Irradiation damage test of Mo/Si, Ru/Si and Nb/Si multilayers using the Soft X-ray laser built at QST

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Abstracts: *The irradiation damage tests for Mo/Si, Ru/Si and Nb/Si multilayer were carried out using X-ray laser generation system built at QST. The created damages were observed by a scanning electronic microscopy and an atomic force microscopy. These observations show that the damage size of Nb/Si multilayer is smaller than the others. This result indicates that Nb/Si is superior than the other multilayers for irradiation damage and thus X-ray multilayer.*

Mo/Si multilayer is one of the most important because of their expected applications for the next generation lithography method, i.e., EUV lithography where the wavelength of 13.5 nm would be used. Recently, the 13.5nm EUV light sources, such as laser produced plasma or X-ray free electron laser, become to have higher output powers and fluences. The high power light sources are effective for high throughput of EUV lithography, but they also make serious problem for damages of Mo/Si multilayer mirrors. These damages are reducing the reflectivity or lifetime of EUV multilayer mirror, resulting in the performance deterioration of the production or measurement using these mirrors and sources. Therefore, the information of damages is important for practical use of Mo/Si multilayer and the future development of high resistance EUV multilayer mirror.

In order to reveal irradiation damage for Mo/Si multilayer, the X-ray laser irradiation system build at Japan Atomic Energy Agency was used. This experiment system has the features; (a) the short time scale for 7 pico-second, (b) narrow bandwidth of ~10^{-4}, (c) small divergence beam and (d) highly brightness. Since the system has an Ag target, 13.9nm EUV light is produced.[1] This system was already used for the observation of irradiation damages of some materials.[2, 3]

The irradiation damage test is applied to Mo/Si, Ru/Si and Nb/Si multilayer. Mo/Si multilayer is usually used around the wavelength of 13.5 nm, and the others are also candidate multilayers for same wavelength. The EUV lights that have fluences of 10-30 mJ/cm^2 are entered into these multilayers.

The damages by irradiations were studied using a scanning electronic microscopy (SEM) and an atomic force microscopy. In these observations, the irradiation damage size of Nb/Si multilayer is smaller than that of the others. This result indicates that Nb/Si multilayer has higher resistance than Mo/Si and Ru/Si multilayer for the higher fluence EUV light.

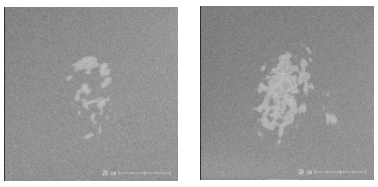

Fig. SEM image for irradiation damages of Nb/Si multilayer (left) and Mo/Si multilayer (right)

1. M. Nishikino et. al., Appl. Opt., 48, 29, 5464, 2009
2. M. Ishino et. al., J. Appl. Opt., 109, 013504, 2011
3. M. Ishino et. al., J. Appl. Opt., 116, 183302, 2014