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

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Introduction

Pd/Y multilayers are high reflectance mirrors designed to work in the 7.5-11 nm wavelength range. Samples, prepared by magnetron sputtering, are deposited with or without B₄C barrier layers located at the interfaces of Pd and Y layers to reduce interdiffusion [1], which is expected by calculating mixing enthalpy of Pd and Y. Details of the composition of the multilayers are revealed by hard x-ray photoemission spectroscopy under x-ray standing waves effect [2]. It consists in measuring the photoemission intensity from samples that perform an angular scan in the region corresponding to the multilayer period and the incident photon energy according to the Bragg law.

1. SUBJECT SYSTEMS

Design goal

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

Sample	Structure	Thickness (nm)
1	[Pd/Y] ₄₀	2/2
2	[B ₄ C/Pd/B ₄ C/Y] ₂₀	1/2/1/2
3	[B ₄ C/Pd/Y] ₄₀	1/2/2
4	[Pd/B ₄ C/Y] ₄₀	2/1/2

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

- B₄C barrier layer is applied (1 nm, located either on Pd-on-Y interfaces or Y-on-Pd interfaces, or both).

2. EXPERIMENTAL METHOD

Highlights

❖ Hard X-ray Photoelectron Spectroscopy (HAXPES).

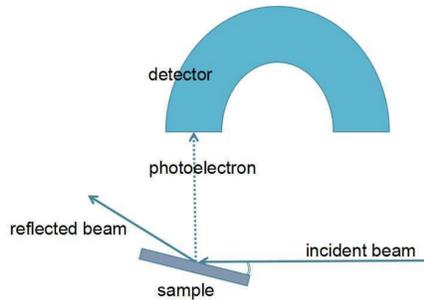
Study of the chemical states within the stacks.

❖ X-ray Standing Wave (XSW)

It reveals the depth distribution of elements, or even chemical states.

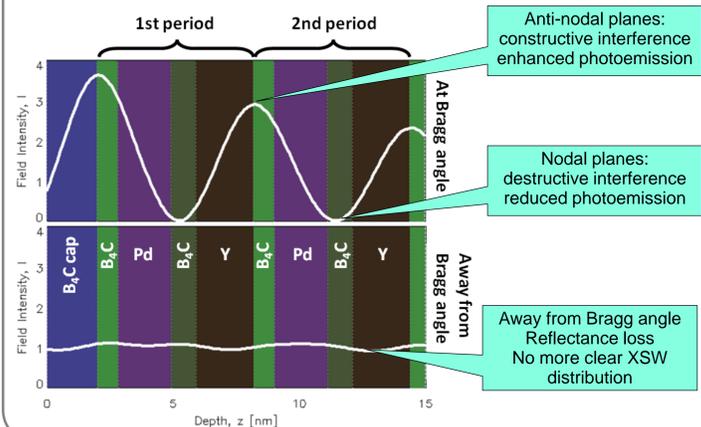
Experimental setup

XSW is generated by the interference of the incident and the reflected photon beams. The energy of the incident beam is 10keV. Energy calibration is carried out with Au 4f spectra.



XSW: the angular dependent periodic electric field distribution.

The variation is related to the structure of the multilayer, incident photon energy and the incident angle. The positioning of XSW enhancement for the photoemission is realized by rotating the grazing incident angle around Bragg angle, where the period of XSW can be considered identical to the period of the multilayer.

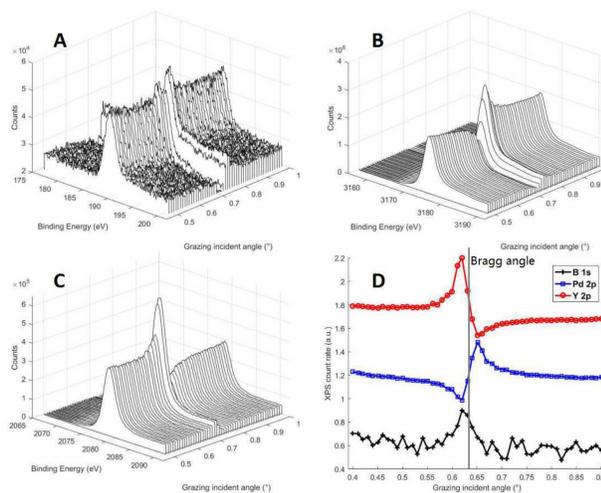


3. HAXPES-XSW CURVES

Photoemission intensity variation due to XSW.

The figure below shows the variations of photoemission of different elements present in a multilayer [B₄C/Pd/B₄C/Y]₂₀ (sample 2). The so-called HAXPES-XSW curves (intensity vs angle), depicted by integrating the photoemission peaks, are also presented.

A: boron 1s, B: palladium 2p_{3/2}, C: yttrium 2p_{3/2}, D: the corresponding HAXPES-XSW curves.



When the incident angle varies through the Bragg angle, the location of the anti-nodal planes moves accordingly toward deeper location from Y layers into B₄C layers then Pd layers.

This angular order of the ionization enhancement of the elements is reflected on the HAXPES-XSW curves. As the grazing angle varies from low to high values, a rise of the Y 2p_{3/2} HAXPES-XSW curve first appears at 0.61°. It is then followed by the rise of the B 1s and Pd 2p_{3/2} curves at 0.63° and 0.66° respectively.

As the B₄C layers are sandwiched between the Pd and Y layers, the B 1s HAXPES-XSW curve is rather more symmetrical instead of appearing as the "Z" form like the Pd and Y curves.

4. INTERFACIAL COMPOUND STUDY

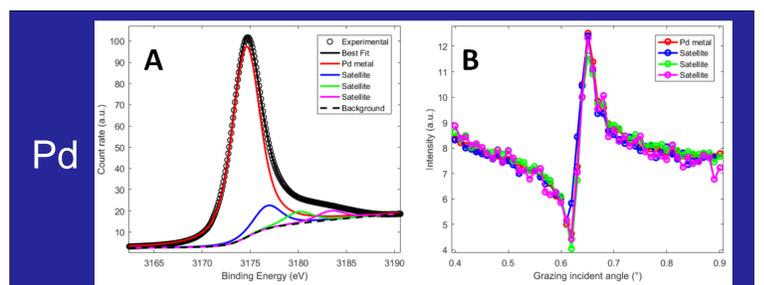
Decomposition of Pd photoemission peak.

A: Decomposition

- Pd metal peak and 3 satellite peaks.

B: HAXPES-XSW curves of the components

- Identical HAXPES-XSW shape indicates an identical depth distribution, which further proves the nature of the 3 additional peaks (satellites).
- Same conclusion for all samples.



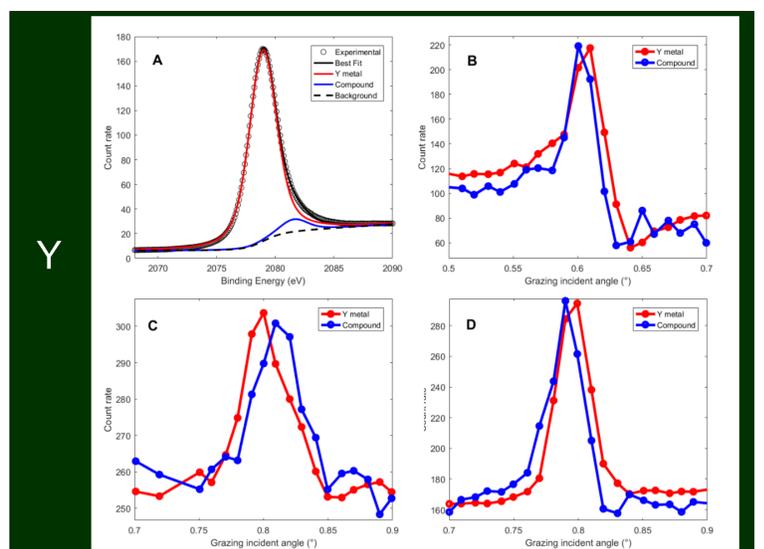
Decomposition of Y photoemission peak.

A: Decomposition

- Y metal peak and Y compound.

B, C, D: HAXPES-XSW curves of the components for sample 2, 3, 4 respectively

- Y compound is always located at the interfaces where Y is in contact with B₄C. It should be either Y-B or Y-C.
- The formation of Y compound has a preference, or is more active, to happen at B₄C-on-Y interfaces than at Y-on-B₄C interfaces.



Conclusion

We explore the nature of the interdiffusion of Pd and Y. The interdiffusion of Pd into the B₄C layers does not form any chemical compound. On the contrary, Y forms chemical compound with either B or C at the Y-B₄C interfaces. The formation of Y compound has a preference, or is more active, to happen at B₄C-on-Y interfaces than at Y-on-B₄C interfaces. Such chemical compound can be the reason why the interfaces are stabilized.

[1] Windt, D. L. & Gullikson, E. M. (2015). *Applied Optics*, 54, 5850.

[2] Giglia, A et al. (2013). *Proceedings of SPIE*, 87770I.