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Design and modeling of 40 keV X-ray optics for Titan experiment

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In 2004 we designed and fabricated a 40 keV W/SiC multilayer coated mirrors with 2.0 nm period thickness that were tested at RAL (UK) in winter 2004/2005. The mirrors reflected from 35 to 70 keV (different grazing incidence angles) and showed high reflectivity. However, there was not enough beamtime at RAL to obtain quantitative results. Similar experiment will now be performed in Titan facility (LLNL). In this report we design and model multilayers with even shorter period than the ones used in 2004/2005 experiments. Our goal is to fabricate 1 nm period W/SiC multilayers with high reflectivity. This will enable operation at higher angle of grazing incidence and simplified the mounting fixture.

Design: Our modeling shows that a 40 keV mirror with 1 nm period W/SiC will reflect at 0.892 degree with over 90% reflectivity if we use 500 bilayers, where the individual W layer thickness is 0.4 nm and the individual SiC layer thickness is 0.6 nm. This calculation assumes there is no interface roughness or interdiffusion and it also assumes perfect instrumental resolution (Figure 1).

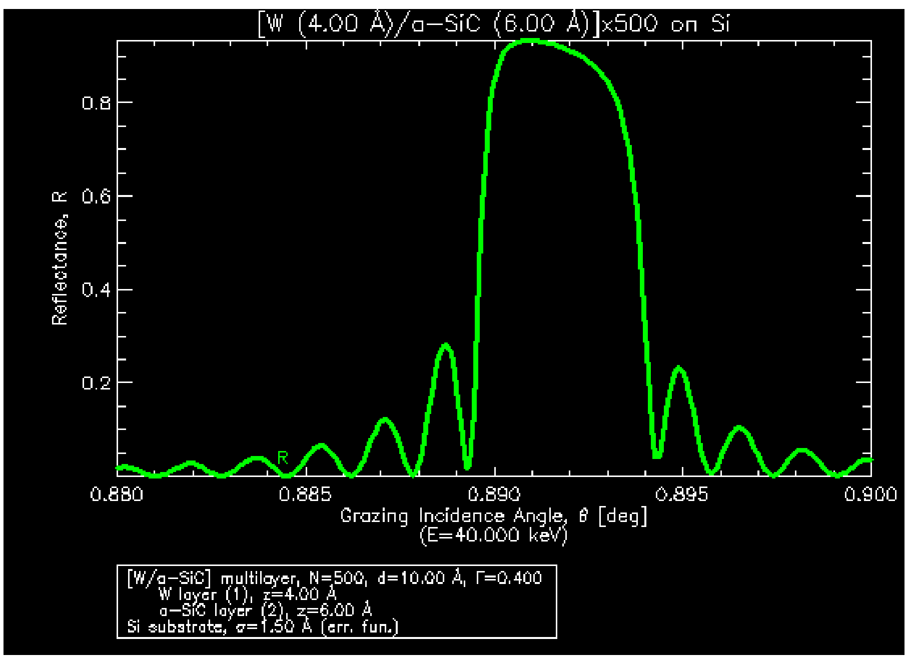

Figure 1: Modeling of W/SiC multilayer at 40 keV with 500 bilayers, ideal structure and perfect instrumental resolution.

Modeling of the same multilayer structure but assuming 0.2 nm interface roughness/interdiffusion (reasonable assumption based on our previous results) reduces the reflectivity from >90% to ~68%.

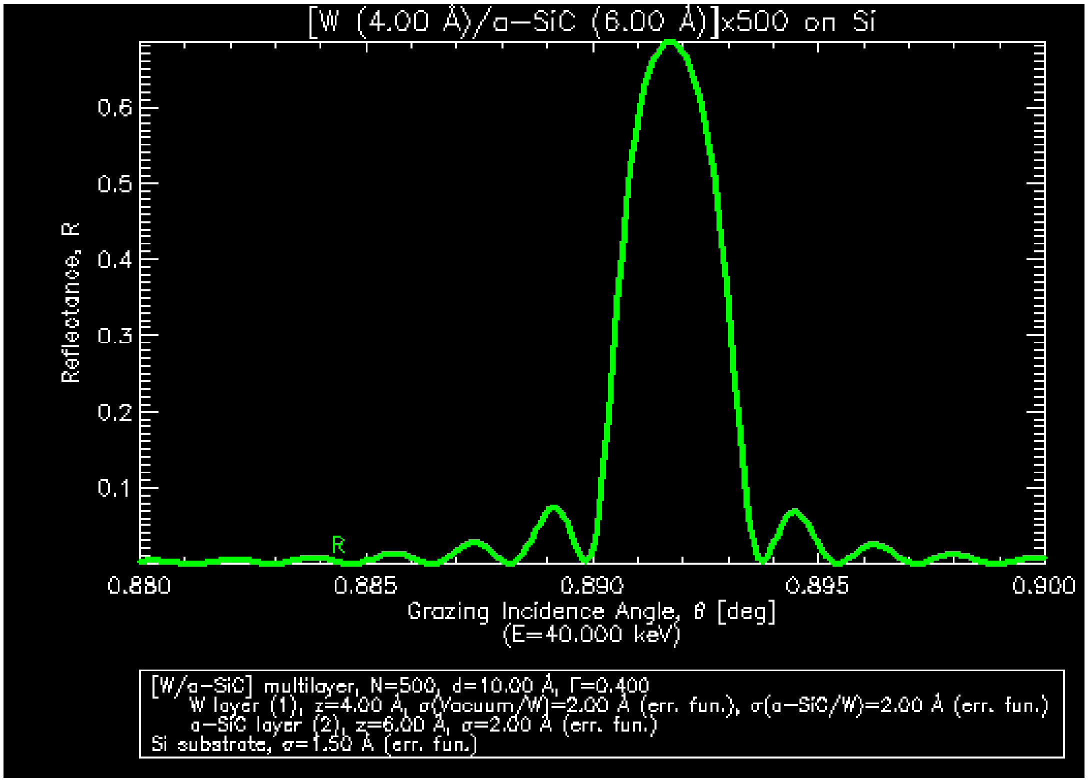

Figure 2: Modeling of W/SiC multilayer at 40 keV with 500 bilayers, perfect instrumental resolution and non-ideal interfaces.

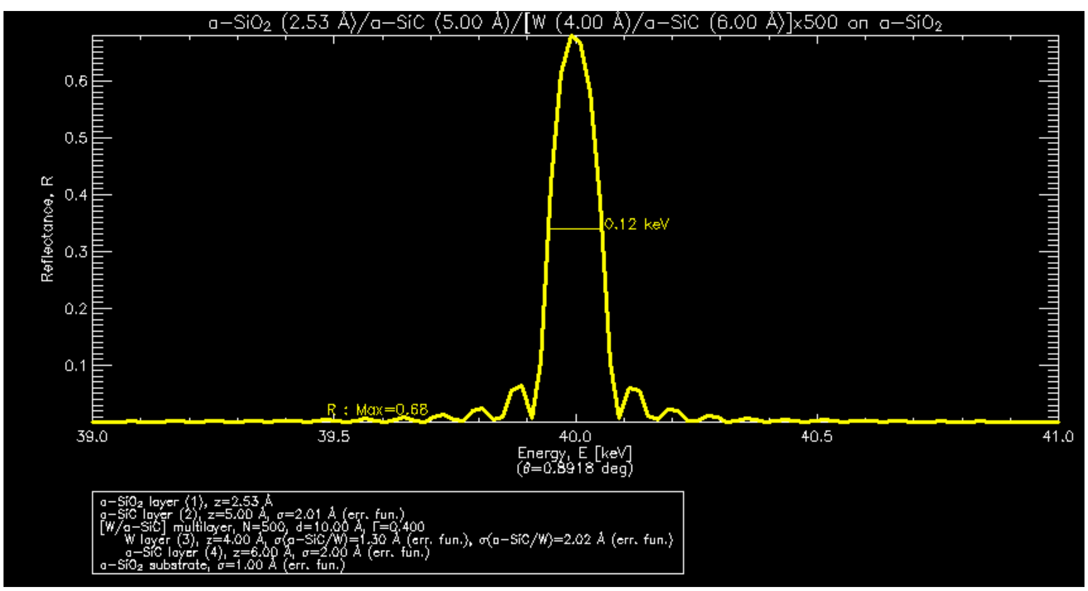

Figure 3: Reflectivity for a multilayer reflecting off at 0.8918 deg (Theta) assuming 500 bilayers, perfect instrumental resolution and non-ideal interfaces.

However, we will calibrate the period thickness and test these multilayers at 8.157 keV (Rigaku X-ray diffractometer). Below are modeled results expected to be obtained on the first Bragg peak assuming perfect multilayer structure and measurements at 8.157 keV. A reflectivity of 78% (Figure 4) is predicted.

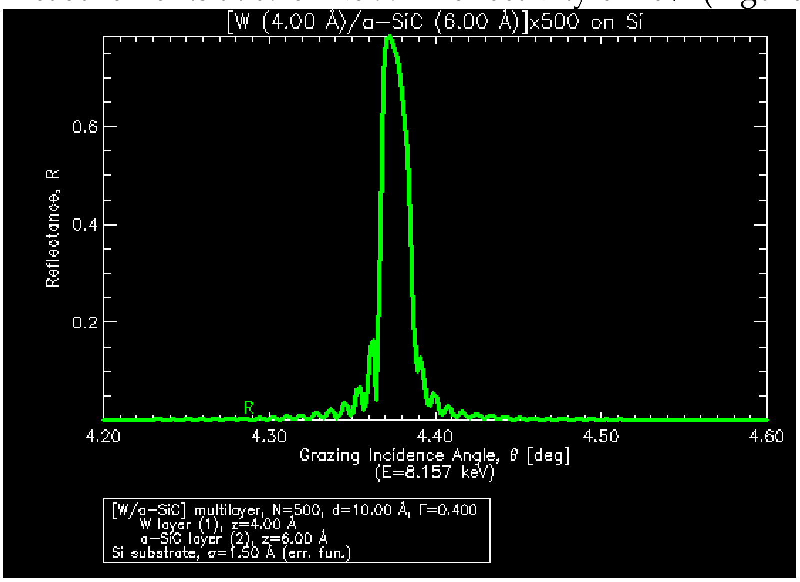

Figure 4: Modeling of W/SiC multilayer measured at 8 keV with 500 bilayers, ideal structure and perfect instrumental resolution.

Another important factor to take into account when modeling the mirror performance is instrumental resolution. Our Rigaku X-ray diffractometer has a limited instrumental resolution (0.015 deg). Therefore even if a mirror has 68% reflectivity we will only be able to measure 37% because of the limited instrumental resolution.

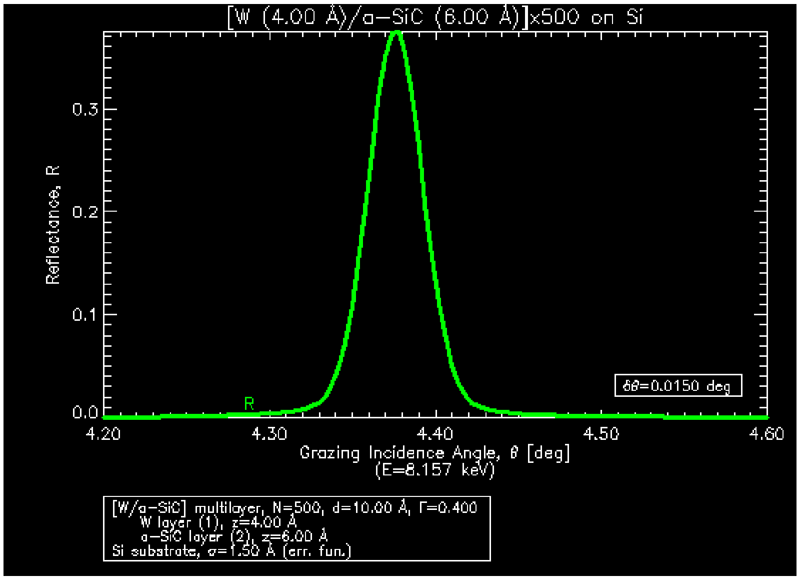

Figure 5: Modeling of of W/SiC multilayer at 8 keV with 500 bilayers, ideal structure and 0.015 deg instrumental resolution.

However, we know that this multilayer system has some interface roughness/interdiffusion and if we take also this into account than the expected reflectivity at 8.157 keV should be 13%.

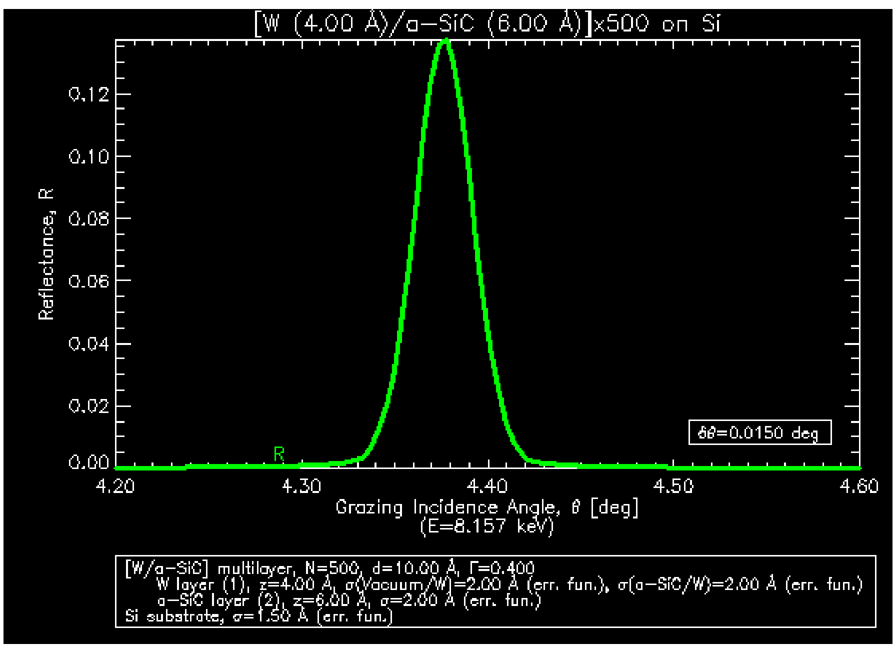

Figure 5: Modeling of of W/SiC multilayer at 8.157 keV with 500 bilayers, 0.015 deg instrumental resolution and non-ideal interfaces.

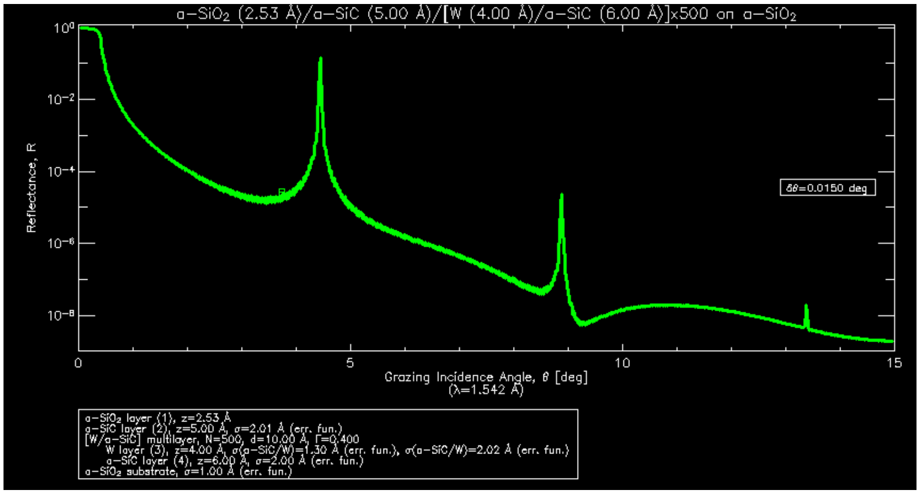

Figure 6: Modeled XRD spectrum from 0 to 15 deg grazing incidence angle of 1 nm W/SiC ML with imperfect interfaces and assuming 0.015 deg instrumental resolution. Since the background count rate is ~ 10^{-8} and therefore we expect to observe only the first two Bragg peaks.