# Performance Evaluation of UV-capped SiC/Mg Multilayers

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## Table of Contents

## List of Figures

Figure | Page



## LIST OF TABLES

Table | Page

## 1.0 Abstract

The Ultraviolet and Visible-light Coronagraphic Imager (UVCI) for the Sounding-rocket Coronagraphic Experiment (SCORE) has three wavelength channels: 30.4 nm, 121.6 nm and 450-600 nm. The expected performances of these three channels have been estimated for different SiC/Mg multilayer (ML) coatings, optimized for the 30 nm, and with different cap layers designed to extend the coating responses to the 122 nm and visible-light. These ultraviolet and visible-light-capped (UV-capped) SiC/Mg coatings have up to a factor 2 to 3 improved performances at 30 nm, with respect to those of the Mo/Si coating. However, their reflectivities at 122 nm and in the visible are lower than those of the Mo/Si with $SiO_2$ cap layer.

The conclusions of the study is that the sample #6026 of the SiC/Mg coating with Cap #2 gives a considerable increase in the reflectivity performances at 30 nm (35%), with respect to those of the $SiO_2$-capped Mo/Si (20-15%), while maintaining - at the same time – a similar reflectivity at 122 nm (27%). At 30 nm, the UVCI throughput with sample #6026 is 4 times higher than that with the Mo/Si, while it remains the same at 122 nm. The reflectivity in the visible-light is a factor of 2 lower (22%) than that of $SiO_2$-capped Mo/Si. However, the polarized brighteness (pB) of the K-corona is intense enough to give an acceptable countrate in the UVCI visible-light channel.

## 2.0 Reflectivity measurements of the UV-capped SiC/Mg coatings

Reflective X-ray Optics (RXO) has prepared several samples of SiC/Mg ML coatings optimized at 30 nm. One set of samples has no cap layer, whereas two other sets have two different UV-cap layers (Cap#1 and Cap#2).

RXO has measured the reflectivity of the samples at 30 nm. Additional measurements ranging from 40 nm to 800 nm were made at the National Synchrotron Light Source (NSLS) Brookhaven National Laboratory, New York.

Figure 1 shows the reflectivity versus wavelength of SiC/Mg MLs without cap layer, as a function of the gamma. Figure 2 and Figure 3 show the same but for Cap#1 and Cap#2, respectively. In order to facilitate the performances comparison among the of UV-capped SiC/Mg MLs, and the $SiO_2$-capped Mo/Si, Figure 4 summarizes all the measurements in graphic format, while Table 1 gives the same information in numerical format. The visible-light reflectivities are averaged over the color filter’s bandpass, that is, 450-600 nm.

A criterion that can be adopted for the selection of SiC/Mg ML is that the reflectivity at 30 nm is at least about twice that of the Mo/Si, while that at 122 nm is not lower than half. Figure 4 and Table 1 show that this criterion is satisfied by the samples with no cap #6012 or #6013, and by sample #6023 and #6026 with Cap#2. This last sample represents the best compromise between the extreme-UV (30 nm) and UV (122 nm) throughput. However, the visible-light throughput is a factor of 2 lower than that of the Mo/Si. This ML represents the ‘baseline’ coating for UVCI/SCORE. In order to verify that this is still acceptable, the countrates in the 3 wavelength bands have been estimated. The results are reported in the following sections.

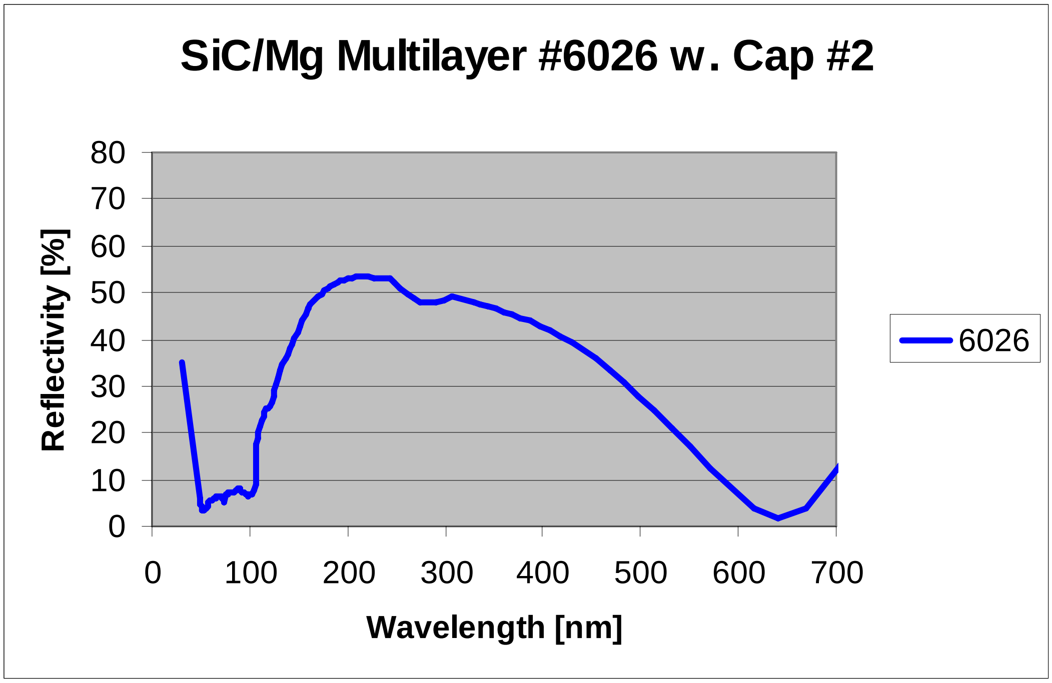


**Figure 1.** Reflectivity versus wavelength and gamma for SiC/Mg ML without cap layer

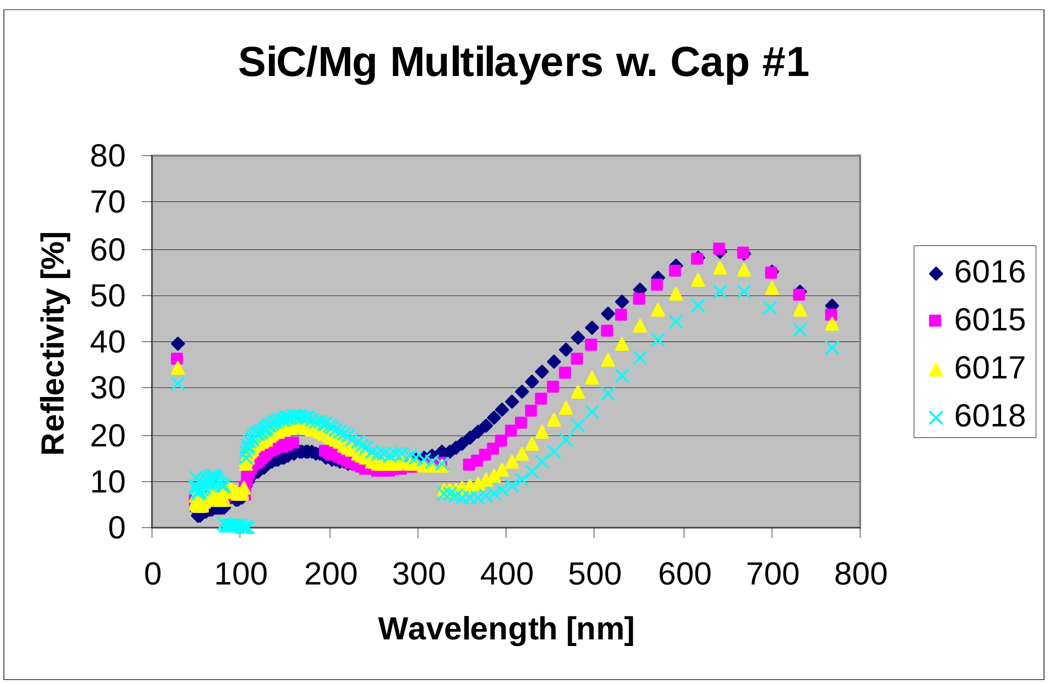


**Figure 2.** Reflectivity versus wavelength for SiC/Mg ML with UV-cap #1

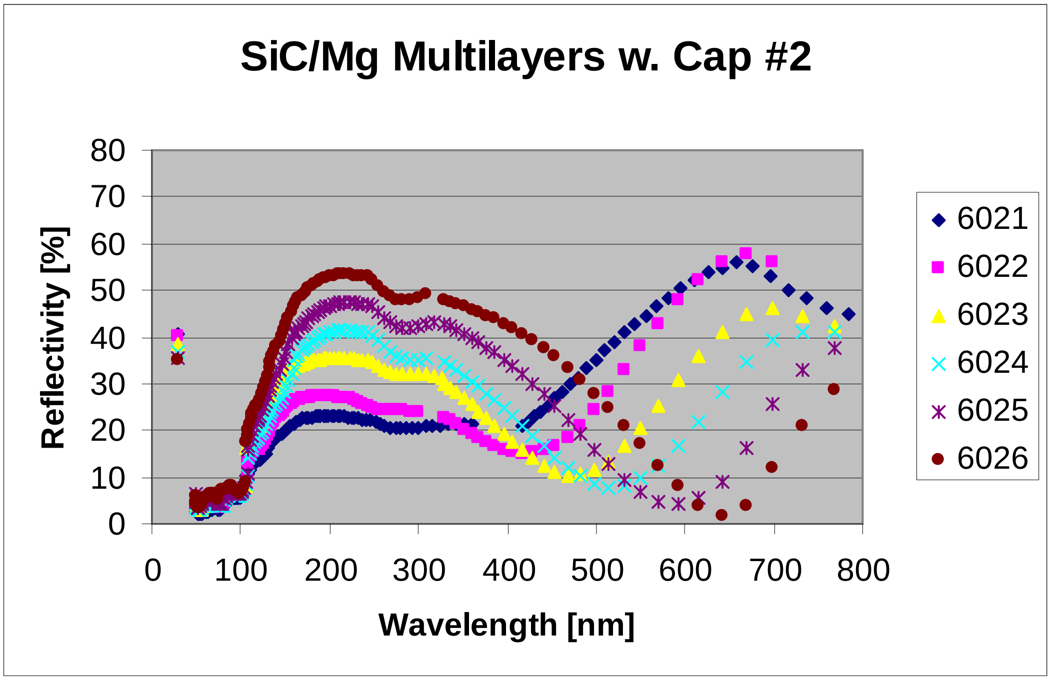


**Figure 3.** Reflectivity versus wavelength for SiC/Mg ML with UV-cap #2

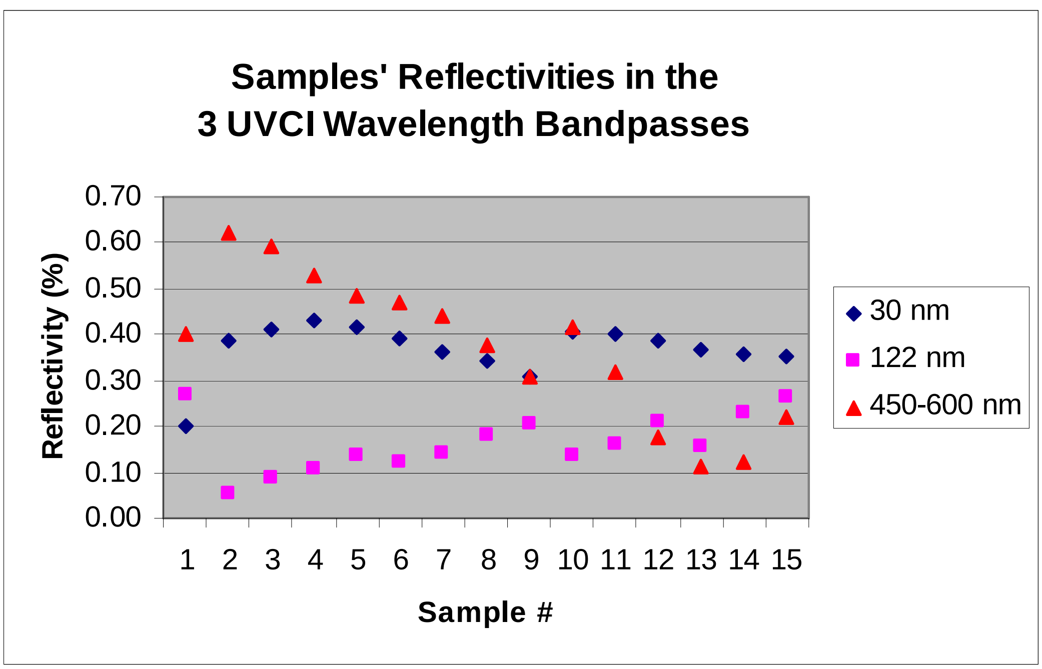


**Figure 4** Summary of the samples' reflectivity in the 3 wavelength bands.(See also **Table 1**)

| Sample # | Coating | 30.4 nm | 121.6 nm | 450-600 nm |
|---|---|---|---|---|
| 1 | Mo/Si | 0.20 | 0.27 | 0.40 |
| | | | | |
| | SiC/Mg | | | |
| | No Cap (Γ) | | | |
| 2 | 6014 (0.19) | 0.39 | 0.05 | 0.62 |
| 3 | 6011 (0.22) | 0.41 | 0.09 | 0.59 |
| 4 | 6012 (0.26) | 0.43 | 0.11 | 0.53 |
| 5 | 6013 (0.30) | 0.42 | 0.14 | 0.49 |
| | Cap #1 | | | |
| 6 | 6016 | 0.39 | 0.12 | 0.47 |
| 7 | 6015 | 0.36 | 0.14 | 0.44 |
| 8 | 6017 | 0.34 | 0.18 | 0.38 |
| 9 | 6018 | 0.31 | 0.20 | 0.31 |
| | Cap # 2 | | | |
| 10 | 6021 | 0.41 | 0.14 | 0.42 |
| 11 | 6022 | 0.40 | 0.16 | 0.32 |
| 12 | 6023 | 0.39 | 0.21 | 0.18 |
| 13 | 6024 | 0.37 | 0.16 | 0.11 |
| 14 | 6025 | 0.36 | 0.23 | 0.12 |
| 15 | 6026 | 0.35 | 0.27 | 0.22 |

**Table 1** Summary of the samples' reflectivity in the 3 UVCI wavelength bands

## 3.0 Countrate Estimates

The countrate in the 3 wavelength bands of SCORE have been computed for coronal radiances of a streamer by adopting an instrument model with the measured component-level throughputs.

## 3.1 Coronal Radiances

Figure 5 shows the K-corona polarized brightness profile adopted for the countrate estimate. Figure 6 shows the coronal radiances of the Lyman-α HeII, 30.4 nm, and HI, 121.6 nm, line-emissions.

For sake of simplicity, the countrate calculations have been performed by using the radiances of a streamer.

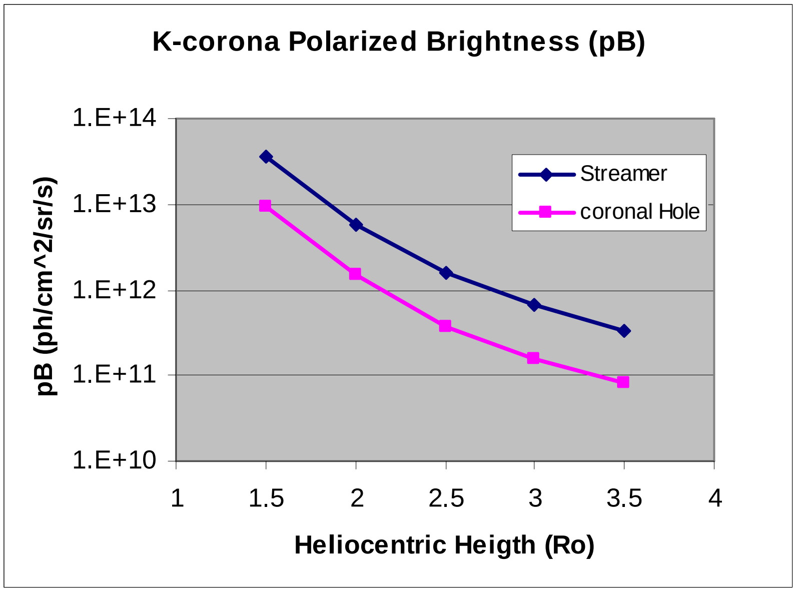


**Figure 5** K-corona polarized brightness integrated in the 450-600 nm band

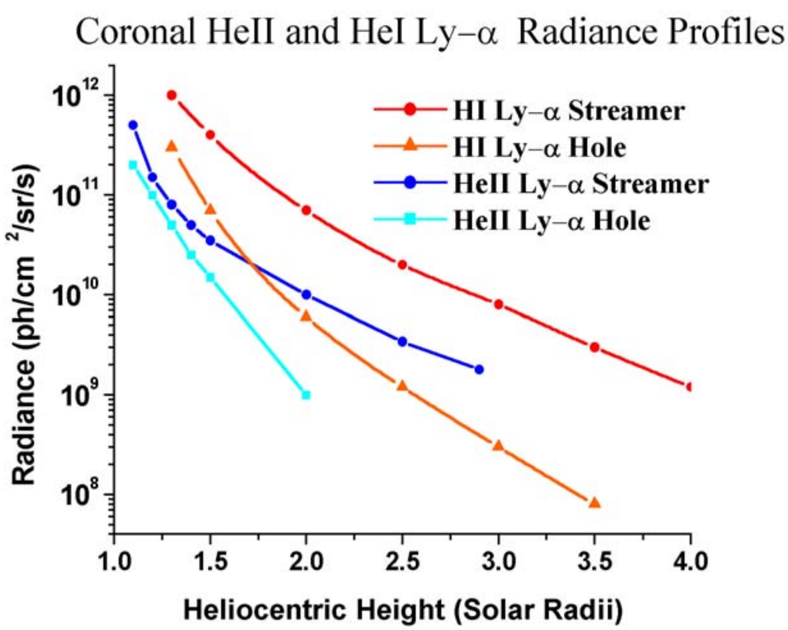


**Figure 6** Coronal radiances of the Ly-α HeII, 30.4 nm, and HI, 121.6 nm.

## 3.2 Instrument Response

Figure 7 shows the UVCI vignetting function adopted for the instrument model, together with the measured component-level throughputs reported in Table 2.

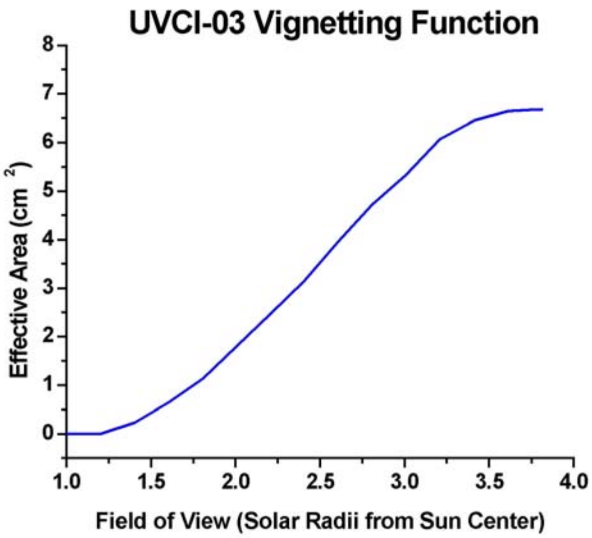


**Figure 7** UVCI/SCORE vignetting function

| Instruments | | Throughput | | |
|---|---|---|---|---|
| **System** | **Components** | **30.4 nm** | **121.6 nm** | **450-600 nm** |
| **Filters** | Aluminum | 0.4 | - | - |
| | Al/$MgF_2$ | - | 0.22 | 0.9 |
| **KPol** | Triplets (x2) | - | - | 0.8 |
| | Hot Mirror | - | - | 0.9 |
| | Color filter | - | - | 0.9 |
| | Quarter wave | - | - | 0.95 |
| | LCVR | - | - | 0.9 |
| | Polarizer | - | - | 0.99 |
| | Total | | | 0.44 |
| **Detectors QE** | MCP | 0.4 | 0.3 | - |
| | CCD | - | - | 0.9 |

**Table 2** UVCI/SCORE components' throughput

The other instrument's parameters relevant to the countrate calculations are:

Effective focal length = 470 mm
Pixel size = 13.5 μm
Read-out ("hardware") pixel binning = $(2 \text{ pixel})^2$

### 3.3 Results

The SiO2-capped Mo/Si ML represents the baseline coating for the UVCI optics. For this reason, the countrates for this ML have been estimated in order to provide a reference benchmark for the comparison with the UV-capped SiC/Mg MLs. This is shown in Figure 8.

The countrates for sample #6012 with no cap show that while the throughput in the EUV increases dramatically with respect to the Mo/Si (5 times), in the UV the throughput drops by a factor of 7 (Figure 9). Sample #6022 with Cap#2 improves the UV throughput, with respect to sample #6012, without changing the EUV one (Figure 10). Sample #6023 brings the EUV and UV throughputs to about the same level (Figure 11). Finally, sample #6026 still increases the UVCI throughput at 30 nm by a factor 4, with respect to that with the Mo/Si, without changing that at 122 nm (Figure 12). The reflectivity in the visible-light is a factor of 2 lower (22%) than that of $SiO_2$-capped Mo/Si. However, the polarized brighteness (pB) of the K-corona is intense enough to give an acceptable countrate in the UVCI visible-light channel (Figure 13).

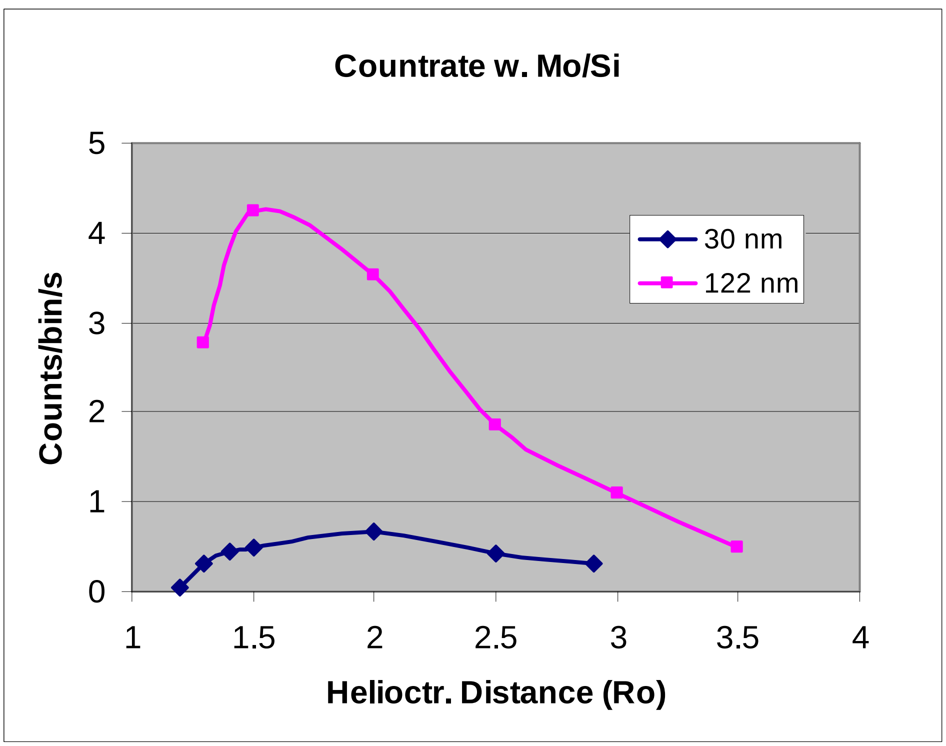


**Figure 8** Countrates in the 30 and 122 nm wavelength bands for the $SiO_2$-capped Mo/Si ML.

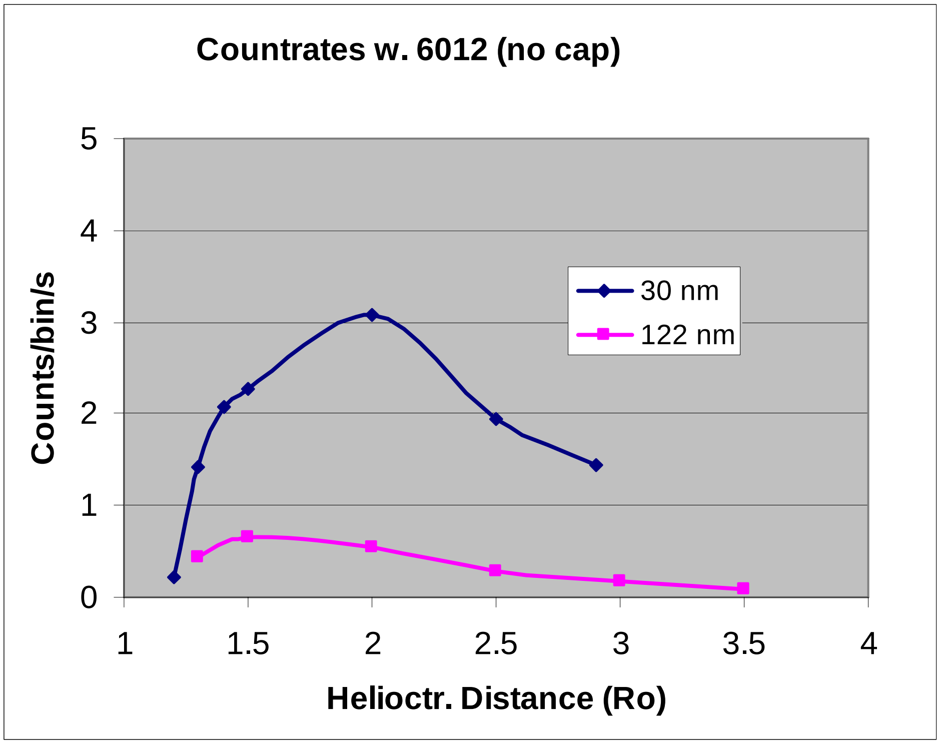


**Figure 9** Countrates in the 30 and 122 nm bands for the SiC/Mg ML #6012 with no cap.

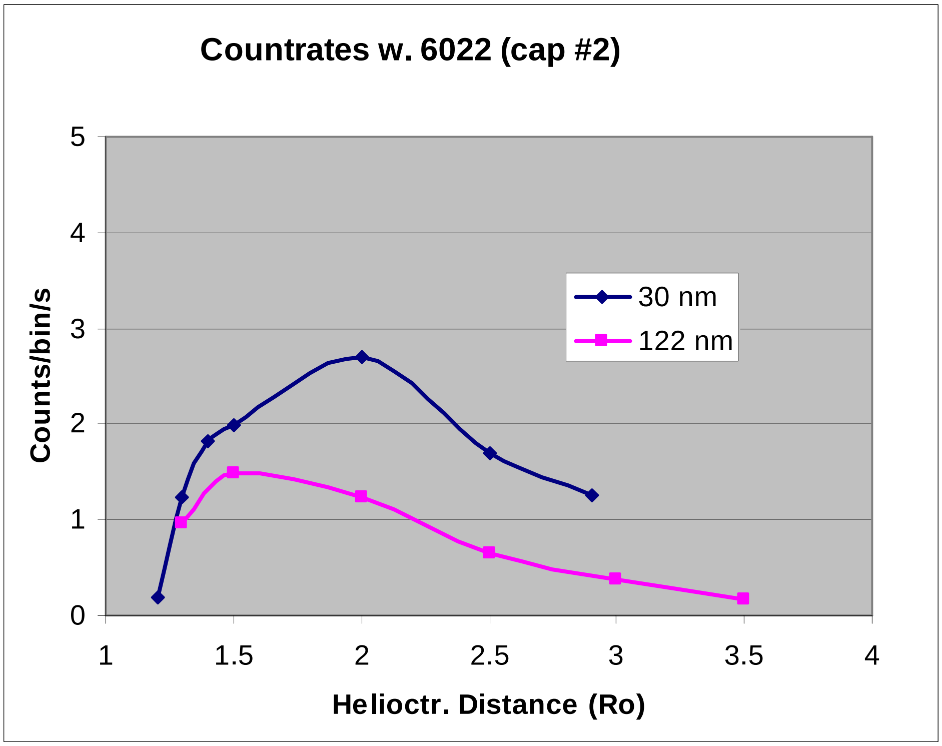


**Figure 10** Countrates in the 30 and 122 nm bands for the SiC/Mg ML #6022 with Cap#2

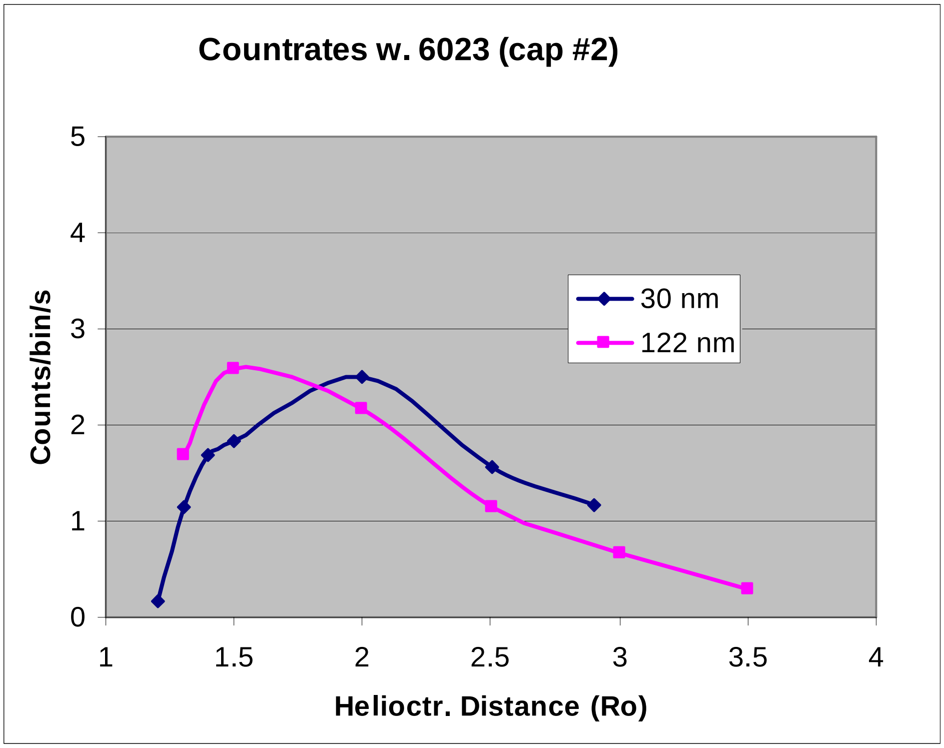


**Figure 11** Countrates in the 30 and 122 nm bands for the SiC/Mg ML #6023 with Cap#2

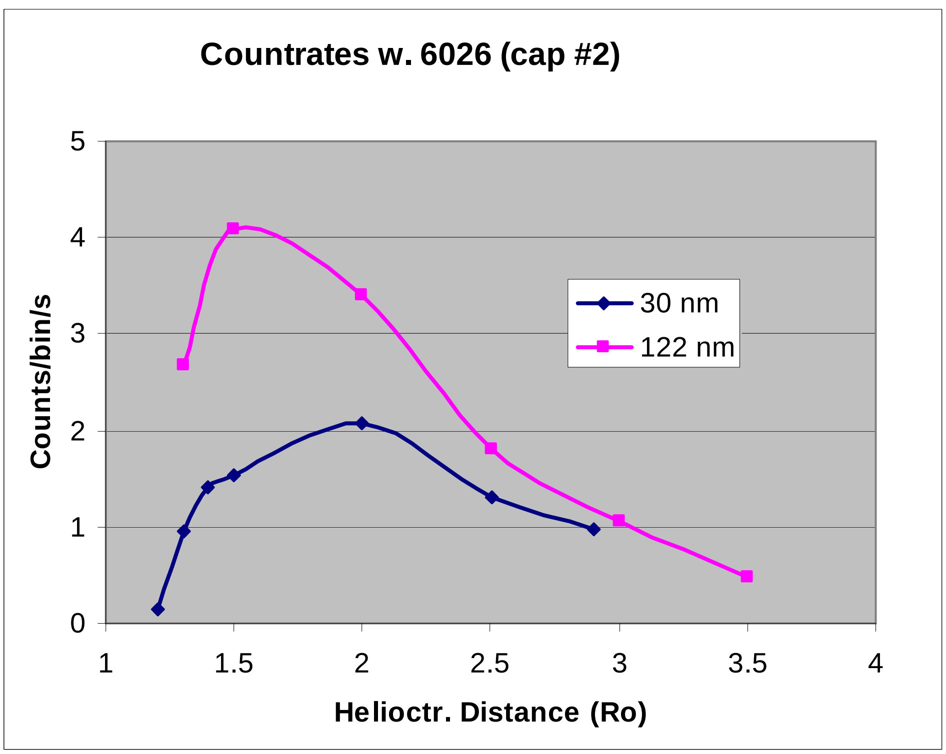


**Figure 12** Countrates in the 30 and 122 nm bands for the SiC/Mg ML #6026 with Cap#2

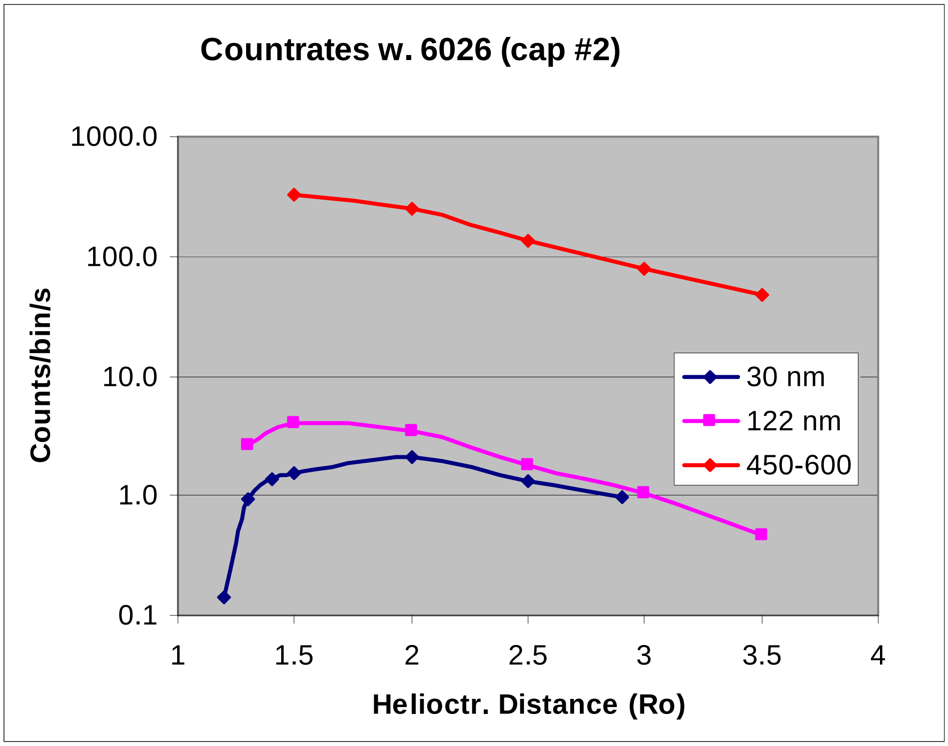


**Figure 13** Countrates in the 30 and 122 nm and visible-light bands for the SiC/Mg ML #6026.

## 4.0 Conclusions

The conclusions of the study show that the sample #6026 of the SiC/Mg coating with Cap #2 gives a considerable increase in the reflectivity performances at 30 nm (35%), with respect to those of the $SiO_2$-capped Mo/Si (20-15%), while maintaining - at the same time – a similar reflectivity at 122 nm (27%). At 30 nm, the UVCI throughput with sample #6026 is 4 times higher than that with the Mo/Si, while it remains the same at 122 nm. The reflectivity in the visible-light is a factor of 2 lower (22%) than that of $SiO_2$-capped Mo/Si. However, the polarized brighteness (pB) of the K-corona is intense enough to give an acceptable countrate in the UVCI visible-light channel.

## APPENDIX A (Abbreviations/Acronyms)

| Acronym | DEFINITION |
|---|---|
| NSLS | National Synchrotron Light Source |
| ML | Multilayer |
| LCVR | Liquid crystal variable retarder |
| pB | polarized brighness (of the K-corona) |
| RXO | Reflective X-ray Optics |
| SCORE | Sounding-rocket Coronagraphic Experiment |
| UV-capped | ultraviolet and visible-light capped multilayer |
| UVCI | Ultraviolet and Visible-light Coronagraphic Imager |