The influence of Mo crystallinity on diffusion in Mo/Si multilayers upon thermal annealing

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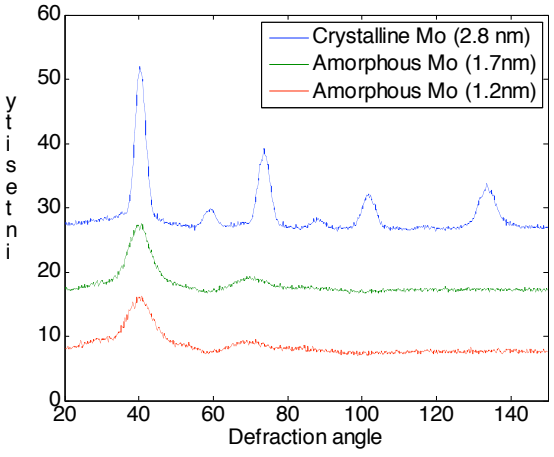
Mo/Si multilayers are being developed for optics to be used at 13.5 nm in EUV projection lithography. Fundamental thin film properties such as layer crystallinity, density and roughness play an important role in determining critical multilayer parameters such as peak reflectance at 13.5 nm, and thermal stability under EUV exposure. It has been shown that the Mo layers crystallize above a thickness of approximately 2 nm. The thickness of the as deposited interlayers is dependant on the structure of the Mo in the multilayer. When Mo is crystalline, the Mo-on-Si interface is thicker than the Si-on-Mo interface, but they are equally thick when Mo is amorphous.

The asymmetry in diffusion speeds at the interfaces during layer deposition that results in asymmetric interfaces has also been shown to lead to asymmetric growth of the interfaces upon thermal treatment. When Mo is crystalline the diffusion through the thick Mo-on-Si interface is faster than that trough the thin Si-on-Mo interface. By blocking either of the interfaces with a diffusion barrier (B_4C) we confirm asymmetric intermixing speeds, but also show that this asymmetry is *not* present when Mo is amorphous.

Figure 1a shows WAXRD (wide angle x-ray diffraction) spectra taken from Mo/Si multilayers with different Mo thicknesses. The difference between samples with amorphous or crystalline Mo layers can clearly be observed. In Fig. 1b the period change upon sequential annealing at different temperatures is shown. It is clearly seen that the period change is equal for B_4C on one or the other interface in the case of amorphous Mo and asymmetric in the case of crystalline Mo, suggesting that diffusion is equally fast through both interfaces in the case of amorphous Mo, but faster trough the Mo-on-Si interface in the case of crystalline Mo. We explain this by assuming that diffusion through amorphous materials is faster than through a crystalline material. In the case of crystalline Mo, in the first stage of Mo growth the Mo is still amorphous (it crystallizes after 2 nm), allowing faster diffusion through the Mo-on-Si interface. At the top of this layer the Mo has crystallized, which makes diffusion through the top layer slower.



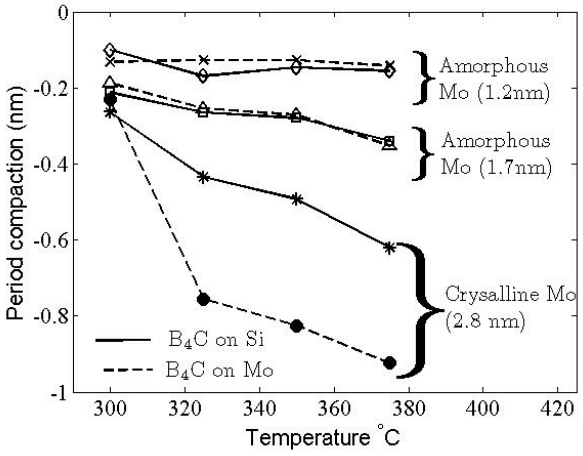


Figure 0a: WAXRD spectra of crystalline and amorphous samples.
Figure 1b: Period compaction after annealing sequentially to the temperatures indicated.