Attività del laboratorio congiunto IOM-UniPg

Maddalena Pedio (CNR-IOM-TS → PG, INFN PG)

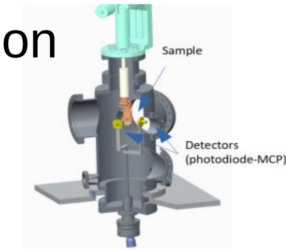
Alberto Verdini (CNR-IOM PG)

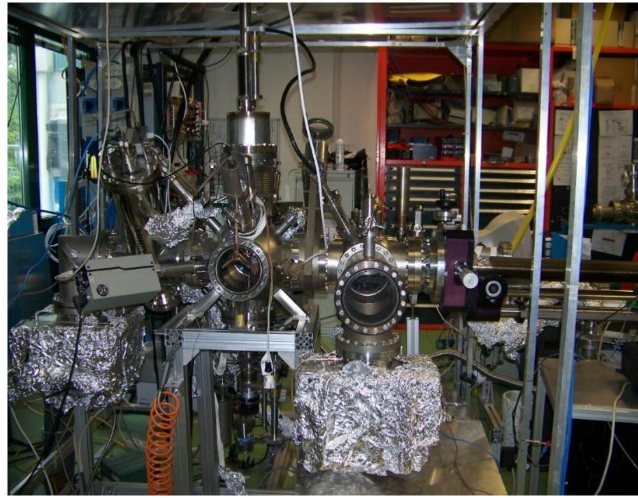
https://www.iom.cnr.it/research-facilities/facilities-labs/analytical-microscopy-and-spectroscopy/sipe/

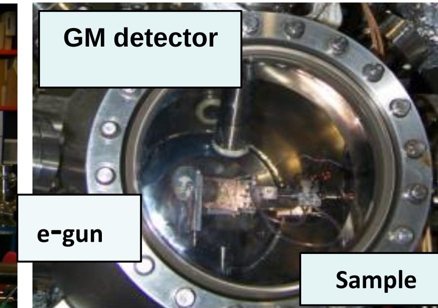
https://www.iom.cnr.it/research-facilities/facilities-labs/analytical-microscopy-and-spectroscopy/across/

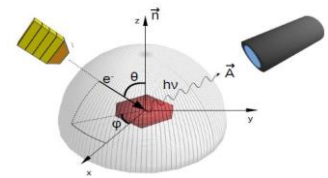
Instrumentation

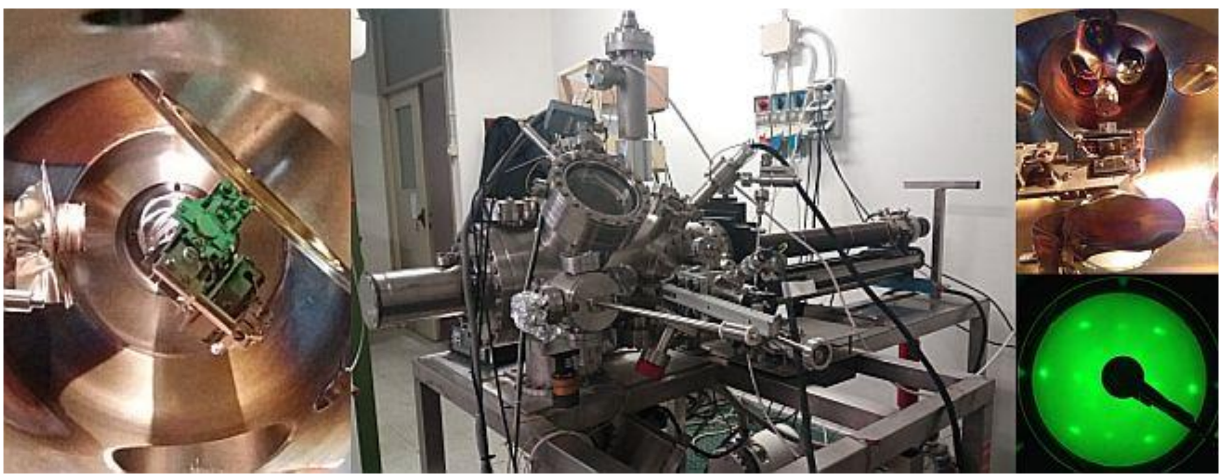
SIPE-nanoStructures Inverse Photoemission and Excitation dynamic











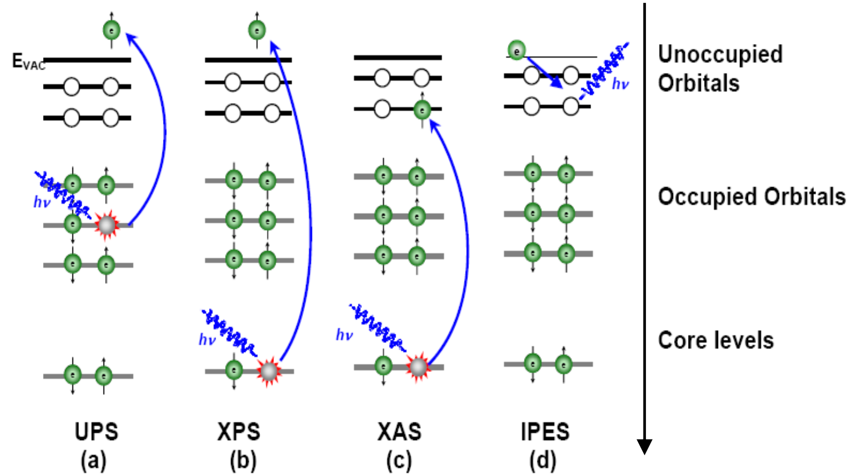
ACROSS –Surfaces, Nanostructures, Electrond Diffraction, Auger and UV Photoemission Spectroscopy

Advanced ChambeR fOr Surface Studies ACROSS

Absorption and Electron spectroscopies

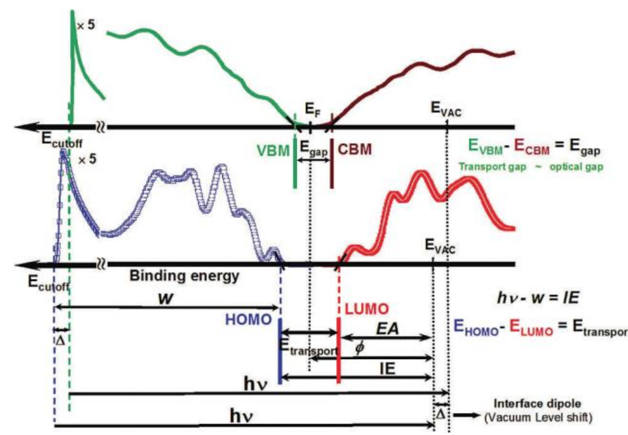
Linear response theory models the spectrum

Final state differs from the ground state



N-1 N+1

Method	Particle In	Particle Out	Information	Technique
Photoemission	Photon	Electron	Filled core states	XPS
Photoemission	Photon	Electron	Filled valence states	UPS
Inverse photoemission	Electron	Photon	Empty states	IPES
Electron energy loss	Electron	Electron	Electronic & vibrational transitions	EELS, HREELS
Auger	Electron	Electron	Filled states	AES
Absorption / emission*	Photon	Photon	Electronic transitions, filled states	UV-Vis, XRF
Core XAS	Photon	photon	empty el states Structure	EXAFS/NEXAFS



Main techniques and methods

In campus

- Ultra-Violet Photoemission Spectroscopy (**UPS**), Inverse Photoemission both Angular Resolved (**KRIPES**) and Angular Integrated (**IPES**), Surface (Photo)Voltage (**SPV**) by spectroscopies, X-Ray Photoemission Spectroscopy (**XPS**)

Large Scale facilities: Synchrotrons, Free Electron Lasers

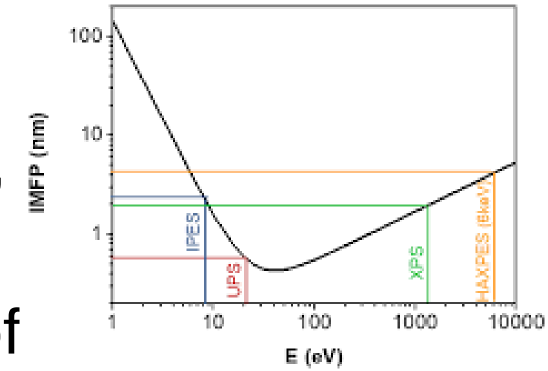
- X-ray Absorption Spectroscopy (**XAS**), Near Edge X-ray Absorption Fine Structure (**NEXAFS**), Time resolved XAS (**TR-XAS**), (Grazing) X-ray Diffraction (**G-XRD**), Photoelectron Diffraction (**PED**), Resonant Photoemission (**RESPES**), Resonant PED (**RESPED**)

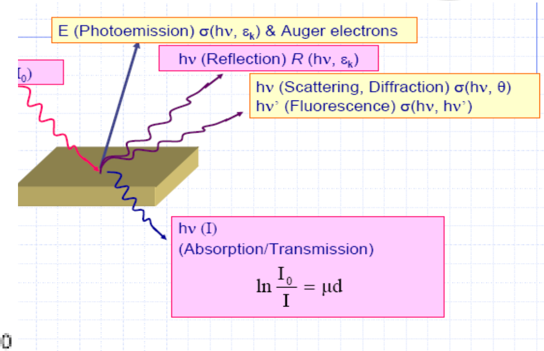
Simulation and modeling

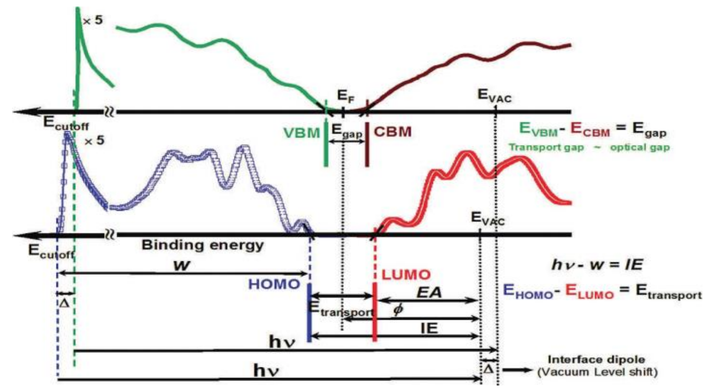
- Multiple scattering applied to XAS (**MXAN**, INFN), Photoelectron Diffraction (MSCD, EDAC codes), Time Resolved-SPV

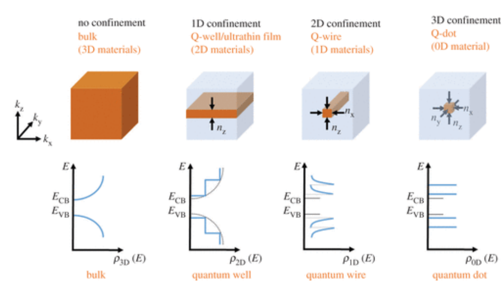
Electron/absorption spectroscopies information

- Chemical sensitivity, Stoichiometry
- Band gap, Density of electronic states
- Transport Phenomena
- Correlation structure-optoelectronic properties
- Quantum confinement
- Phase transitions
- Non-equilibrium phenomena









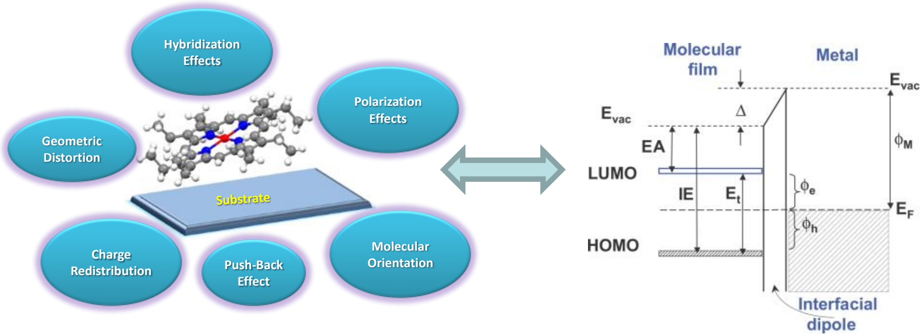
Ambiti del PTSR:

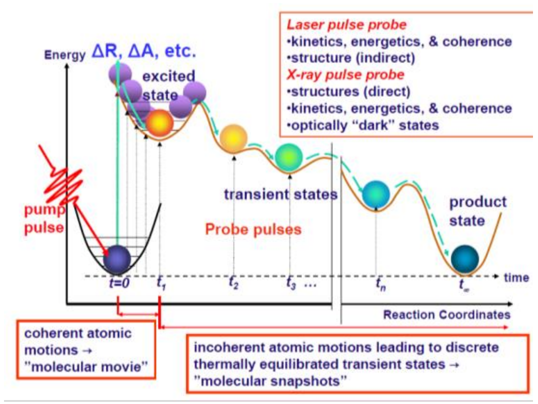
- **Nanoscienze ambito 5,**
- Spettroscopie elettroniche e di assorbimento applicate a campioni a bassa dimensionalità e a sistemi nanostrutturati. Correlazione fra proprietà fotoelettroniche, morfologia e struttura. Accesso a Large Scale Facilities. Sviluppo detectors nel UV.

- **Neutroni, LdS, FEL ambito 8**
- Sviluppo strumentazione per assorbimento di raggi X anche risolto in tempo. Sviluppo di programmi di analisi dati di fotoemissione, assorbimento, fotoemissione risonante, diffrazione di (foto)elettroni

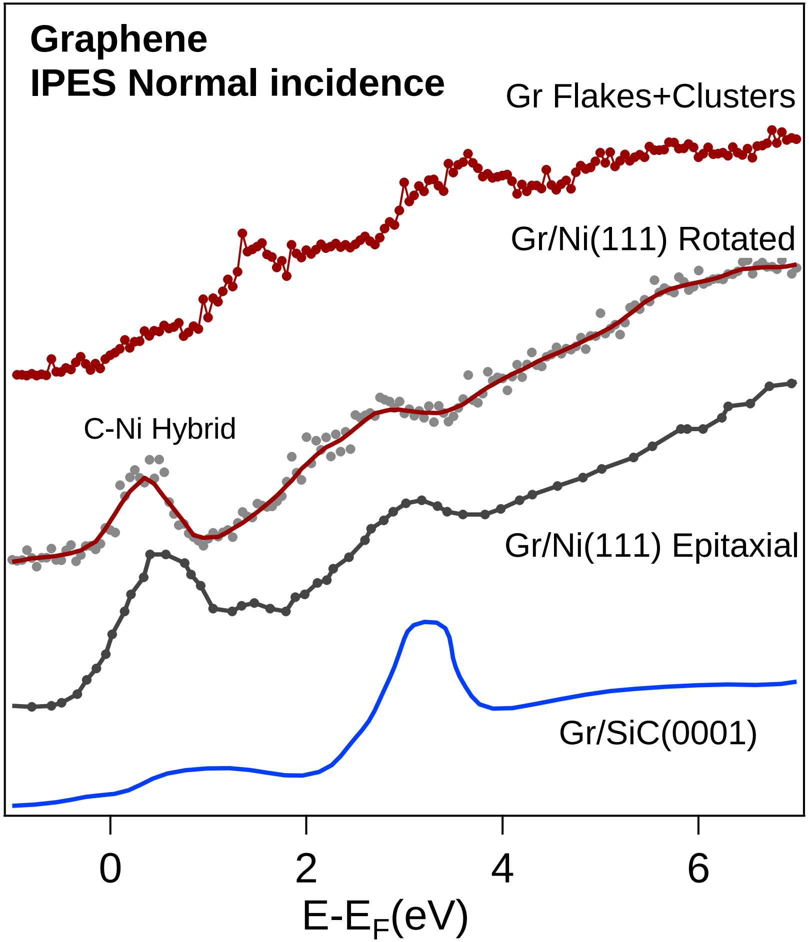
NEXT 3 Years SIPE

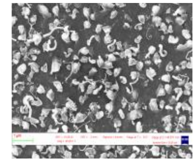
- C-based systems
  - Graphene/ topological 2D-3D materials
  - Carbon and SiC NanoTubes
- Graphyrin
- Heterojunctions, Organic Films spintronic & photovoltaic applications
- Photocatalytic materials, Hydrogen production and storage
- Carrier Dynamics

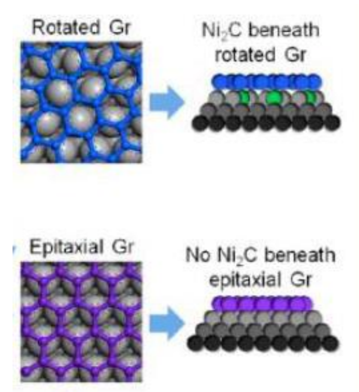




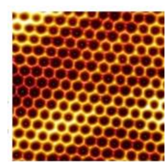
Graphene electronic properties







Interacting Graphene

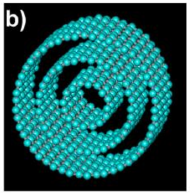


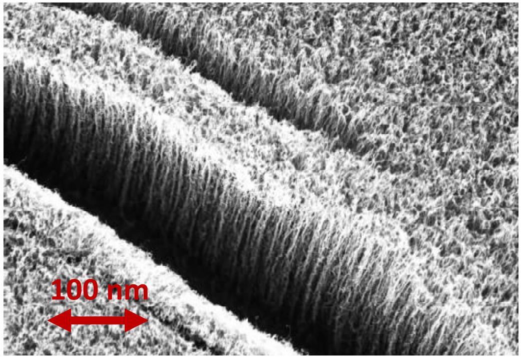
No interacting Graphene

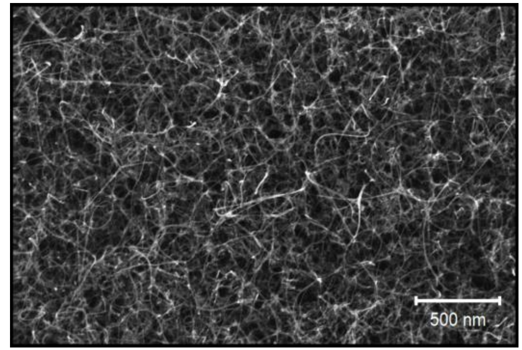
Applications: anti-corrosion coatings and paints, efficient and precise sensors, faster and efficient electronics, flexible displays, efficient solar panels, …..

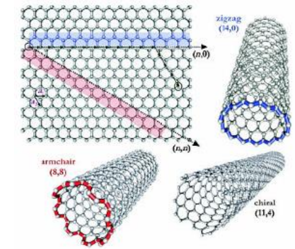
Coll. C. Cepek, C. Africh

C-based materials: Carbon Nanotubes growth and characterization

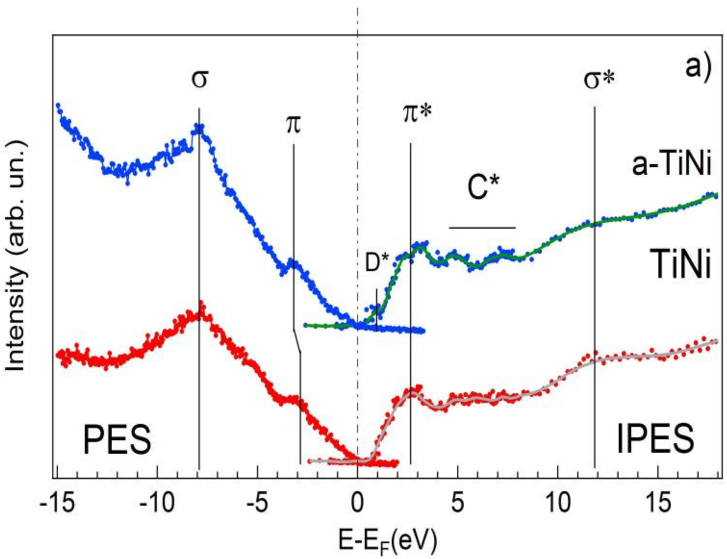


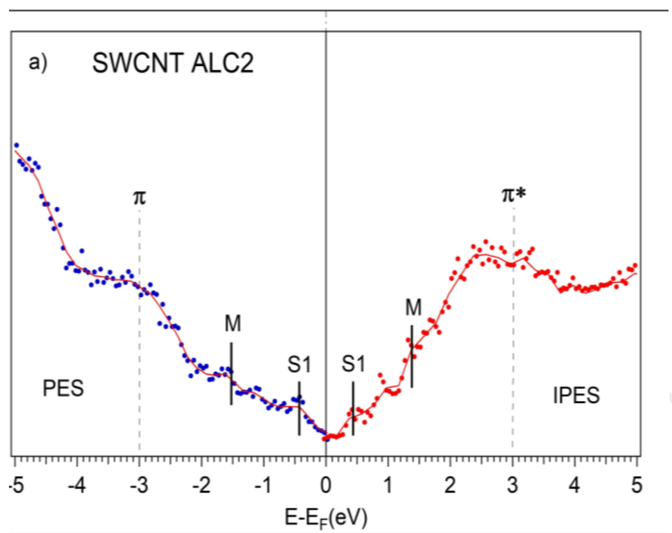


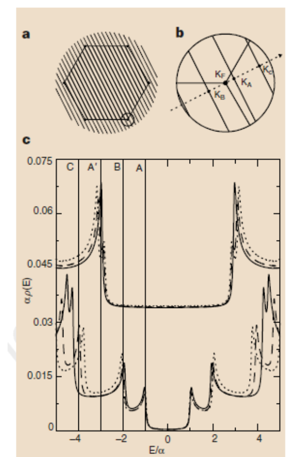




SWCNTs n=m, n-m=3i metallic



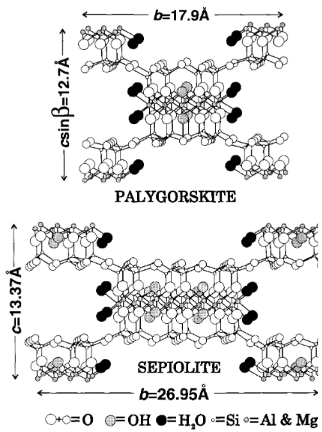




Van Hove singularities in Single Wall

Coll. C. Cepek IOM-CNR TS

Spectroscopies useful for mineral?



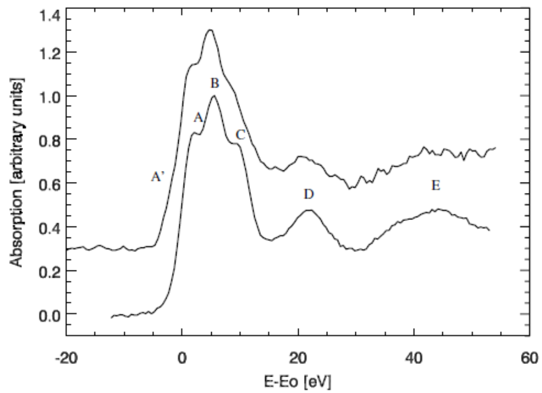
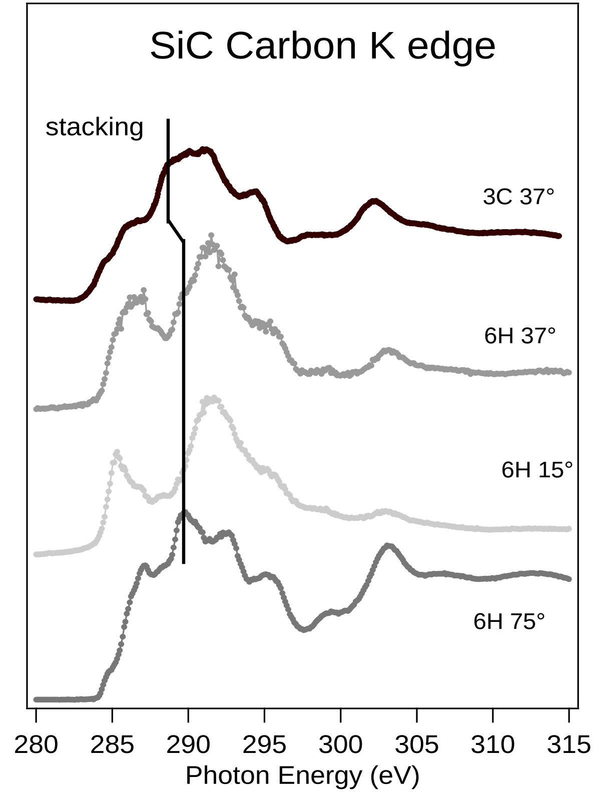
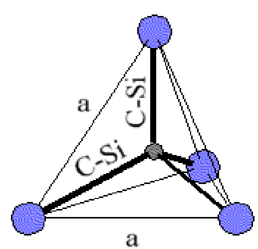


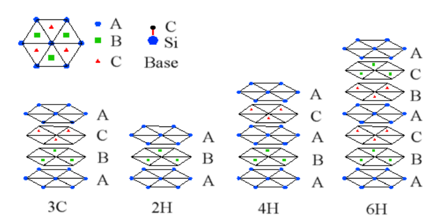
Fig. 1. Magnesium K-edge XANES spectra of palygorskite (top) and sepiolite (bottom).



Maya Blu:Nanostructured systems Renewed interest

Sepiolite and palygorskite: fibrous clay minerals which differ from laminar clays by having channels in their structure





Stacking sequencies of double layers of SiC polytypes

M. Sanchez del Rio, M. Pedio

Active collaboration UNIPG SIPE

- Real devices

– Si:H INFN Gruppo V 3D-SIAM, Haspide

M. Menichelli, L. Servoli & PhD PON

IR Prof. P. Sassi, UniPG Chimica,

L. Comez IOM

AFM, Raman S. Tacchi, S. Caponi IOM

– Defects in SiO_2 INFN&CNR F. Moscatelli

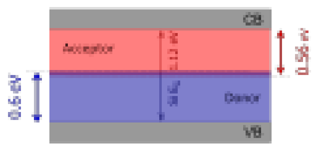
S. Tacchi, C. Soncini IOM

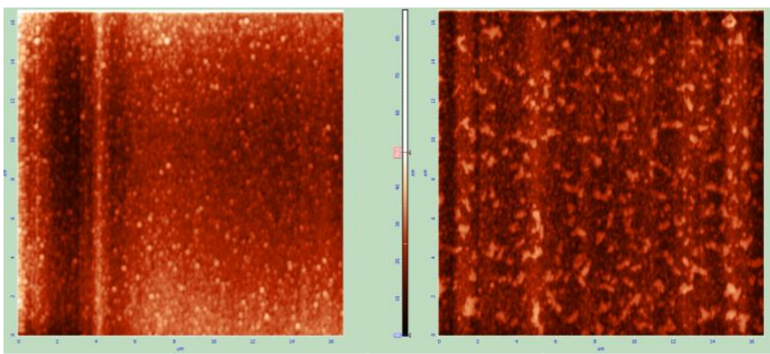
Active collaboration UNIPG SIPE

"New Perugia Model"

general radiation damage model

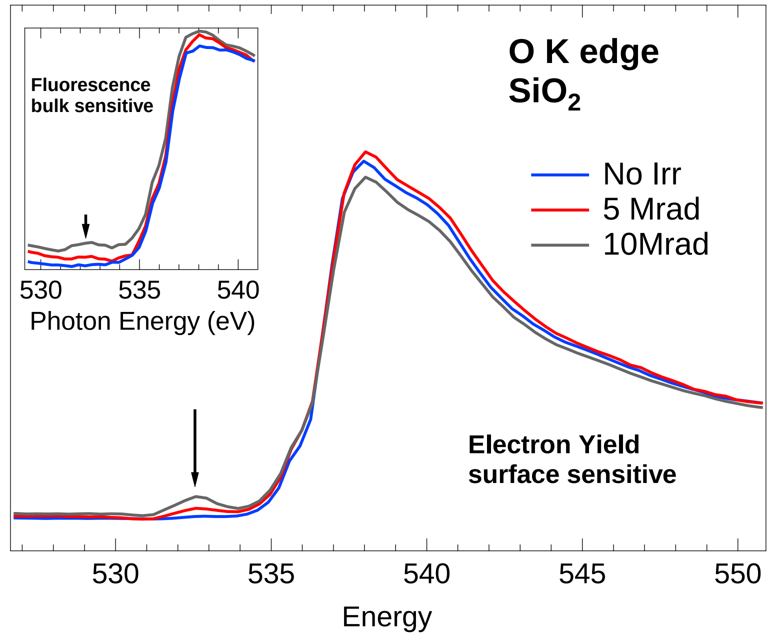
F. Moscatelli, et al., Nucl. Instr. Methods Phys. Res. A, 2018 & Nucl. Instr. Methods Phys. Res. A, 2019





	D defects	Area defects	Roughness
No Irr	250±50	2.5%	4
5 Mrad	900±200	15.6%	7.5

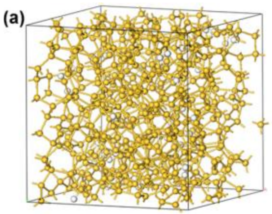
Bulk and **surface radiation damage** taken into account by the introduction of deep level radiation induced traps



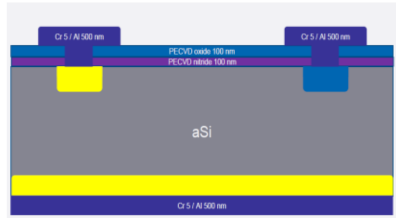
AFM and **XAS** (BACH beamline) recent measurements on samples before and after irradiations (S. Tacchi, C. Soncini, E. Magnano, I. Pis, R. Gotter, M. Pedio)

Active collaboration UNIPG SIPE

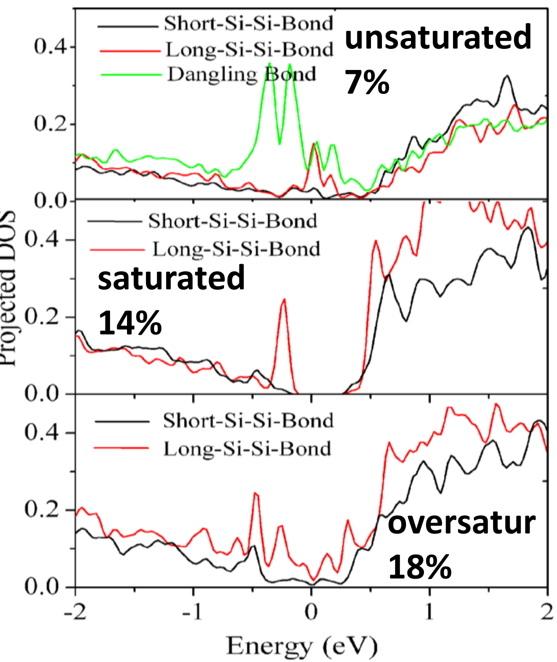
Amorpous Hydrogenated Silicon

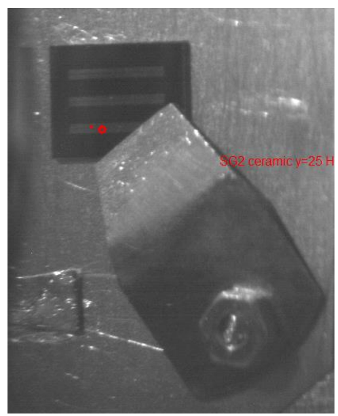


Legesse et al 2014



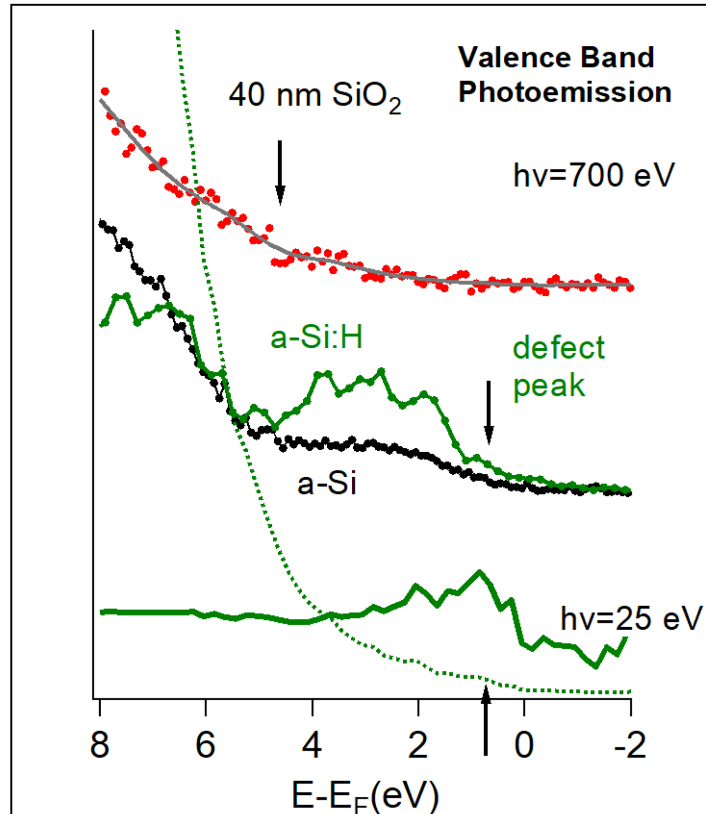
M. Menichelli et al 20 20 JINST 15 C04005





Red circle: X-Ray spot

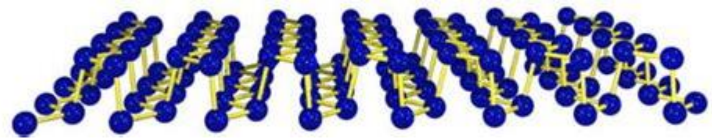
Photoemission Valence Band No Irradiated reference samples (EPFL, N. Wyrsch)



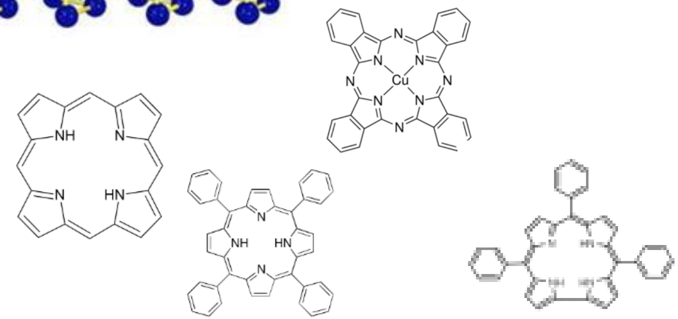
INFN Gruppo V progetti:3D-SIAM HASPIDE

NEXT 3 Years ACROSS

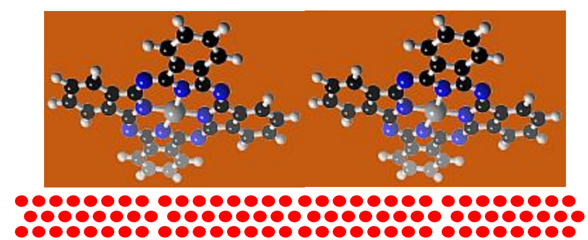
- Phosphorene



- Tetrapyrroles -> Porphyrins



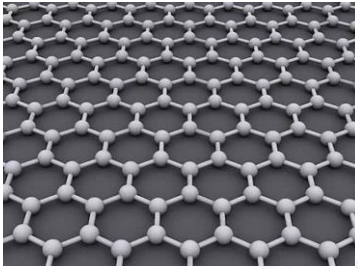
- Organic/Inorganic Heterojunctions



- New coatings for next-gen mirrors (S. Rubini IOM TS, A. Trapananti , F. Travasso UNICAM)

UNICAM
Università di Camerino
1336

2D Monoatomic Materials



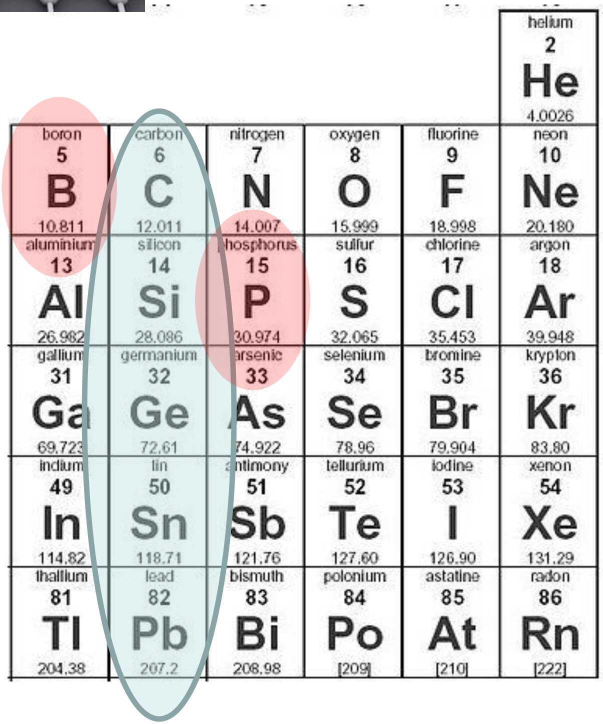
Graphene

Silicene

Germanene

Stanene

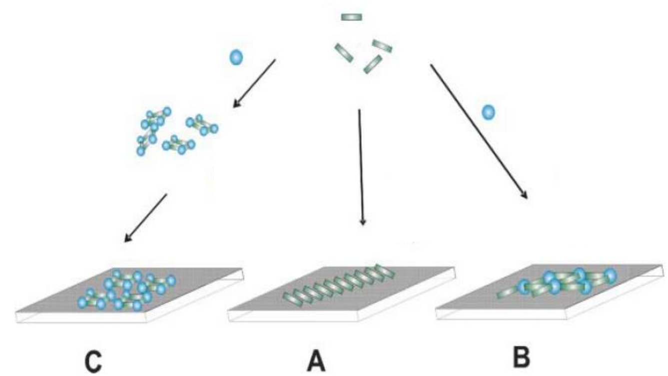
Plumbene



Borophene

Phosphorene

Growth driven by the surface

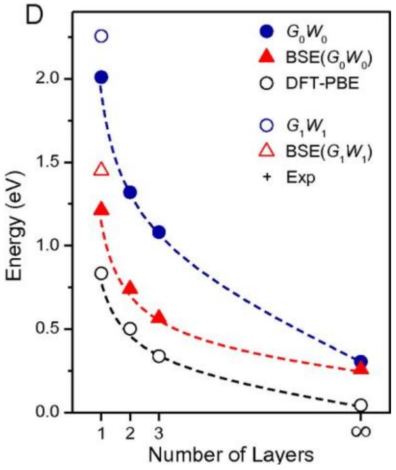


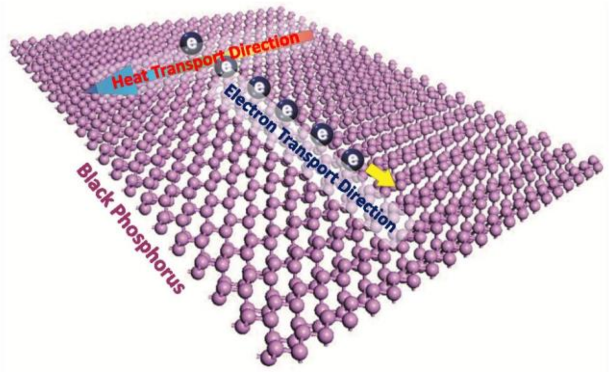
N. Lin et al., Dalton Trans., 2006, 2794–2800

Phosphorene

Black Phosphorous:

- Gap depends on the number of layers
- In-plane anisotropy pf transport properties (electronic/heat)





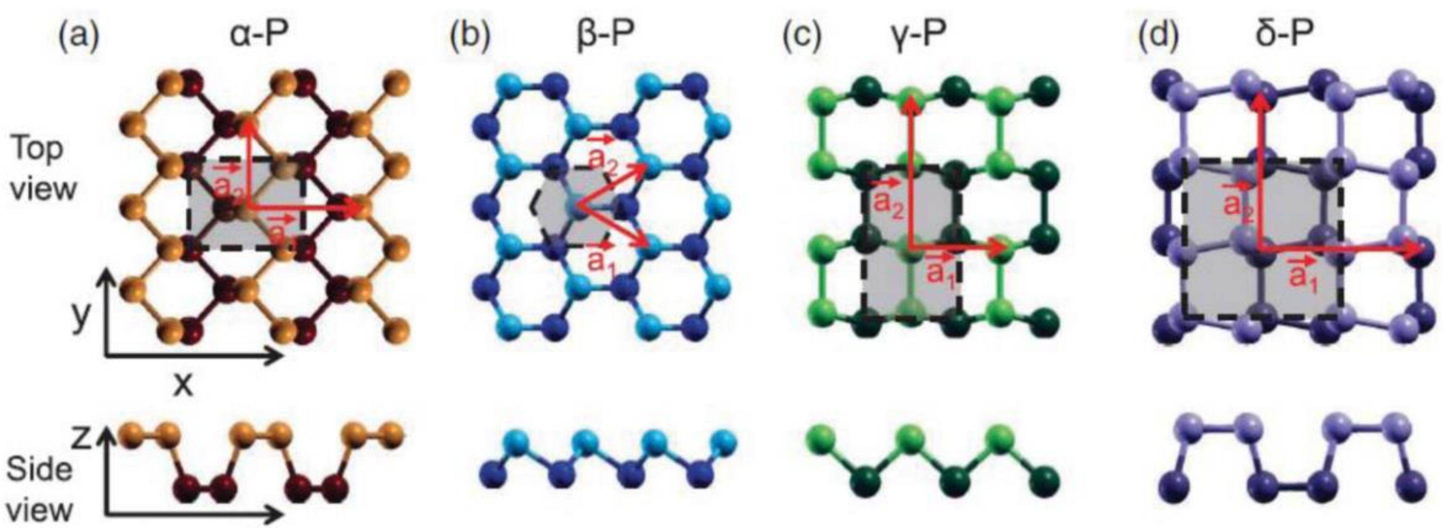
Applications

- FET Transistors
- Opto-electronics
- Solar Cells
- Photocatalysis
- H_2 Water Splitting
- Li-Ion Batteries
- Sensors

X. Ling et al., PNAS - April 14, 2015 112 (15) 4523-4530

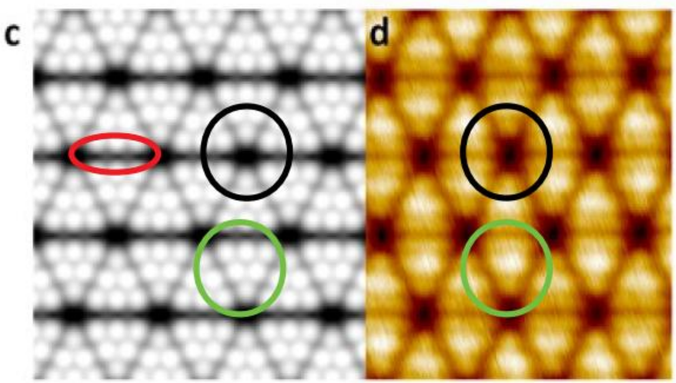
P monolayer – possible stable structures

Black Blue Green Purple

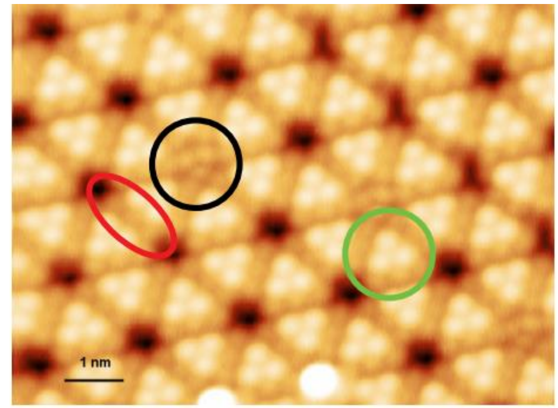


J. Guan et al, PRL 113, 046804 (2014)

Blue Phosphorous grown on Au(111)

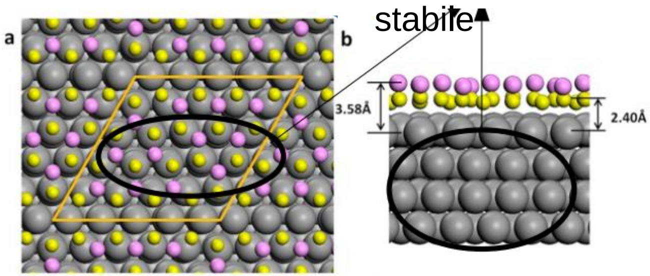


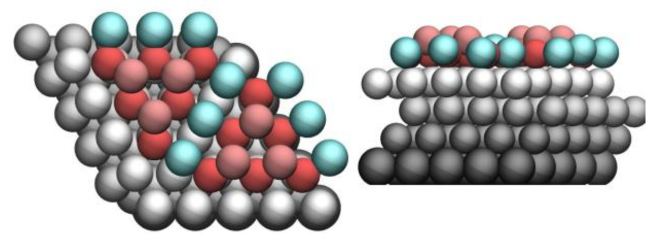
[1]J.L. Zhang et al., Epitaxial Growth of Single Layer Blue Phosphorus: A New Phase of Two-Dimensional Phosphorus, Nano Lett. 16, 4903-4908 (2016)



Our expSTM image - P_{16} x 2 model

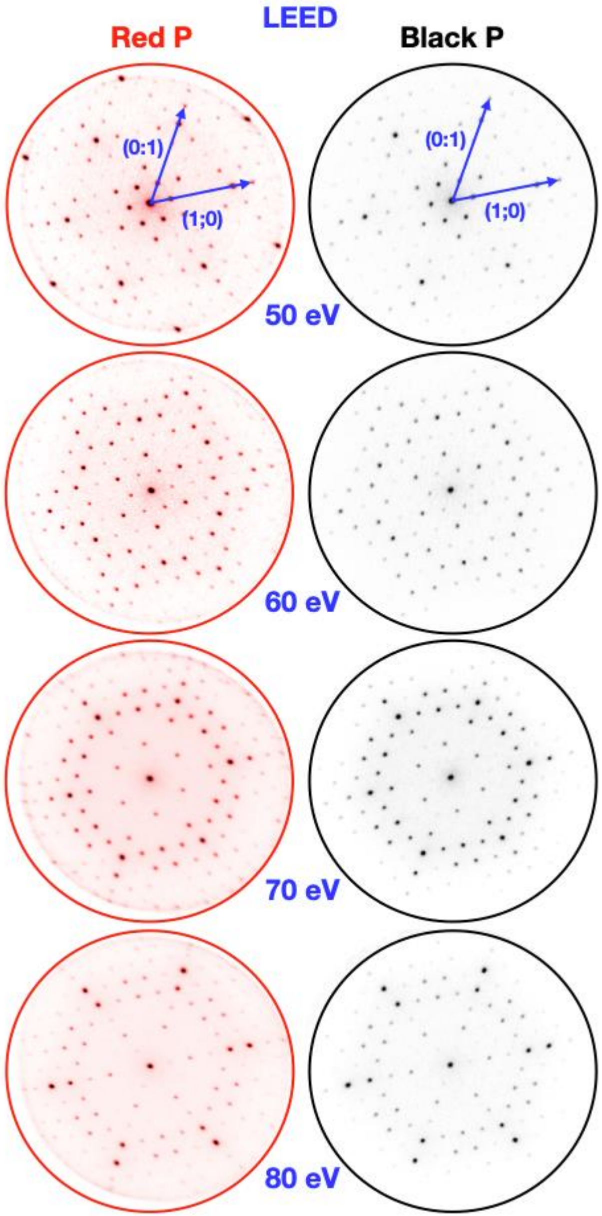
Struttura non stabile





A. Sala @ IOM TS
M. Peressi S. Dal Puppo @UniTS

Electron Diffraction



Why not using as evaporant Red phosphorus (very very cheap) instead of the Black one (very very expensive)?

SAME STRUCTURES

⇩

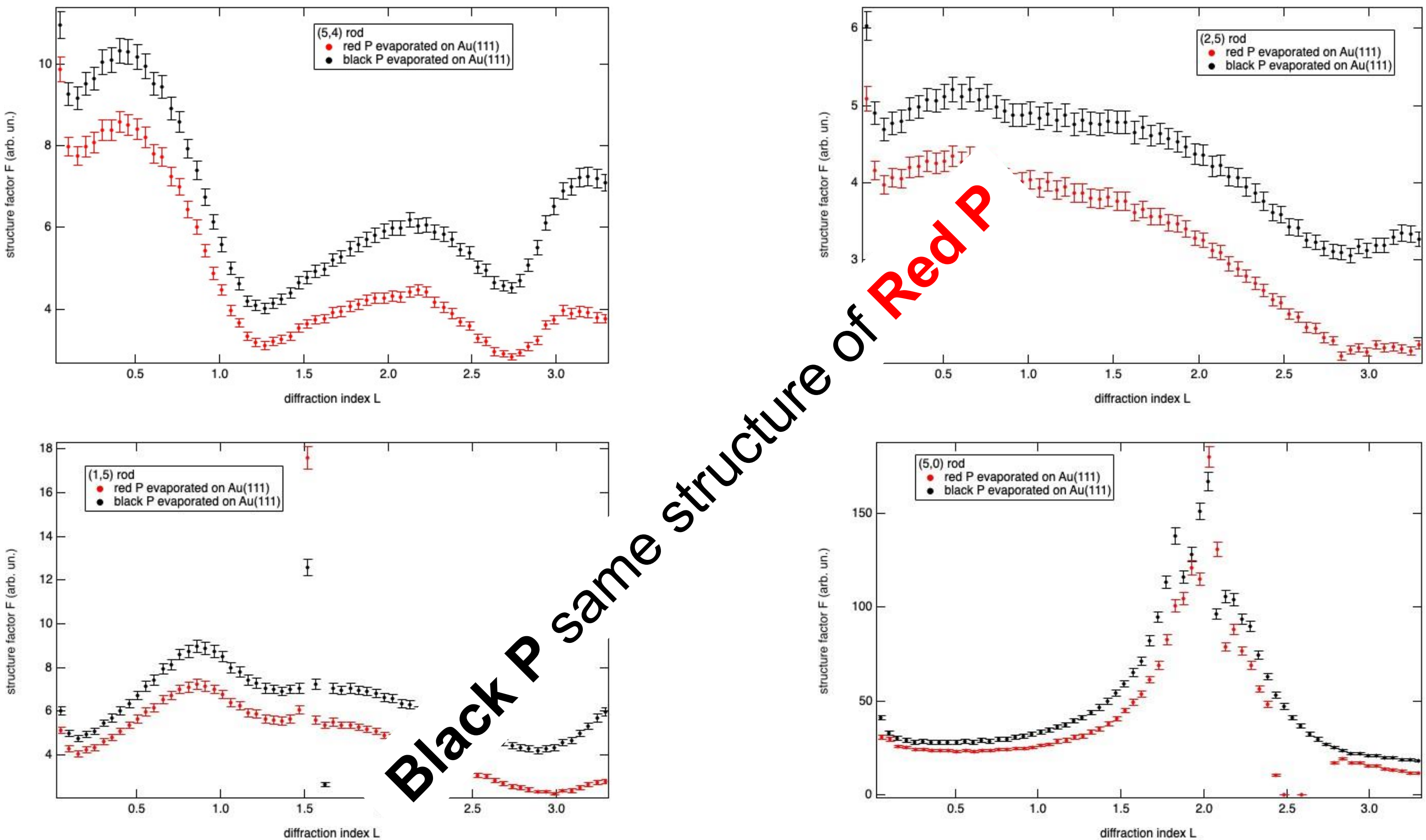
YES!

⇩

Lowering the costs of any possible device

A. Verdini et al. Paper in preparation

Surface X-ray Diffraction agrees

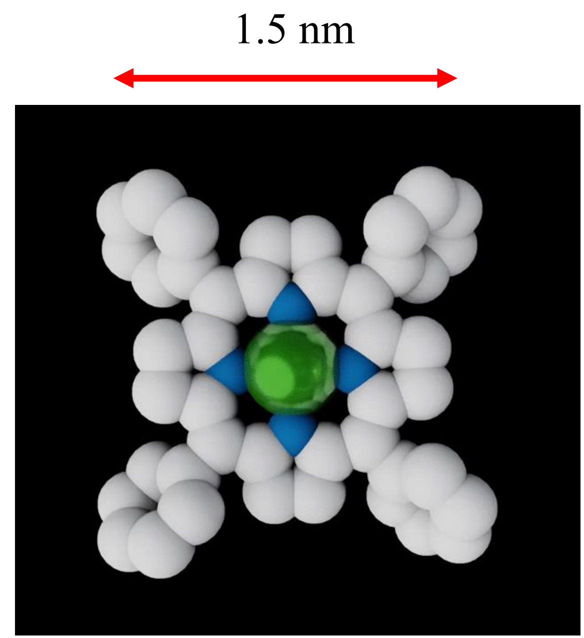


A. Verdini et al. Paper in preparation

Porphyrins

Metallorganic molecule (Tetrapyrrole)

Functionalization: ligands and metal in the center: Cu, Zn, Ni, Fe, Pd, ….

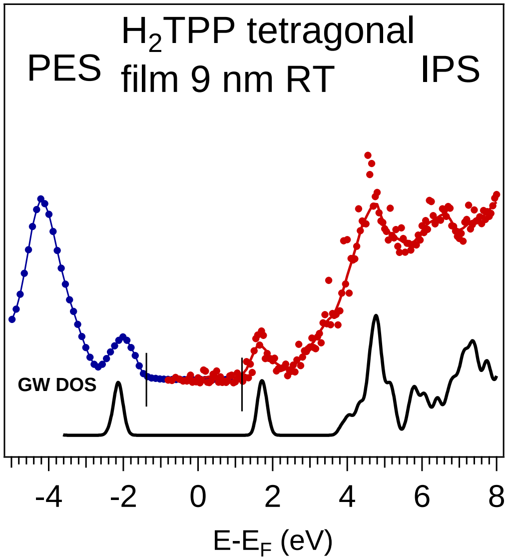


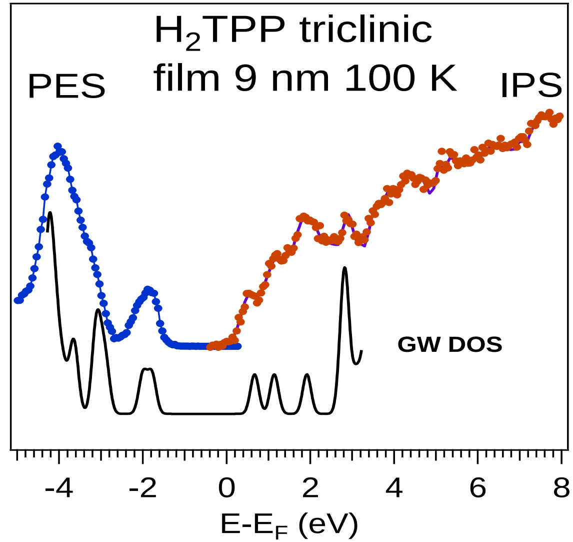
Applications:

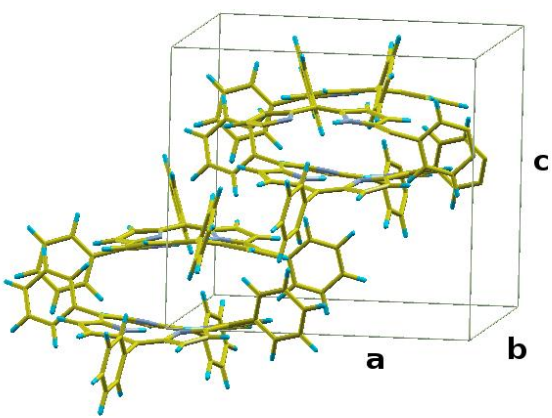
- Solar Cells
- Low-consumption electronic devices
- Molecular Transistors
- Spintronics
- H_2 Water Splitting
- Sensors
- Quantum Computing
- Anti-cancer therapies

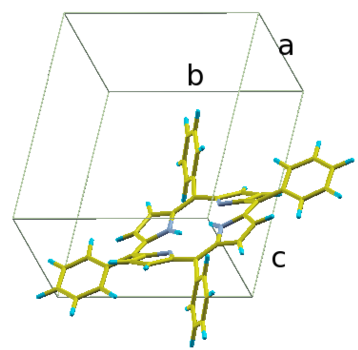
Fundamental Biological processes: Hemoglobin, Chlorophyll, Coenzyme F430

H_2TPP films - Combined UPS/IPES





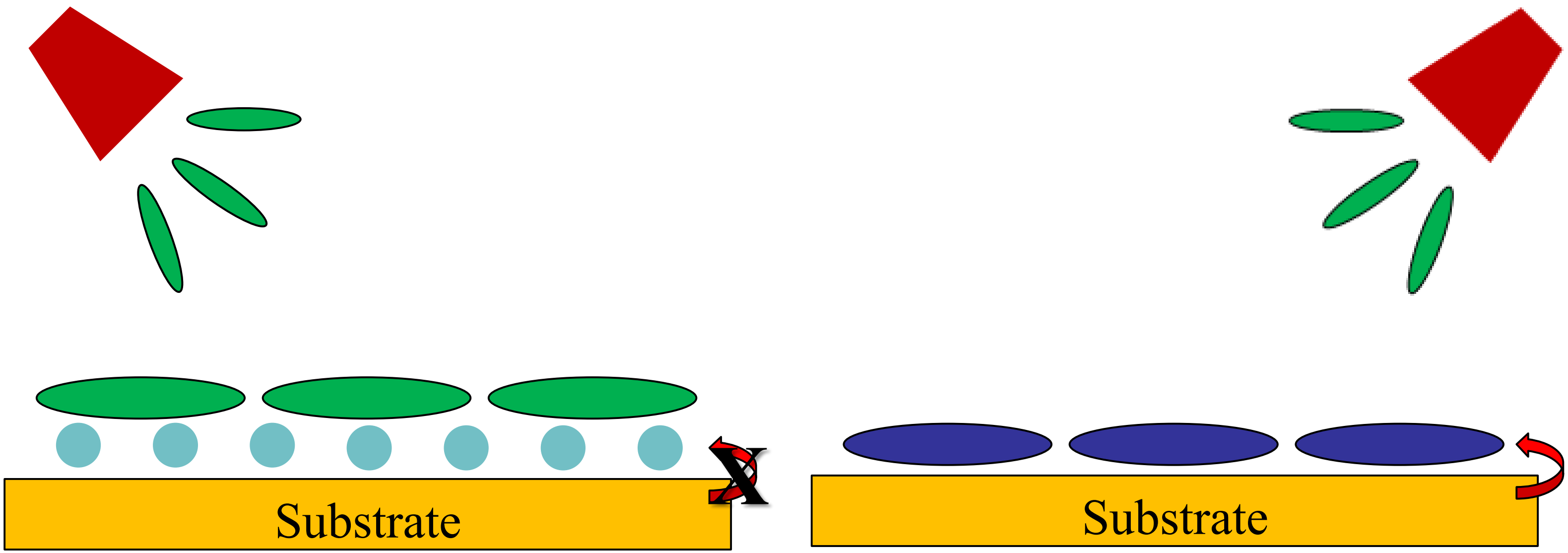




M. Pedio et al. Paper in preparation

Surface Trans Effect

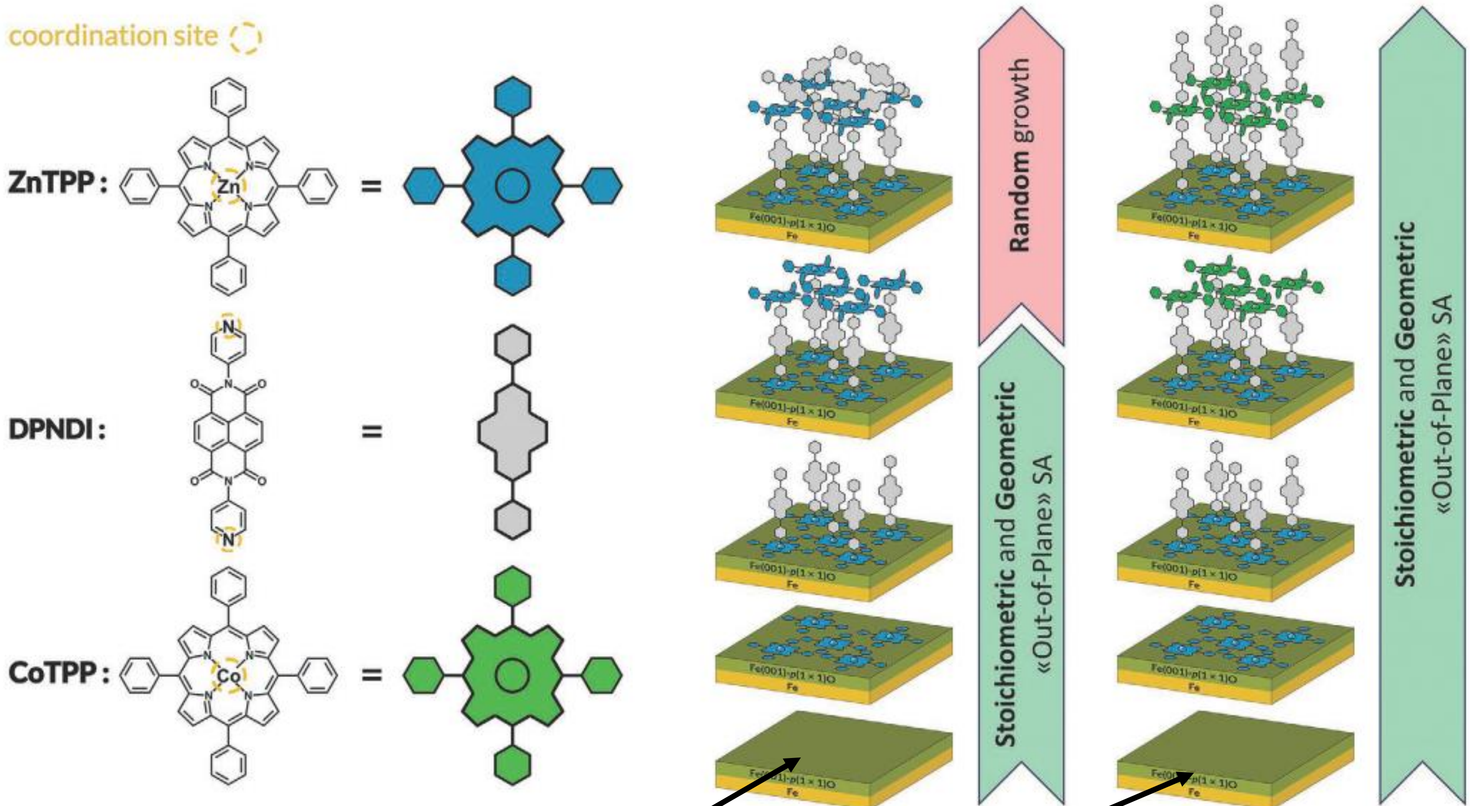
Use of P monolayer as non-interacting buffer layer



No Surface Interaction
=>
Good device

Surface Interaction
=>
No good device

3D self assembly

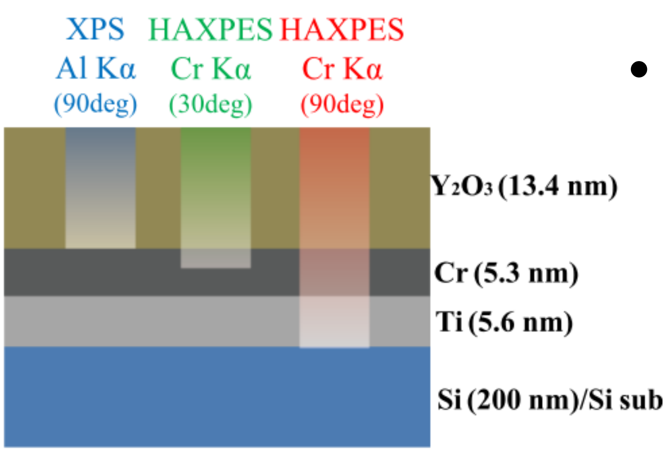


Non interacting surface

A. Bossi, A. Orbelli Biroli @CNR-SCITEC MI
G. Bussetti et al. @Polimi
L. Floreano, L, Schio @CNR-IOM TS
Adv. Funct. Mater. 2021, 31, 2011008

ACROSS Upgrades

- ✓ Cooled Multicell for organic molecules deposition
- ✓ Electron Analyzer + 2D detector
- ✓ UV Source
- ✓ Camera for LEED I-V measurements



In the future

- (Monochromatized) X-ray Source
- Hard X-ray Photoemission Photoemission (HAXPES, Cr source, lateral resolution below 1 μm,…)

Activities within UniPG

- Students training within the Lab Course of 1° year LM
- Tirocinio (2 students so far)
- PhD students PON @UniPG
- Project of a PCTO course for high-school students UHV funded by Fondazione Cassa di Risparmio di Perugia (G. Carlotti)
- Course “Spectroscopies applied to nanomaterils” for the Phd Course
- Course for the LM “Fondamenti di Fisica delle Superfici”

Possible collaborations with Unipg groups

- Heavy metal thin film (~ 1nm), interaction with the substrate, sample growth, aging, oxidation, water… -> Nanomagnetism
- Chemical analysis in drop-cast solutions, stoichiometry, oxidation, CO/gas exposure, thermal treatment,….. -> Bio-related materials
- Chemical analysis of samples, artificial aging,… -> Geology
- Materials/Interfaces for Solar Energy Harvesting –> NiPS lab
- Band Structure (ARUPS/KRIPES) of (Complex) Materials
- UHV -> Astro-Physics, Astro-Chemistry and Astro-Biology
- Transport phenomena, Time- resolved XPS/XAS
- Measurements @Synchrotron Radiation and Free Electron Lasers

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You are welcome

Thanks to

Giovanni Carlotti (Uni PG)

Francesco Moscatelli (CNR-IOM PG, INFN PG), Silvia Tacchi (CNR-IOM PG)

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Mattia Bassotti, PhD student @Uni PG PON

Francesca Peverini, PhD Student @Uni PG PON 50%

Thanks for your attention