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INTERACTION OF MULTILAYER OPTICS WITH INTENSE FEMTOSECOND XUV PULSES

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Multilayer coated optics are used for control of XUV and soft X-ray radiation in many fields of science and technology, and has experienced a considerable boost of technology due to the application in advanced photolithography. A new field is the application in experiments at short wavelength Free Electron Lasers. This includes the x-ray sources – LCLS (USA), XFEL (Europe) & SPRING8 (Japan) and the XUV source – FLASH (Germany), ELETTRA (Italy). Multilayer coated optics are most promising candidates for optical schemes at such sources, fulfilling extreme requirements in terms of figure and roughness errors, wavefront preservation, and stability. It enables deflection angles much larger than those reasonably achieved with monolayer mirrors. In addition, due to its good wavelength selectivity, it can be used as a narrow band filter.

The photon flux from short wavelength Free Electron Lasers is extremely high. In the case of FLASH, operating in the XUV regime the ~10 fs long pulses can have energy of up to 50 µJ, corresponding to 10^{11} W/cm^2 for a 4 mm beam spot on the optics. This is at least 10 orders of magnitude higher than in the case of lithography. Damage or even destruction of the optics can be expected. Moreover, for some application the mirrors have to be placed in the focused beam. In this case the intensity on the optics is even higher and can reach 10^{14} W/cm^2. Under such conditions the optical properties of the reflecting elements would be changed already during the pulse and the mirror would not work. These two effects, permanent damage of the coatings and change of the optical properties of materials under high intensity XUV irradiation, can limit the performance of the multilayer optics.

We have carried out research on the flux resistivity of a standard MoSi multilayer for a wavelength range in the soft X-ray / XUV part of the spectrum by means of exposures at FLASH. Samples were irradiated at different intensity levels with single shots. Morphological and structural surface changes were measured with phase-contrast microscopy, atomic force microscopy and scanning transmission electron microscopy. The dynamics of damage were studied by means of time resolved microscopy. The damage mechanisms was determined as an ultrafast silicides formation induced by enhanced diffusion in a melted Si layer.

The other operating regime where multilayers can be used is when the coating reflects only during the pulse (and is possibly damaged shortly after): the range of single shot optics. However, under irradiation with ultrashort intense pulses the mirror reflectivity can decrease even within the timeframe of the fs pulse due to the change of the layers' optical properties – namely the real and imaginary part of the refractive index. The responsible physical process is a strong electron gas excitation during the pulse [1] which depends on the structure of the multilayer and materials used. The phenomenon was studied by means of angular resolved reflectivity measurements at different intensities.

The results will be used as input for the further development of multilayer coatings for the short wavelength FEL optics.

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