DIRECTIONAL DEGRADATION OF SPECTRALON DIFFUSER UNDER IONIZING RADIATION FOR CALIBRATION OF SPACE-BASED SENSORS

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ABSTRACT

Assessment of the effect of Vacuum Ultra Violet (VUV) irradiation on the Bidirectional Reflectance Distribution Function (BRDF) of Spectralon is presented in this paper. The sample was a 99% white Spectralon calibration standard irradiated with VUV source positioned at 60^o off the irradiation direction for a total of 20 hours. The BRDF before and after VUV irradiation was measured and compared at number of wavelengths in the UV, VIS and IR. Non-isotropic directional degradation of Spectralon diffuser under ionizing radiation was detected at different BRDF measurement geometries primarily at UV spectral range. The 8^o directional/hemispherical reflectance of the same sample was also measured and compared from 200nm to 2500nm.

Index Terms— BRDF, Reflectance, Multiangular, Spectralon, Remote Sensing

1. INTRODUCTION

The goal of the current study is to better understand the non-isotropic changes of Spectralon calibration standards caused by ionizing VUV irradiation. Although there are a number of studies on the Spectralon use as a diffuser standard for pre-flight and on-orbit calibration, including polarization properties [1], long-term studies [2], UV stability [3] and low-level irradiation, [4] so far little attention has been devoted to the case of non-isotropic degradation under ionizing radiation in laboratory conditions. The current study was initiated to address the requirements of ongoing on-orbit calibration of MODIS (Moderate Resolution Imaging Spectroradiometer), a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites by experimenting with irradiating Spectralon with VUV radiation and we will see if we can directionally induce dependent reflectance degradation. The MODIS solar diffuser pre-flight contamination witness assembly made from space-grade carbon-loaded Spectralon is shown in Fig.1.a.

2. MEASUREMENTS

The Spectralon, which is one of the trademarks of polytetrafluoroethylene (PTFE), is not a perfect Lambertian diffuser but it is a best known material used as a reflectance standard in the UV-VIS-NIR spectral range for remote sensing instrument calibration. The data was obtained at Goddard Space Flight Center's Radiometric Calibration Facility, a secondary calibration facility with reflectance measurements traceable to those made by the Spectral Tri-function Automated Reference Reflectometer (STARR) facility at the National Institute of Standards and Technology (NIST). The sample was a 25.4 mm diameter, 99% white Spectralon target fabricated by Labsphere. The 10mm tick Spectralon puck is shown in Fig.1.b.

Fig.1.a: Spectralon solar diffuser pre-flight witness assembly

The BRDF is defined in radiometric terms as reflected surface radiance in a given direction divided by the incident surface irradiance from another direction.

The incident irradiance is the radiant flux incident on the surface. The reflected surface radiance is the light flux reflected through solid angle **Ω** per projected solid angle:

$$BRDF = \frac{P_r / \Omega}{P_i \cos\theta_r} \qquad (1)$$

where P_r is the reflected radiant power, Ω is the solid angle determined by the area of detector aperture, A, and the radius from the sample to the detector, R. The solid angle can be computed as $\Omega = A/R2$. P_i is the incident radiant power, and θ_r is the reflected zenith angle.

Fig.1.b: 99% white Spectralon test diffuser

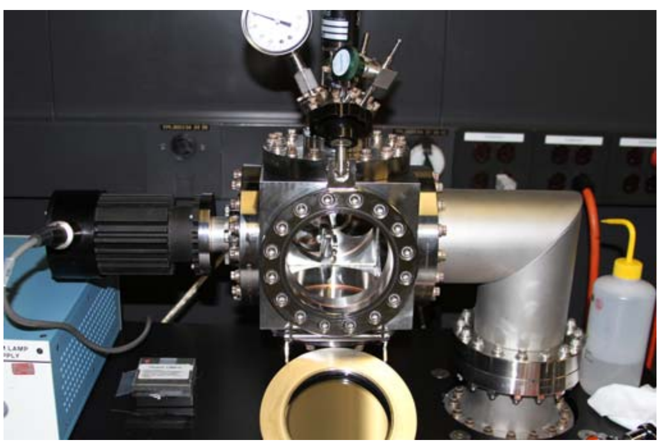

Fig.2: Irradiation monitoring system in the vacuum chamber

The irradiation was performed in a custom built vacuum chamber shown in Fig.2. McPherson 632 Deuterium Vacuum Ultra Violet (VUV) lamp was used for irradiation the sample 2 times by 10hours for a total of 20hours. One hour of irradiation time in the Lab corresponds to about one hour irradiation on orbit. The sample was tilted at 60^o off the irradiation direction. The lamp characteristics are shown in Fig.3. The intensity of the lamp on the sample was monitored with monitoring system, which consists of preamplifier photodiode 1 – full range and photodiode 2 – with deposited filter.

A xenon lamp/monochromator tunable assembly with a well-defined incoherent illumination was used at this study. The sample was tested before and after irradiation by measuring the Bidirectional Reflectance Distribution Function (BRDF) at 250nm, 275nm, 300nm, 350nm, 400nm, 500nm, 700nm and 900nm at incident angles of 0^o, 45^o and 60^o, and at viewing angles from 0^o to 80^o, step 5^o, Fig.4. The BRF results were then compared to a long-term data set of GSFC and NIST Spectralon calibration measurements. The 8^o directional-hemispherical reflectance from 250nm to 2.5 μm was also measured and compared pre- and post-irradiation. A xenon lamp/monochromator assembly with a well-defined incoherent illumination was used for BRDF measurements and Perkin-Elmer 150mm integrating sphere was used for 8^o directional/hemispherical measurements. The total combined uncertainty for BRDF and 8^o directional/hemispherical measurements is less than 1%.

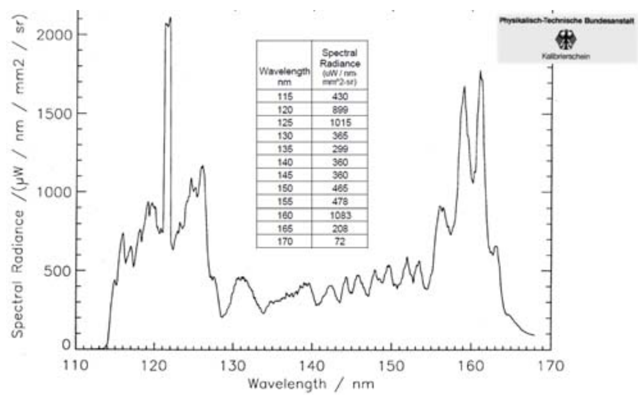

Fig.3: Calibration data of McPherson Deuterium lamp from 113nm to 167nm

3. RESULTS AND DISCUSSIONS

The BRDF ratio after/before irradiation with VUV lamp is presented for angle of incidence 45^o, wavelengths of 250nm, 300nm, 400nm, and 700nm for 10 hours irradiation, Fig.3 and 20 hours irradiation wavelengths of 250nm, 300nm, 350nm, 400nm, 500nm and 900nm, Fig.4. The measured data is also fitted for better presentation. The BRDF change shows non-isotropic directional degradation of Spectralon after irradiation of 10 hours at 250nm, and 300nm and also degradation at 250nm, 300nm and 350nm after irradiation of 20 hours. Although there is a small directional change in BRDF at longer wavelengths they are into the measurement uncertainty. The measured directional BRDF difference after 10 hours irradiation is -6.35% at 250nm, and -4.79% at 300nm. The same difference after 20 hours irradiation increases to -16.52% at 250nm, -9.28% at 300nm, -3.42% at 350nm and -1.93% at 400nm. We studied also the directional dependence of BRDF when measured at angle of incidence 60^{o}, shown on Fig.5 for wavelength of 275nm as a BRDF ratio after/before 10 hours and 20 hours irradiation.

The 8deg directional/hemispherical reflectance was also measured before and after 10 hours and 20 hours of VUV irradiation in addition to the BRDF characterization. The degradation of the Spectralon diffuser is better pronounced in the UV spectrum, but also in the visible spectrum after 20hours of irradiation, Fig.6, could be as high as 38% at 200nm and as low as 2% at 450nm.

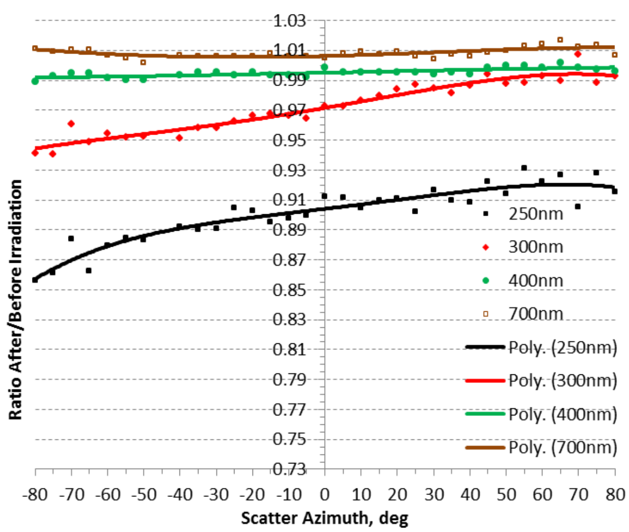

Fig.3: BRDF ratio after 10hours irradiation measured at AOI = 45^{o}

Currently we are considering a couple reasons for the directional degradation of BRDF after VUV irradiation. Pure geometrical – illumination path difference, shadowing and obscuration effects caused by the roughness of the sample, spatially non-uniform distribution of outgassing products, and in-depth irradiation effects are more pronounced at shorter wavelengths. Our initial results indicate that the directional degradation is not geometric effect only as the degradation is not increasing linearly with the time of irradiation. The shadowing and obscuration effects contribute to some degree but the initial outgassing process should be over by the time the measurements were performed.

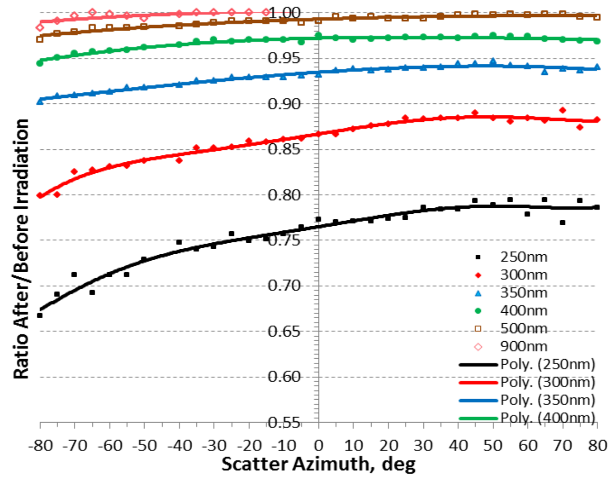

Fig.4: BRDF ratio after 20 hours irradiation measured at AOI = 45^{o}

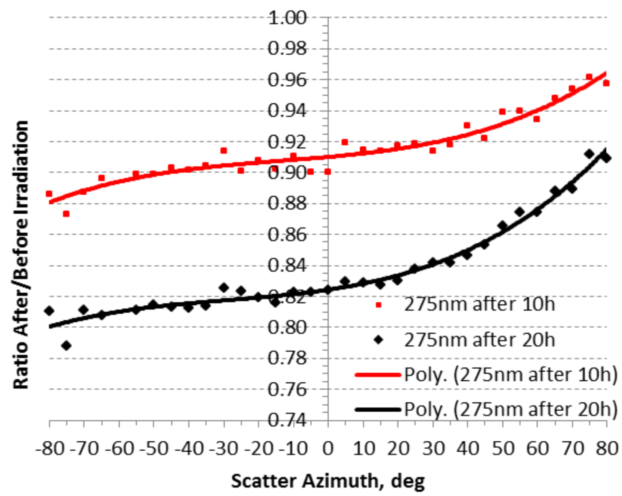

Fig.5: BRDF ratio after 10 and 20hours irradiation measured at AOI = 60^{o}

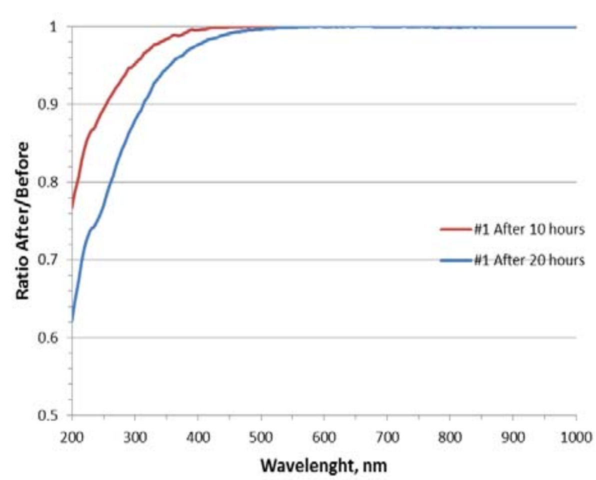

Fig.6: Directional Hemispherical Reflectance ratio after 10 and 20 hours irradiation

4. CONCLUSIONS AND FUTURE WORK

Our current results indicate that the often overlooked impact of VUV irradiation on Spectralon diffusers used on-orbit and at pre-flight calibrations may cause a directional dependent degradation that may need to be considered as the requirements on accuracy of remote sensing data continue to become more stringent. The degree of the degradation depends on several factors as (i) the irradiation geometry, (ii) the intensity and time of the irradiation, (iii) the BRDF measurement geometry, and (iv) the wavelength at which the BRDF is measured. The Spectralon diffusers show degradation as well after VUV irradiation when their 8^{o} directional/hemispherical reflectance is compared before and after 10 hours and 20 hours of VUV irradiation. The results from studies such as the one presented here will be of interest to the remote sensing community both in developing sensor design requirements and in providing constraints for modeling and correction efforts of airborne and satellite-based data. We are expanding the current work with more irradiation hours to confirm the current results and explain the possible causes of the observed directional dependent degradation due to VUV irradiation. The presented data will improve our understanding of processes occurring on-orbit and their impact on the solar diffusers. The data of this study is also compared to our previous characterization efforts of Mie scattering volume diffuser [5]

5. REFERENCES

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