Interaction of powerful plasma jets with Mo/Si multilayers

Abstract. The paper presents some results of experimental studies of Mo/Si multilayer degradation under UV exposure from compressed plasma jets in air. Such high current plasma flows generate broadband powerful UV radiation fluxes. A single exposure caused a slight decrease of reflectivity from 0.54 to 0.47 due to the coating contamination by the debris from the plasma light emitter.

1. Introduction

The high current emitters based on compressed plasma jets are sources of powerful broadband radiation (with fluxes of $\approx 10^{20}$–$10^{22}$ photon/s per a single pulse) [1]. Ponderomotive forces lead to formation of a high temperature plasma focus with a brightness temperature of $\approx 30$–100 kK [2]. The maximal spectral brightness lies within the range of $\approx 30$–100 nm. Operation of the minimal wavelength is possible by a choosing of background gas in the discharge chamber [3]. The presented emitters can be a basis of novel systems for EUV lithography.

Mo/Si multilayers are used as mirrors for transport of EUV/VUV fluxes from the emitters to the irradiated surface [4]. We note that such bilayers can degrade due to coating contamination, partial evaporation, etc. The previously reported study presented some results of temperature damage of Mo/Si bilayer with formation of molybdenum silicides [5]. The high pressure plasma light sources emit such high broadband radiation fluxes which are characterized by a global temperature and stress fields in the irradiated substrates. A complex nature of interaction (mechanical impact, VUV exposure) provides a lot of transformation processes including morphology changing, chemical reaction, surface degradation etc. This can decrease reflectivity and reduce the mirror quality. So, the aim of the present study is experimental evaluation of degradation efficiency.

2. Experimental procedures

Mo/Si multilayers were prepared by magnetron sputtering on fused silica bars (15×8×3 mm). The corresponding experimental vacuum setup is presented in figure 1. A total thickness was 3420.0 nm. Bilayer thickness was 11.4 nm at the bilayer number of 300.

Irradiation of the Mo/Si multilayers was carried out with a coaxial plasma accelerator – magnetoplasma dynamic compressor with a capacitive source. This is a high current ($I>100$ kA) setup which generates strong shock waves, high brilliance EUV/VUV radiation fluxes (with a brilliance
temperature of \(\approx 30\)–100 kK) etc. The samples were installed in the chamber which was fulfilled by a background gas (neon and air). Pressure in the chamber was \(\approx 300\)–400 torr. A single radiation exposure was studied. A stored energy in the capacitor was \(\approx 3.6\) kJ. The original and irradiated coatings were studied with X-ray reflectometry (XRR, CDP systems, Moscow) and electron microscopy (TESCAN VEGA 3 XMU, Czech Republic) with a system of energy dispersive spectroscopy EDX (AZTEC Energy Analysis System). Interpretation of XRR spectra was made with the technique [6].

Figure 1. Experimental setup for Mo/Si multilayer preparing

3. Results and discussion
UV/VUV exposure in neon with the maximum quanta energy of 21.56 eV (discharge in neon) led to a significant surface degradation [1]. Surface erosion was detected. The coating was damaged. But no changes were detected for irradiation by soft quanta for discharge in air (\(\approx 6\) eV). Figure 2 presents XRR spectra of original and Mo/Si multilayers irradiated in air. We found that even a single exposure in air led to a slight decrease of reflectivity from 0.54 to 0.47.

Figure 2. XRR spectra of original (red) and irradiated in air (violet)
Such degradation was caused by a local damage of the surface by molten debris from electrodes. But sufficient changes of Mo/Si bilayer thickness were not found. The typical EDX spectrum of irradiated in air Mo/Si multilayers is presented in figure 3. This contains the spectral lines of Fe, Cr and Ni. Their appearance was caused by contamination of condensed vapors which were generated by electrode evaporation.

**Figure 3.** EDX spectra of Mo/Si multilayer irradiated in air

### 4. Conclusion
Coaxial plasma accelerators (so called magneto plasma compressors) are sources of strong shocks and broadband radiation (including hard UV and VUV quanta). Irradiation of materials (including thin multilayers) leads to a complex of phase and chemical transformations and modification. Exposure of powerful UV/VUV radiation in air (with a maximal energy of ≈6 eV) caused minimal changes in the studied Mo/Si multilayers. As found, a single exposure decreased a reflectivity from 0.54 to 0.47 due to surface damage by debris emission and vapor condensation.

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