Extreme Ultraviolet Optical Coatings Development at LUXOR

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Recent results obtained at LUXOR on the development of a-periodic ML coatings for applications in EUV lithography, space science, and atto-science are shortly presented. In addition to this characterization techniques of the designed structures developed in order to recover both secondary electron photoemission and phase are described.

1 Introduction

The development of optical coatings for EUV is based on multilayer (ML) structure designs. Typically these structures correspond to periodic deposition of thin layers of different materials in order to get constructive interference among the different reflected components at various interfaces. For this reason these structures show a spectrally narrow reflectivity curve. The a-periodic design has opened the window on the possibility of tailoring the performances of the ML according to various experimental requirements. In this paper we report on the design and deposition of a-periodic structures in order to get high reflectivity, stable even in an aggressive environment, like for EUV photolithography, or to efficiently reflect some spectral band while rejecting some others or capable of reflecting without distortion or even to compress ultrashort pulses down to attosecond duration.

2 ML structure design

An optimization procedure has been developed to select structures having for example**:** best peak reflectivity (for one or more reflections), or large spectral bandwidth (for one or more reflections)**,** or the best match with spectral source distribution and or specific phase properties. The optimization is made by defining a suitable merit function, MF. The optimization procedure is based on an algorithm able to acquire domain knowledge based on the merit function values. Computation and optimization take into account roughness at interfaces, inter-diffusion between layers, roughness at the substrate, and can include any other parameter related to a real deposited multilayer structure. Resulting structures are characterized by having aperiodic design, i.e. thickness layer varying with depth[1]. When the EUV radiation interacts with the structure, the superposition of the incident and reflected electromagnetic waves generates a standing wave field distribution in the ML. An aperiodic design allows the regulation of the distribution of this field, attributing specific properties to the ML.

3 MLs for EUV lithography

The MF used to maximize the EUV lithographic apparatus flux is $\int I(\lambda)R(\lambda)^{10}d\lambda$ where $I(\lambda)$ is the intensity distribution of the source, $R(\lambda)^{10}$ is the reflectivity of a ten reflective elements optical system. The results have been experimentally tested showing that structures insensitive to the optical properties of the capping layer and with double efficiency compared with a standard periodic one, for a ten element system, can be realized [2, 3].

4 MLs for solar physics

Solar emission lines correspond to different plasma parameters. For example Fe-IX/X @17.1 nm (T=0.6-1.0 106 K), Fe-XII@19.5 nm (T=1.5 106 K), Fe-XV@28.4 nm (T=3.25 106 K), He-II@30.4 nm (T=0.08 106 K). For this reason imaging spectroscopy is a valuable technique to address various fundamental problems concerning several physical processes in the Sun, like CME's, solar wind acceleration etc. To get an image at 28.4 nm it is necessary to avoid the contamination of the detected signal due to the nearby strong 30.4 HeII line. By a suitable design of a periodic ML structure optimized at 28.4 covered with a capping layer designed to absorb the 30.4 line, the possibility of obtaining high reflectivity peak coupled with strong rejection has been proved [4].

5 Multilayer for atto-physics

Design and deposition of a-periodic Mo/a-Si multilayer with specific reflectivity and phase characteristics, able to compensate a Gaussian pulse with a bandwidth of 30 eV and a phase chirping of 0.3 fs^2 have been realized. It has been demonstrated that pulses of 450 as, can be compressed up to 130 as. Such structure can reflect and synchronize the odd order harmonics spanning from 49 to 67 in the case of HOH generated by the interaction of Ti:Sa fs laser pulses with gas-jet [5, 6].

6 Characterization techniques

The Total Electron Yield (TEY) data is proportional to the standing wave pattern and consequently to the multilayer phase according to

$$TEY(E) \approx \left(1 + R(E) + 2\sqrt{R(E)}\cos\phi(E)\right)$$

The TEY method proposed is insensitive to the materials irregularity present on the multilayer surface due to oxidation or carbon film formation/modification on top of the ML [6].

The oxidation of a ML for EUVL depends on the interaction between EUV photons and the multilayer material, which creates secondary electrons in the top layers of the multilayer [7]. In fact, oxidation process can be attributed mainly to secondary electron, therefore structure with lower SEY signal should be more stable with respect to oxidation. We have experimentally proved that the design proposed has a lower SEY compared with standard periodic design [2].

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