Surface Canada 2013--workshop

Photoemission Spectroscopy

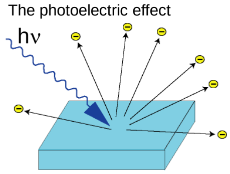
Dr. Xiaoyu Cui
May.11.2013

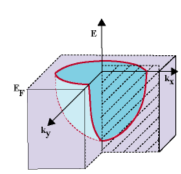
Outline

- Introduction
- What you need to know…
- Scientific view
- Other…

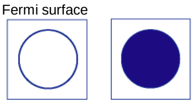
Introduction

The photoelectric effect





Fermi surface

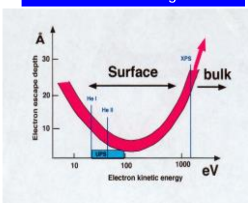


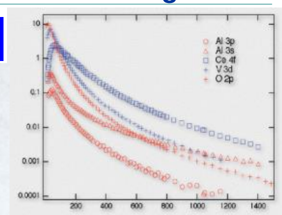
First experimental work performed by H.Hertz (1886), W.Halwachs(1998),von Lenard(1900)
Theoretical explanation by Einstein(1905)

Many properties of solids are determined by electrons near E_F;
(conductivity, magnetism, superconductivity)
Only a narrow energy range around E_F is relevant for those properties

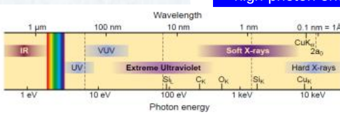
Advantage or disadvantage

PES is really surface sensitive Within VUV region





Cross sections are very small at high photon energy region!!



What's the interest in PES community?

Physicist:

Know: sample quality; physical properties (resistance; magnetic..)

Want to know: Why? How to build the connection?

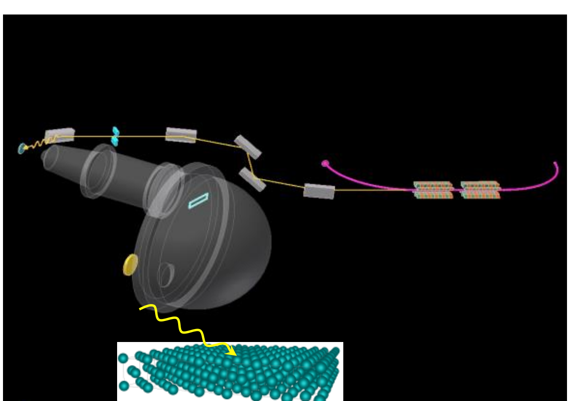
Prefer to use: Angular resolved photoemission spectroscopy (ARPES)

Chemist:

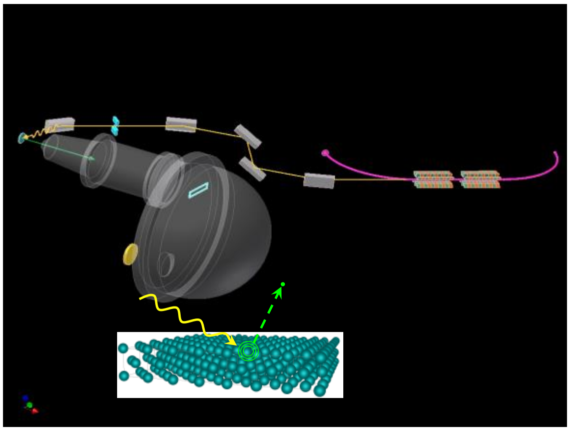
Know: possible elements or compounds inside the system.

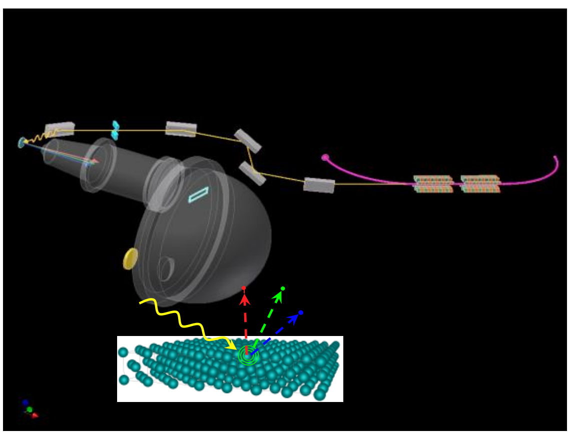
Want to know: Chemical shifts? Bonding? Procedure? Reaction?

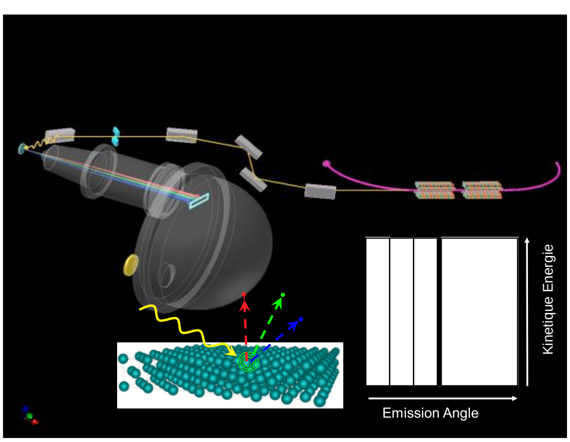
Prefer to use: Traditional photoemission spectroscopy (XPS); Ambient pressure photoemission spectroscopy (APPES)

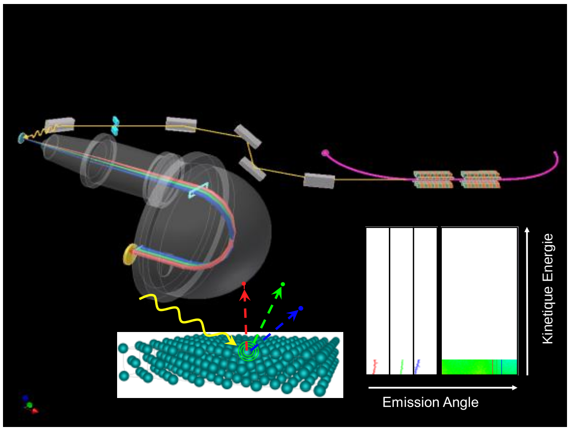


Courtesy of Luc Patthey (SLS)






Kinetique Energie
Emission Angle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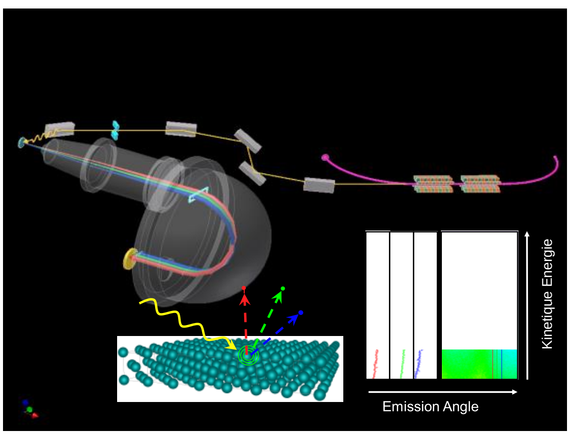
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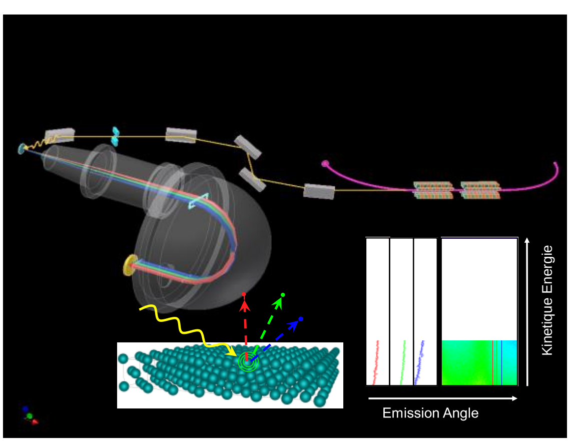
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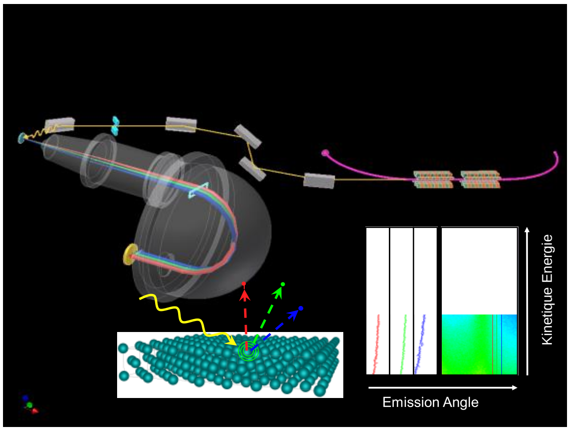
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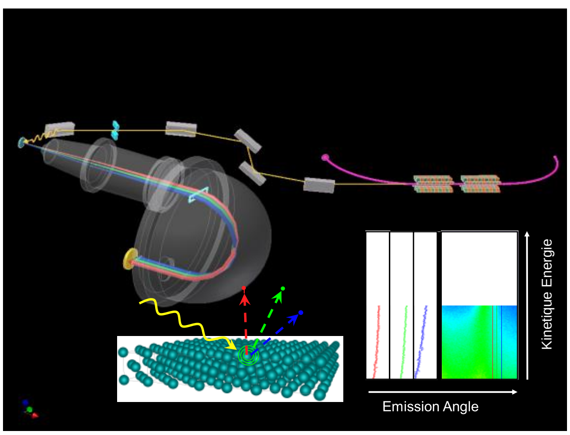
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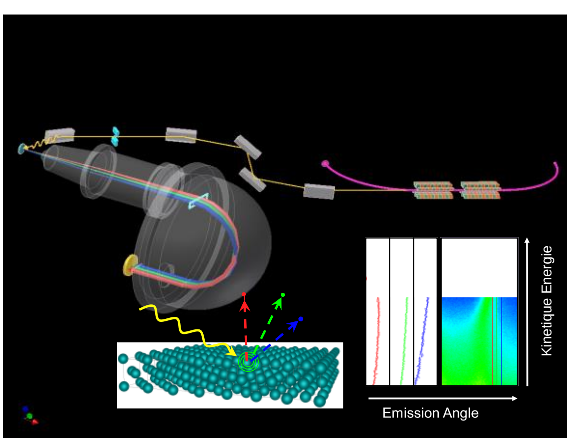
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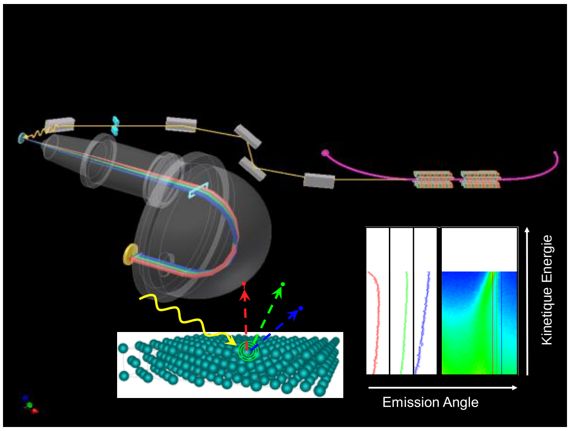
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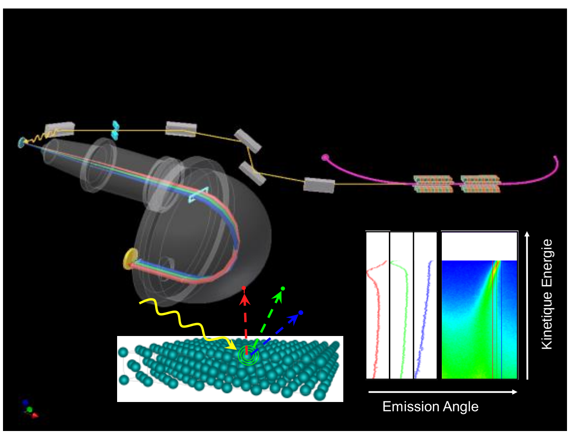
Emission Angle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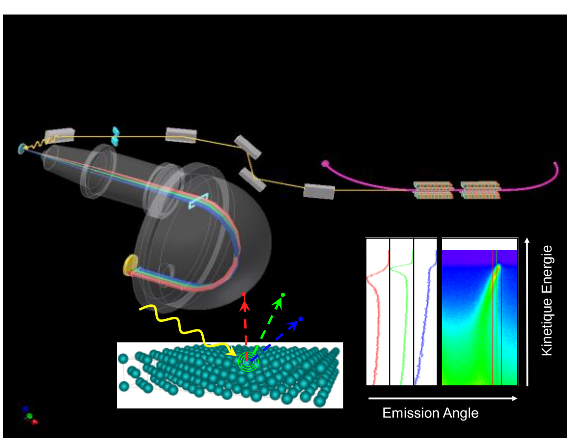
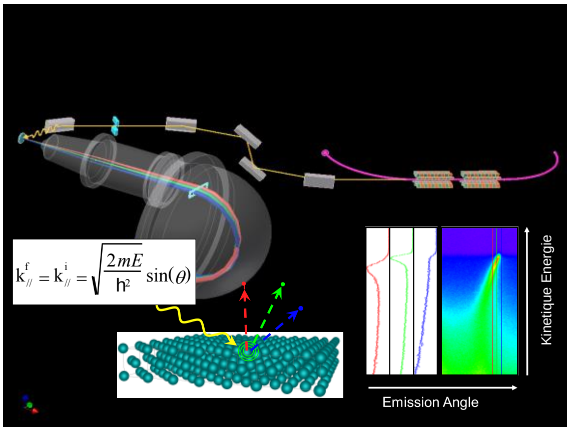
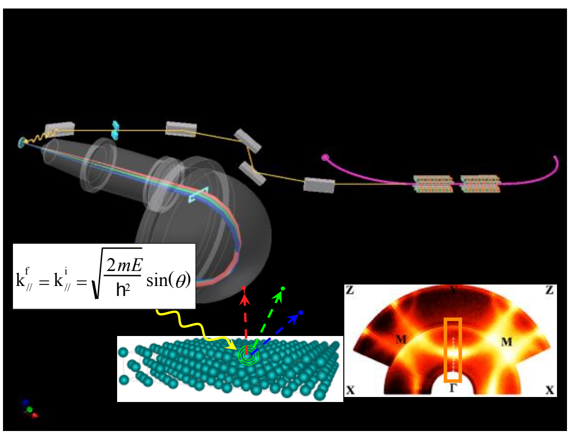
Emission Angle


Kinetique Energie
Emission Angle


$k^{f}_{//} = k^{i}_{//} = \sqrt{\frac{2mE}{\hbar^2}}\sin(\theta)$
Kinetique Energie
Emission Angle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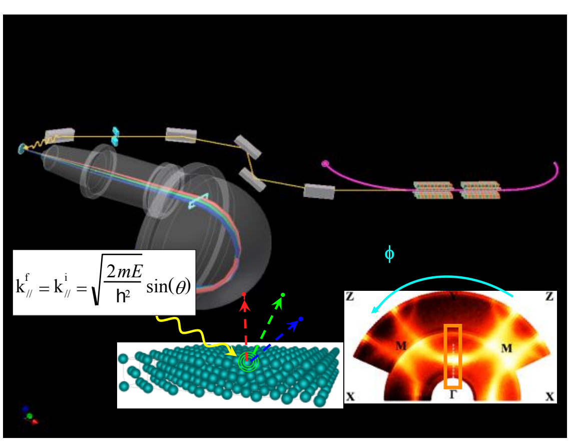
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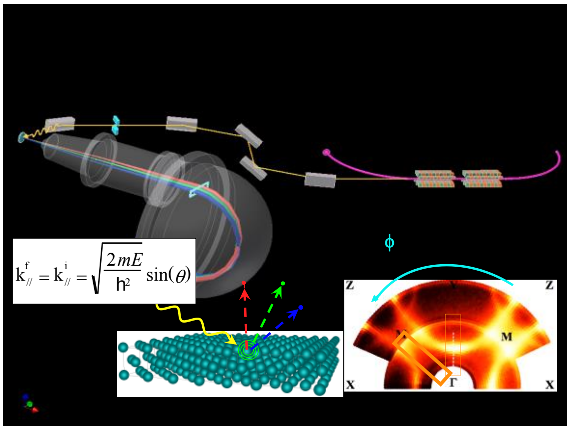
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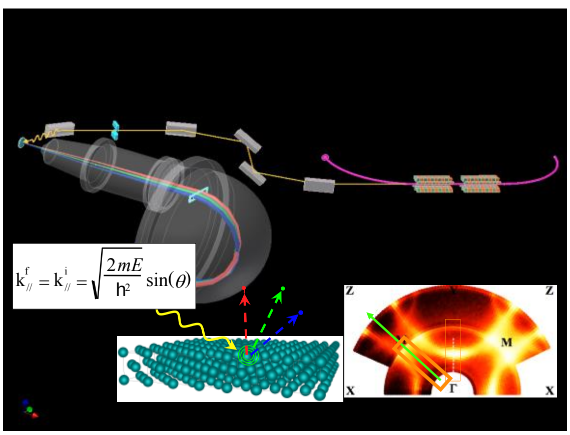
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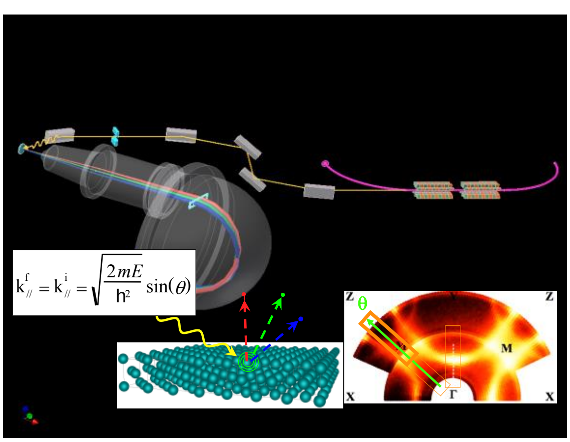
$k^{f}_{//} = k^{i}_{//} = \sqrt{\frac{2mE}{\hbar^2}} \sin(\theta)$
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WHAT HAPPENED IN YOUR XPS LAB..

Energy Conservation

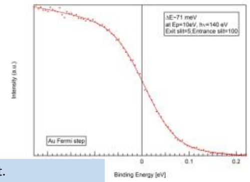
$$E_{kin} = h\nu - \phi - |E_B|$$

You know hν from Lab XPS using Al; Mg sources.
Excitation energy are fixed at **1486.6** and **1253.6** eV

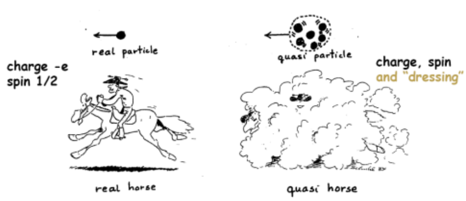
You should ask for ϕ (work function) from lab scientist.
(ask them to make a Au Fermi at the same time if possible)
*Work function will change with different system by few hundred meV

You know how to transfer to binding energy from kinetic energy

YOU ARE A EXPERT NOW!!!!!!!!



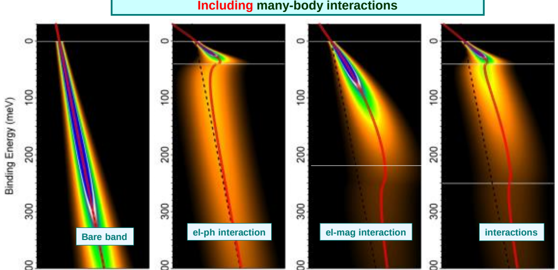
Quasi-particle



Many-body interactions lead to a renormalization of the non-interacting electron dispersion (changes the effective mass of electrons) and a finite lifetime

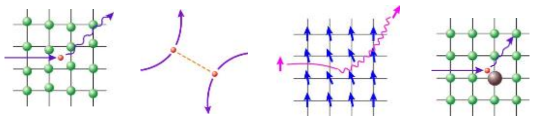
Interaction Effects in Band Dispersion

Computer simulation of Quasi-particle dispersion Including many-body interactions



High-resolusion ARPES with tunable synchrotron radiation to determine the mass enhancement **m^*/m_b**

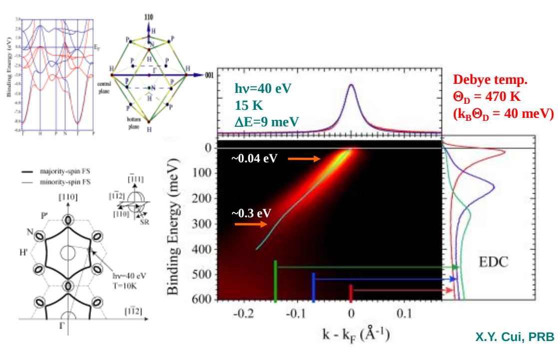
Lifetime broadening mode



electron-phonon coupling	electron-electron interaction	electron-magnon coupling	electron-impurity scattering
Γ_{el-ph}	Γ_{el-el}	Γ_{el-mag}	Γ_{el-imp}
Debye temp. ~0.04 eV	Band width 3~5 eV	Mag. DOS ~0.4 eV for Ni, Fe	energy indep.

Final state effect

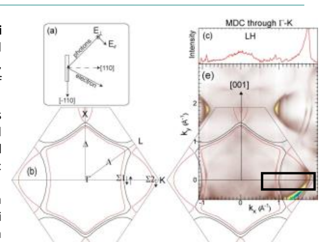
Quasiparticle evidence



X.Y. Cui, PRB

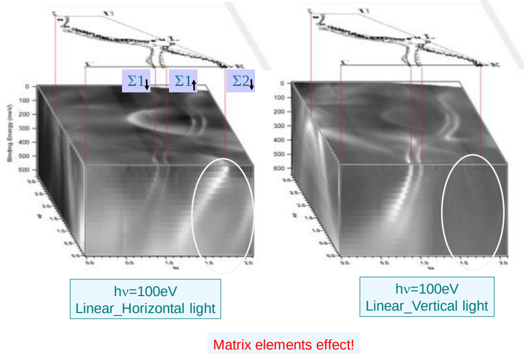
Fermi Surfaces

In condensed matter physics, the **Fermi surface** is an abstract boundary useful for predicting the thermal, electrical, magnetic, and optical properties of systems.
The shape of the Fermi surface is derived from the periodicity and symmetry of the crystalline lattice and from the occupation of electronic energy bands.
The existence of a Fermi surface is a direct consequence of the Pauli exclusion principle, which allows a maximum of one electron per quantum state.

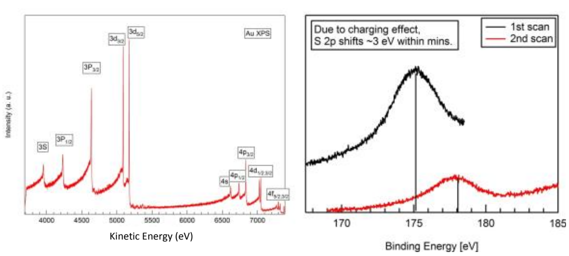


Fermi Surface of Ni(110)

Fermi Surfaces



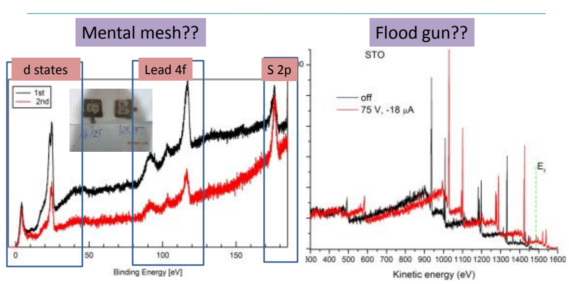
Charging effect



metal

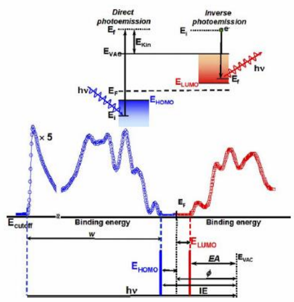
Insulator

How to fix it?

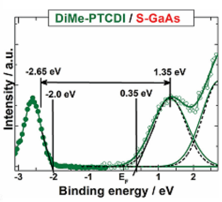


Possible factor: Charge density; Sample homogeneity.

Inverse photoemission

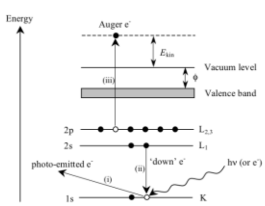


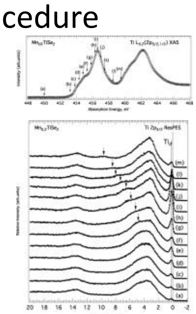
15 nm thick film of DiMe-PTCDI



D.R.T. Zahn, G.N. Gavrila, M. Gorgoi
Chem. Phys., 325 (1) (2006) 99

Auger procedure

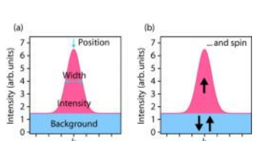


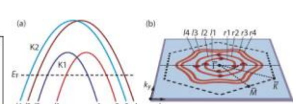


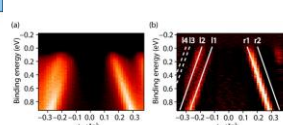
Fixed kinetic energy ➡ $E_{kin} = h\nu - \phi - |E_B|$

A N Titov's group

Spin-polarized photoemission





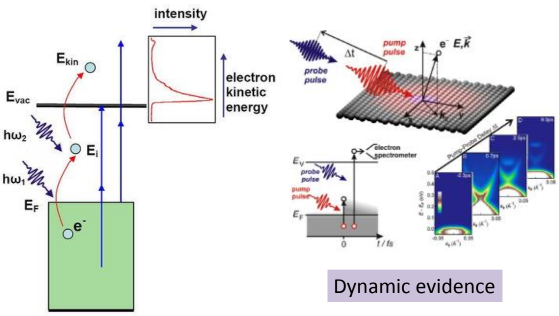


Bi film on Ag(111)

Surface states with different spin

COFFEE DATA FROM SLS

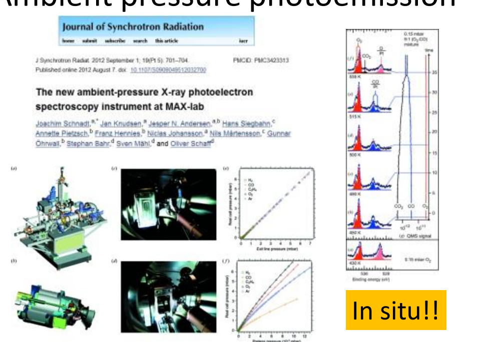
Time-resolved photoemission



Dynamic evidence

Uwe Bovensiepen's data

Ambient pressure photoemission



In situ!!

Thursday AM

SS4 **2104 A**

Recent Avances in Photoemission

Organizer(s) - T. Ellis, Y. Hu, T.-K. Sham
Chair(s) - T. Ellis, X.Y. Cui

08:00 02000 Probing the Electronic and Magnetic Properties of Bulk Materials, Buried Layers and Interfaces with Standing-wave and Hard-X-ray Photoemission **Fadley C.S.**
08:40 02001 De-Excitation Spectroscopy at the Ce L3-Edge of CePt3: The Auger Electron and the Fluorescence X-Ray Channel **Sham T.K.**, Liu L, Thiess S, Drube W, Gordon R.A.
09:00 02002 Quantum Material Spectroscopy Center at the Canadian Light Source **Gorovikov S.**, Yates B., Damascelli A., Hallin E., Reininger R.
09:20 02003 Site-specific Electronic Properties of Compositionally Precise Gold Nanoparticles from X-ray Spectroscopy *$**Zhang P.**
10:00 **Coffee Break**
10:20 02004 In Situ Electron Spectroscopy at the 3-way Interface of Vapor/Water/Nanoparticle *$**Brown M.A.**
11:00 02005 Photoemission Overview at Canadian Light Source Inc. - From UPS to HXPS *$**Cui X.Y.**
11:40 02006 Ceria Nano-Cubes: Dependence of the Electronic Structure on Synthetic and Experimental Conditions **Revoy M.N.**, *Scott R.W.J., $Grosvenor A.P.
12:00 02007 Oxide Thickness on a Ga-In Eutectic Alloy (EGaIn): An Angle-Resolved Photoemission Study *$**Sodhi R.N.S.**, Brodersen P., Mims C.A., Cademartiri L., Thuo M.M., Nijhuis C.A.
12:20 End of Session

Thursday PM

SS4 **2104 A**

Recent Avances in Photoemission

Organizer(s) - T. Ellis, Y. Hu, T.-K. Sham
Chair(s) - T.-K. Sham, G.M. Bancroft

14:00 02145 Recent Advances in High Resolution XPS of Non-conductor Oxides and Silicates ***Bancroft G.M.**, $Nesbitt H.W., Biesinger M.
14:40 02146 Industrial Applications of X-ray Photoelectron Spectroscopy in GE Research and Development Laboratory *$**Piao H.**
15:20 02147 Cryo-XPS Study of the Adsorption of Xanthate on Pyrite **Karpuzov D.**, Deng M., Liu Q., Xu Z.
15:40 02148 Frontiers of Photoelectron Spectroscopy *$**Bergersen H.**, Ahlund J., Moberg R.
16:00 02149 Novel Applications in Surface Science: In Situ Sample Analysis in Extreme Environments **Schulmeyer T.**
16:20 02150 A New Type of Detector for Dynamic XPS Measurements Baumann P., Kroemker B., Pruemper G., *Winkler K., $Feltz A., **Henn F.**
16:40 End of Session