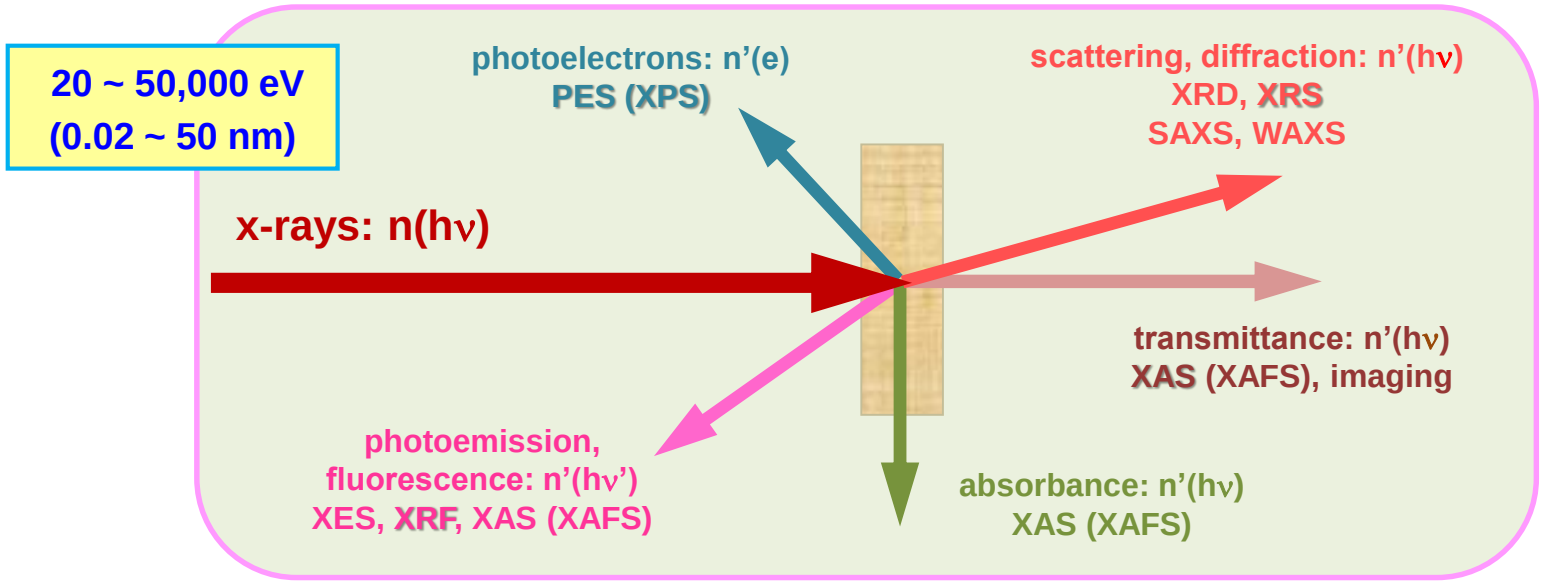
Pohang synchrotron radiation facility (PLS-II) and its application activities

신 현 준

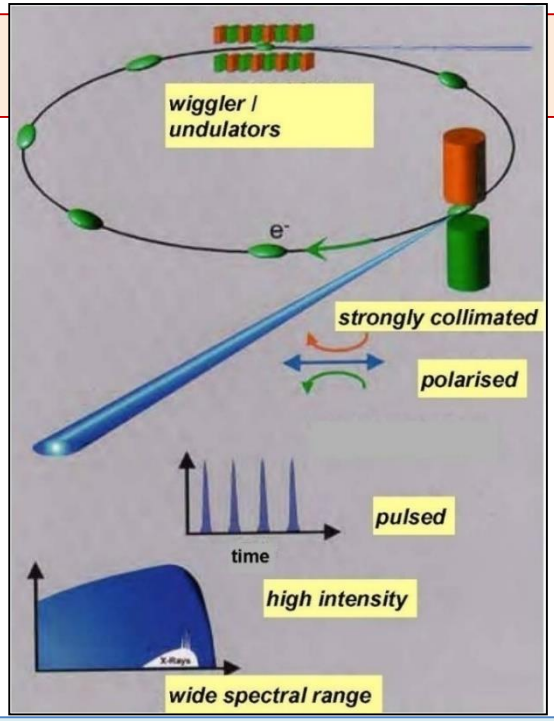
방사광연구단, 포항가속기연구소

Use of x-rays; a probe based on light-matter interaction...



PES: photoemission/ photoelectron spectroscopy
XPS: X-ray photoemission/ photoelectron spectroscopy
XRD: X-ray diffraction
XRS: X-ray scattering
SAXS: Small angle x-ray scattering
WAXS: Wide angle x-ray scattering
XAS: X-ray absorption
XAFS: X-ray absorption fine structure
XES: X-ray emission spectroscopy
XRF: X-ray fluorescence

Synchrotron-radiation X-rays (soft – hard) !!!

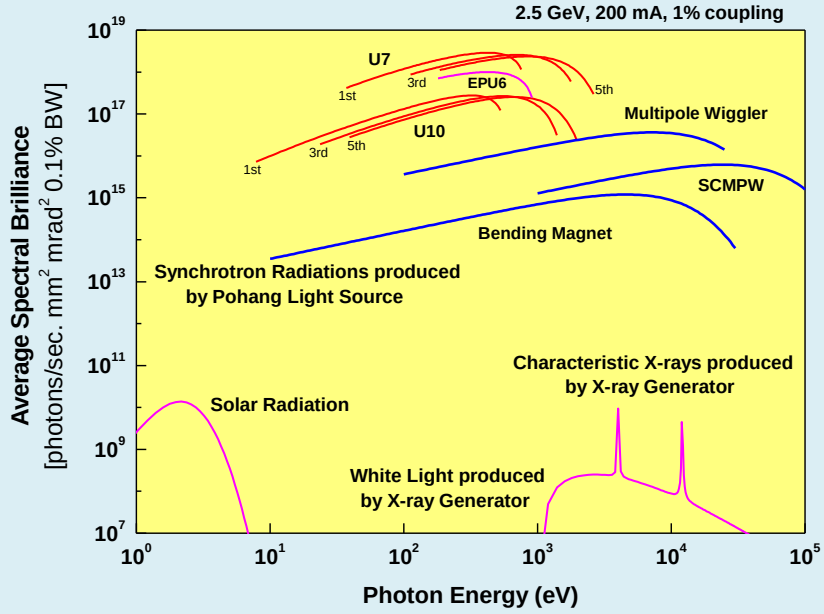


PLS-II storage-ring parameter;

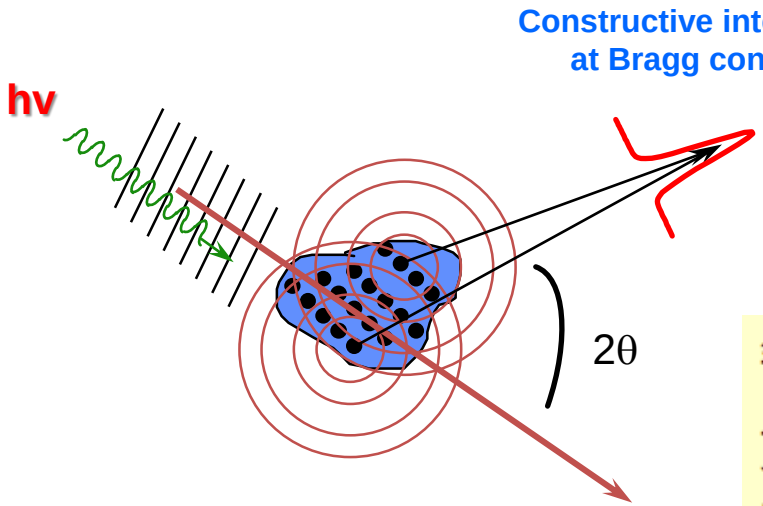
- Electron beam energy: 3 GeV
- E-beam current: 300 ~ 400 mA, top-up fill (3-5 min.)
- **User beam time: 190 days/year**
- Emittance: 5.8 nm.rad
- Straight sections for ID: 20
- Circumference: 281.8 m, 12 Cells, DBA
- Linac: 170 m, 3GeV

Compared to other x-ray sources;

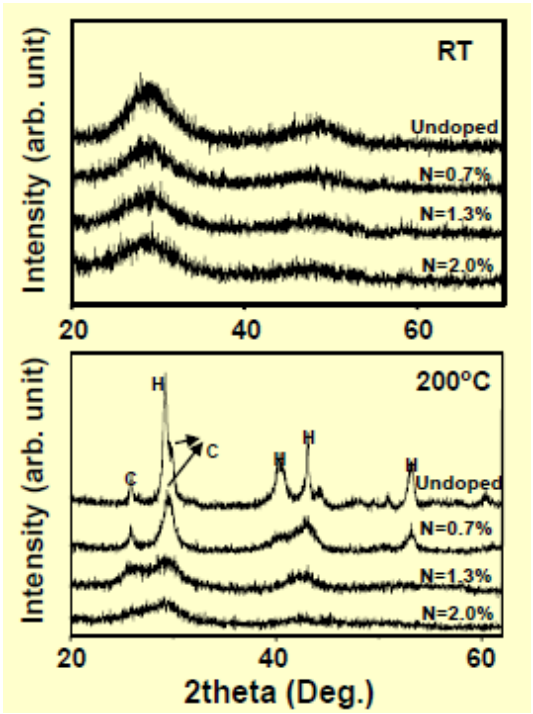
- **Intense and bright**
- **Wide spectral range: tunable...**
- **Stable**
- Pulsed x-rays: ~ 2 ns, ~ 30 ps
  (1 bunch ~ 500 MHz, 1 turn ~ 1 MHz)
- Small source size: coherent...
- Polarized x-rays: linear, circular

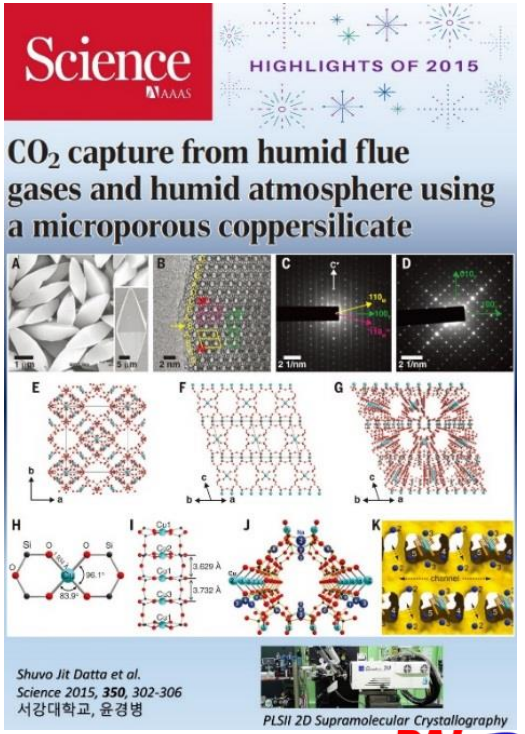


x-ray scattering (XRS), x-ray diffraction (XRD)



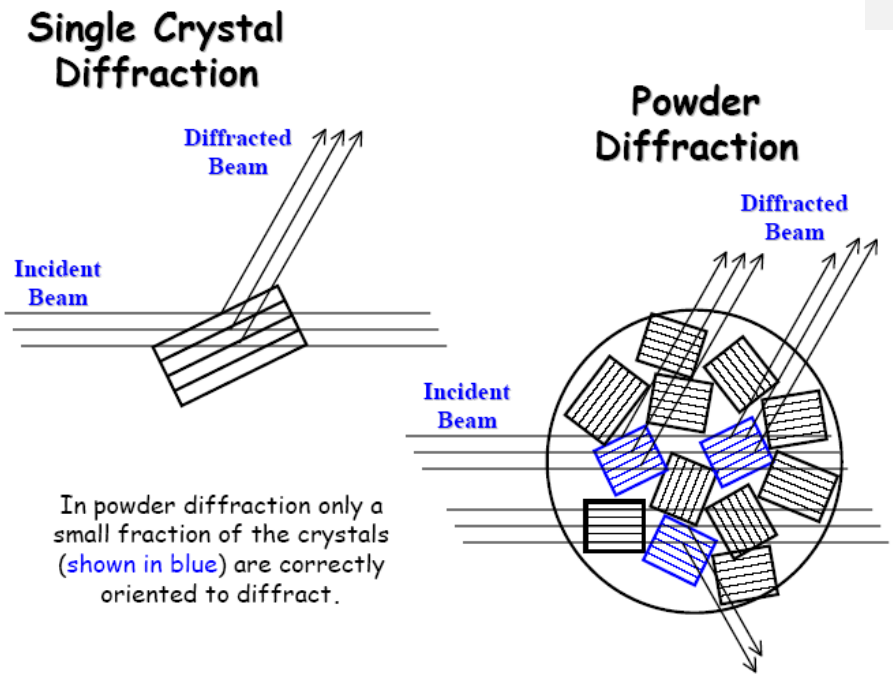
$$2d\sin(\theta) = \lambda \quad \Rightarrow \quad d = \lambda / 2\sin(\theta)$$
$$\theta : 0.01° \sim 90° \quad \Rightarrow \quad d : 1\mu\text{m} \sim 0.02\ \text{nm}$$

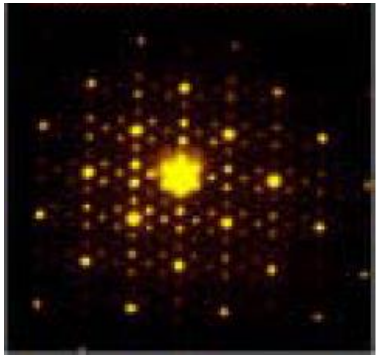




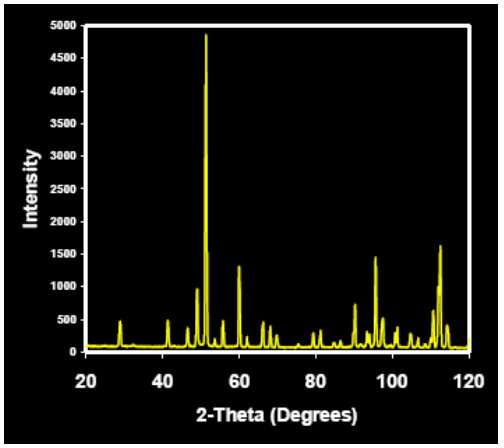
Powder Diffraction

Courtesy of Dr. D. C. Ahn





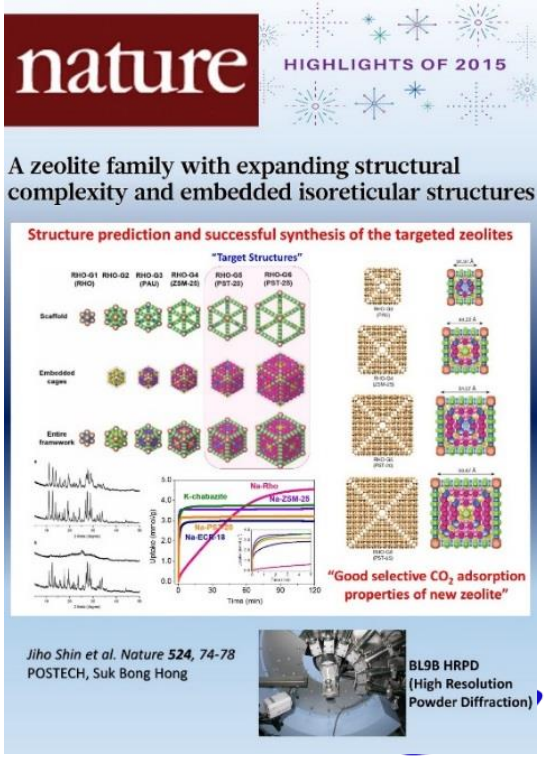
Single Crystal Diffraction (3 dimensional)



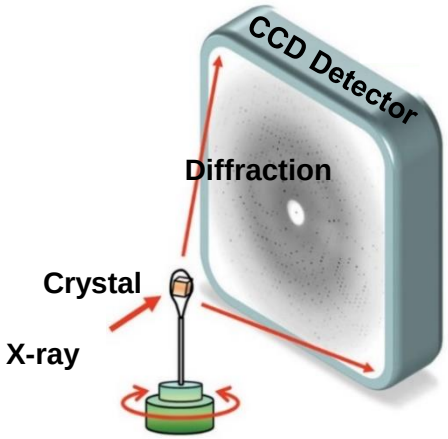
The ideal "powder" sample contains tens of thousands of randomly oriented crystallites

$$I_{hkl} \propto \left|F_{hkl}\right|^2$$

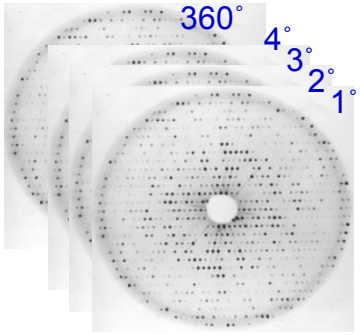
$$F_{hkl} = \sum_{j=1}^{m} N_j f_j \exp\left[2\pi i(hx_j + ky_j + lz_j)\right]$$



Protein crystallography



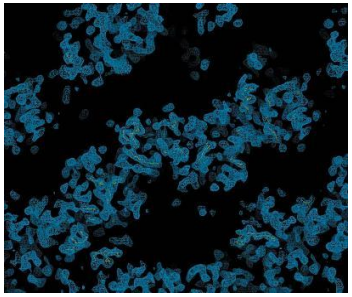
Oscillation



Diffraction images

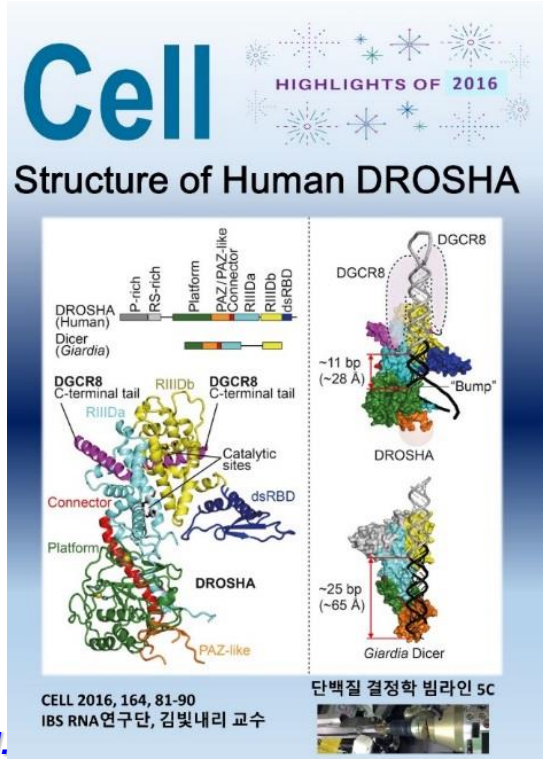
Fourier transform

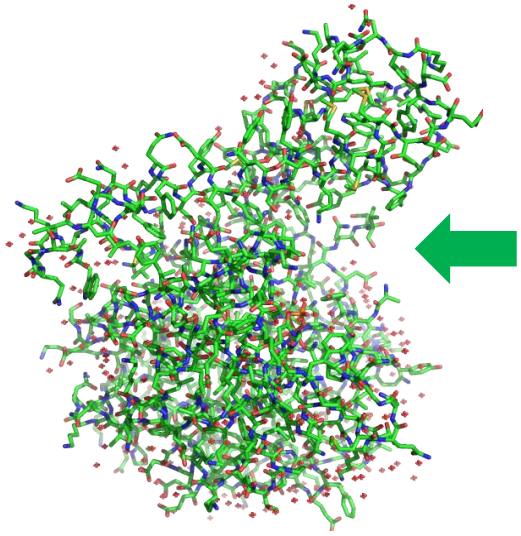
HKL2000
Phenix
CCP4

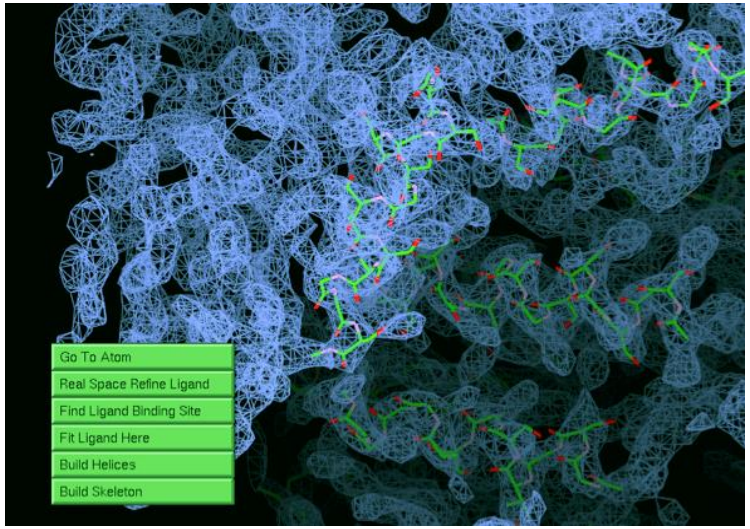


Electron density map

Model building refinement





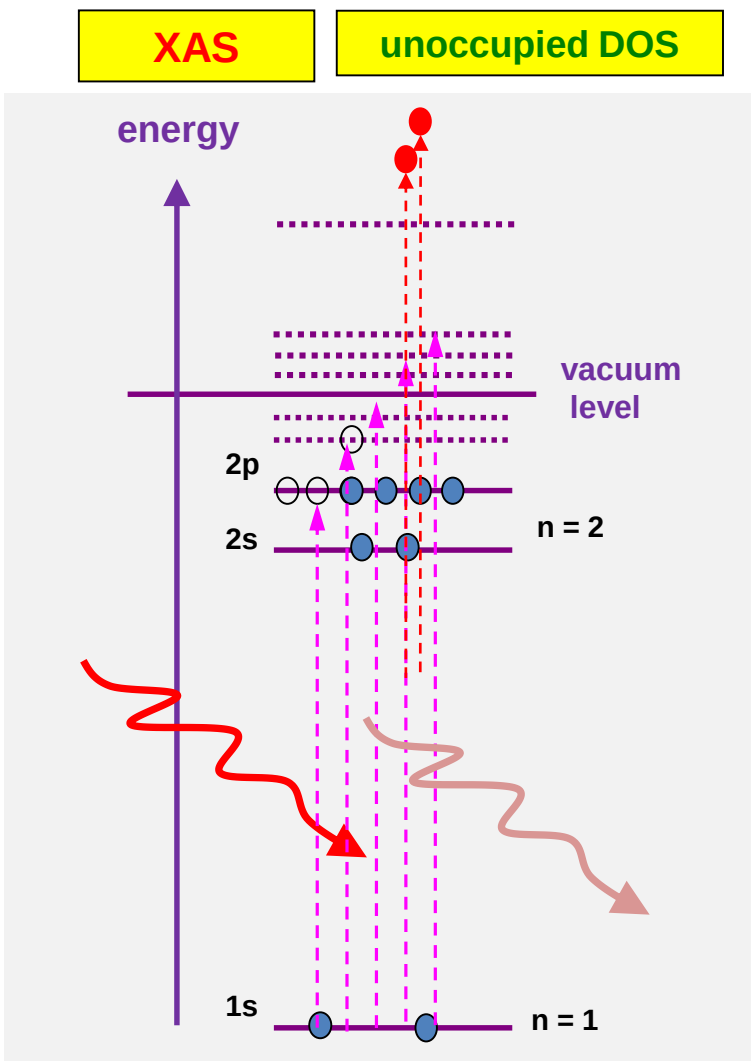


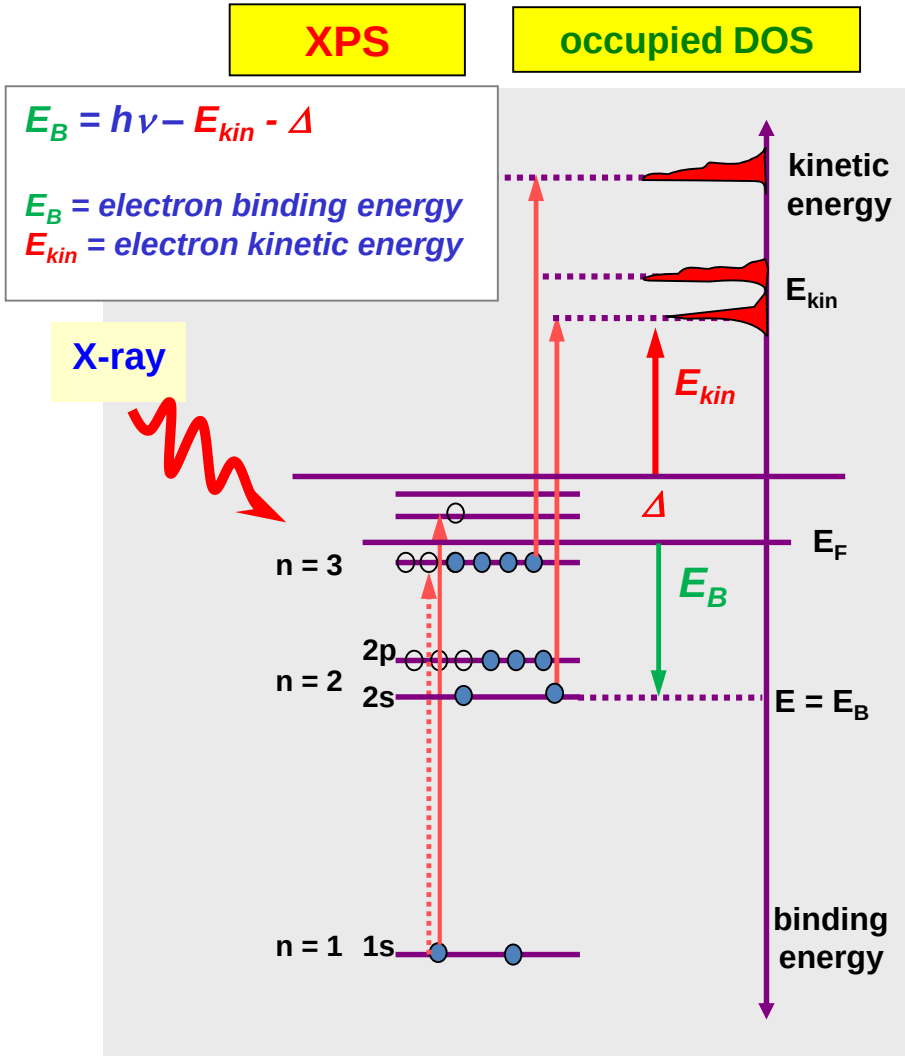
Final molecular model

Courtesy of Dr. Y. Kim

H.

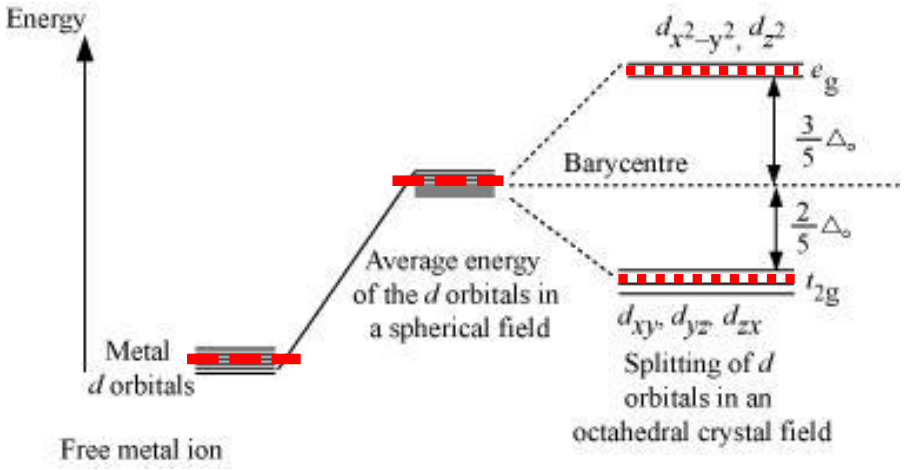
Spectroscopy (electronic structure); XAS & XPS basic …



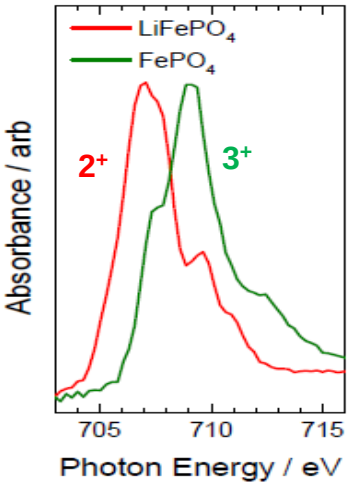


X-ray absorption spectroscopy (XAS): practical use of soft x-rays...

O-TM-O

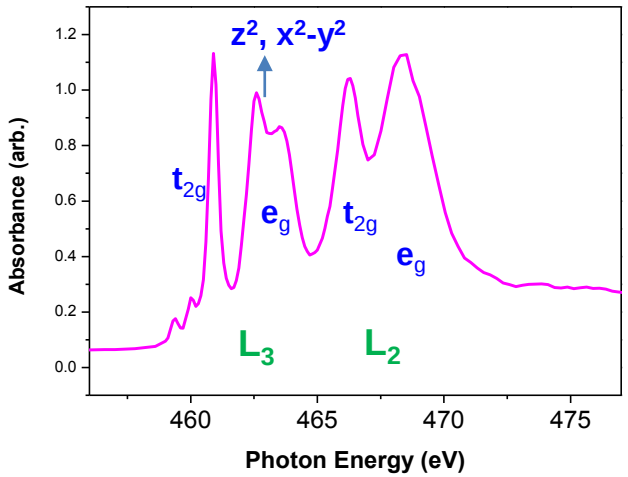


Fe L–edge

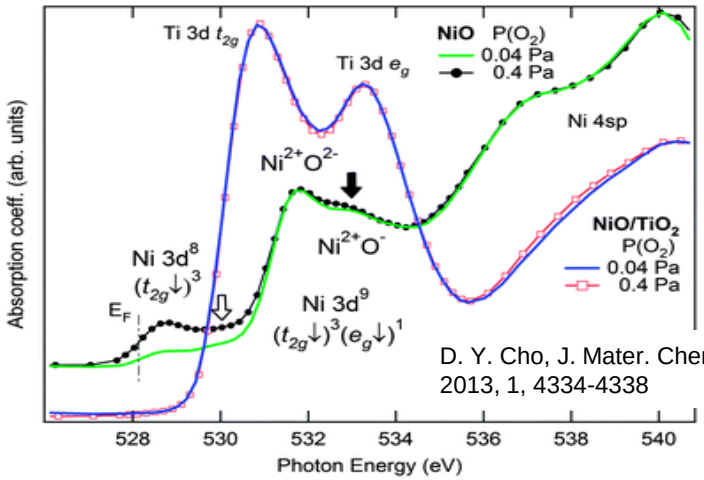


W. C. Chueh et al, Sandia Report, 2012.

Ti L–edge (anatase)



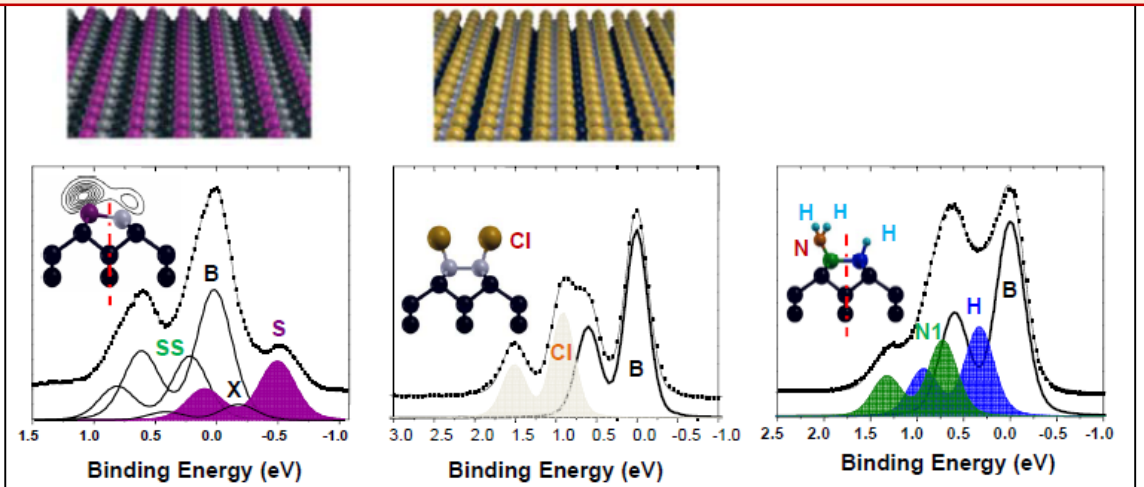
O K-edge



D. Y. Cho, J. Mater. Chem. C. 2013, 1, 4334-4338

element, crystal structure, oxidation state, chemical states, magnetic moment, electronic structure, …

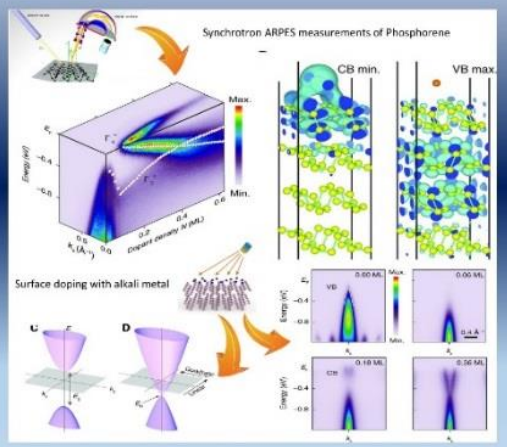
XPS & XAS; practical use of spectroscopy…



Moon et al., Adv. Mat. 19, 1321 (2007)
Appl. Phys. Lett. 91, 193104 (2007)

Science AAAS HIGHLIGHTS OF 2015

Observation of tunable band gap and anisotropic Dirac semimetal state in black phosphorus

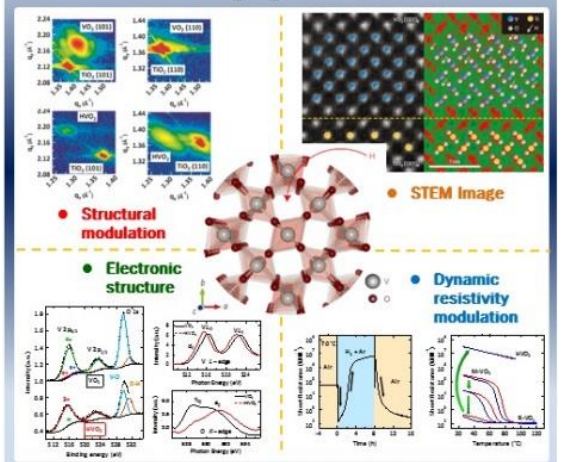


Jimin Kim et al. Science ***349****, 6249*
POSTECH, Keun Su Kim

4A1 u-ARPES Beamline

nature materials

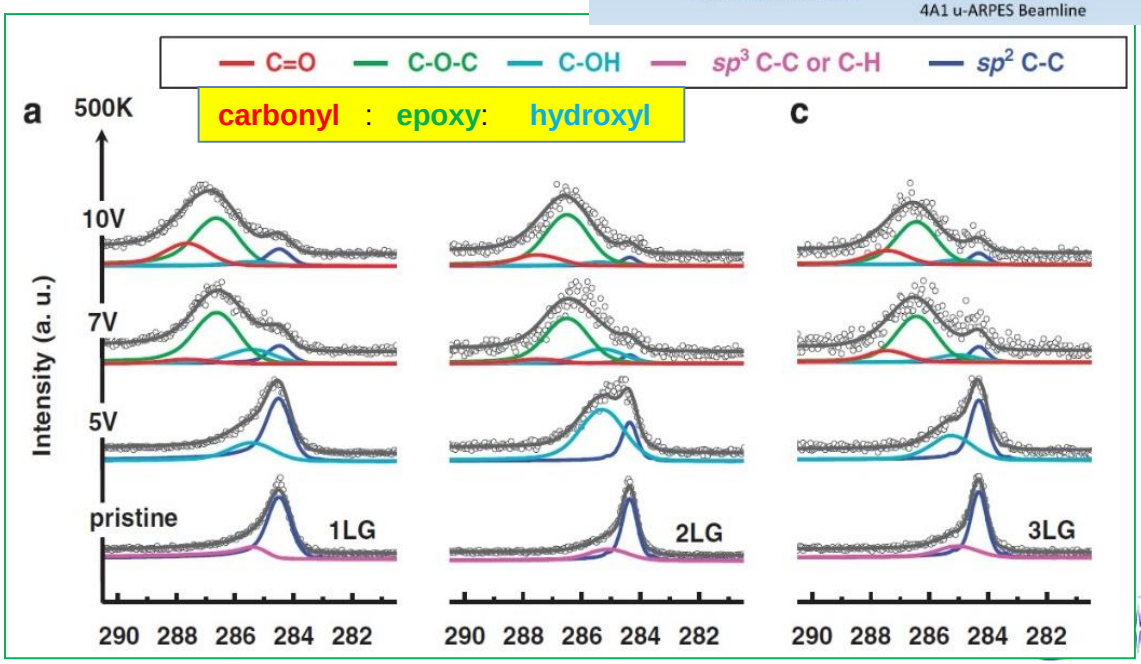
Reversible phase modulation and hydrogen storage in multivalent VO_2 epitaxial thin films



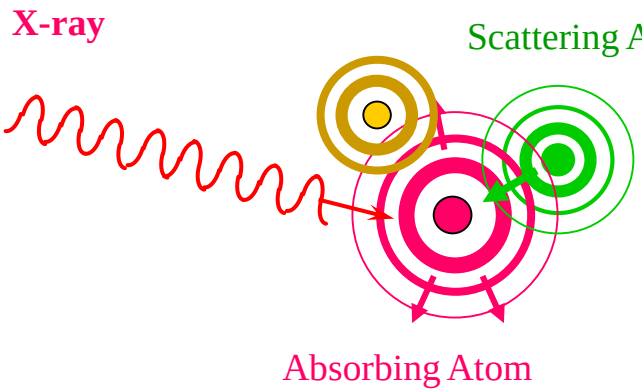
Nature materials, 15, 1113 (2016)
포항공대, 손준우 교수

4D 광전자분광빔라인

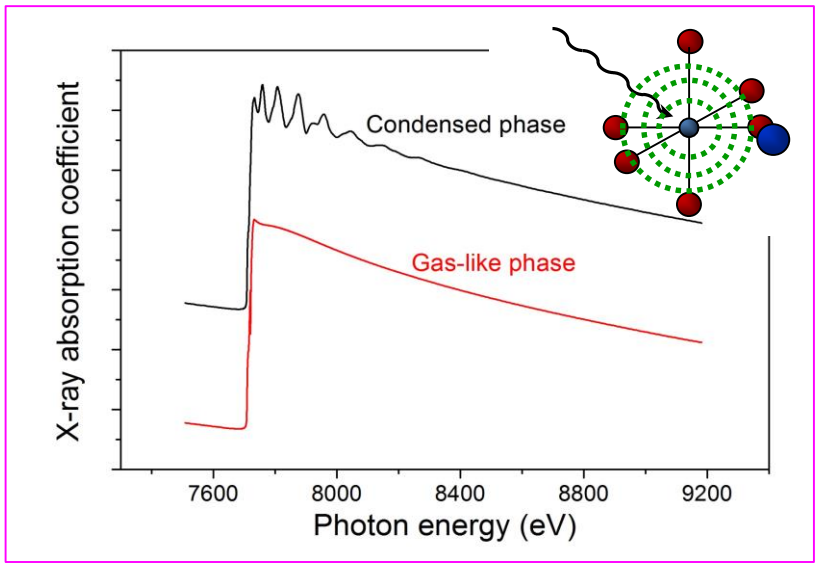
I.–S. Byun, NPG Asia Mat. (2014)



Extended X-ray Absorption Fine Structure (EXAFS)



$$E_{(photon)} - E_{o(electron\ binding)} = K.E. = \frac{h^2k^2}{2m_e}$$



Science
AAAS

HIGHLIGHTS OF 2017

REPORT

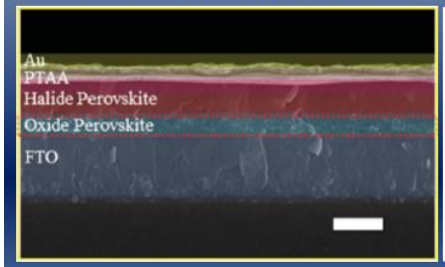
SOLAR CELLS

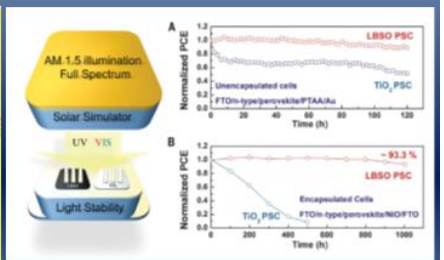
Colloidally prepared La-doped $BaSnO_3$ electrodes for efficient, photostable perovskite solar cells

Perovskite solar cells (PSCs)

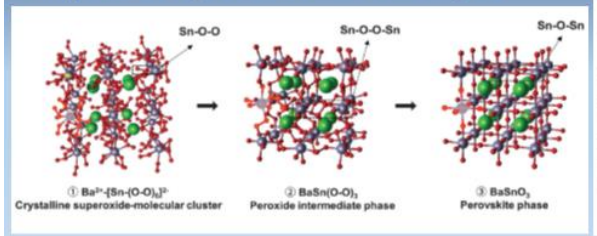
Lanthanum (La)–doped $BaSnO_3$ (LBSO) perovskite as an electron-transporting layer :

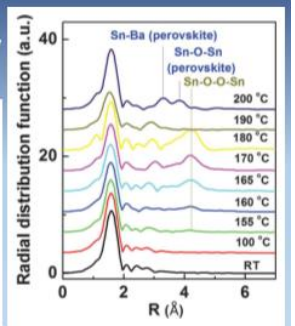
a steady-state power conversion efficiency of 21.2%, versus 19.7% for a mp-TiO_2 device





Structural Evolution of Cubic Lanthanum (La)–doped BaSnO3 (LBSO) perovskite through Low temperature synthesis below 200 degree

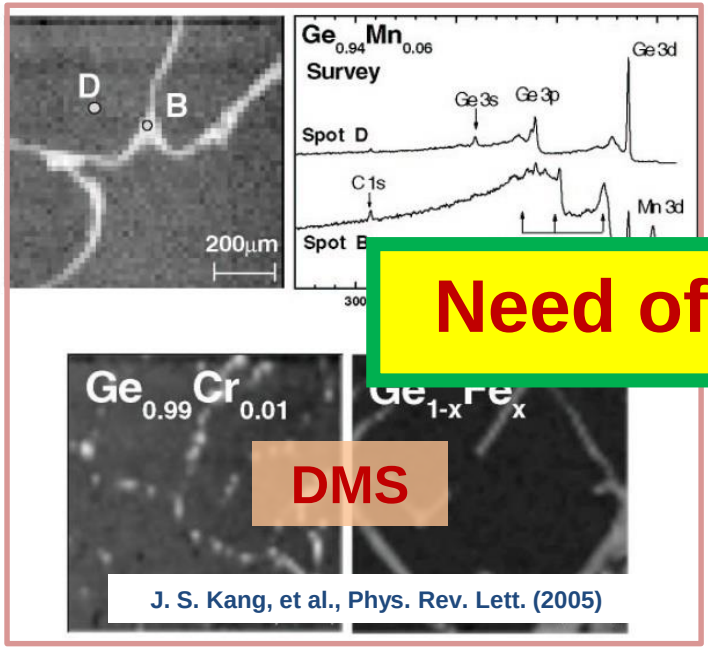




***Science*, 356, 167–171 (2017)**

유니스트, 석상일교수

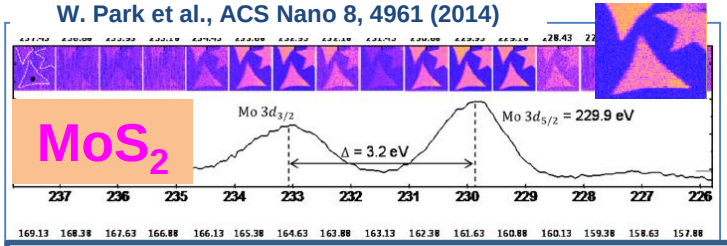
Need of spectro-microscopy

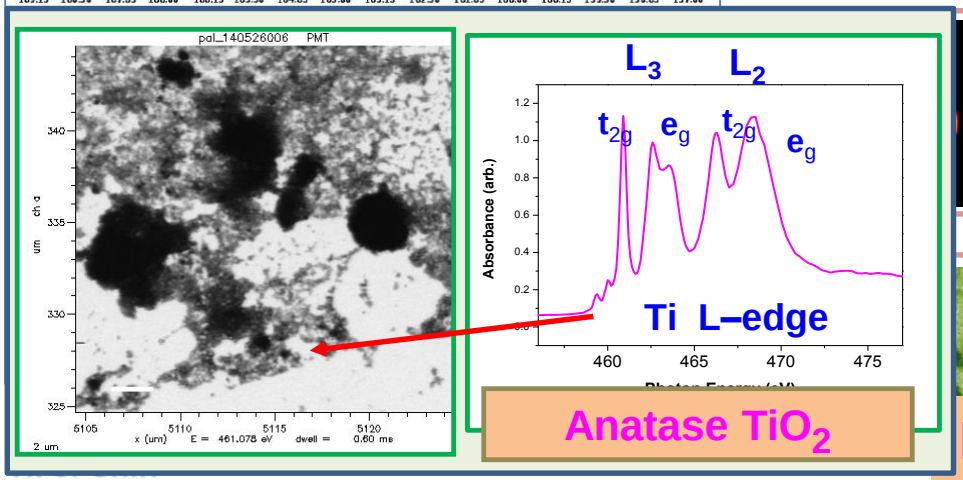


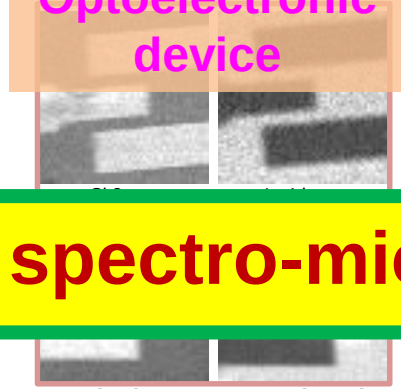
J. S. Kang, et al., Phys. Rev. Lett. (2005)

I. Song et al., Angew. Chem. Int. Ed. 53, 1266 (2014)

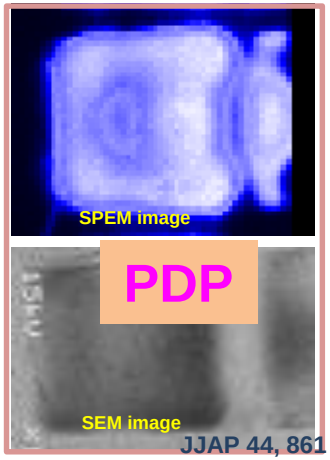
W. Park et al., ACS Nano 8, 4961 (2014)







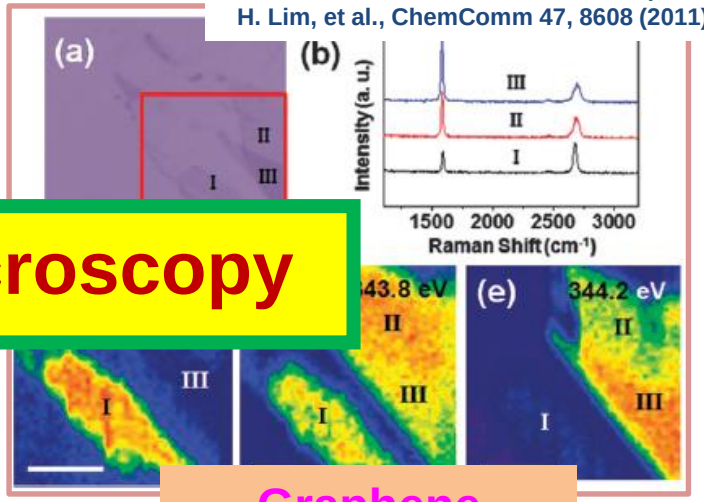
Appl. Phys. A 78, 623 (2004)

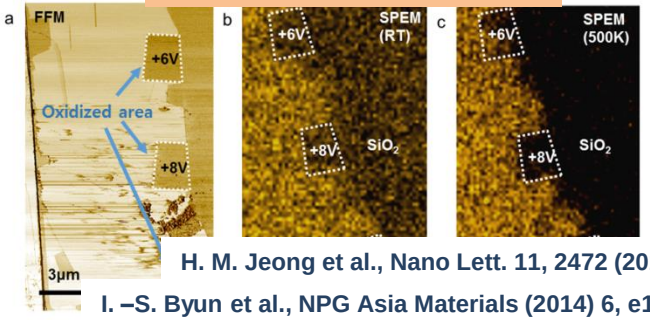


JJAP 44, 861 (2005)

K.J. Kim et al., Adv. Mater. 20, 3589 (2008)

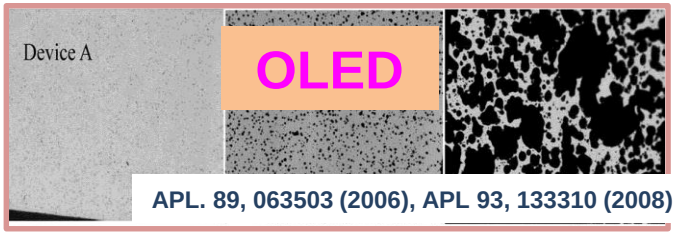
H. Lim, et al., ChemComm 47, 8608 (2011)



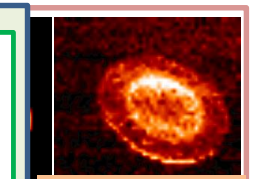


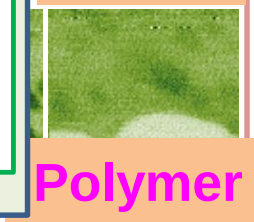
H. M. Jeong et al., Nano Lett. 11, 2472 (2011)

I. –S. Byun et al., NPG Asia Materials (2014) 6, e102



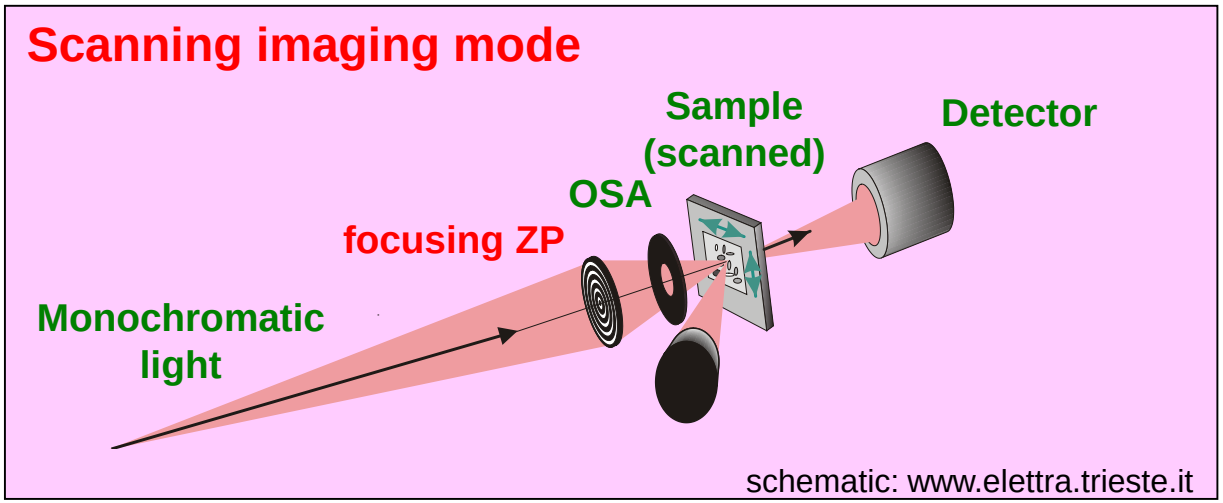
APL. 89, 063503 (2006), APL 93, 133310 (2008)





J. Chung et al., Org. Electron. 9, 869 (2008)

Microscopy-spectroscopy /// Spectro-microscopy (Nanoscopy)



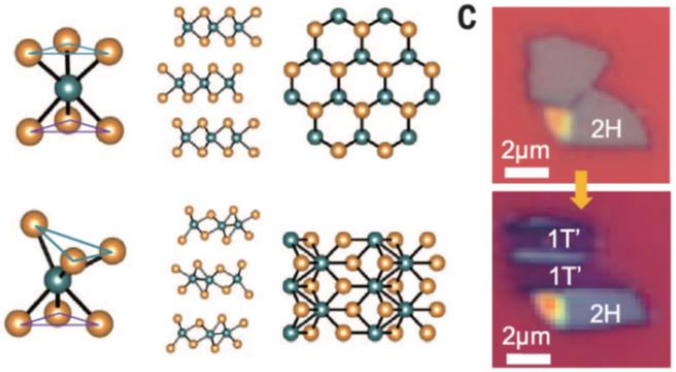
- improvement of focal power/ focusing lens ...
- minimal variation of focal position ...
- detectors for fast imaging ...
- nice softwares ...

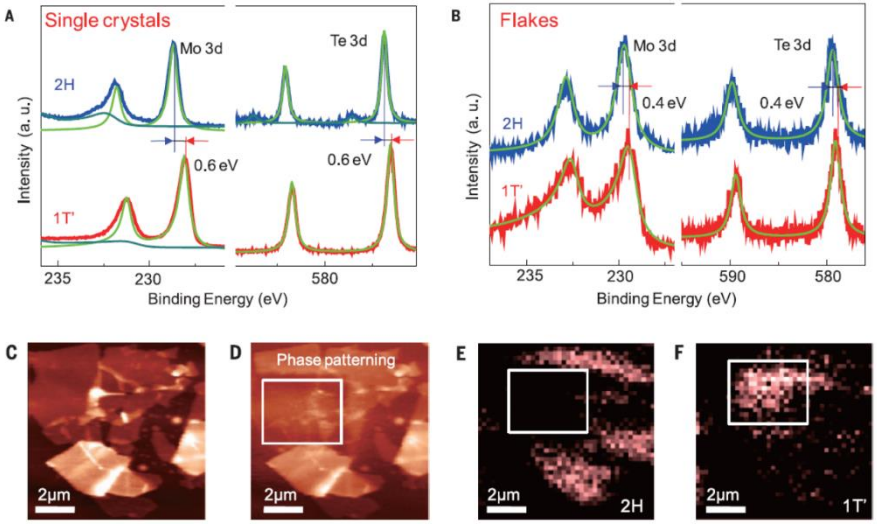
$MoTe_2$

Heterophase in homojunction

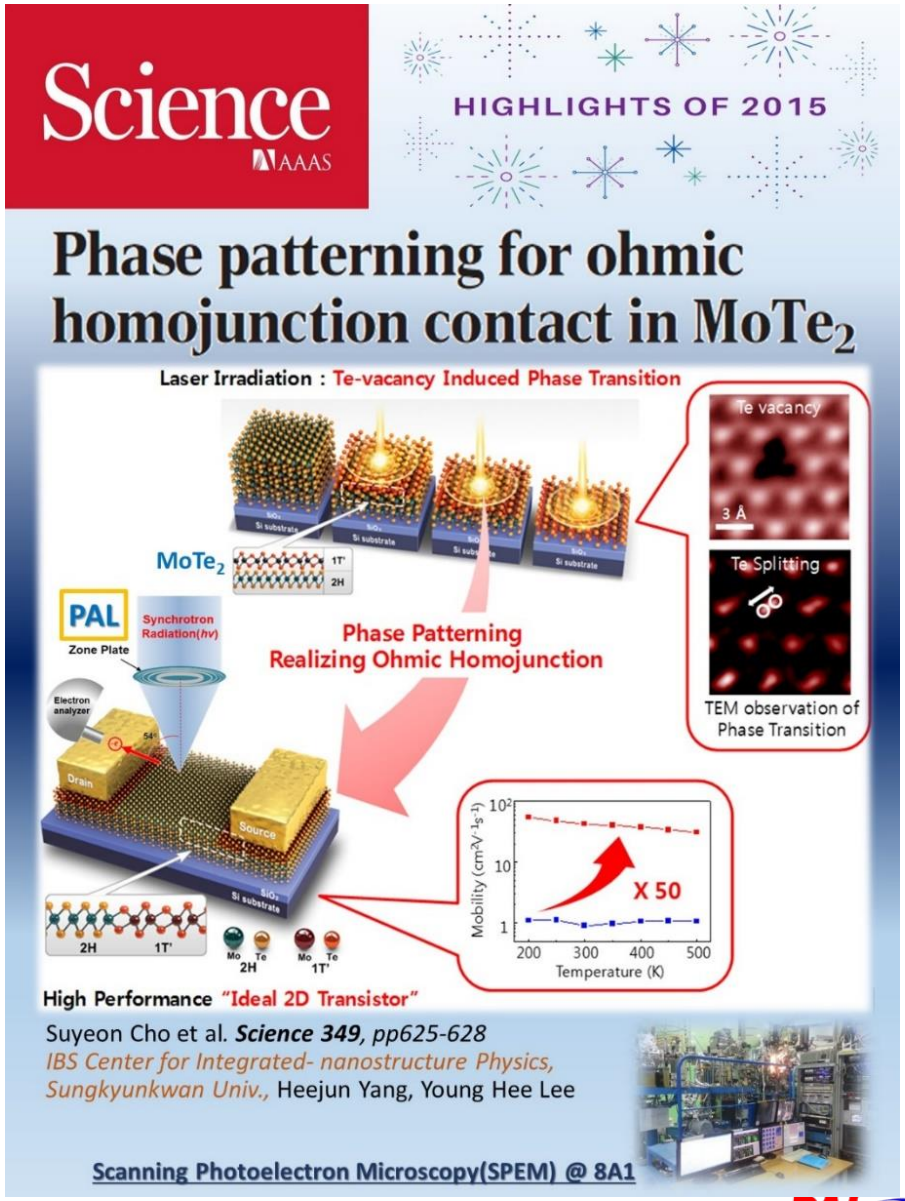
hexagonal
2H

metallic
monochlinic
1T'





Different lattice symmetry
No MoO_3, TeO_2, other element..



PAL

and ... ...

- 개발 여지가 많음: 정밀도 (에너지분해, 공간분해, 편광 정도), 첨단화 (사용의 편의성, 효율, 자동화, 실시간, operando), 새로운 원리 (편광, 검출기, 시분해, two photon), ...

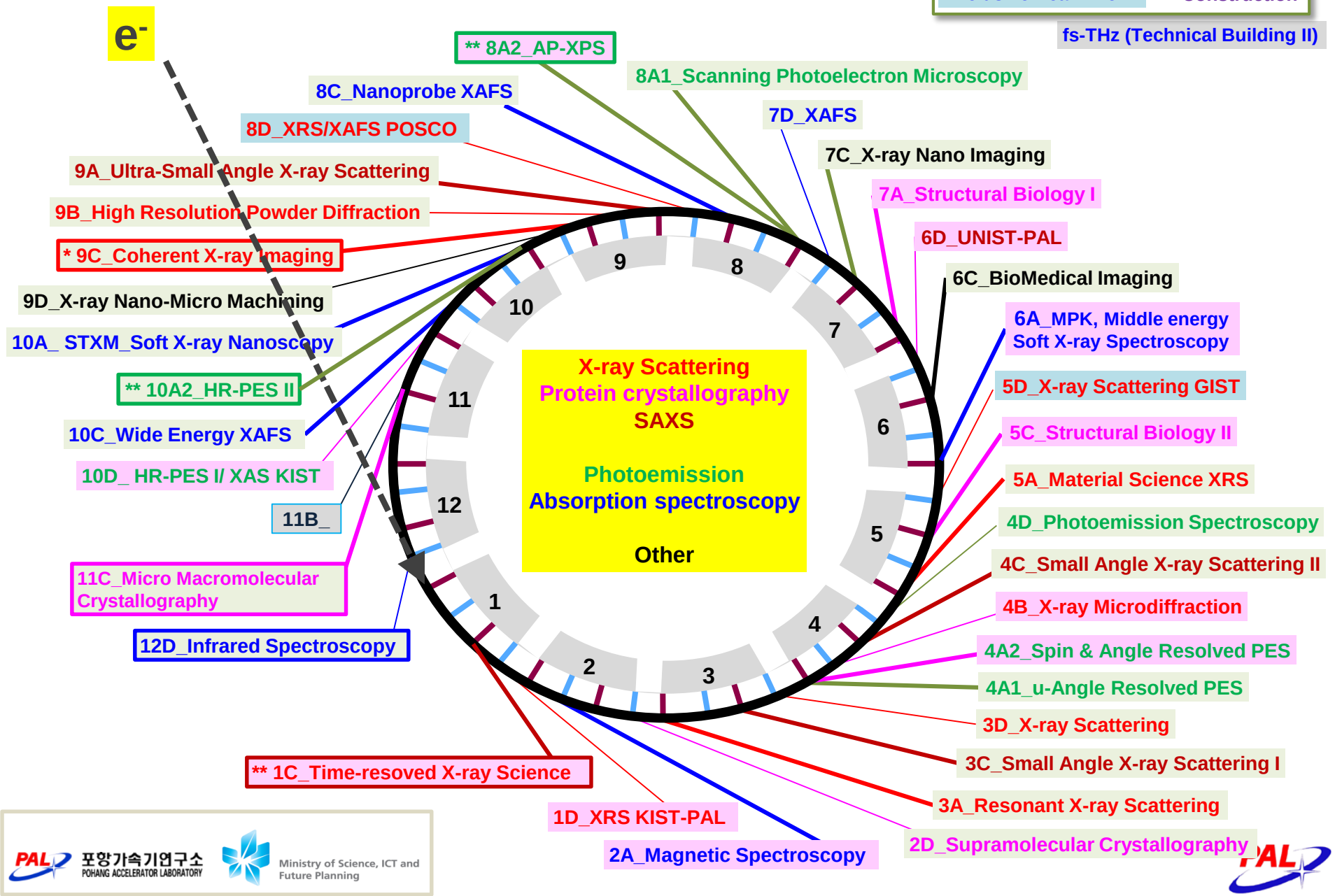
Status: beamline map..

~ 34 PLS II Beamlines

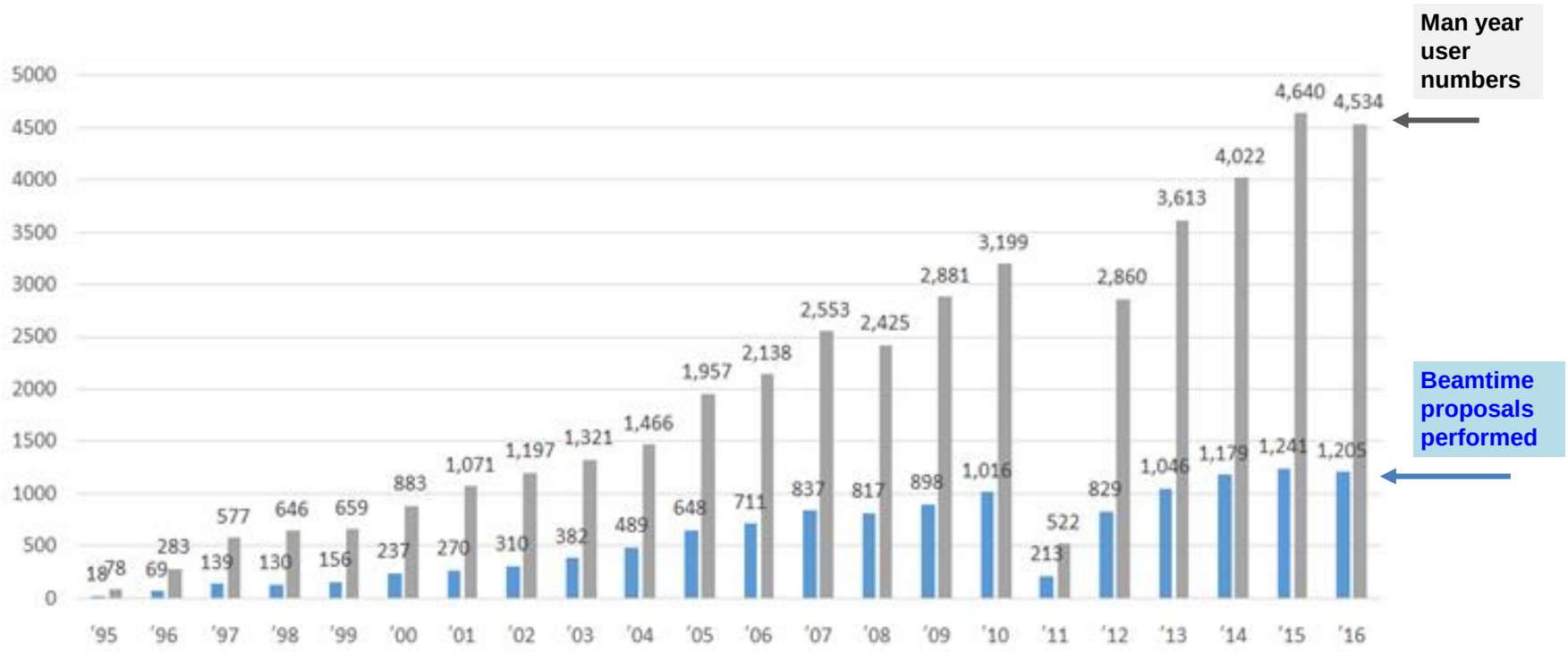
http://pal.postech.ac.kr

Public Beamline: 23
Agreement Beamline: 7
Exclusive Beamline: 4
I D
BM
** Construction

fs-THz (Technical Building II)



Performed beamtime proposals and user numbers … publication status…



Number of publication and average IF.

구 분	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	합계
SCI 논문수	3	14	48	77	64	112	145	163	179	188	256	326	390	385	407	451	293	353	551	451	418	4,856
편당 I.F.	2.6	1.8	2.6	2.5	2.4	2.5	3.1	3.2	3.1	3.5	3.4	3.6	3.8	3.6	3.3	3.8	3.9	4.4	4.24	5.86	6.19	

Beamlines:

Agreement beamlines; KIST (2), GIST, UNIST, KRIBB, POSTECH

Exclusive beamlines; POSCO, GIST, MPK, IBS

Beamline department subsections:

- Structural biology
- Materials chemistry
- Eco-friendly materials
- Energy Materials
- Nano-materials spectroscopy
- Spectro-nanoscopy
- ITCC

Applications to :

- New materials: semiconductor, energy, bio, life-science, geoscience, natural resources, catalysts, battery, nano & bio, etc.
- putting an emphasis on industrial application.

Analysis on beamline types…

General purpose beamlines: we are trying to maintain competitiveness over other worldwide techniques.

XRS, SAXS, WAXS, PX
PES (XPS), XAS, XAFS
u-probe (u-XRF, u-XAFS)

→ **multimodal, in-situ techniques.**

Top notch science/technique beamlines:

Uniqueness, world best, world first…
State of the art instrumentations.
Top notch scientific objectives (strongly correlated systems, vortex, …)

SAR-PES, AP-XPS, XMCD & multimodal, XAS in medium energy,
CDI, PCXS, Ptychography
tr-XRS, tr-THz
nano-imaging, nano-XAS, nano-XPS
full automation, high throughput, …

→ **multimodal, in-situ techniques.**

Industrial application: * ITCC *

High throughput → FBDD (2018-2020 yr.)/ SAXS/ Imaging
High energy x-ray imaging for thicker samples.
Spectro-microscopy (u-XAFS, u-XRF, STXM, SPEM)
AP-XPS, XPS on 2D materials, semiconducting device materials

→ **multimodal, in-situ techniques.**

Beamlines under consideration

→ Putting efforts on industrial application has become our new mission…

5C PX FBDD (2018-2020): → endstation to be upgraded.
Full automation and FBDD facility setup

2C high energy x-ray science (HE – XRS) (MPW): (2019 ? – 2021 ?) → to be constructed.
Hard x-ray imaging for tomographic information..
High energy extreme condition science;
includes high pressure science (strong user consortium is established)

Beamline renovation plan to attract industries:

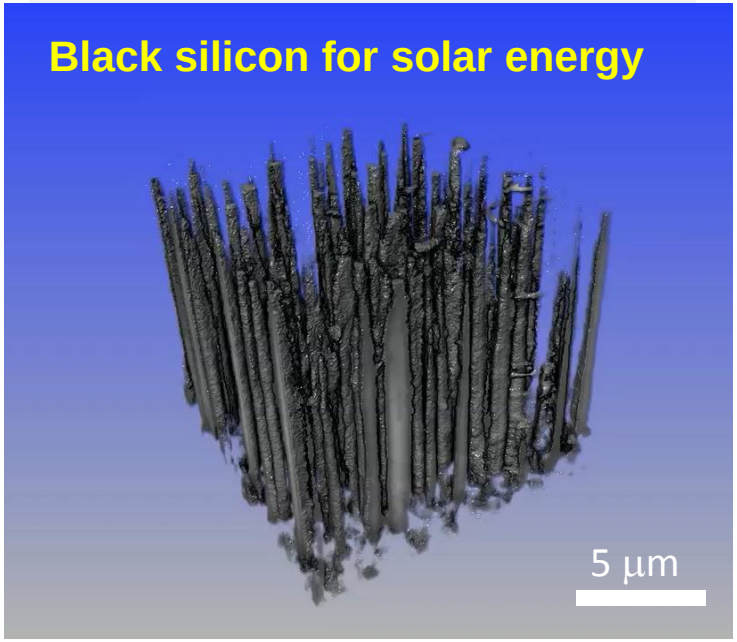
- ✓ A company is requiring an hard x-ray insertion device beamline for SAXS.
- ✓ Collaboration is on-going with POSCO and SKhynix, and other companies are showing interests…

→ We may have to construct beamline(s), or renovate existing beamline(s), or build an efficient platform (comprised of several beamlines) for industrial application.

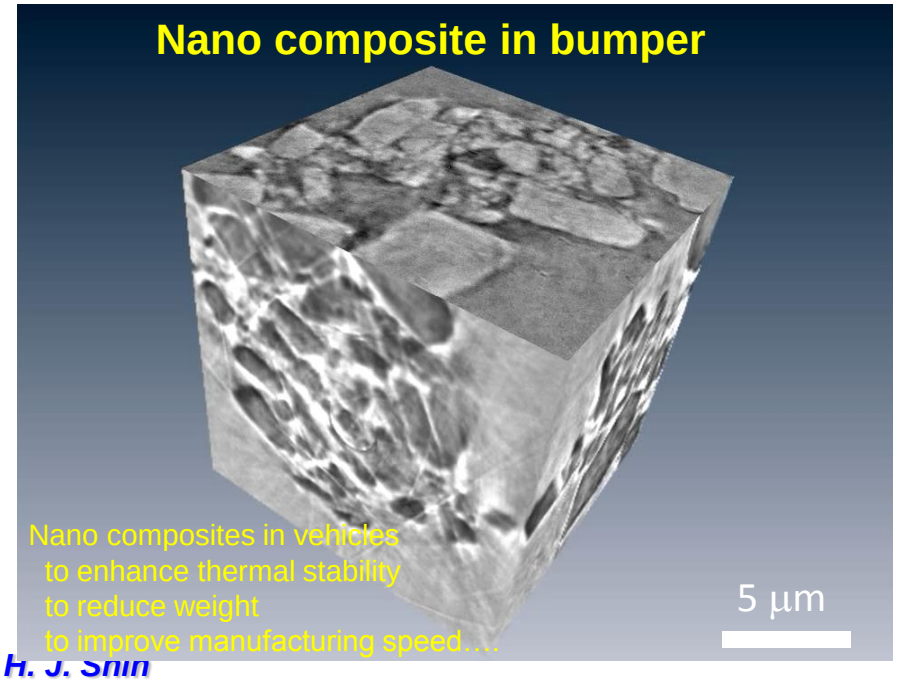
3D nano structure inspection

Courtesy of Dr. J. Lim

Black silicon for solar energy



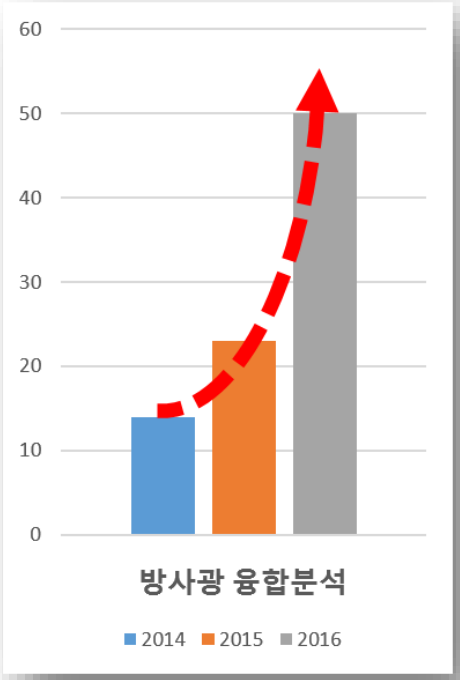
Nano composite in bumper

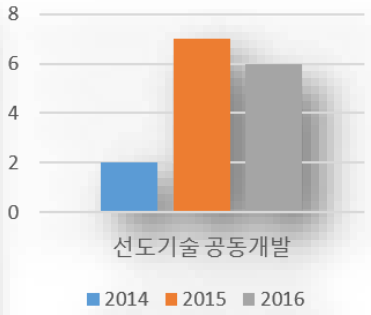


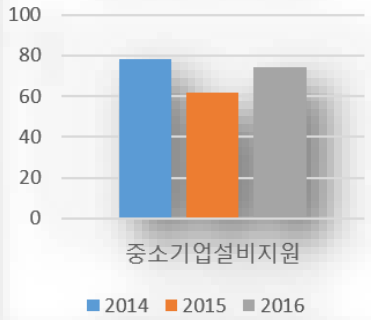
Nano composites in vehicles
to enhance thermal stability
to reduce weight
to improve manufacturing speed…

H. J. Shin

방사광 융합 분석 실적 추이







항목	2014	2015	2016
방사광 융합분석	14	23	**50 건**
중소기업 설비지원	78	62	**74 건**
선도기술 공동개발 (기업 과제)	2	7	**7 건**
기업초청 및 현장방문세미나	27	19	**15 회**

Thank you !