Bragg reflection from nanometer multilayers can be utilized to realize optics for both soft and hard X rays. Optical elements of that type provide high reflectivity at angles much higher than the angle of total reflection and can be configured with a layer curvature or a gradient in layer thickness. Therefore, these multilayer mirrors exhibit a wide range of applications, e.g. as focusing optics or as monochromators, and are commonly used in laboratory X-ray diffractometers and spectrometers. Due to their wide band-pass, multilayers can be also advantageous compared to crystal monochromators when flux rather than spectral resolution is desired. With respect to the use at synchrotron facilities with high flux, a high thermal and radiation stability is required. While illuminating with the intense synchrotron radiation in the hard X-ray range, the heat load can produce structural changes of the multilayer stack. This can be a result of diffusion, chemical reactions or relaxation of internal stress, among other influences caused by misfit at the layer interfaces. Intrinsic stress can act as an additional energetic contribution which lowers the temperature limit for structural changes. With B₄C and C diffusion barrier layers the inter-diffusion can be hindered whereby thermal stability increases [1].

The aim of this work was to investigate the thermal stability of multilayers in intense polychromatic synchrotron radiation as well as the physical processes taking place during and after exposure. Here we want to present results of some preliminary studies.

Mo/B₄C, W/B₄C and Cr/B₄C multilayer systems were provided by Fraunhofer IWS in Dresden and were deposited on (100) oriented Si substrates of 6.35 mm thickness and 25.4 mm diameter using a DC magnetron sputtering technique. A coating consists of 500 bilayers with period thicknesses of about 1.5 nm.

Grazing incidence X-ray reflection measurements were performed at beamline E2 (RÔMO) at HASYLAB using a Si (111) double crystal monochromator, σ-polarized radiation and a NaI scintillation detector.

Fig. 1: Reflectivity versus grazing angle Θ, normalized to the position of the first order Bragg maximum Θ, for (a) Cr/B₄C, W/B₄C and Mo/B₄C at photon energies of 8 keV and (b) Mo/B₄C at 8 keV, 16 keV and 24 keV.
All samples were investigated with incident photon energies of 8 keV, and additionally with 16 keV and 24 keV for the Mo/B\textsubscript{4}C system. The Bragg reflection curves were measured near the 1\textsuperscript{st} order maximum with a step size of $\Delta \Theta = 0.0002^\circ$. The X-ray polarization vector was parallel to the sample surface. In addition we installed a one-dimensional spatially resolving detector in order to measure the distribution of diffuse scattered X-rays. The detector covered a range of 3.8 $^\circ$ in the vicinity of the 1\textsuperscript{st} Bragg maximum. We then repeated the measurement for Mo/B\textsubscript{4}C at 8 keV photon energy.

The results shown in Fig. 1 suggest that the samples are of high quality and are very suitable for our further intended investigations. Except for W/B\textsubscript{4}C, the angular resolution is below 0.3 % and, hence, the multilayers provide a spectral resolution of the same magnitude. The measured angular resolution for W/B\textsubscript{4}C is about 0.6 %. Reflectivity maxima strongly depend on the photon energy and range from approximately 45 % to above 75 %.

Additionally, reciprocal space mapping at E=8keV were carried out on the Mo/B\textsubscript{4}C sample (Fig.2). The MYTHEN linear position sensitive detector was used for this type of measurements. The obtained data will be used to monitor through diffuse scattering the possible effects of high heat load on the interface of the layered structure.

![Image of Fig. 2: Distribution of scattered radiation in a range of 3.8 $^\circ$ in vicinity of the 1st order maximum versus the grazing angle $\Theta$ for the Mo/B\textsubscript{4}C multilayer at 8 keV radiation.]

In forthcoming experiments we plan to study the effects which annealing as well as radiation exposure can have on reflectivity and resolution. Also we intend to perform further reciprocal space mapping measurements to gain a better insight into the origin of diffuse scattering in multilayers produced by magnetron sputtering.

**References**