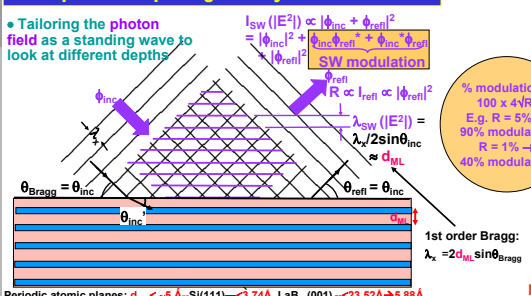
Probing multilayer nanostructures with hard x-ray standing wave photoemission

B. Balke[1,2,*], C. Papp[1,2], S. Döring[3], U. Berges[3], F. Schonbohm[3], S.-H. Yang[4], M. Gorgoi[5], S. Ueda[6], H. Yoshikawa[6], Y. Yamashita[6], S.L. He[6], C. Sakai[6], K. Kobayashi[6,7], G. Conti[8], L. Plucinski[9], A. Gray[1,2], C. Westphal[3], C. Felser[*], D. Buergler[9], C.M. Schneider[9], and C.S. Fadley[1,2]

[1]Materials Sciences Division, LBNL; [2]Physics, UC Davis; [3]Physics, Tech. Univ. Dortmund ; [4]IBM Almaden Research Center; [5]BESSY, Berlin; [6]SPring8, Japan; [7]NIMS, Japan; [8]Applied Materials, CA, USA; [9]Research Center Jülich; *Present address: Inorganic and Analytical Chemistry, University of Mainz

INTRODUCTION AND MOTIVATION

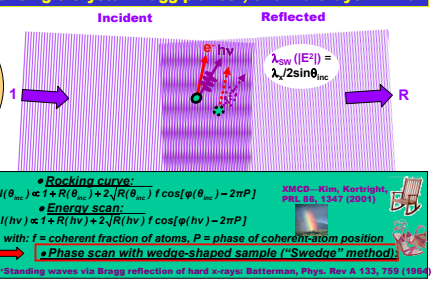
Standing wave formation in reflection from a surface- a unique tool for probing multilayer nanostructures



Periodic atomic planes: $d_{ML} \leq$ ~5 Å--Si(111)—≤3.74Å, LaB_6(001)--≤23.52Å→5.88Å, mica—10.0 Å; or Synthetic multilayers: $d_{ML} \approx$ ~20-40 Å

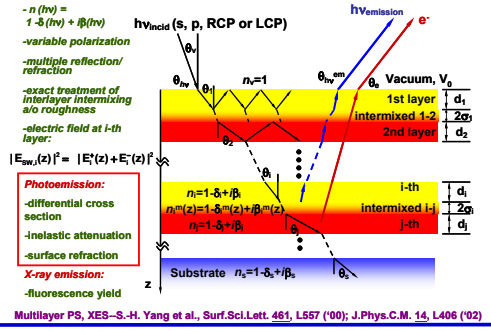
% modulation ≈ 100 x 4√R: E.g. R = 5% → 90% modulation, R = 1% → 40% modulation

Standing wave formation in reflection from a surface, or single-crystal Bragg planes*, or a multilayer mirror



*Standing waves via Bragg reflection of hard x-rays: Batterman, Phys. Rev A 133, 759 (1964)

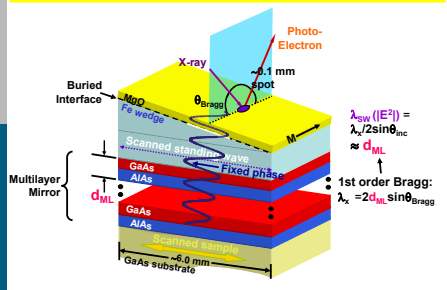
Calculating XRO effects on spectroscopy--Yang

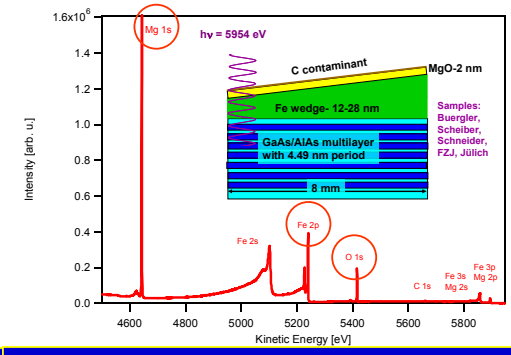


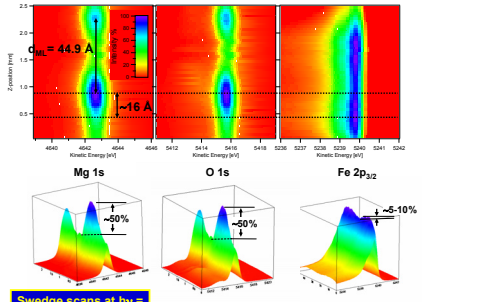
Multilayer PS, XES--S.-H. Yang et al., Surf.Sci.Lett. 461, L557 ('00); J.Phys.C.M. 14, L406 ('02)

HARD X-RAY PHOTOEMISSION FROM SPring8 – 5.9 keV EXCITATION FROM AN EPITAXIAL MULTILAYER: MgO/Fe

Probing Buried Interfaces: The Standing Wave-Wedge ("Swedge") Method



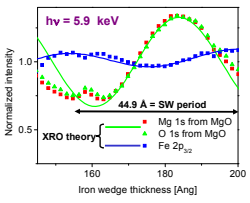




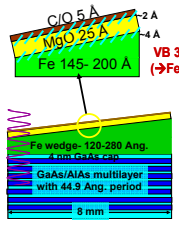
Swedge scans at hν = 5.9 keV

Papp, Balke, Ueda, Yoshikawa, Yamashita, He, Sakai, Kobayashi, Fadley, et al. SPring8, BL15XU

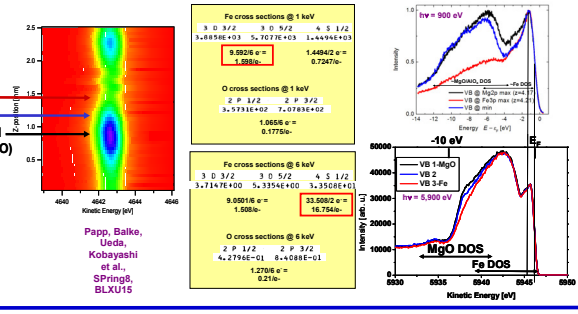
Interface mixing from fits to wedge-scan data



Papp, Balke, Ueda, Kobayashi et al.

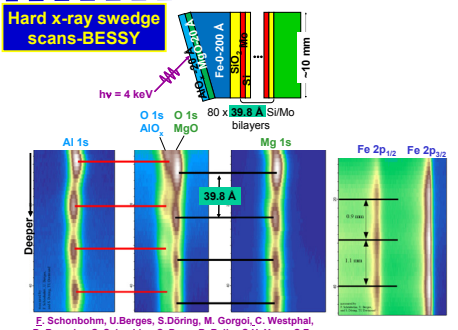


MgO/Fe depth dependent densities of states info. at 0.9 keV and 5.9 keV



Papp, Balke, Ueda, Kobayashi et al., SPring8, BLXU15

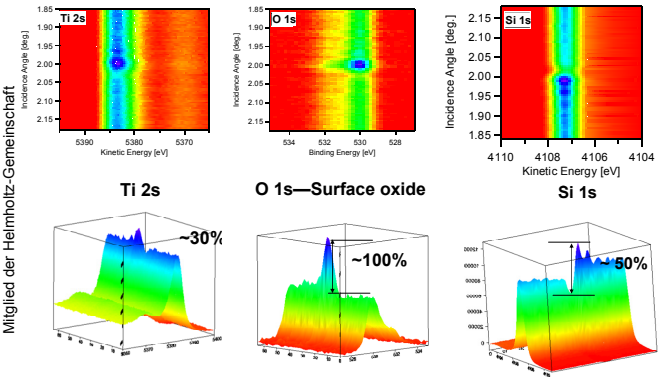
Hard x-ray swedge scans-BESSY



F. Schonbohm, U.Berges, S.Döring, M. Gorgoi, C. Westphal, D. Buergler, C. Schneider, C. Papp, B. Balke, S.H. Yang, C.F...

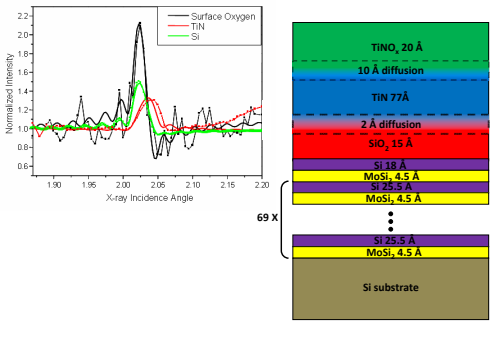
HARD X-RAY PHOTOEMISSION FROM SPring8 – 5.9 keV EXCITATION FROM A SEMICONDUCTOR-RELATED OVERLAYER: TiN ON SiO_2/Si

Rocking curves for 90 Å TiN/[Si/Mo multilayer-30 Å period]



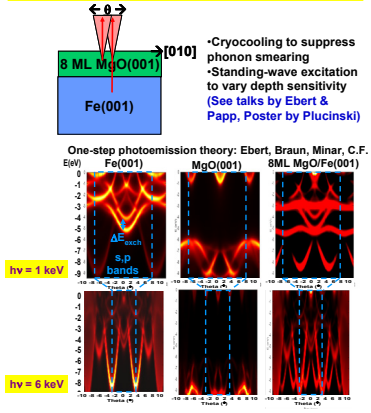
Ti 2s — O 1s—Surface oxide — Si 1s

Depth-resolved composition from simulations of the rocking curves



FUTURE PROJECTS IN MULTILAYER SPINTRONIC SYSTEMS

Angle-resolved photoemission through overlayer insulators: A new probe of buried layer/interface electronic structure? Fe/MgO



Mitglied der Helmholtz-Gemeinschaft