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http://lcpmr.cnrs.fr/content/interfaces-mutimatériaux-sources-et-optique-x

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Report on PhD manuscript "Formation of an interface in multilayer Mo/Si and Mo/Be nanostructures: the effect of barrier layers and annealing temperature on its composition, extension, and reflectivity of mirrors" by Gaisin Aidar URALOVICH.

The work concentrates on the characterization of innovative periodic multilayers designed as optical components for the soft x-ray and extreme UV ranges. Many multilayers have been developed in the past and continue to be developed nowadays, but most often their design relies on some recipes. Because the optical properties of these systems depend heavily on the quality of their numerous interfaces, it is a good to develop a knowledge-based approach, as it is explained in this manuscript, so that the properties can be anticipated from the interface characterization.

In the Introduction, the candidate presents his work and the scientific motivation. This is clearly done and the reader can appreciate the work to be presented in the following of the text. The presentation could have been more general, for example discussing other methods enabling the study of deep interfaces between nanometer thin films or considering other systems of thin films.

Chapters 1 and 2 present the physical principles regarding the use of the multilayers and about x-ray photoemission spectroscopy which is thoroughly used throughout this work. The instrumental details are also given and demonstrate that the candidate used state of the art apparatus for the deposition of the samples and their characterization. In the following chapter, the methodology to estimate the interface thickness and their composition is explained and first application is performed on bilayer stacks (multilayers with only one period) and on periodic multilayers. At this occasion, the asymmetry of the Mo-Si interfaces and the presence of beryllides in the Mo-Be multilayers is demonstrated. My main concern is the fact that the work strongly relies on the decomposition process of the XPS spectra, but that this process is hardly described in the text. For example, a better explanation of the calibration of the binding energies with those of the literature enabling to ascribe the chemical state of the considered atoms or a better description of the instrumental uncertainties together with those coming from the decomposition procedure, would have made the reader much more confident to the given compositions of the interphases and to the existence of the low-intensity components of the XPS peaks.

In Chapter 4, the candidate is making interface engineering to try improving the structural and optical properties of the considered multilayers. This is done by introducing at interfaces some very thin films of a third material, which should play the role of a diffusion barrier and

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help to obtain abrupt interfaces. The considered materials are Be (in Mo/Si), Si (In Mo/Be) as well as boron carbide. It is clearly demonstrated through the decomposition of XPS peaks that this strategy can minimize the formation of interfacial silicides in Mo/Si systems and beryllides in Mo/Be systems. However, in this last case some other compounds can form. Finally, the reflective properties of the multilayers do not change so much upon such introduction of diffusion barriers.

The stability of the multilayers is an important property of such devices frequently used in harsh environments. Thus, it is wise to characterize the interfaces of the Mo/Be multilayer as a function of the annealing temperature and to try correlating with the optical properties as is done in Chapter 5. At this occasion, the candidate also studies the effect of annealing on multilayers with diffusion barriers, developed in the previous chapter. As expected, it is found that the heat treatment leads to the increase of the content of interfacial beryllides and that all the Mo layers can be consumed in this process at the highest temperatures. The beneficial effect of the diffusion barriers is demonstrated by showing that the multilayer can keep most of its reflectivity up to 300°C, while it is limited to around 200°C with barrier layers.

The Conclusion chapter is a mere abstract of the work presented in the previous chapters. It would have been nice to find some perspectives regarding the future possible applications of the studied multilayers, with and without barrier layers, as well as regarding the use of x-ray photoemission for the study of thin films and their interfaces.

Finally, I would like to stress the strategy of the candidate who to better analyse periodic multilayers, first study simpler systems with only one, two or three periods. This led to a considerable number of samples and to numerous XPS analysis, which Mr. URALOVICH performed with rigour and method, and a convincingly presented in a clear way. Owing to the quantity, quality and scientific interest of the presented work, I think that Mr. URALOVICH has written a manuscript worth of a PhD degree and that he deserves the obtention of such a degree.

Dr. Philippe JONNARD