

Study of Pd/Y based multilayers with B₄C barrier layers using high energy photoemission spectroscopy combined with x-ray standing waves

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Introduction

We characterize Pd/Y multilayer coatings and several derivative systems with B₄C barrier layers for the development of new optics designed to work in $\lambda=7.5-11$ nm wavelength range. Samples were measured using hard x-ray photoemission spectroscopy (HAXPES) combined with x-ray standing waves [1]. 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 leading to the enhancement/modulation of the photoemission intensity is realized by rotating the grazing incident angle around Bragg angle.

SUBJECT SYSTEMS

Design goal

High reflective mirror working in 7.5 – 11nm range deposited on Si substrate by magnetron sputtering.

Designed Structure	Period (nm)	Pd (nm)	Y (nm)	B ₄ C (nm)
[Pd/Y] ₄₀ + B ₄ C cap	4	2	2	2.5

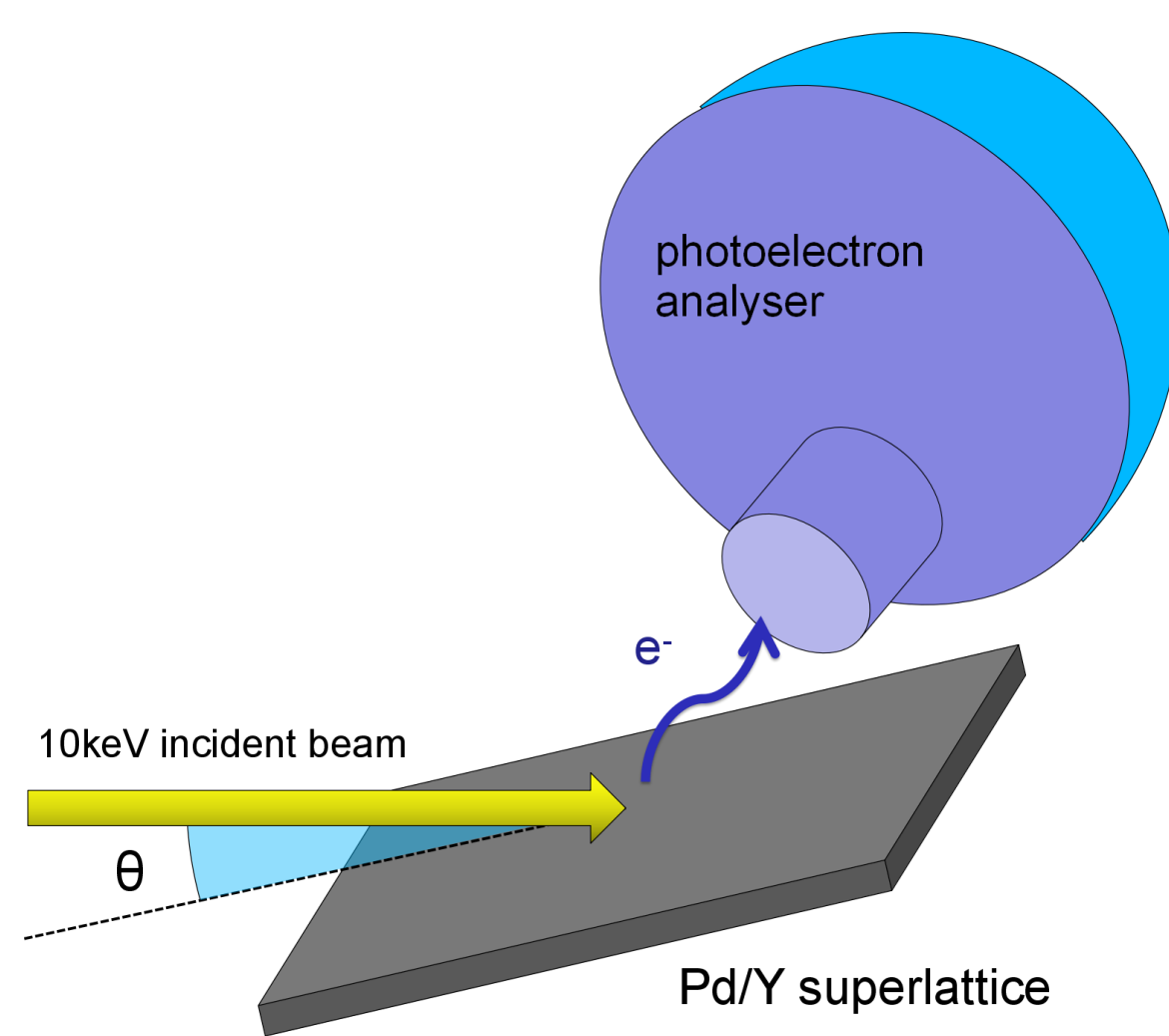
To reduce inter-diffusion and improve thermal stability, derivative systems are also studied.

- B₄C barrier layer is applied (1 or 2nm, located either on Pd-on-Y interfaces or Y-on-Pd interfaces, or even both interfaces).

EXPERIMENTAL DETAILS

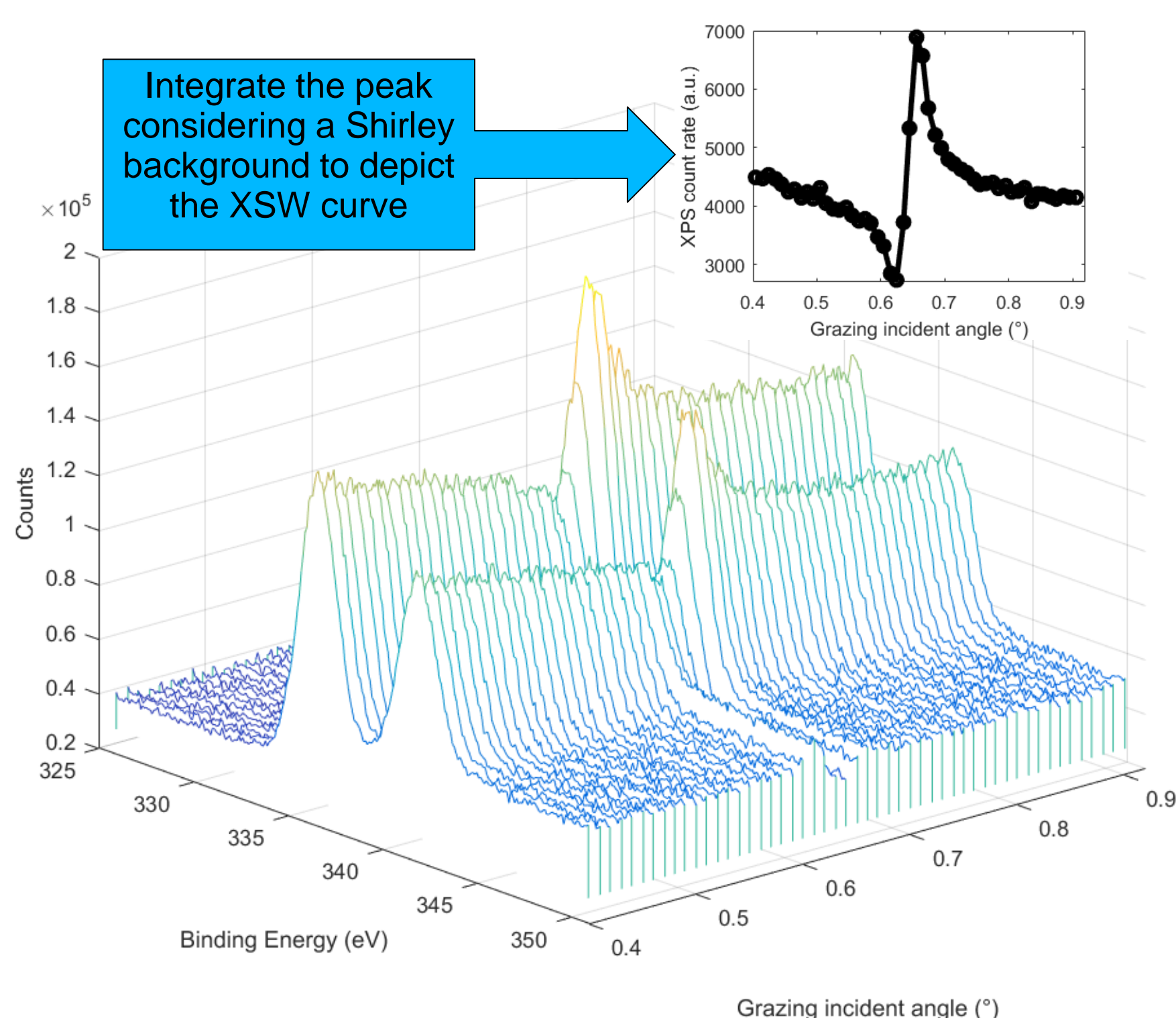
Experimental setup

The positioning of x-ray standing waves is realized by rotating the grazing incident angle around Bragg angle. The energy of the incident beam is 10keV. Electron kinetic 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 Pd 3d spectrum of the sample [B₄C/Pd/B₄C/Y]₂₀+B₄C cap 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 after the deposition of the sample.

❖ Hard X-ray Photoelectron Spectroscopy (HAXPES).

Study of the chemical states of elements present within the stacks. The selected photon energy (10 keV) enable us to probe a depth about 5-6 periods into the sample.

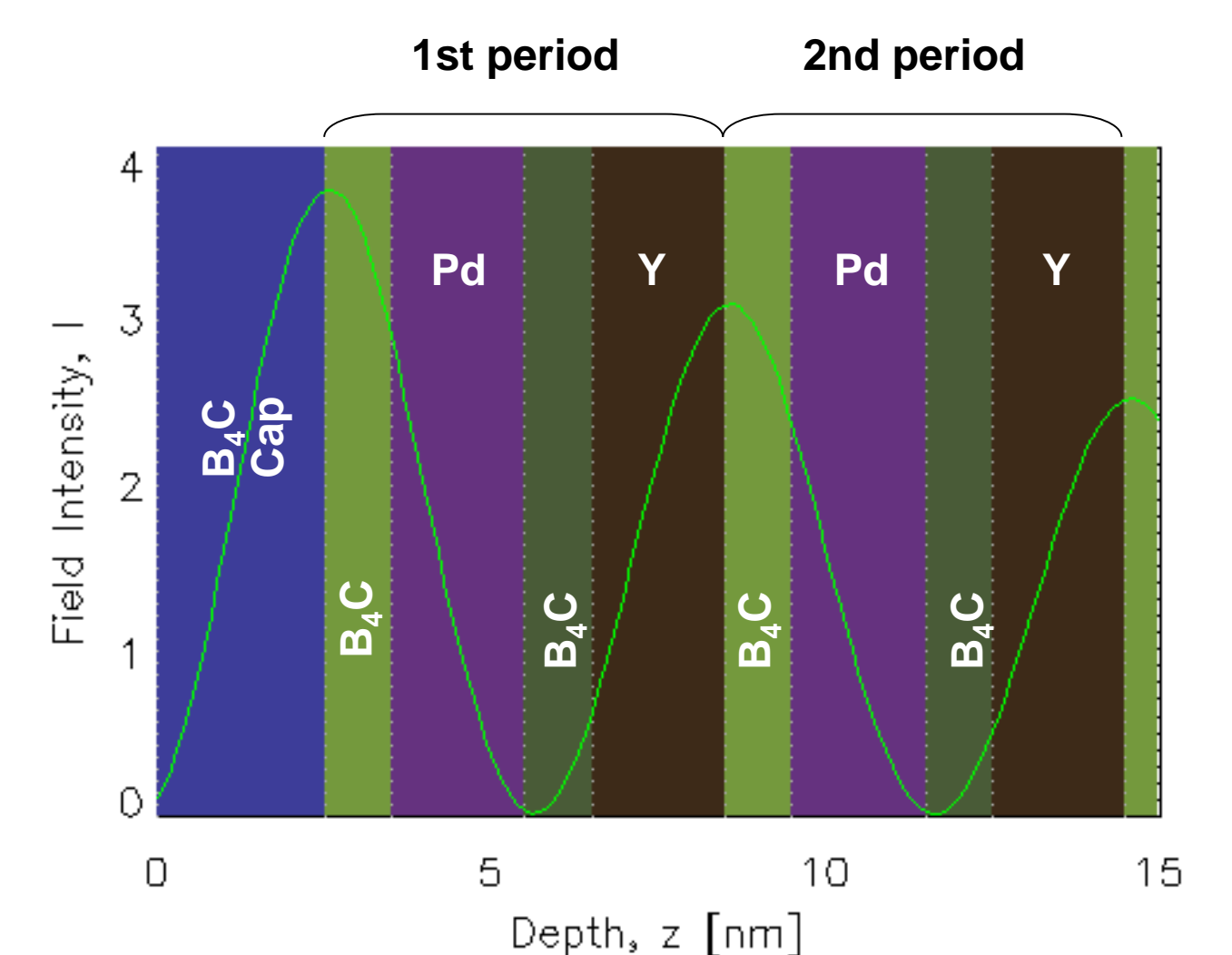
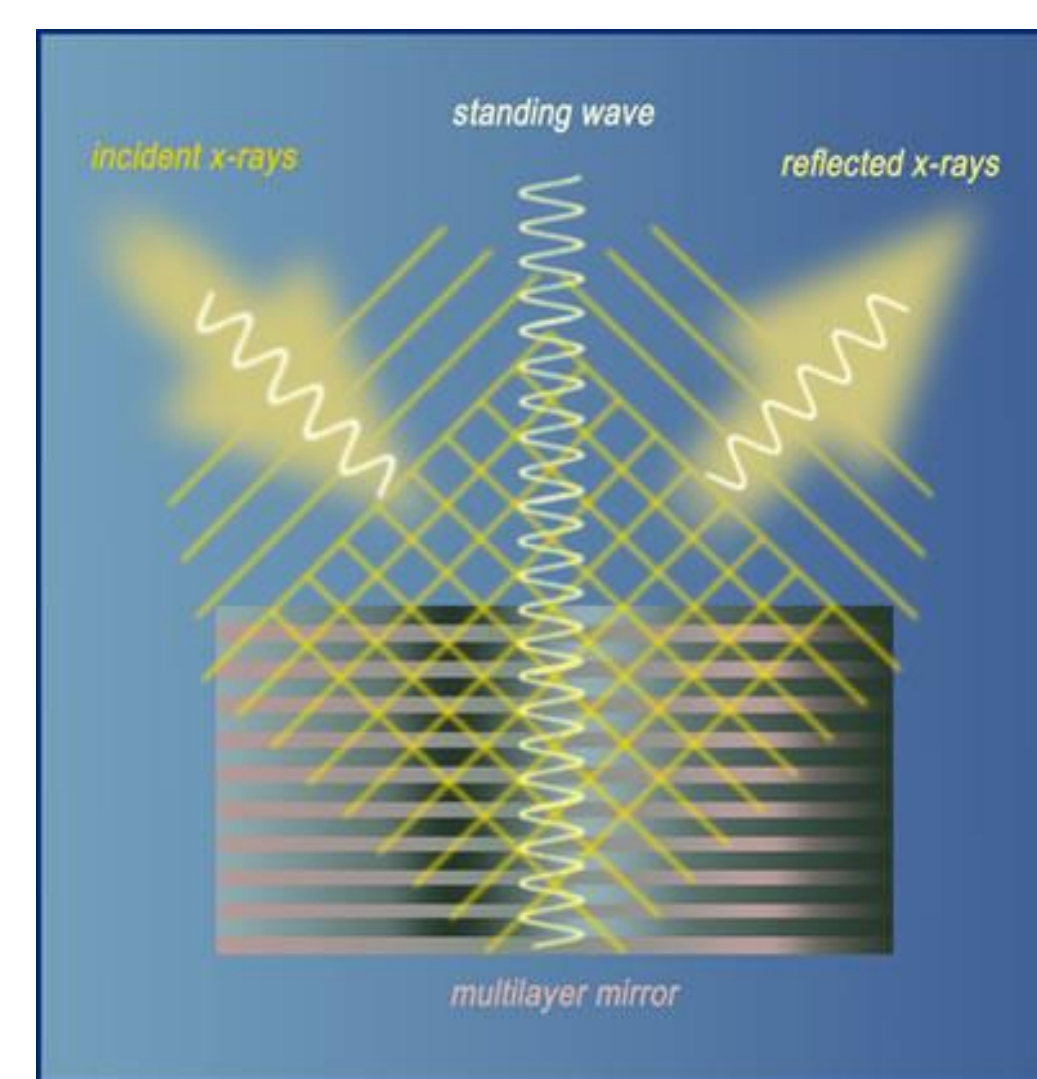
❖ X-ray Standing Wave (XSW)

Sensitive to interfaces. D=period of the stack (scan around Bragg angle).

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

[B ₄ C/Pd/B ₄ C/Y] ₂	Period (nm)	B ₄ C (nm)	Pd (nm)	B ₄ C (nm)	Y (nm)
Designed	6	1	2	1	2
Determined	6.2	1.0	2.1	0.8	2.3

GIXR and fitting result of a Pd/Y based multilayer: [B₄C/Pd/B₄C/Y]₂₀+B₄C cap.

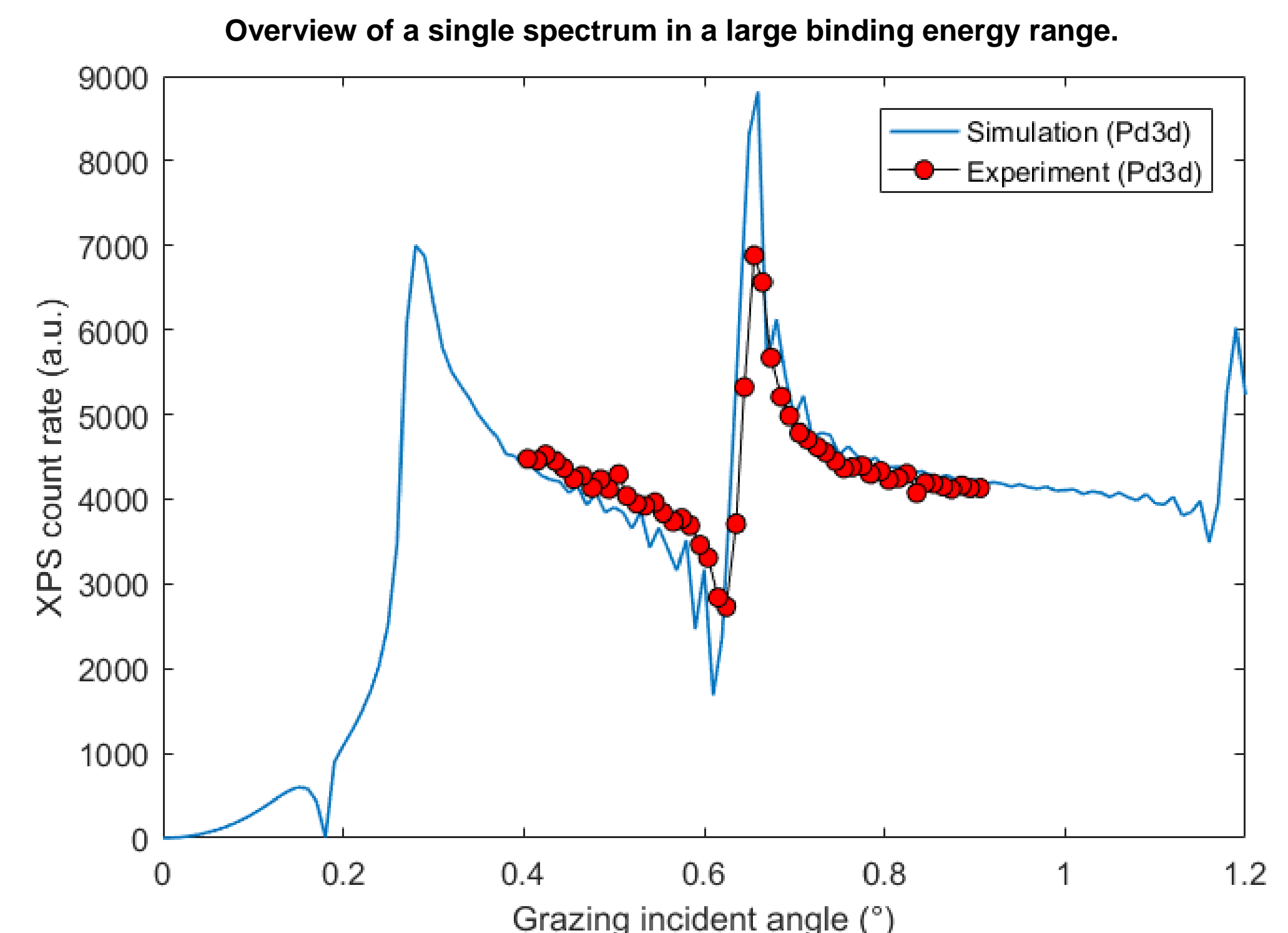
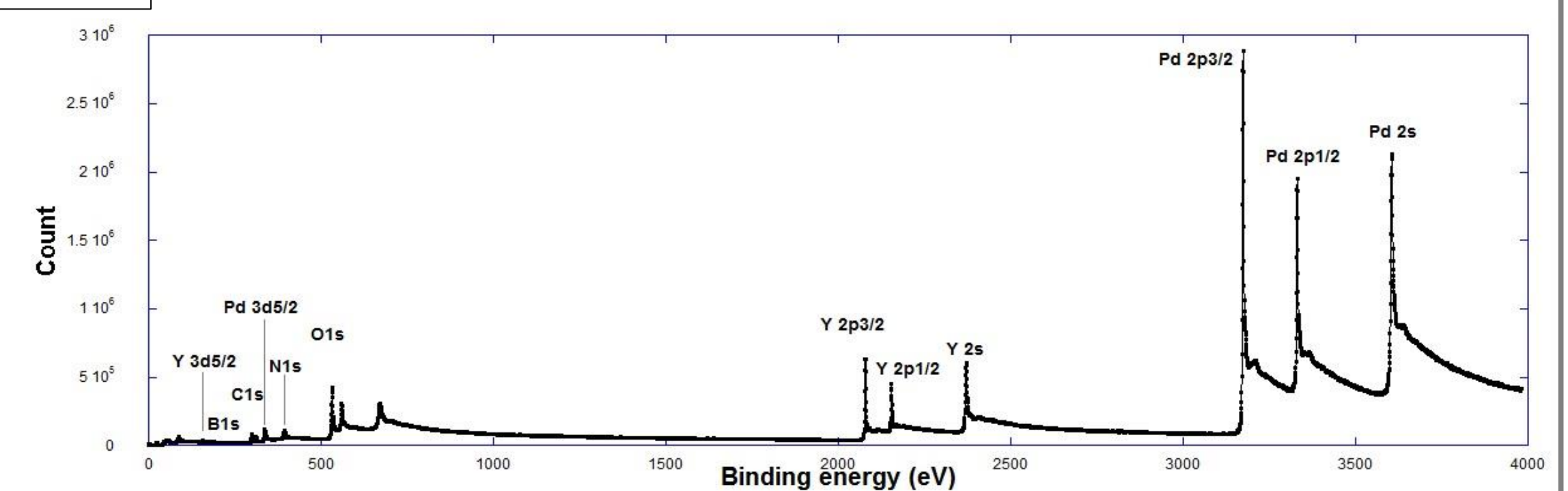
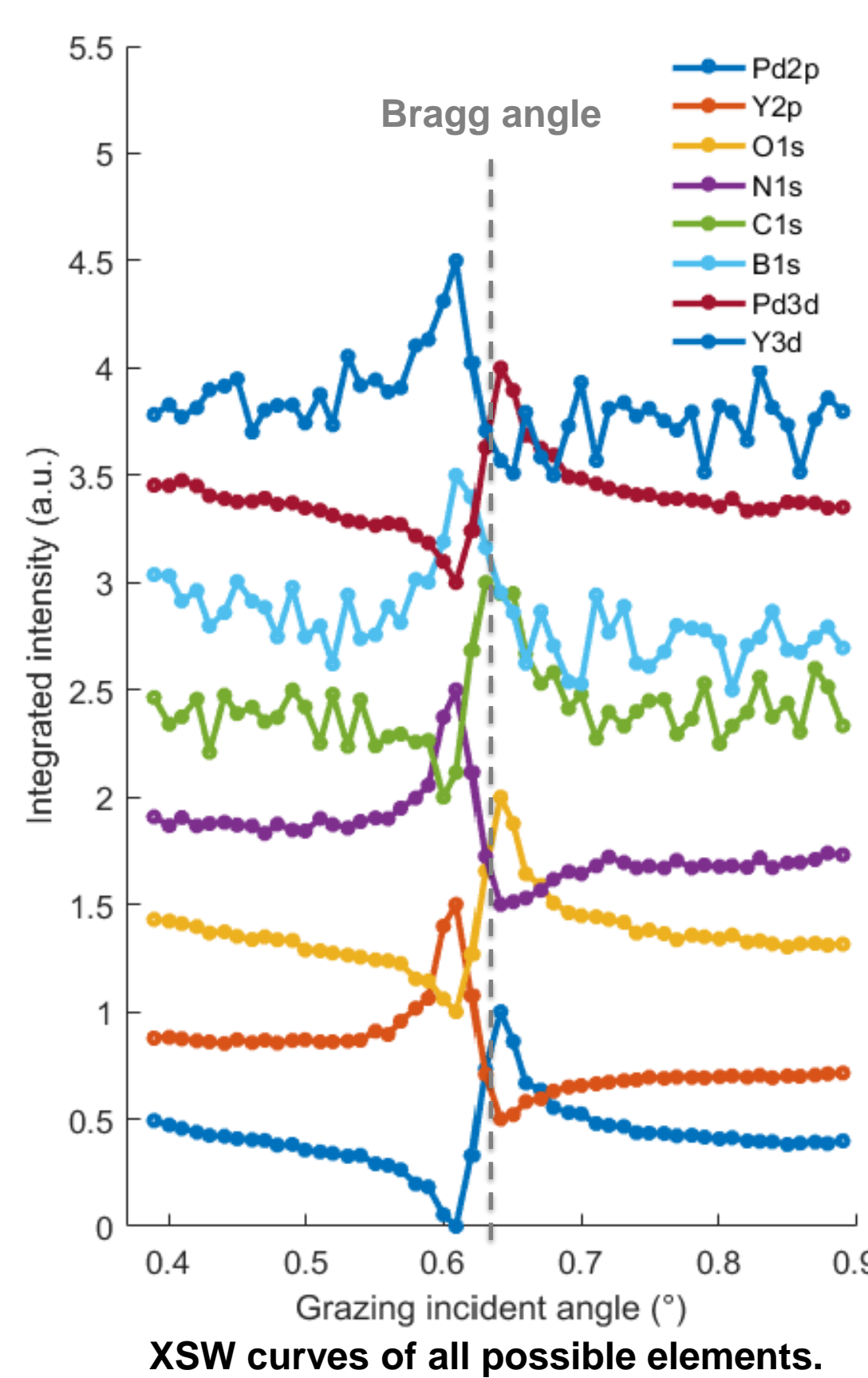


Simulation of the electric field of the same sample described above under 10keV irradiation. Grazing incident angle is set at its Bragg angle (0.62°).

RESULTS

Results

In this section we present an example: the sample [B₄C/Pd/B₄C/Y]₂₀+B₄C cap. Photoelectron of Pd2p, Pd3d, Y2p, Y3d, O1s, N1s, C1s, B1s photoemission peaks are measured.



Comparison of the experimental XSW curve and the simulation [2]. There is an obvious difference in the oscillation contrast.

Conclusion

The effect of X-ray standing wave enhancement/modulation is clearly observed. The information of elemental distribution is then obtained indicating a chemical selectivity among the elements.

The contrast of experimental XSW curve is lower than the simulated one, indicating a increased roughness/interdiffusion level of the sample compared to the structure determined by GIXR. Sample stability needs improvement.

[1] Zegenhagen, J, Kazimirov, A, [The X-Ray Standing Wave Technique: Principles and Applications], World Scientific (2013).

[2] S.-H. Yang, A. X. Gray, A. M. Kaiser, B. S. Mun, B.C. Sell, J. B. Kortright, and C. S. Fadley, "Making use of x-ray optical effects in photoelectron-, Auger electron-, and x-ray emission- spectroscopies: total reflection, standing-wave excitation and resonant effects", Journal of Applied Physics 113, 073513 (2013).