Optical performance, structure and thermal stability of Al/Zr multilayers designed for the 17–19nm range

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Abstract
We report on the optical performance, structure and thermal stability of periodic multilayer films containing zirconium (Zr) and silicon doped aluminum (Al(1%wtSi)) or aluminum (Al(pure)) layers designed for use as extreme ultraviolet (EUV) high reflectivity mirrors in the range of λ=17–19nm. The comparison of Al/Zr (Al(1%wtSi)/Zr and Al(Pure)/Zr) multilayers fabricated by direct–current magnetron sputtering shows that the Al(1%wtSi)/Zr multilayer have the lowest interfacial roughness and highest reflectivity, which also presents good thermal stability in the EUV region. However, there is a large difference between the theoretical and experimental reflectivity of Al(1%wtSi)/Zr multilayer. Transmission electron micrograph images reveal that the interfacial roughness is associated to the Al and Zr crystallites. For less than 40 periods in the multilayer, the roughness components are smaller. For more than 40 periods, both surface and interfacial roughness increase with the period number. Based on the X–ray photoelectron spectroscopy, the interface consists of an amorphous Al–Zr alloy owing to large interdiffusion between Al(1%wtSi) and Zr layers. From fits of the EUV reflectivity curves, we found that four factors are responsible for the loss of reflectivity the inhomogeneous crystallization of aluminum, contamination in the multilayer, surface oxidized layer and interdiffusion between Al(1%wtSi) and Zr layers. The thermal stability of Al(1%wtSi)/Zr multilayers is checked by annealing at temperatures from 100 °C to 500 °C in a vacuum furnace. The presence at the interfacial aluminide is detected by x-ray emission spectroscopy. As the results of grazing incident X–ray reflection show, the Al(1%wtSi)/Zr multilayers annealed up to 200 °C maintained the same initial multilayer structure as the as-deposited sample. From 300 °C, the amorphous Al–Zr alloy has transformed to the polycrystalline ZrAl15 alloy in the interface, but do not destroy the multilayer structure completely.