-8625, Type II, Class 2, Black	0.15 ± 0.02
CMH	Machined Cast Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.14 ± 0.02
CPH	Polished Cast Aluminum, Anodized (MIL-A-8625, Type III, Class 1, Non-dyed)	0.56 ± 0.02
CRB	Raw Cast Aluminum, Anodized (MIL-A-8625, Type II, Class 2, Black)	0.57 ± 0.02
SMN	Machined Stainless Steel, Electroless Nickel Coat (MIL-C-26074)	5.46 ± 0.02
SPN	Polished Stainless Steel, Electroless Nickel Coat (MIL-C-26074)	76.3 ± 0.02
F07	Hatchbox Black 3D Printed ABS 1.75mm (diameter) filament printed at 225C	
P06	Black RTV on glass plate	
P09	Aeroglaze Z306 Flat Black	
P19	Duranar XL Stellar Black 9778 with BN5C103B Clear Coat (ppgideascapes.com)	
P21	Culture Hustle Black 2.0 Acrylic paint (culturehustle.com)	
T01-1	Black Heat Shrink Tubing	
T01-2	Black Heat Shrink Tubing – Shrunk	

Table 1. List of materials with new or updated measurements.

TOTAL REFLECTANCE

We used a Hitachi High-Tech U-4100 UV-Visible-NIR Spectrophotometer at the Texas A&M University Materials Characterization Facility (MCF) and obtained reflectance profiles for the samples. The U-4100 dual beam spectrophotometer uses two different lamps to cover a wide range of wavelengths. A deuterium lamp covers the far UV (< 345 nm), and a tungsten lamp is used for UV, visible, and near-IR measurements. The U-4100 is capable of measuring both reflectance and transmittance of solid and liquid samples. With this system we measured precise reflectance values at each wavelength (in 1 nm steps) for the wavelength range 250 nm < λ < 2500 nm. Figure 1 shows the instrumental setup of the Hitachi High-Tech U-4100 UV-Visible-NIR Spectrophotometer.

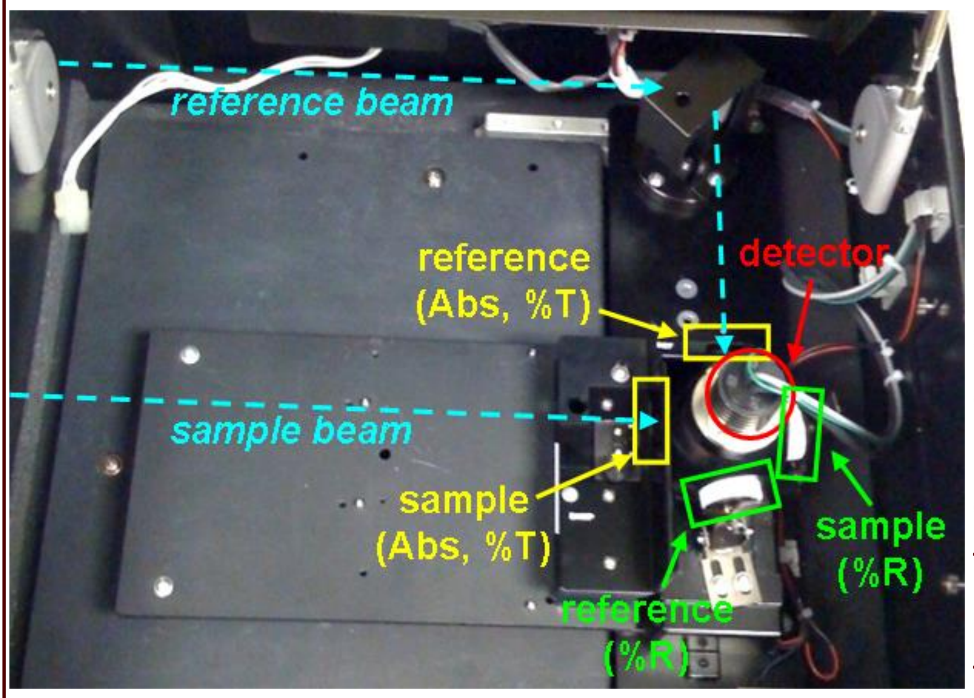

Figure 1. The reference and test sample are placed in the 6 o'clock and 3 o'clock positions of the integrating sphere, respectively. A baseline measurement at each wavelength of the reference BaSO4 wafers (~ 100% reflectance) in both the reference and sample slots of the dual beam spectrophotometer is obtained. We then measure a second reference sample having 5% reflectivity (Labsphere SRS-05), and measure the reflectivity of the test sample. A ratio of the reference sample to the values provided by the manufacturer is used to construct the absolute reflectivity of the test sample as a function of wavelength.

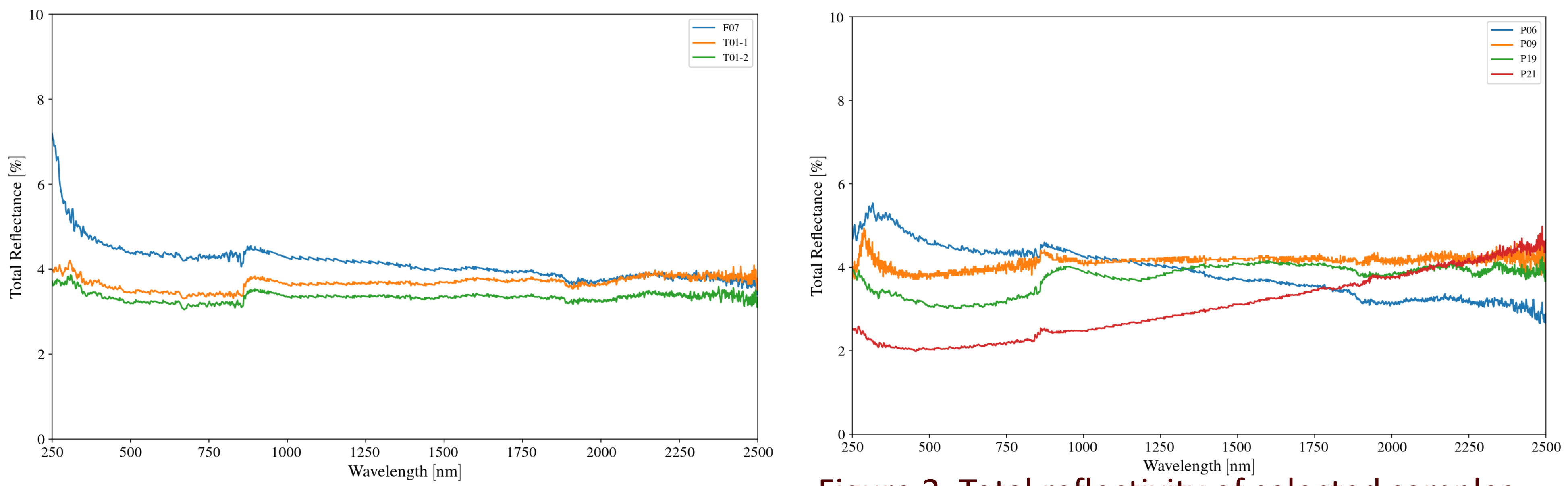

Figure 2. Total reflectivity of selected samples.

SPECULAR REFLECTANCE

The first paper in this series[1] included preliminary results measuring the specular fraction of the total reflectance. The 2014 values were reported as the average specular reflectance measured at 10°, 22°, and 44° divided by the total reflectance measured at the MCF. We now report on updated measurements using MADLaSR[2] (MultiAngle Detection of Lambertian and Specular Reflectivity). MADLaSR consists of a HeNe laser and Gentec photodiode mounted on movable arms that allow for testing the reflected power of the laser off of a sample at variable angles. With MADLaSR, we measure the specular reflectance every 2°, so the new specular fraction uses the average of all measurements between 10° and 44°.

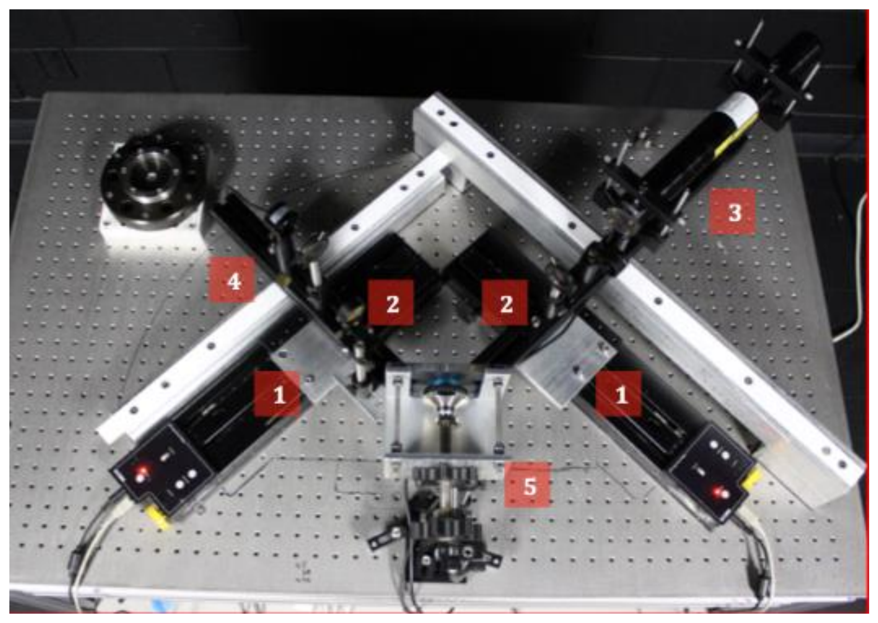

Figure 3. MADLaSR top view configured for specular reflectance testing. Two linear motorized stages (1), rotating arms (2), HeNe light source (3), Photodiode (4), and sample holder (5).

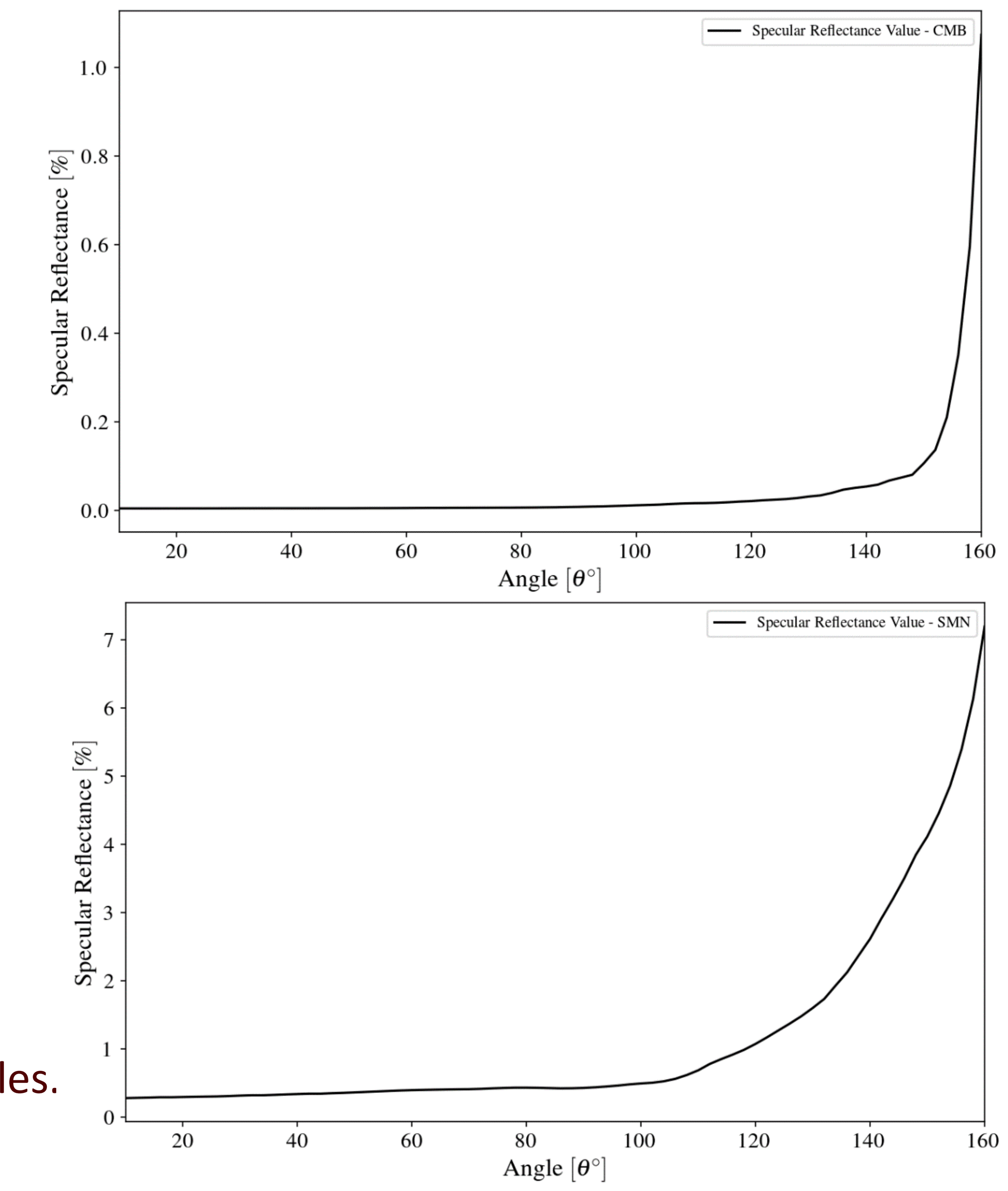

Figure 4. Specular reflectivity as a function of angle for selected samples.

CONCLUSIONS

We have presented additional total and specular reflectance measurements of various materials that may be used to minimize stray and scattered light within optical and near-infrared astronomical instruments. Expanded capabilities for testing the specularity of materials and the specular fraction of the total reflectance have enhanced the utility of this project. Control of stray light within an instrument is an important concern and the material choice and surface treatment within the instrument requires careful consideration.

Information about all of the samples including reflectivity plots and text files of the calibrated data will be made available at **http://instrumentation.tamu.edu/reflectance.html**. We are in the process of updating the plots to be interactive, allowing a user to zoom in on a particular region of interest and then save it as an image as well as better features for comparing materials. The same page includes information on how to suggest or submit a sample for testing.

References

[1] Marshall, J. L., Williams, P., Rheault, J.-P., Prochaska, T., Allen, R. D., and DePoy, D. L., "Characterization of the reflectivity of various black materials," Proc.SPIE 9147 (2014).

[2] Gardner, L. E., Prochaska, T., Schmidt, L. M., Marshall, J. L., Sauseda, M., Torregosa, M., and DePoy, D. L., "Madlasr: multi-angle detector of Lambertian and specular reflectivity," Proc.SPIE 10706 (2018).

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