Influence of ion beam irradiation on the structure of Ni/C multilayer during etching

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The purpose of this work is to specify the degree of ion beam influence during ion etching of super-thin films of Ni and C in multilayer fabrication process. The multilayers were fabricated by alternative deposition of Ni- and C-layers from e-beam evaporation sources onto Si-substrates. For etching we used Kr^+ ions (E = 300 eV, α = 45°). An *in situ* control of the layer thickness during deposition as well as etching was achieved by interference of reflected x-rays (N$K\alpha$ radiation, angle of incidence 25°). Studied samples consisted of 10 periods with approximately the same periodicity of ~ 4 nm. All fabricated multilayers were also characterized by diffraction using Cu$K\alpha_1$ radiation (λ = 0.154 nm).

We started to investigate the effect of "polishing" applied to Ni as well as C. During fabrication of these Ni/C multilayers as a rule 1 - 4 nm of excess carbon or nickel were deposited and removed with ion beam. In all cases when Ni films were etched, smoothing of Ni layer surface was observed. Etching of C layer turned out to result in roughening of the carbon layer surface. Development of the C layer surface roughness during etching has turned out to practically compensate the smoothing effect of Ni layer surface in such way that reflectivities of etched and non-etched multilayers are the same in both hard and soft X-ray regions. For all samples after deposition of first 5-6 periods a noticeable (1.5 - 2.0 times) development of the roughness towards the multilayer surface is observed. Mean multilayer roughness changes from 0.5 to 0.6 nm if Ni- or C-layers are etched only, correspondingly.

We continued our experiments by investigating ion induced interface damage caused during the nickel etch process. In these experiments we kept the periodicity constant and we reduced the nickel layer thickness by variation of the Ni / C ratio (β_{nom}) per period from 0 - 0.5. The deposited excess nickel layer thickness was chosen to allow a following etch procedure to remove ~ 4 nm for all substrates. For the case of $\beta_{nom} \to 0$, this corresponds to a deposition of 4 nm carbon, followed by the deposition of 4 nm nickel and removing the complete deposited nickel layer. Here results measured using soft and hard X-rays differ significantly. Resulting reflectivity at λ = 3.16 nm is a monotonic function of β_{nom}, and the multilayer reflectivities differ 30 times for the extreme values of β_{nom}. Hard X-ray measurements show much lower reflectivity scale for studied samples ranging 2.5 times only. Multilayer with β_{nom} ~ 0.5 and β_{nom} ~ 0.15 demonstrate almost the same reflectivity (6.6 and 7.2 %, correspondingly). More than 10% difference in period values is observed for the Ni/C multilayers with β_{nom} ~ 0.5 and $\beta_{nom} \to 0$. Analysis of reflecting curves at λ = 0.154 nm showed that up to 30 vol. % of Ni could be present in the multilayer samples with $\beta_{nom} \to 0$. Intermixing mechanisms at the boundary of thin film of Ni and C are discussed.

This work is supported by EC project INTAS 96-0128.