Asymmetrical diffusion at interface of Mg-based multilayer films

Jingtao Zhu1, Haochuan Li1, Zhanshan Wang1, Karine Le Guen2, Philippe Jonnard2

1 MOE Key Laboratory of Advanced Micro-structured Materials, Institute of Precision Optical Engineering, School of Physics Science and Engineering, Tongji University, Shanghai 200092, China
2 Laboratoire de Chimie Physique – Matière et Rayonnement, UPMC Univ Paris 06, CNRS UMR 7614, 11 rue Pierre et Marie Curie, F-75231 Paris cedex 05, France

Multilayer mirrors have been widely used as reflective element in the extreme ultra-violet (EUV) and soft x-ray regions. Interfacial diffusion is one of the most efficient defects that will reduce the reflectance. However interfacial diffusion in these nanoscale multilayers is a phenomenon not as well understood as diffusion in bulk materials. In this report, interface structure of Mg-based multilayer films as EUV reflectors has been studied. We deposited a series of multilayers with the structure of [X1/Mg/X2]×5 (X1,2 = SiC, Si, and C). The nominal thickness of Mg is 5.0 nm and that of X1,2 is 2.5 nm. All multilayers were deposited onto polished Si (001) wafer at ambient temperature by direct current magnetron sputtering. The pressure of residual gas before deposition was 5.0×10^{-5} Pa and that of sputtering gas Ar was 0.13 Pa. X-ray grazing reflectivity (XRR) measurements were made for each sample using Cu Kα source (λ = 0.154 nm) to determine the multilayer structure (Fig.1). The measured curves were fitted to obtain the interface width. X-ray photoelectron spectroscopy measurements were carried out for the three [X/Mg/X] multilayer samples. Depth-profiles were obtained by Ar etching. Transmission electron microscopy (TEM) measurements were carried out for another three [X/Mg/X] multilayer samples having the same structure with the period repeat number N=80. The cross-section samples for TEM were prepared by focused ion beam etching. X-ray diffraction measurements in the symmetric (θ–2θ) geometry were performed using Cu Kα source (λ = 0.154 nm). The experimental results show that asymmetry is found on the interlayer thickness at all three interfaces. The thickness of the interlayer at Mg-on-Si (>7 nm) and Mg-on-C (>5 nm) is larger than that at Si-on-Mg (3 nm) and C-on-Mg (2.5–3 nm). In the Mg/SiC multilayer, opposite asymmetry is found as the thickness of the interlayer at Mg-on-SiC (1 nm) is smaller than SiC-on-Mg (2.5 nm). Based on the XRD, XPS and TEM measurement results, different mechanisms for interfacial diffusion are proposed. These results are not only of fundamental importance in understanding the nanoscale interfacial diffusion but are also beneficial for improving the performance of Mg/SiC multilayers as EUV reflector by means of inserting diffusion barrier layers.

Fig. 1. XRR measured and fitted curves of [X1/Mg/X2]×5 multilayers.

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