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Elettra Sincrotrone Trieste



Synchrotron radiation photoelectron and soft X-ray absorption spectroscopy: *applications to irradiated materials*

Igor Piš

CNR - National Research Council of Italy

BACH - Beamline for Advanced diCHroism
Elettra synchrotron facility



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Science Park Basovizza

 National Research Council
of Italy (CNR)



Elettra

Research fields

- Condensed matter physics
- Nanoscience
- Biophysics

www.iom.cnr.it



Trieste

ICTP

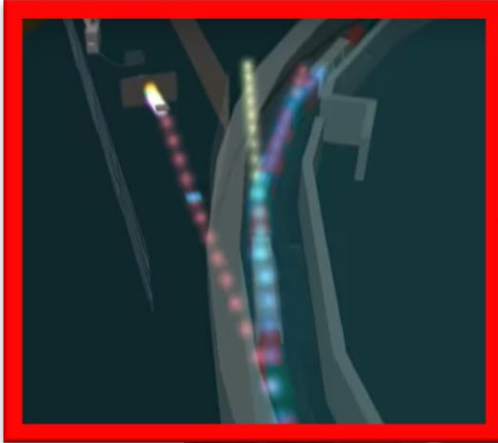


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Elettra

3rd – Generation Synchrotron Radiation Facility

Beamlines

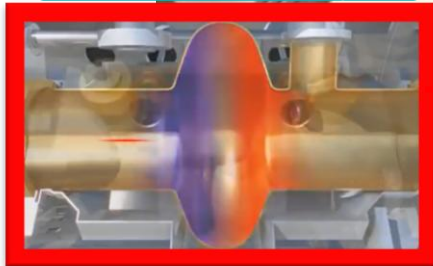


Relativistic electrons (2 GeV)
velocity: $0.999999967 c$

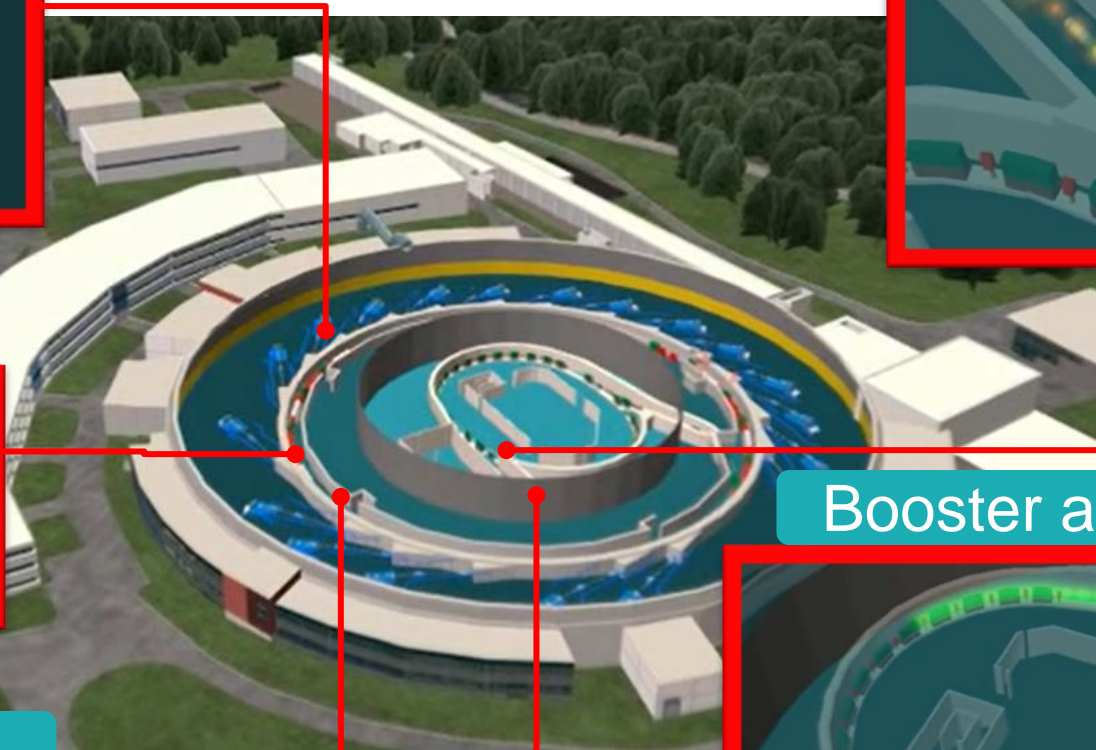
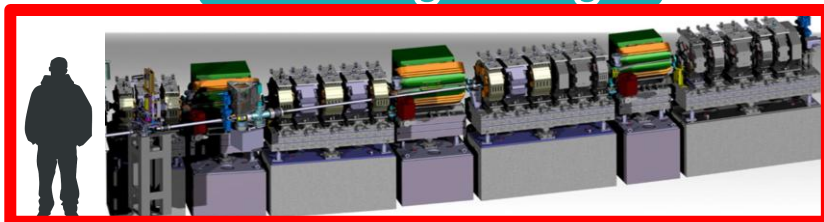
e-gun, LINAC



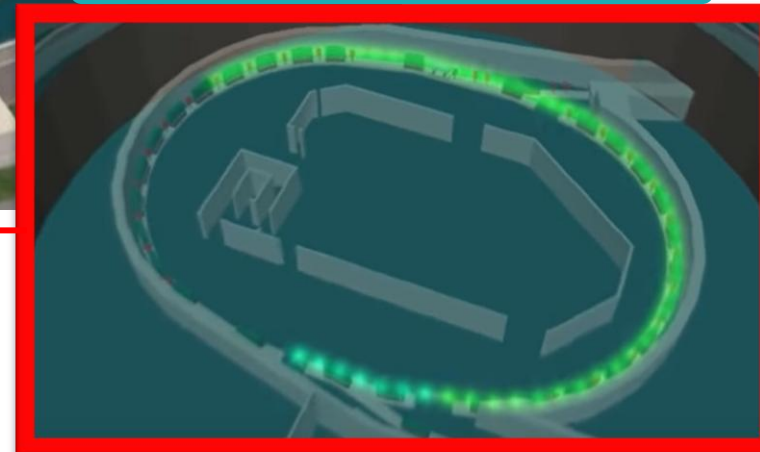
RF Cavity



Storage ring

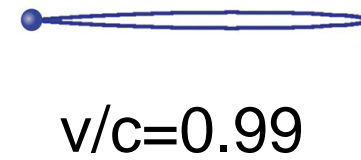
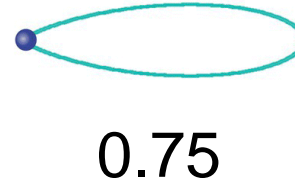
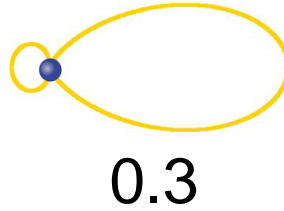
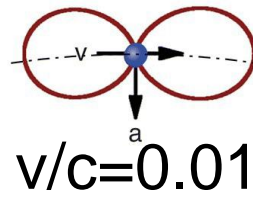


Booster accelerator

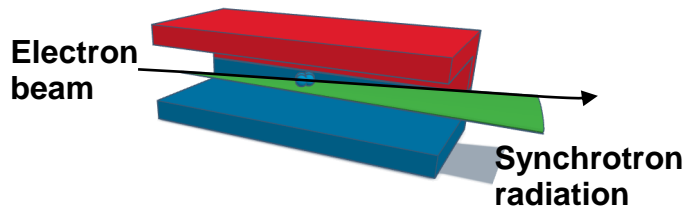


www.elettra.eu

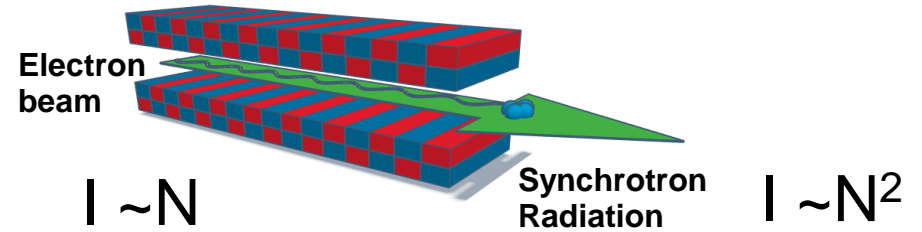
Synchrotron radiation



Bending magnets

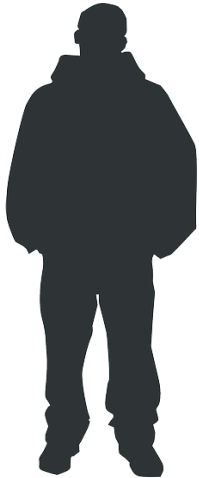


Insertion devices



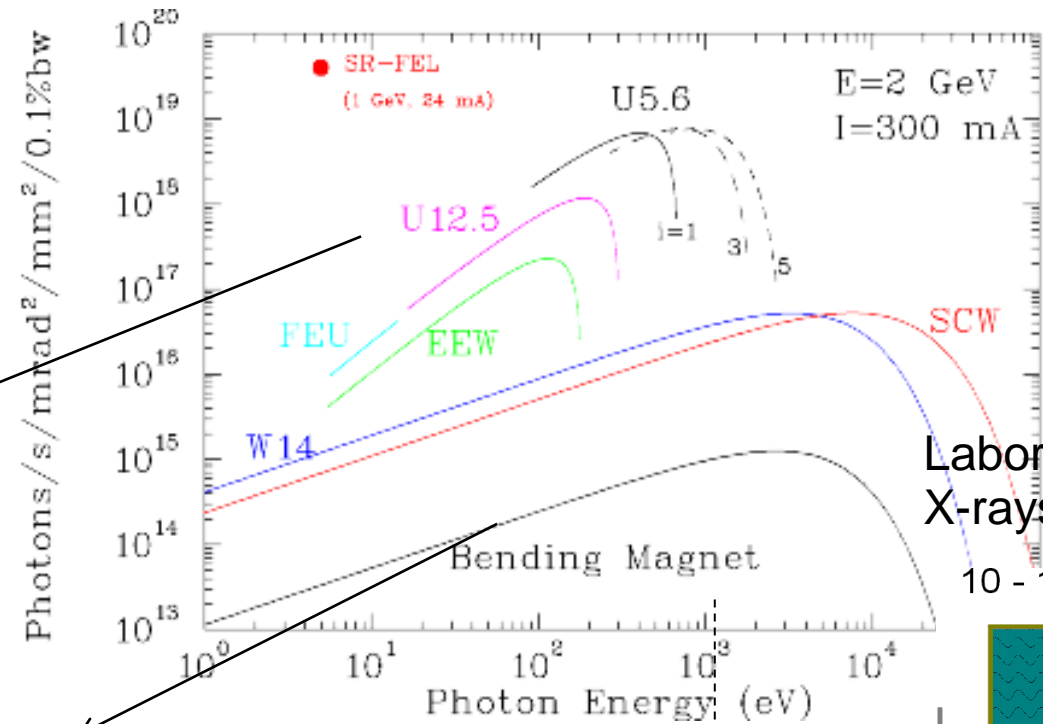
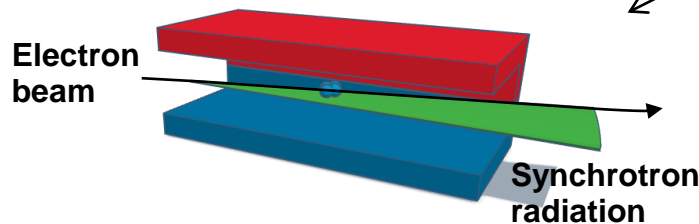
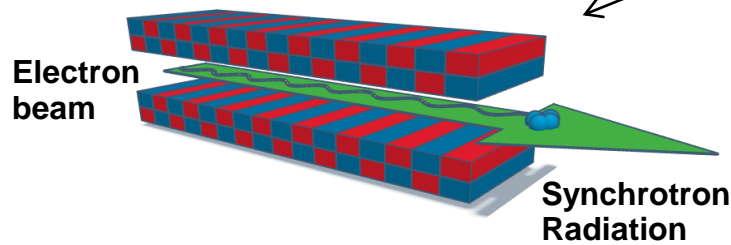
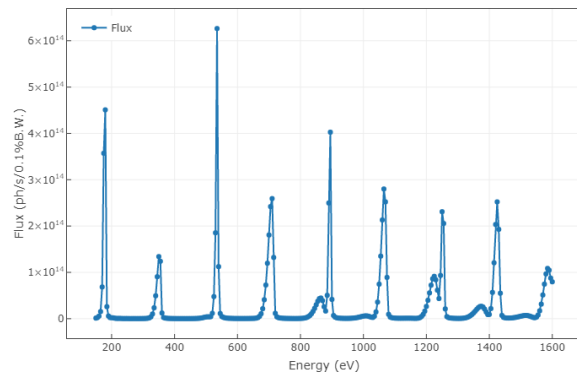
Wigglers

Undulators



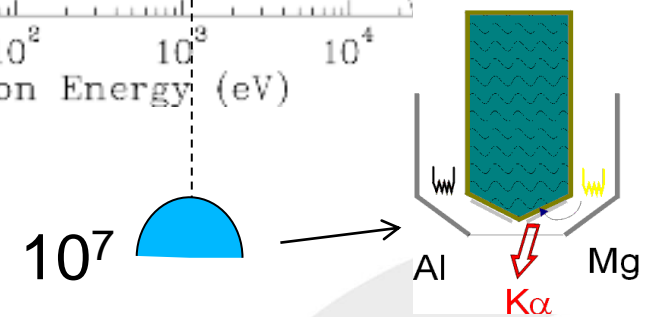
Synchrotron radiation

- TUNABLE WAVELENGTH
- HIGH BRILLIANCE
- NARROW BEAM
- POLARIZATION



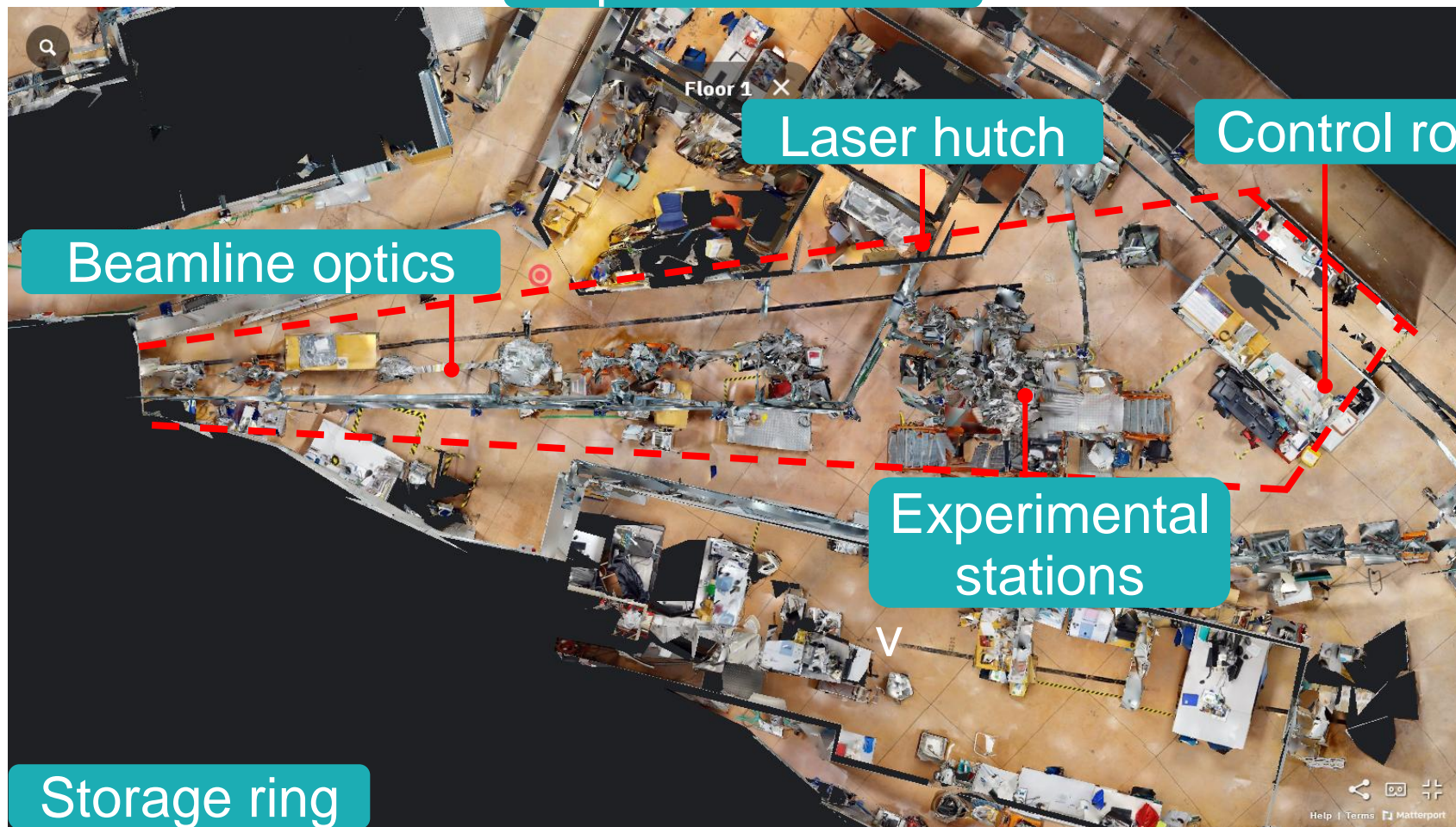
Laboratory
X-rays source

10 - 15 kV



BACH beamline

Experimental hall



Laser hut

Control room

Beamline optics

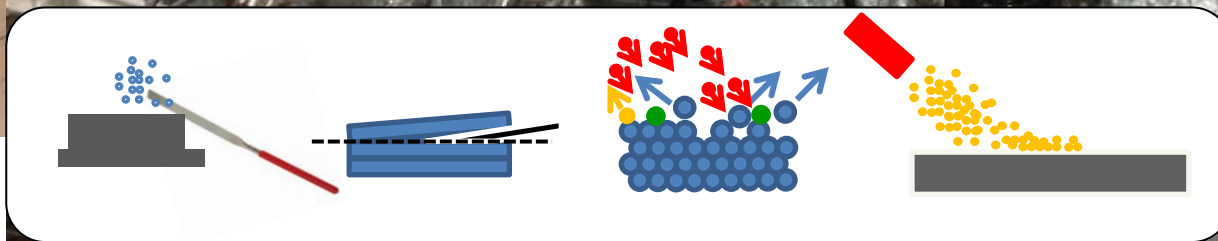
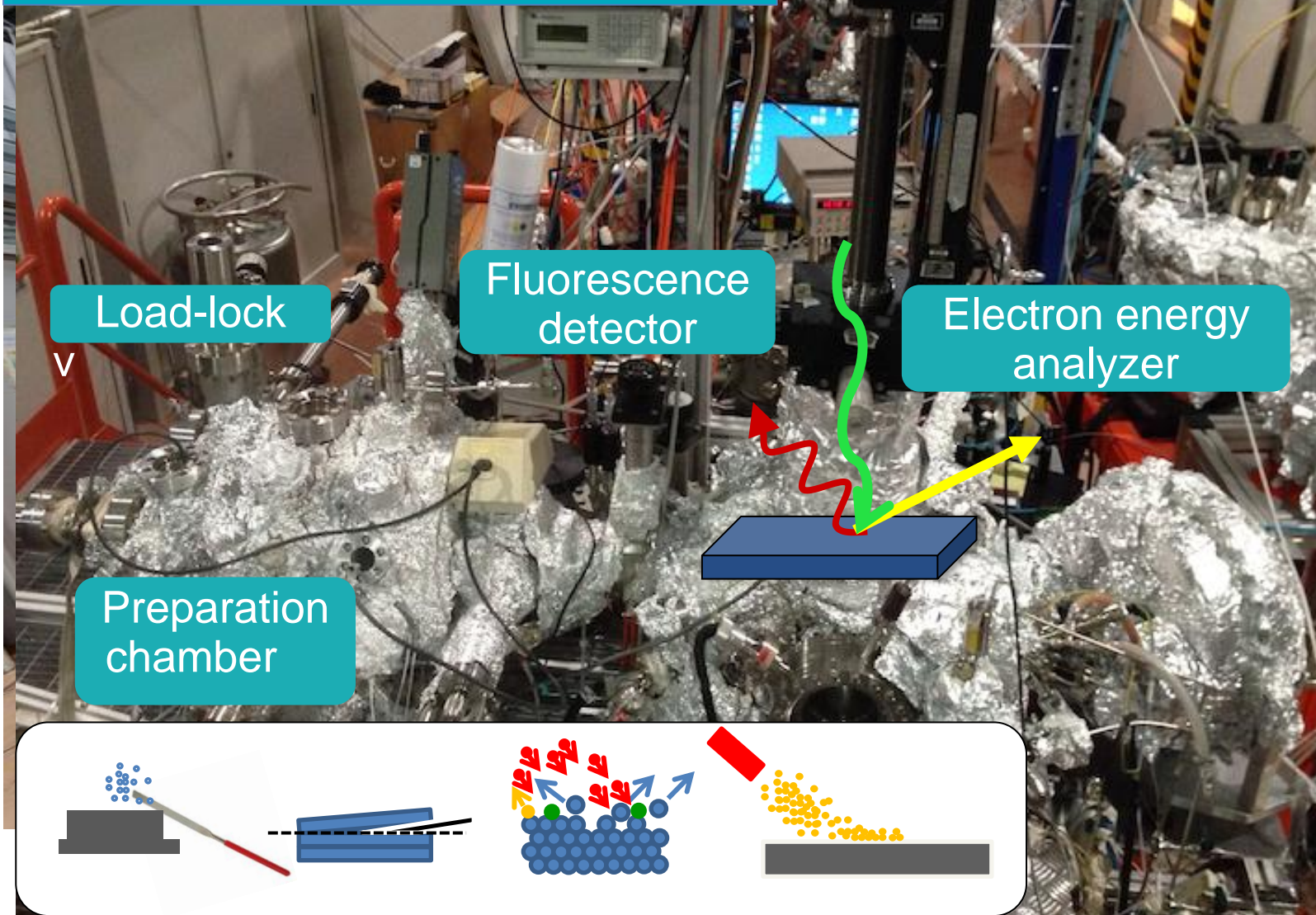
Experimental
stations

Storage ring

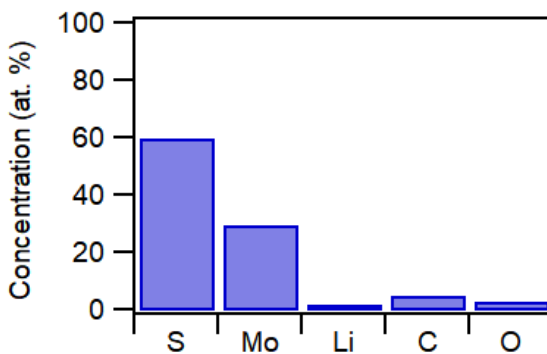
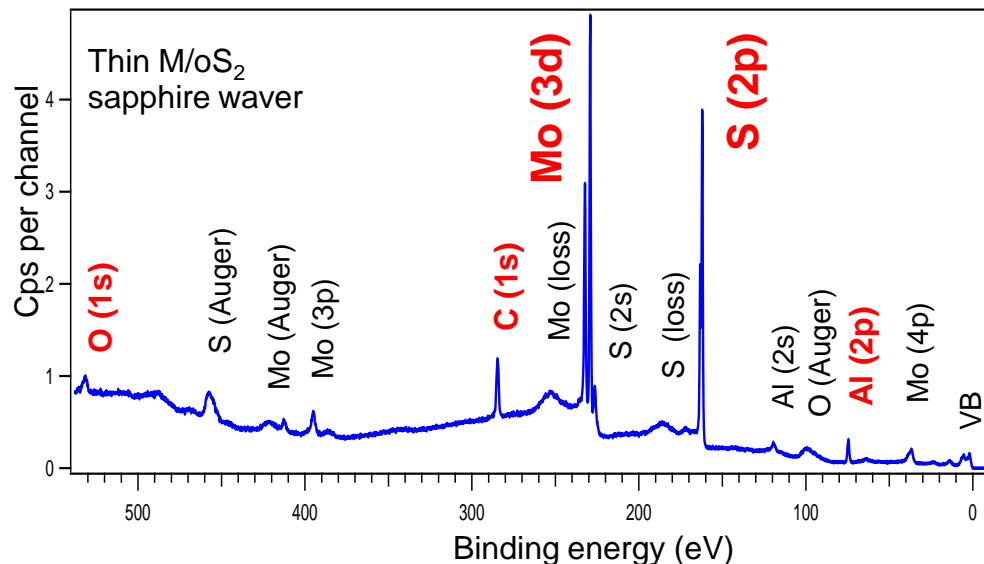
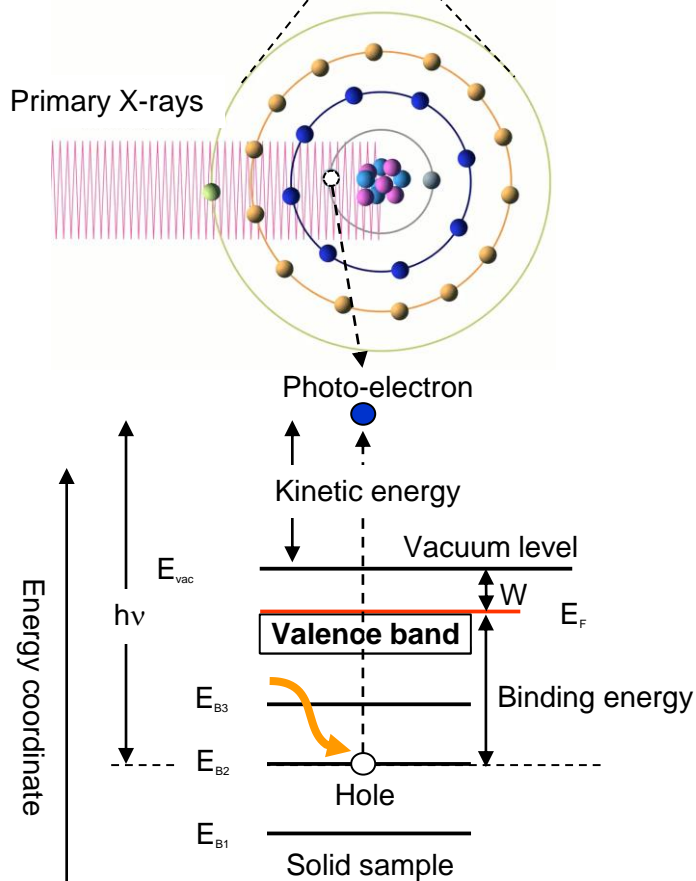
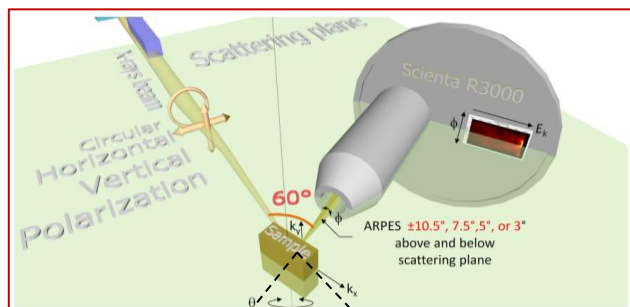
Experimental station

EUV – Soft X-rays: 44 – 1600 eV
Variable polarization:
Horizontal, vertical, circular

Electro-chemical
Microfluidic cell



Photoelectron spectroscopy (XPS)



- The energy of the electron is characteristic of the element
- The intensity: element concentration

$$h\nu = W + E_k + E_b$$

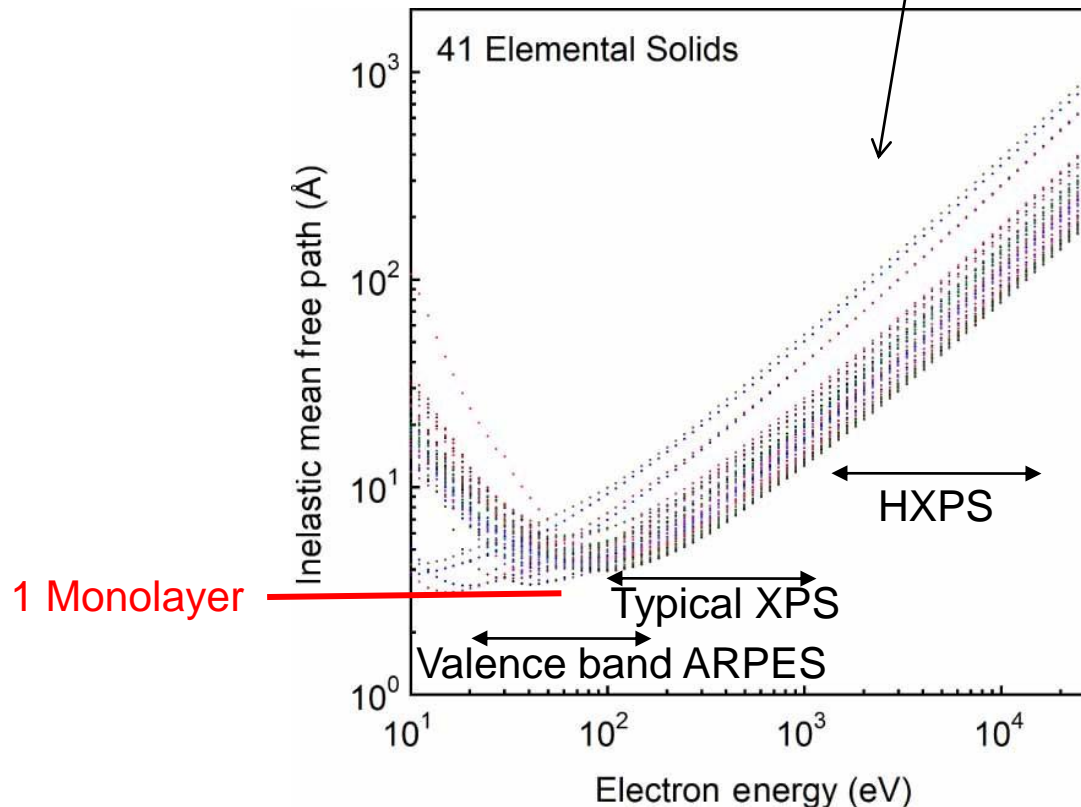
$$E_B = E(N_e - 1) - E(N_e)$$

– relaxation energy

Chemical shift

Surface sensitivity

$$dI_i^A = \Phi DN^A \sigma_i^A \exp\left(-\frac{x}{\lambda \cos \theta}\right) dx$$



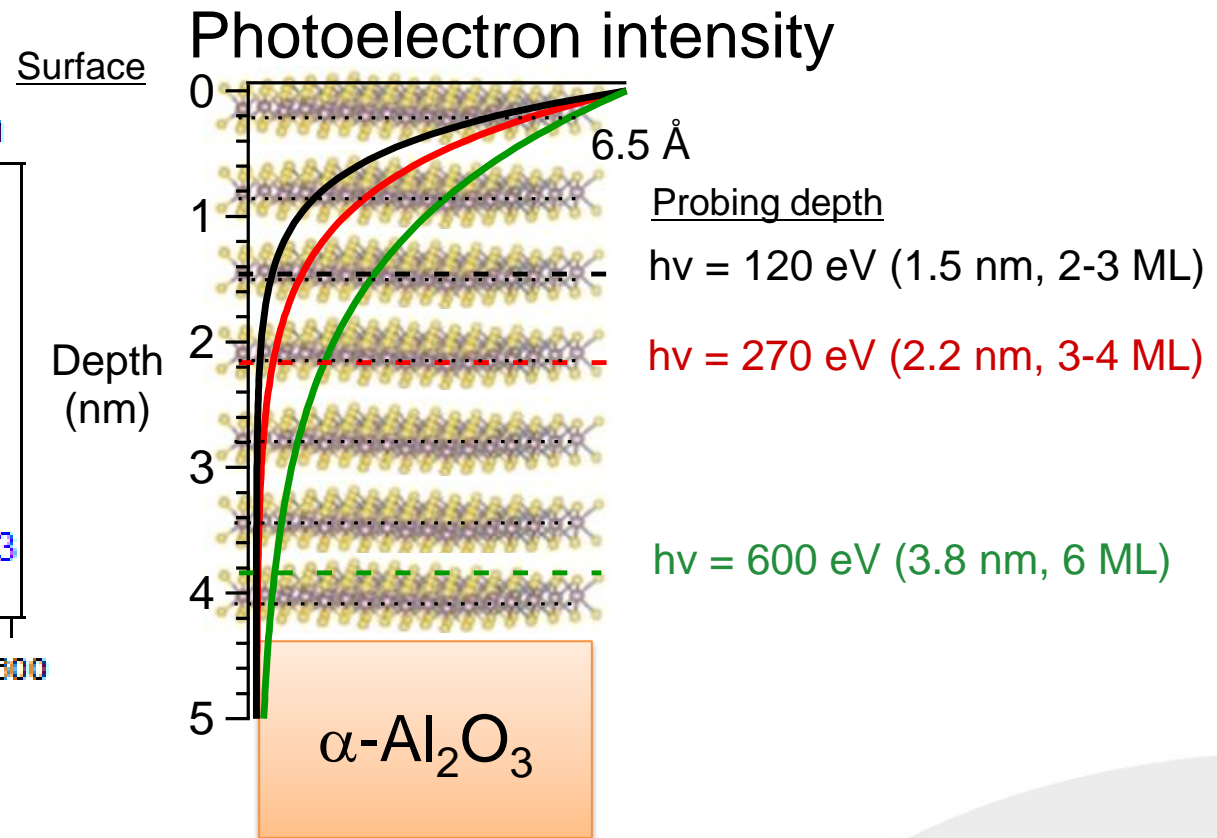
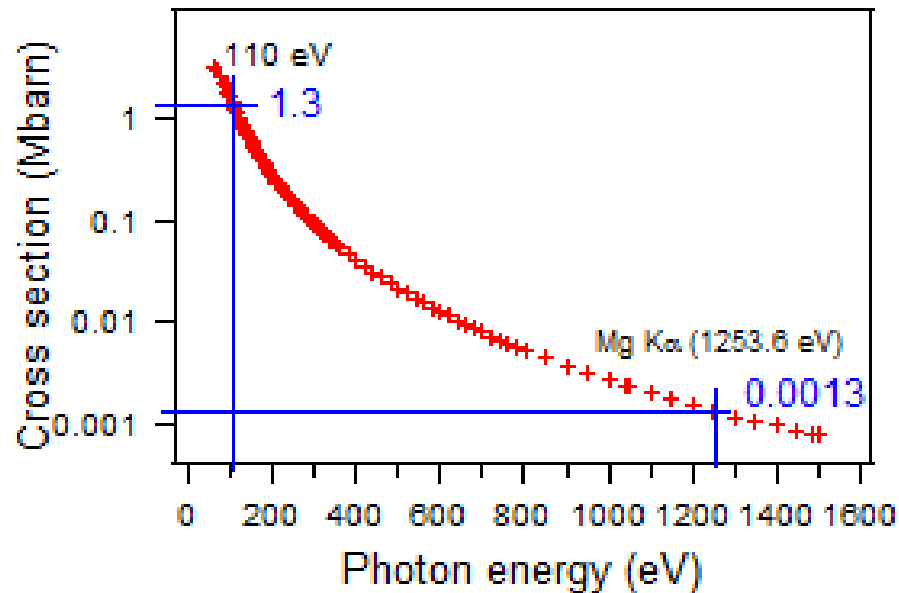
Surface and Interface Analysis, Volume: 43, Issue: 3, Pages: 689-713, First published: 08 February 2011, DOI: (10.1002/sia.3522)

Tunable X-rays source enables to tune the probing depth from the top most surface layer to subsurface region , typically up to **5-10 nm**.

Photon source tunability

- 600, 270, 120 eV
- Variable element sensitivities
- Variable probing depth (depth profiling)

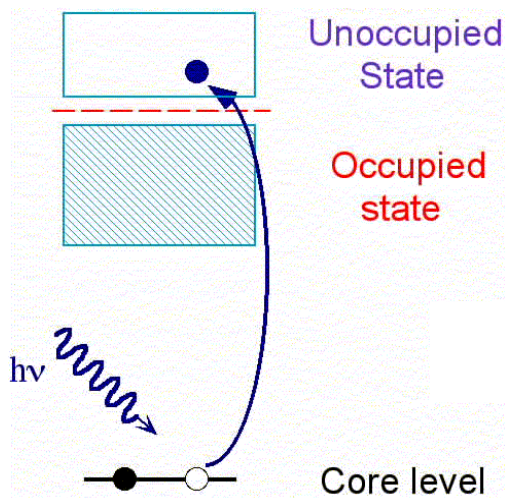
Li 1s Photoionization cross section



X-ray Absorption Spectroscopy - XAS

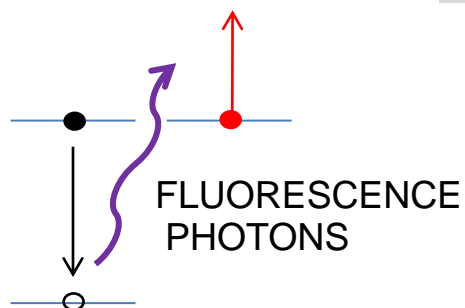
X-ray Absorption

Tunable source
of X-rays



CREATION OF
A CORE HOLE

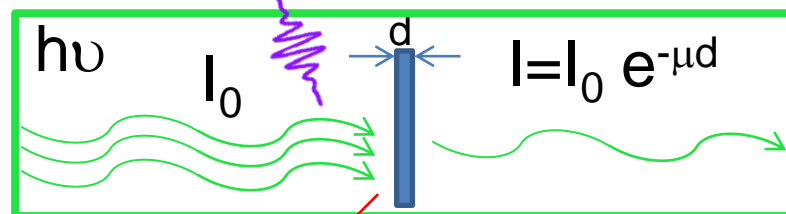
AUGER ELECTRON



DECAY

XAS techniques

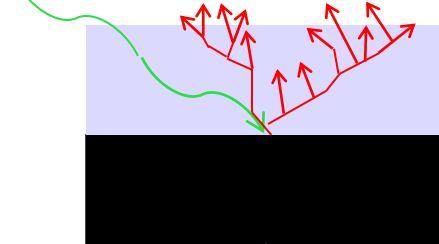
FLUORESCENCE YIELD



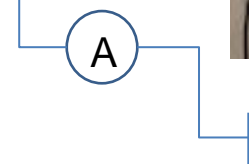
TRANSMISSION

AUGER YIELD

SECONDARY ELECTRONS



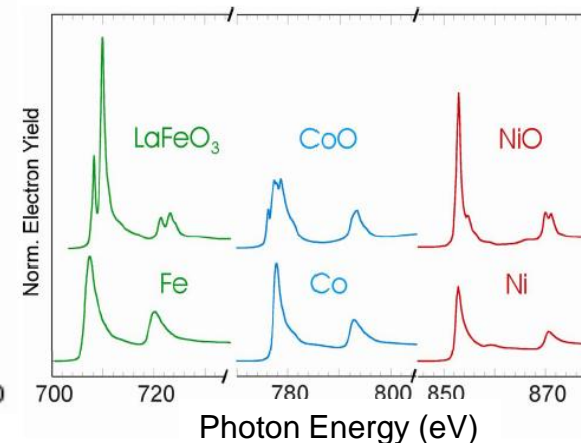
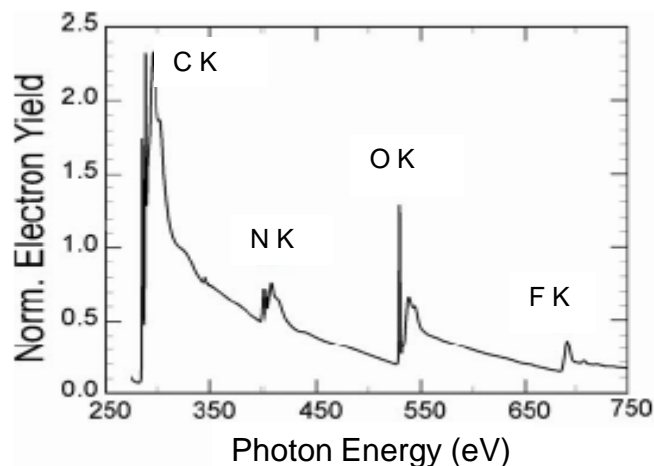
ELECTRON YIELD



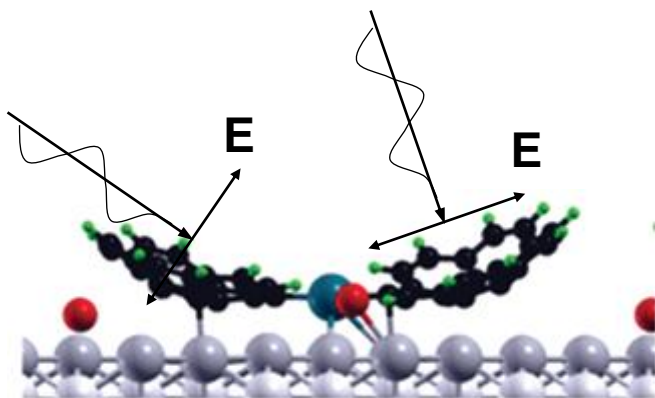
X-ray Absorption Spectroscopy - XAS

Element specific

SENSITIVITY TO THE CHEMICAL ENVIRONMENT

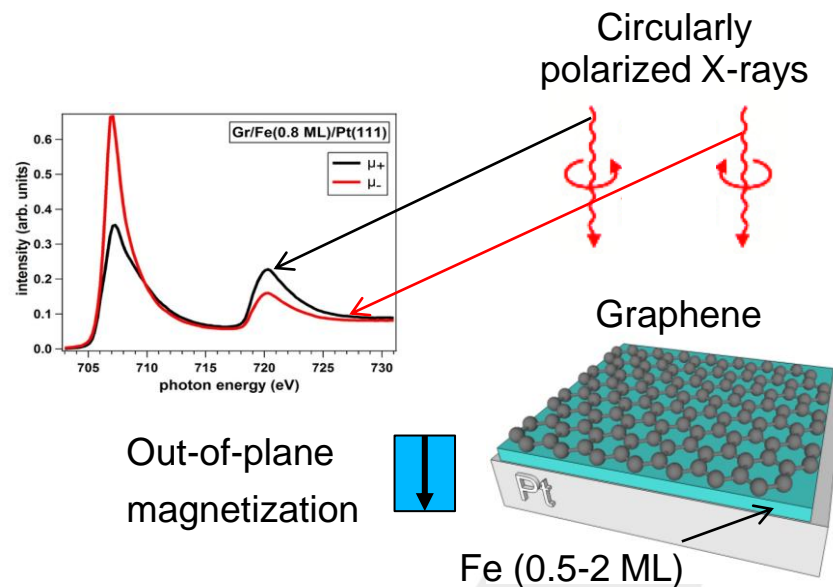


Linear Dichroism - bond orientation

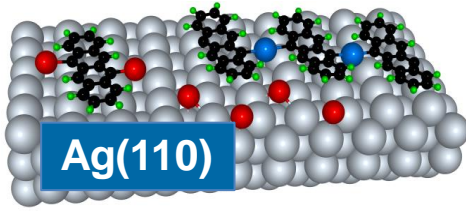


Phys. Chem. Chem. Phys., 2018,20, 26161-26172

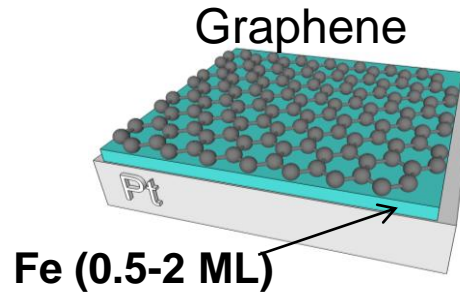
Magnetic dichroism (XMCD)



Chemical reactions at surfaces

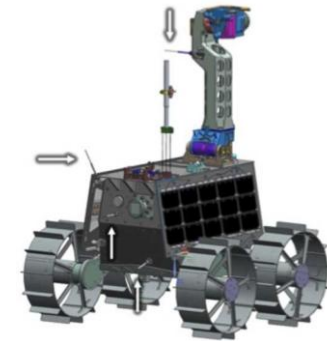


Magnetic thin-films

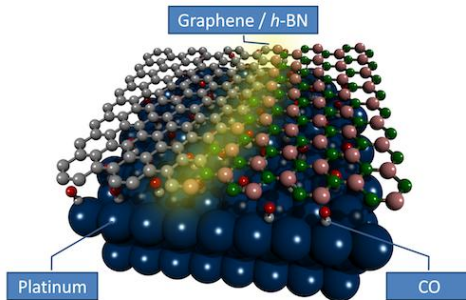


Space technologies

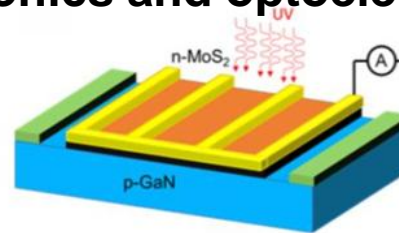
Rashid I, lunar rover (2023)



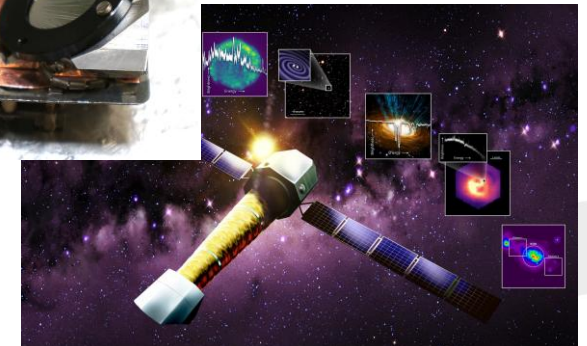
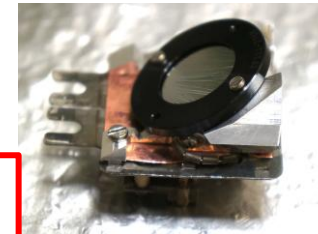
Heterogeneous catalysis



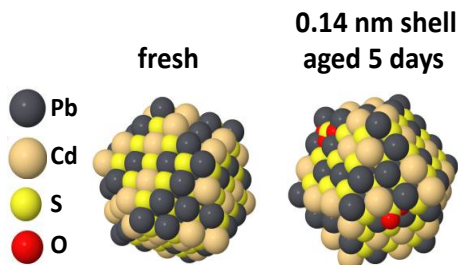
Electronics and optoelectronics



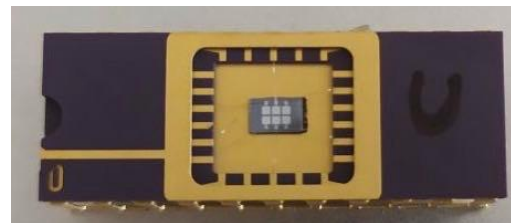
Optical filters for X-ray detectors in space



Quantum materials



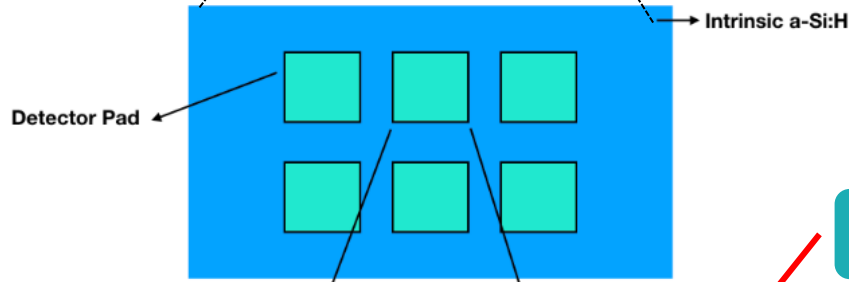
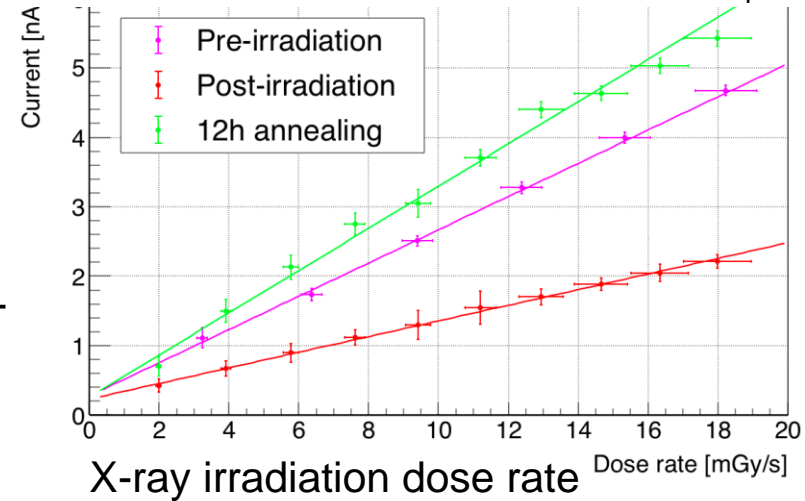
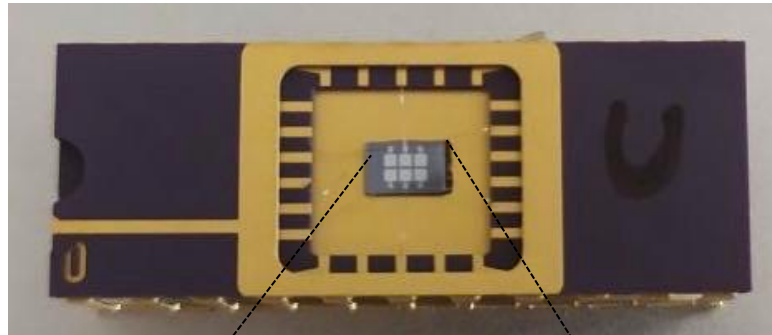
(Radiation) detectors



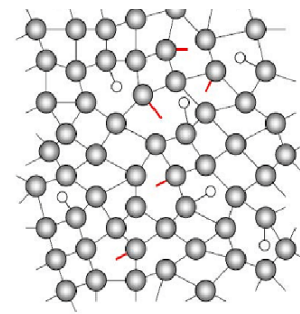
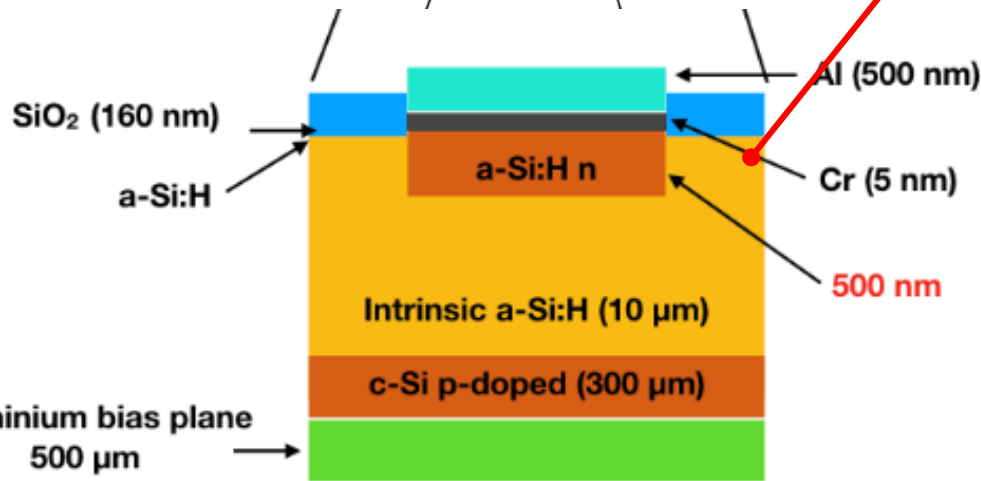
PIN diode X-ray dose detector

Device sensitivity drop after irradiation with **neutrons**

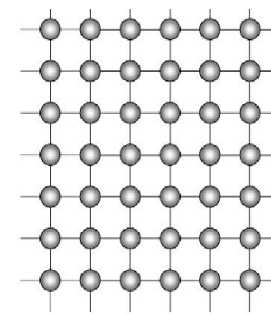
$10^{16} n_{eq}(1MeV)/cm^2$



Hydrogenated amorphous silicon

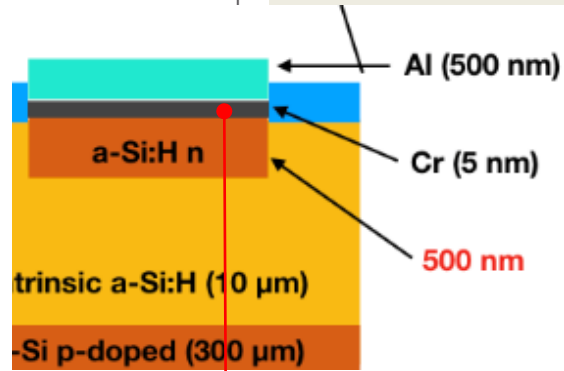
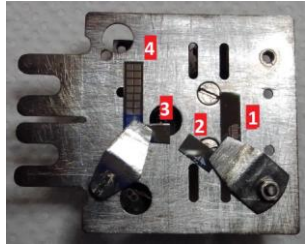
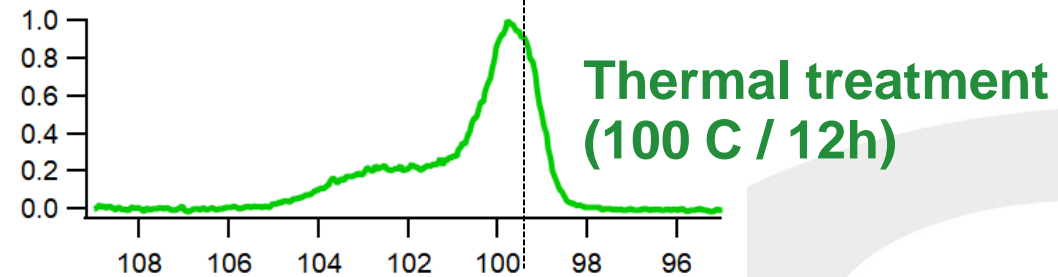
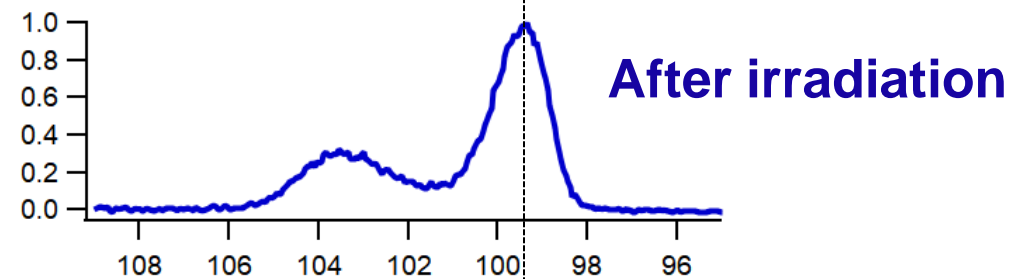
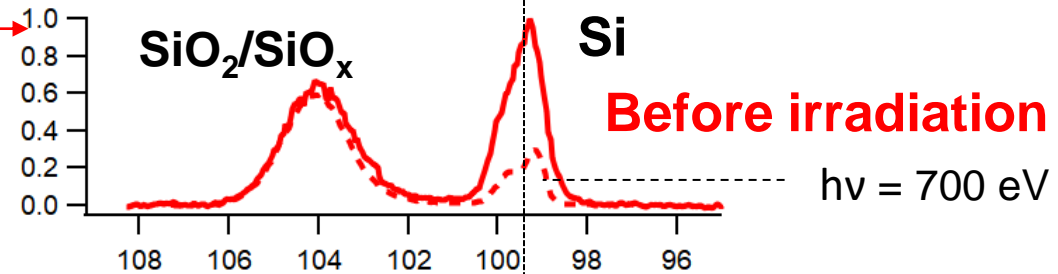
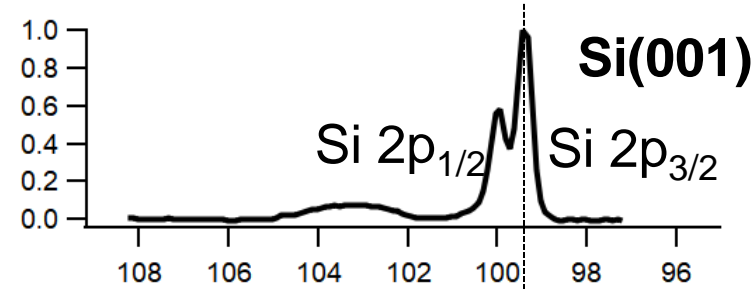


Amorphous



Crystalline

Si 2p XPS spectra


 $h\nu = 1400 \text{ eV}$


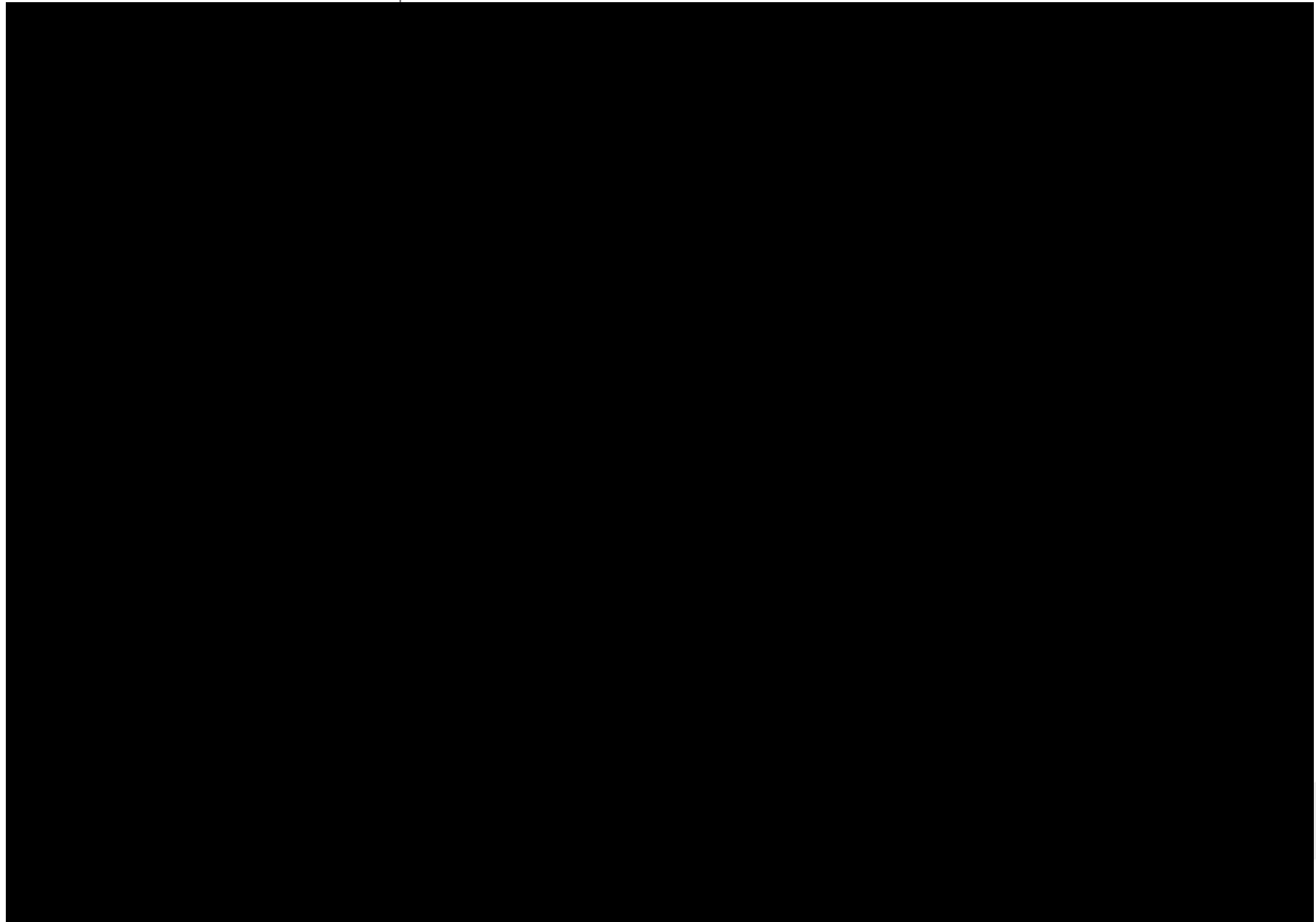
Reported Si 2p_{3/2} binding energies

Compound	BE (eV)	Std.dev.
Si ⁰	99.4	0.1
def-Si	99.1	0.1
Si-H	99.7	0.1
Si-C	100.1	0.3
Si ⁴⁺	103.6	0.3

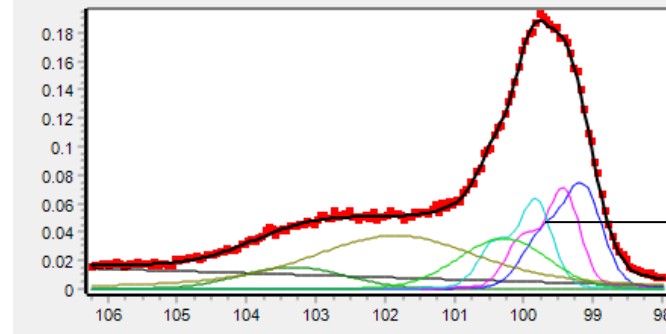
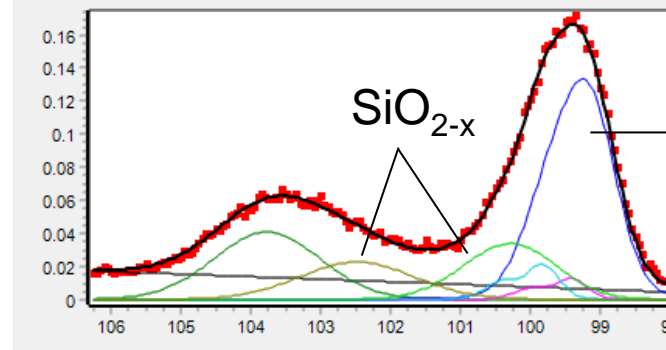
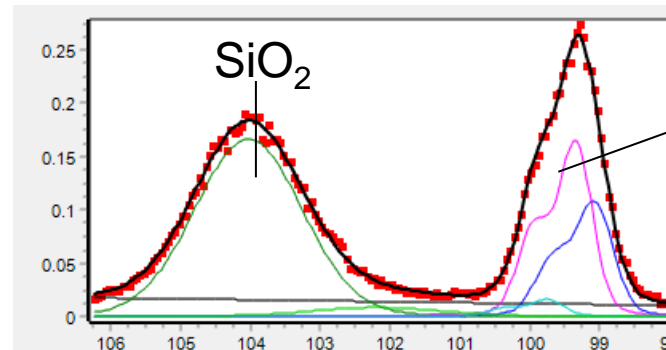
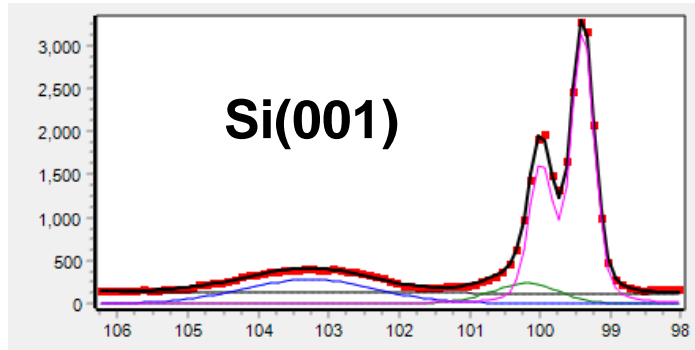
Normalized intensity

Binding energy (eV)

Si 2p XPS spectra – peak fitting



Si 2p XPS spectra – peak fitting



XAS absorption spectroscopy

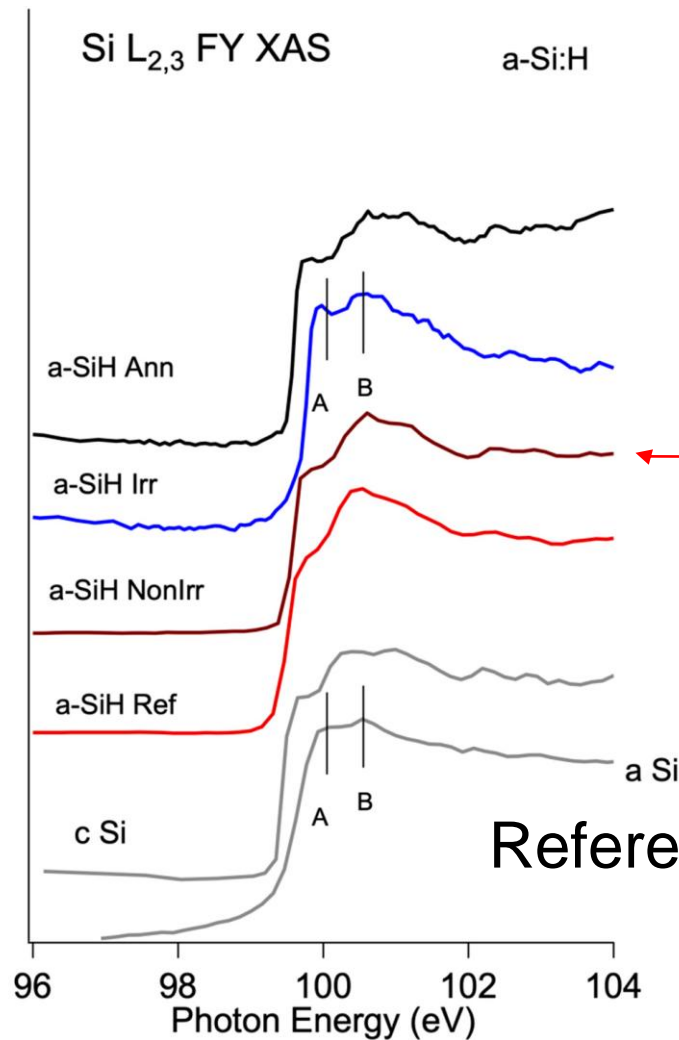
XAS probing depth: 80 nm (Fluorescence yield)

XPS probing depth: 9 nm

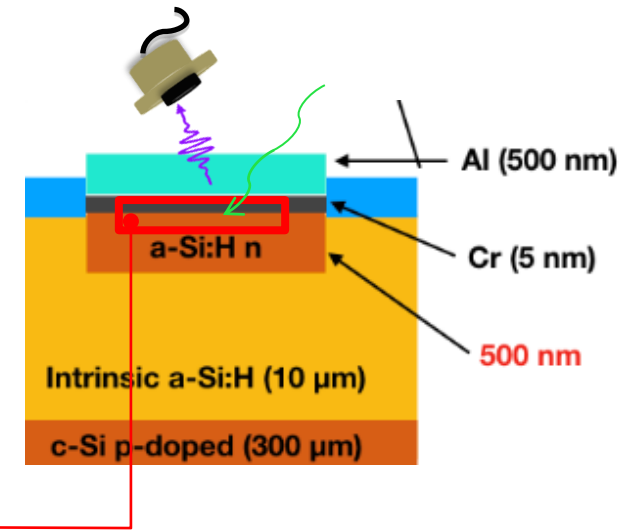
**Thermal treatment
(100 C / 12h)
a-Si:H**

**After irradiation
a-Si**

**Before irradiation
a-Si:H**



Reference samples

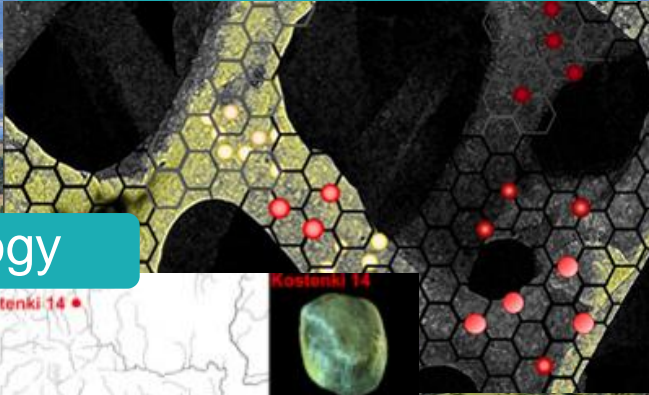




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Enjoy the Elettra!

Nanotechnologies and
New materials



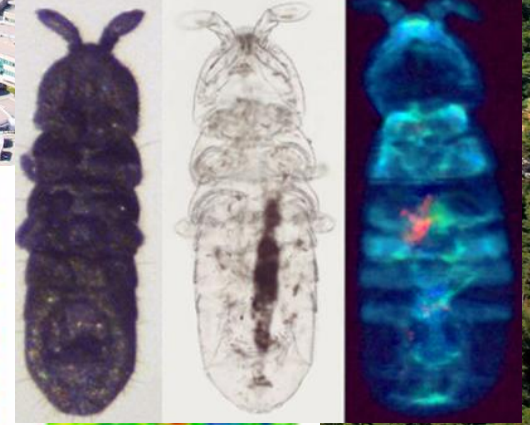
Medical research and
structural biology



Archeology



Environment



Microscopy

