Mo/Si Multilayers for 13 nm Spectral Region

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We have studied dc and rf magnetron sputtered Mo/Si multilayers as promised candidates for the EUV-lithography. For their studies, the various methods were used such as cross-section transmission electron microscopy (TEM), small angle diffraction (SAD) of hard X-rays (λ Cu K_{α}=0.154 nm), soft X-ray (13 nm) reflectometry, high-resolution Auger depth profiling, and AFM.

TEM has been used to study the correlation between growth conditions and a local structure of multilayers. Since silicon wafers were used as substrates for Mo/Si mirrors, to prepare cross-section TEM objects we applied the cleavage technique, which based on the ability of crystal to split mainly along cleavage planes. This preparation method offers the opportunity to characterize many specimens for a short time and does not damage the sample structure.

During TEM investigations of cross-sections we found that our multilayers consist of polycrystalline metal layers separated by amorphous silicon in the all range of growth conditions. Under a small deposition rate, Mo layers have nonoriented fine-grained polycrystalline structure, and sizes of crystals significantly smaller the layer thickness. The increase in deposition rate of Mo induces enlargement of Mo crystals as well as their alignment to axial texture with the axis [011] directed perpendicularly to the film plane. A striking feature of the multilayers is a seen asimmetry of the interlayers between Mo and Si so that the interlayer width on the interface of Mo on Si is larger than that of Si on Mo.

The TEM observation of asymmetry in Mo/Si multilayers is supported by our SAD spectra. The simplest model of a multilayer is rectangular electron density profile with the interfacial roughness distributed in accord with the normal law, and all the interfaces are identical. However, SAD spectra of real multilayers can not be explained in frameworks of such a model. We have assumed that the observed discrepancy can be caused by difference in the interfaces that were formed by deposition of Mo on Si and Si on Mo. Such assymetry was earlier revealed both experimentally [2] and theoretically [3]. We have verified these data by using SAD spectra. In the case of the identical interfaces and the equal Mo and Si thickness (h_{Mo}/d=0.5, h_{Mo} is the thickness of Mo layers, d - period), the X-ray intensity of the odd diffraction orders (m=2,4,..) must be equal to zero. In order to verify such a SAD spectrum behavior, we have prepared a series of the Mo/Si multilayers that have the periodicity of 7.0 nm   the number of layer pairs of 10. We followed by the behavior of the X-ray intensity in the second diffraction order in dependence of h_{Mo}/d in vicinity of 0.5. The values of h_{Mo}/d were controlled both by ratio of second and third order intensities and by the measurement of the total external reflection angle [1]. The observed difference between experimental and theoretical dependencies indicates asimmetry of the interfaces. Bearing in mind the results of TEM, we estimated the width of the alloyed layer that results from Mo deposition on Si. This estimate is based on the assumption that, under Si deposition on Mo, the ideal interface forms while the electron density on the other interface is a linear function of coordinate. The estimations show, that the observed intensity in the second order corresponds to 0.7 nm. Such estimate well agrees with the results of [3] as well as our TEM data.

The work was supported by the contract with firm Carl Zeiss and grant INTAS #96-2102.

References

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