Plasma Etched ESR Reflective Film Transmittance and Reflectance Measurement Report

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Abstract: This report contains the results from the relative transmittance and reflectance tests of the 3M ESR reflective film material of both the plasma etched samples and the reference samples taken with the Shimadzu UV-3600 spectrophotometer at the University of Warsaw. The results do not show a significant difference in either the reflectance nor the transmittance of the etched samples compared to the reference samples for the visible spectrum range (380 - 700 nm).

Introduction: The ESR reflective film will coat the inside of the inner veto of the Darkside-20k experiment to keep photons inside so that they can be detected with the vPDUs. As radioactivity in the materials is a concern for the noise of this experiment, there is an effort to remove as much radioactivity from the material as possible. The ESR reflective material contains radon in the surface, so etching with plasma was used in an attempt to remove this contamination. As a result, the high reflective property of this material may be compromised.

Methods:

Spectrophotometer

The Shimadzu UV-3600 spectrophotometer was used with the LISR-3100 150 mm diameter Integrating Sphere Attachment which is shown in figure 1. This sphere is coated with white reflecting powder, barium sulfate ($BaSO_4$), which has a 98% diffuse reflectivity. The photodetector is at the bottom of the sphere and captures all ambient light reflected off of the sample in position 1 for the reflectivity test and transmitted through the sample in position 2 for the transmittance test.

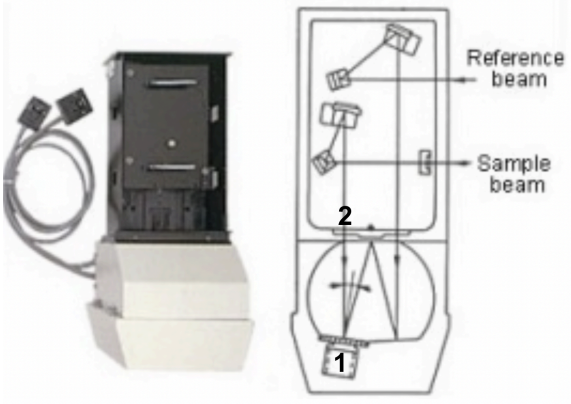

Figure 1 LISR-3100 150 mm diameter Integrating Sphere Attachment. Sample is placed in position 1 for the reflectivity test and in position 2 for the transmittance test.

Samples

We tested three different samples of the plasma etched film and three samples of the reference material. We tested both sides of each sample, denoted by greenside and silverside (except for reference sample 2 which we only measured the reflectivity of the green side). Photos of the reference and etched films are shown in figure 2. The silver side is allegedly only slightly more reflective (~1%) than the green side, so the silver side is the one which will be facing the inside of the inner veto. This material is reported to have a nominal reflectance of >98.5% over the visible spectrum which is reported by the company and confirmed experimentally [1]. The green side is the one that was plasma etched. Both protective films were removed before the measurements.

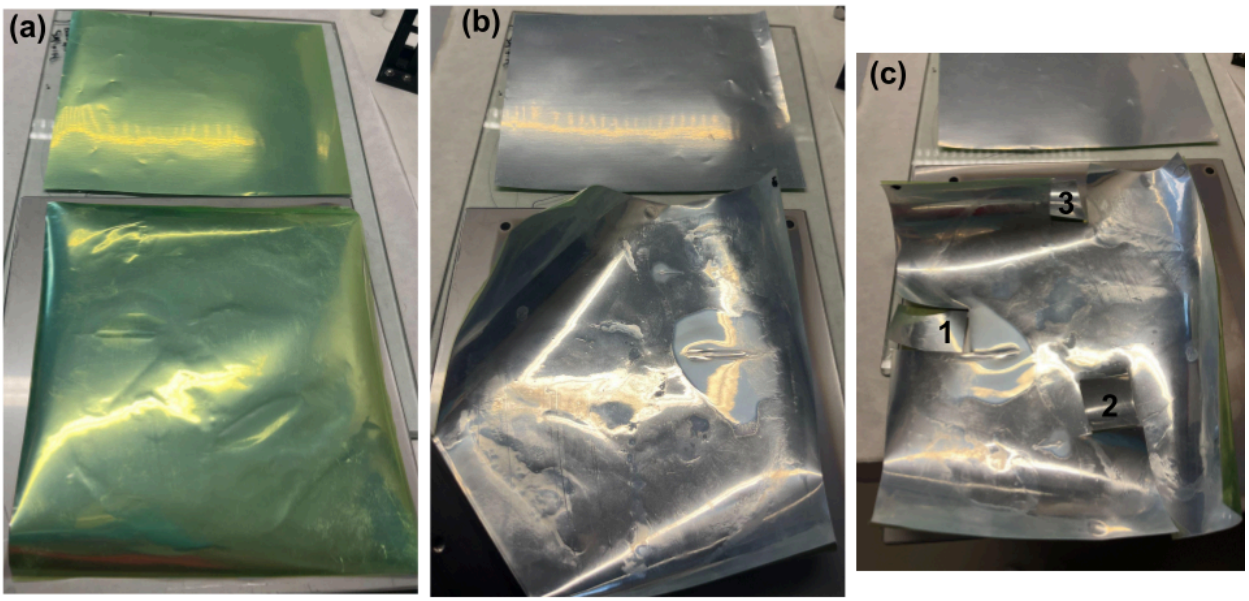

Figure 2 Sample photos – reference film is on the top and etched film is on the bottom. (a) green side (b) silver side (c) shows where each of the etched samples were cut from.

Results:

As a disclaimer, we must note that ESR is made of interleaving layers of PMMA and PEN, which is fluorescent. So below 380 nm, the spectra is dominated by fluorescence and can no longer be interpreted as reflectance or transmittance. Although this is speculative, changes below 380 nm may indicate a change in the material terminating the film, perhaps due to plasma etching.

Reflectance

The most notable differences come from the shorter wavelength end of the spectrum below 380 nm. The plot of reflectance shown in figure 3 shows both sides of all samples, with each sample being denoted by a single color, and the green side having thick lines while the silver side has thin lines. From this we can clearly see that the silver side consistently has a higher intensity in the low wavelength range with a highest value of 96.3% and are roughly similar for both etched and unetched samples. However, the etched green sides are much lower in intensity than their reference counterparts. While the reference green sides intensity is around 80%, the etched green sides drop to about 50%. The long wavelength regime, which is zoomed in on for clarity, shows more of a spread among the etched and reference samples as well as between the green and silver sides.

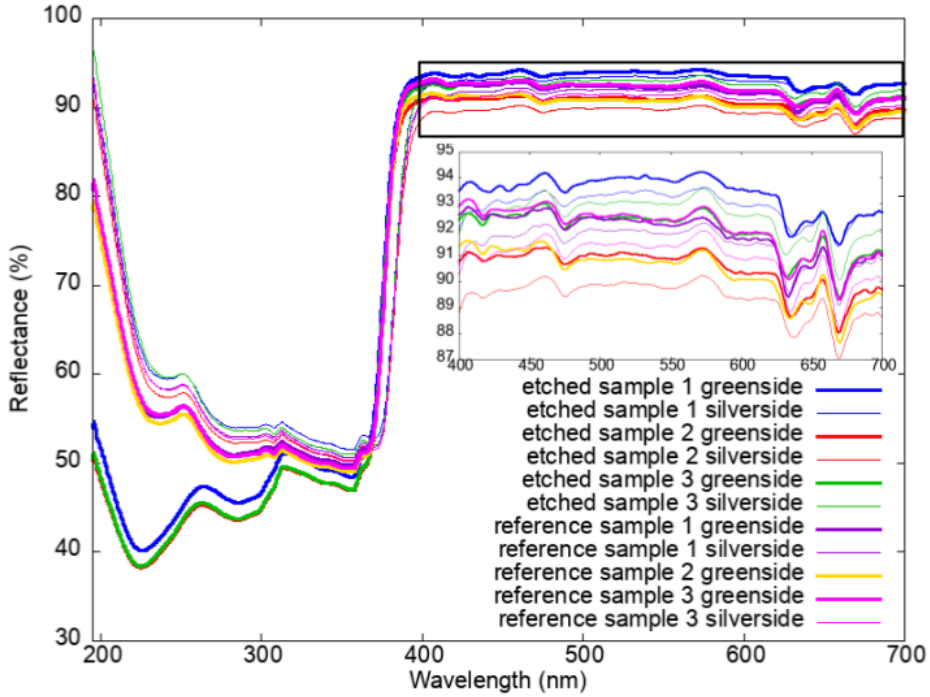

Figure 3 Reflectance vs Wavelength

Figure 4 shows the reflectance only for the visible light range, >390 nm, parsed out by the green sides, figure 4 (a), and the silver sides, figure 4 (b). One difference between these two is that the etched sample 3 (green) has a higher reflectance on the silver side than the green side, which is not the case for the rest of the samples. It also seems that the silver side drastically decreases in intensity with decreasing wavelength before the greenside does.

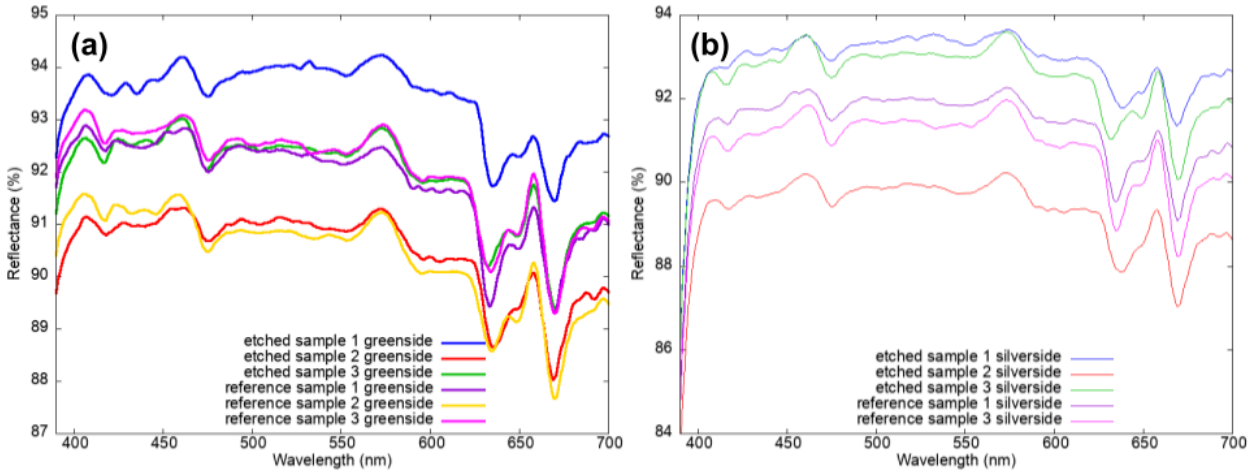

Figure 4 Reflectance vs Wavelength above 390 nm (a) green sides (b) silver sides

Transmittance

Shown in figure 5 is the transmittance of all samples from 195 nm to 700 nm. Once again, the most notable differences come from the shorter wavelength end of the spectrum, below 380 nm. All of the silver sides, from the etched samples or not, remain very low in intensity with a lowest value of 4.1%. The reference samples' green sides reach the highest peak of 27.8% while the etched green sides fall to 11%. The long wavelength end of the spectrum is zoomed in for clarity, and it can be seen that the peak at ~630 nm is consistently higher for the reference samples for both the green and silver sides. Aside from that one small difference, the long wavelength regime seems to be very similar among both sides of the etched and reference samples.

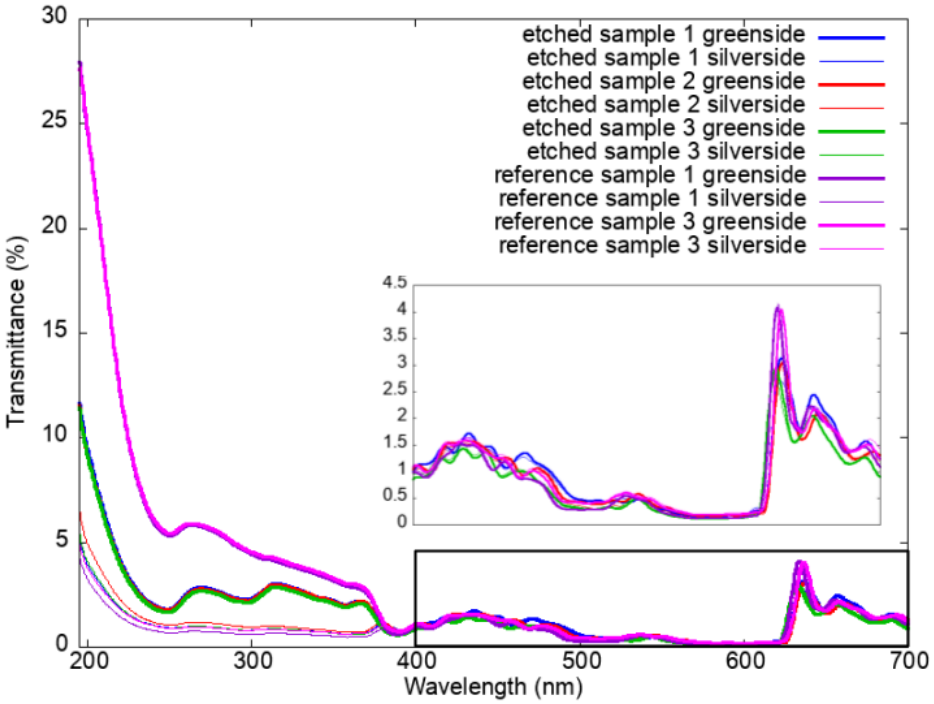

Figure 5 Transmittance vs Wavelength

Figure 6 shows the reflectance only for the visible light range, >390 nm, parsed out by the green sides, figure 6 (a), and the silver sides, figure 6 (b). In these plots, we see slight differences among the peaks between etched and reference samples, however the most obvious difference is the peak at 630 nm which is greater for the reference samples.

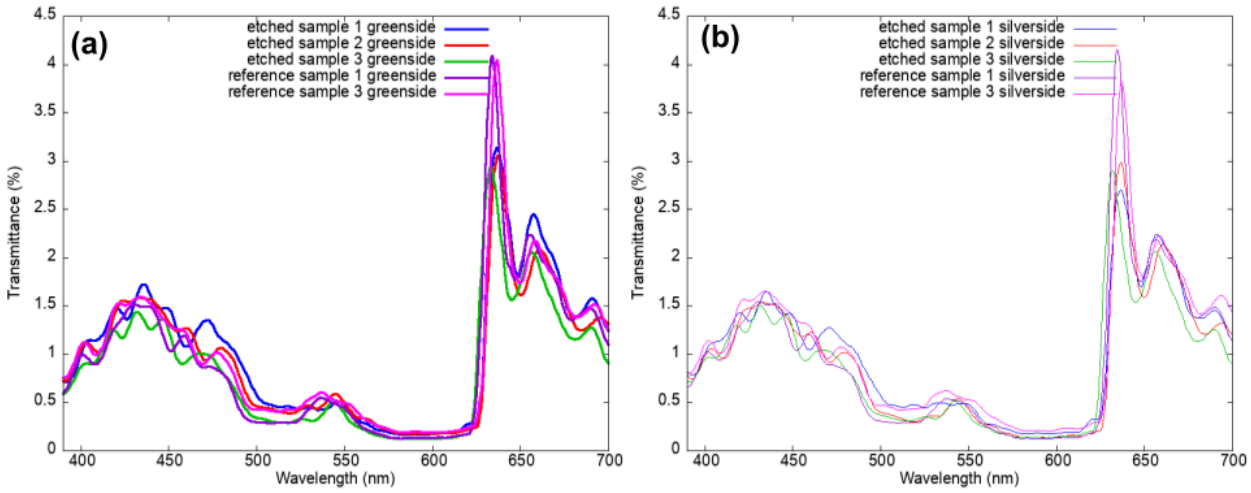

Figure 6 Transmittance vs Wavelength above 390 nm (a) green side (b) silver side

Conclusion:

These results suggest that the process of plasma etching on this material changes the intensity of fluorescence of light in the UV range (195 - 380 nm). The reflectance and the transmittance of the visible light range (380 - 700 nm) remains roughly the same except for a small decrease in the transmittance on the peak around 630 nm. A change in specularity due to etching could cause more diffuse light distribution systematically increasing the reflectance or transmittance by a few 1%. It also shows the difference between the green side and the silver side which is most evident in the intensity due to fluorescence below 380 nm. Furthermore, the company, 3M, reports the nominal reflectivity of this material to be over 98.5% in the visible light range, but our results show the visible light range reflectivity to not reach even 95%. This is because no absolute calibration was performed during this measurement.

References:

[1] Francis Loignon-Houle, Catherine M. Pepin, Serge A. Charlebois, Roger Lecomte, "Reflectivity quenching of ESR multilayer polymer film reflector in optically bonded scintillator arrays", *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, Volume **851**, 2017, Pages 62-67, ISSN 0168-9002, https://doi.org/10.1016/j.nima.2017.01.051.