Characterization of chemical processes and interfacial diffusion in Pd/Y multilayers using HAXPES induced by standing waves

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Introduction

We characterize Pd/Y multilayer and several derivative systems [1] for the development of new optics designed to work in λ=7.5-11 nm range based on multilayer coatings. Samples were measured using hard x-ray photoemission spectroscopy (HAXPES) combined with x-ray standing waves [2]. Investigation of the structure of the samples and the relation to the experimental performance will help optimize the deposition process and improve the optical properties of the multilayer mirrors. The positioning of x-ray standing waves enhancement for the emission is realized by rotating the grazing incident angle around Bragg angle.

SUBJECT SYSTEMS

Design goal

High reflective mirror working in 7.5 – 11nm range for X-UV scientific instruments deposited on Si substrate.

Sample Structure	Period (nm)	Pd (nm)	Y (nm)	B_4C (nm)
$[Pd/Y]_{40}$ + B_4C cap	4	2	2	2.5

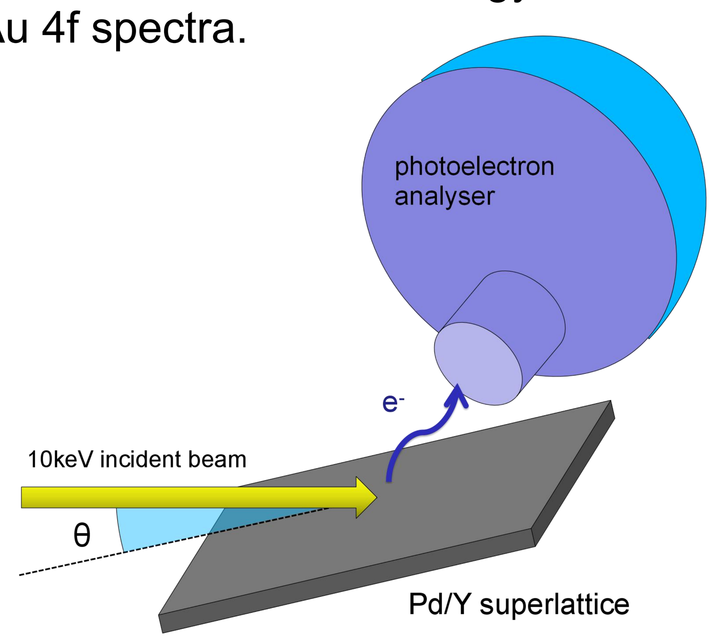
To reduce inter-diffusion and improve thermal stability, derivative systems are also studied.

- **B_4C** barrier layer is applied (1 or 2nm, located either on Pd-on-Y interfaces or Y-on-Pd interfaces).
- **N_2** is introduced into Ar sputtering gas during the deposition process (2%, 4%, 6%, 8%).

EXPERIMENTAL DETAILS

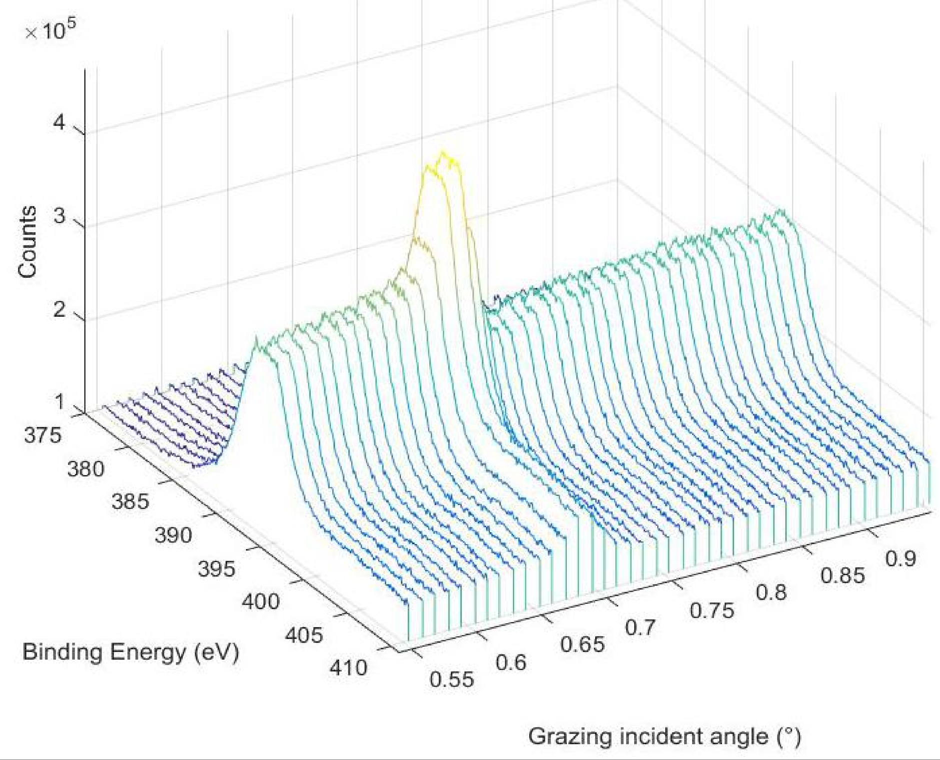
Experimental setup

The positioning of x-ray standing waves enhancement for the emission is realized by rotating the grazing incident angle around Bragg angle. The energy of the incident beam is 10keV. Energy calibration is carried out with Au 4f spectra.



Variation of photoelectron count as a result of XSW enhancement.

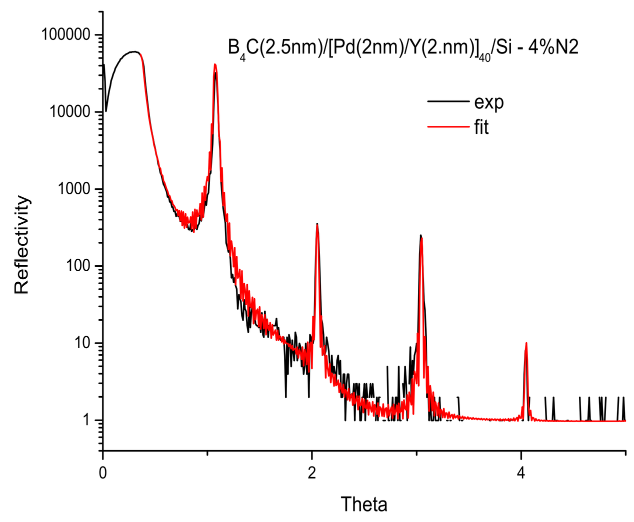
The figure below gives an example: variation of N 1s spectra of the sample $[Pd/Y]_{40}$+B_4C cap deposited in Ar and 4% N_2 as the grazing incident angle moves through its Bragg angle.



METHODS

Highlights

❖Grazing Incident X-ray Reflectometry (GIXR).
The physical structure of the sample was predetermined by GIXR.



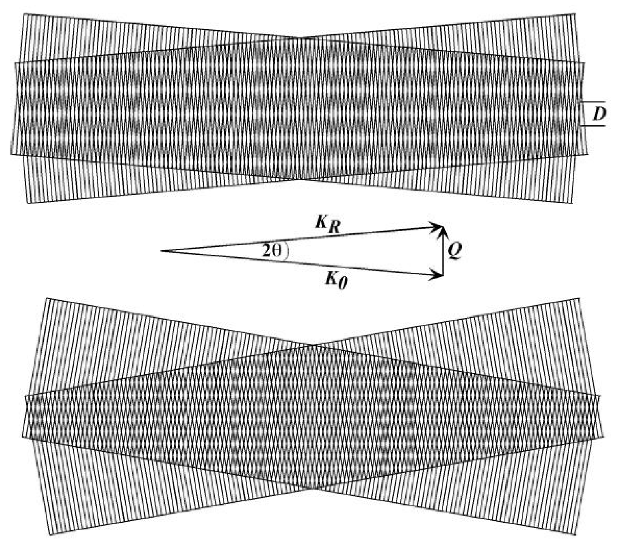
$[Pd/Y]_{40}$ + B_4C cap	Period (nm)	Pd (nm)	Y (nm)	B_4C (nm)
Designed	4	2	2	2.5
Determined	4.51	2.25	2.26	2.74

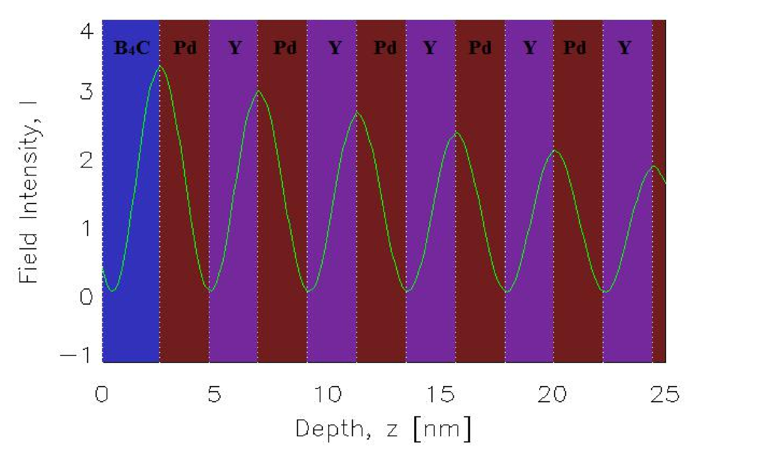
GIXR and fitting result of a Pd/Y multilayer deposited with Ar and 4% N_2 as sputtering gas.

❖Hard X-ray Photoelectron Spectroscopy (HAXPES).
Study of the chemical states within the stacks.

❖X-ray Standing Wave (XSW)
Sensitive to interfaces. D=period of the stack (scan around Bragg angle).

$$D = \frac{\lambda}{2\sin\theta} = \frac{2\pi}{Q}$$



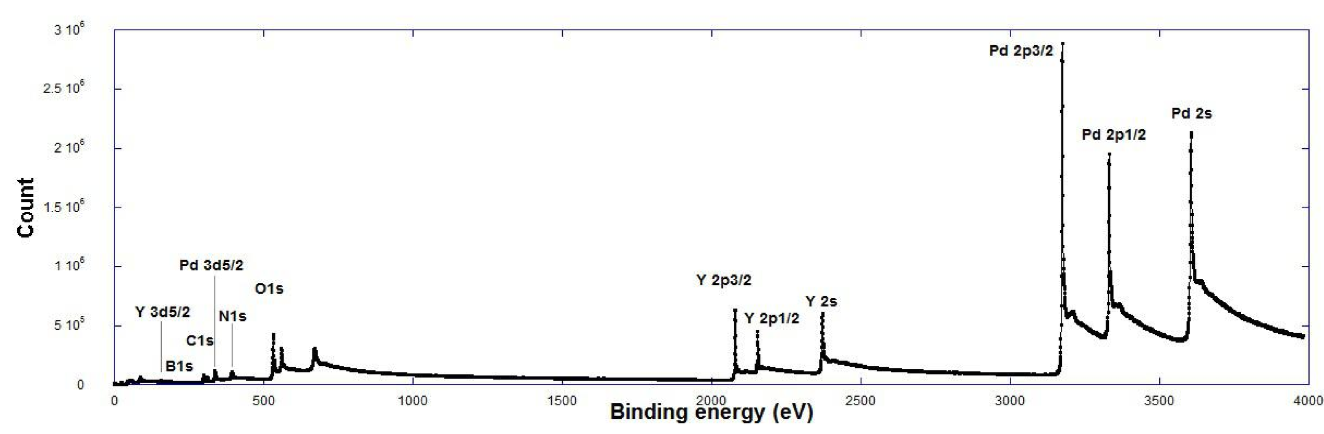


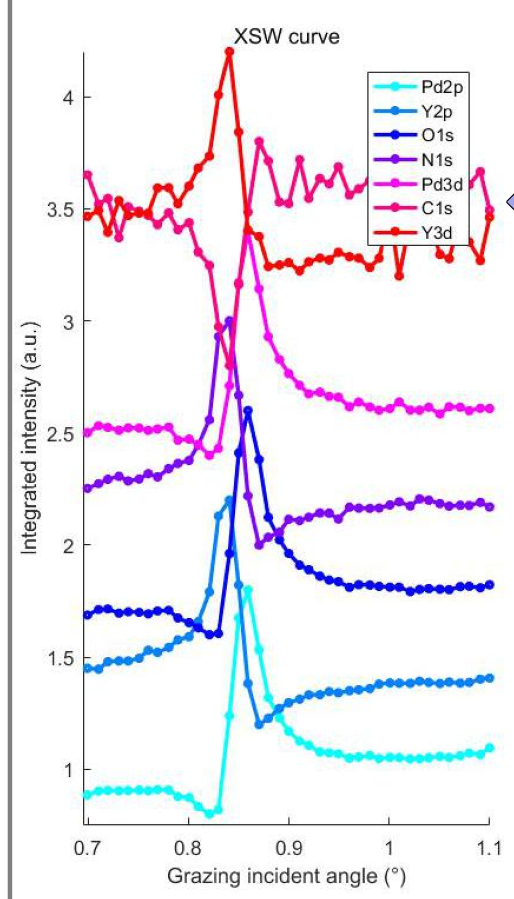
Simulation of the electric field of the same sample described above under 10keV irradiation. Grazing incident angle is set at its Bragg angle.

RESULTS

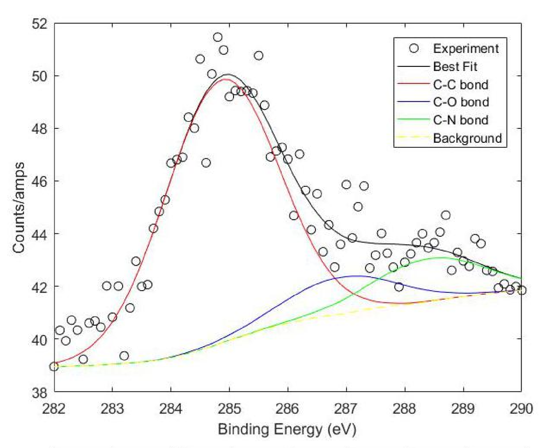
Results

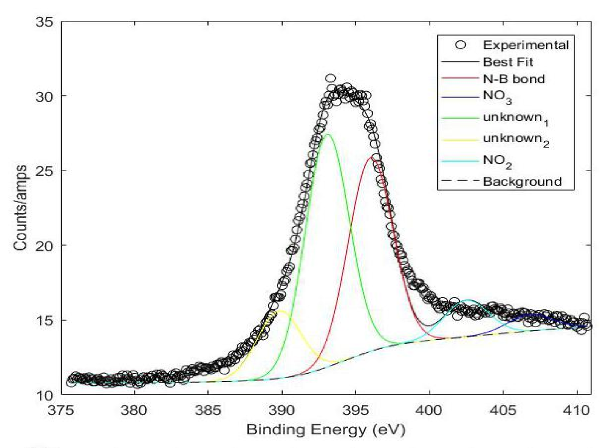
In this section we present an example: the sample $[Pd/Y]_{40}$+B_4C cap layer deposited in Ar and 4% N_2. Photoelectron of Pd2p, Pd3d, Y2p, Y3d, O1s, N1s, C1s are measured. Overview of a single spectrum is shown in the figure on the right.



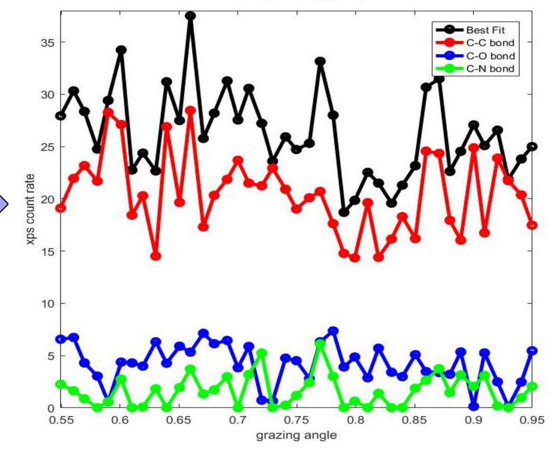


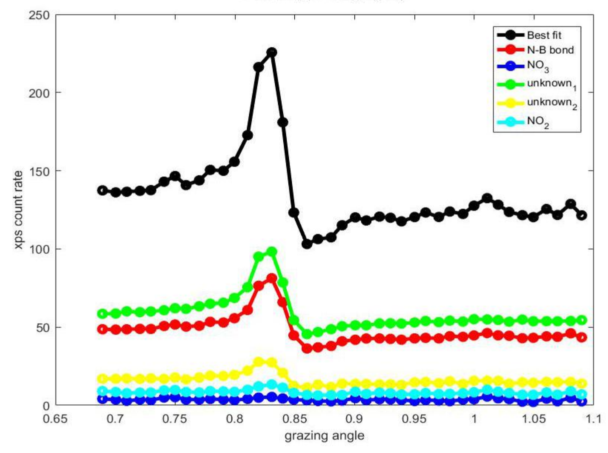
XSW curves give information of elemental distribution.





Decomposition of XSW curves gives information of detailed chemical states. (examples: C 1s (left) and N 1s (right)).





Conclusion

The effect of X-ray standing wave enhancement is clearly observed. The information of elemental distribution is then obtained indicating a chemical selectivity among the elements. Chemical analysis is still in process, preliminary result indicates little variation between different chemical states.

[1] Dechao. Xu et al. Enhancement of soft X-ray reflectivity and interface stability in nitridated Pd/Y multilayer mirrors, Opt. Express, OSA, 2015, 23 (26), pp.33018-33026.
[2] A. Giglia et al. Thermal effects on Co/Mo2C multilayer mirrors studied by soft x-ray standing wave enhanced photoemission spectroscopy, Proc. SPIE, 2013, 8777, 87770I.

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