THAI SYNCHROTRON NATIONAL LAB

Synchrotron: Solution for sustainable food and agricultural research

Dr. Waraporn Tanthanuch
SLRI, Thailand

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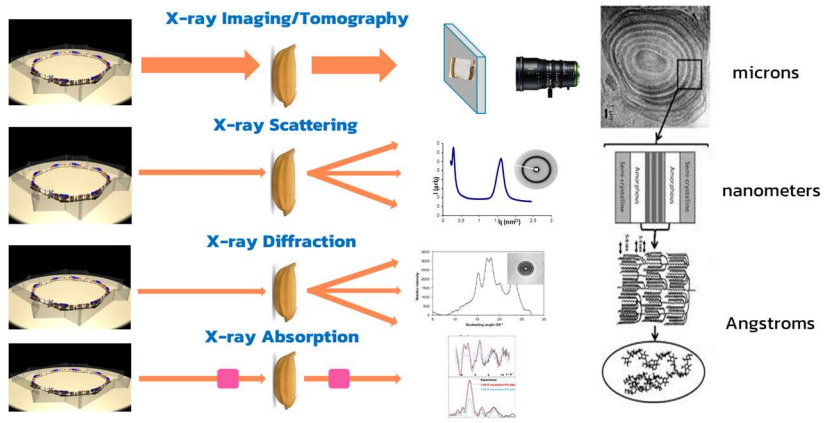
Synchrotron Advanced Technology



Nondestructive	Chemical composition	Molecular structure	Microstructure
Depth information	Characterizations	Atomic structure	Nanostructure

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Synchrotron around the world

ทั่วโลกมีแหล่งกำเนิด

แสงซินโครตรอนประมาณ 50 แหล่ง

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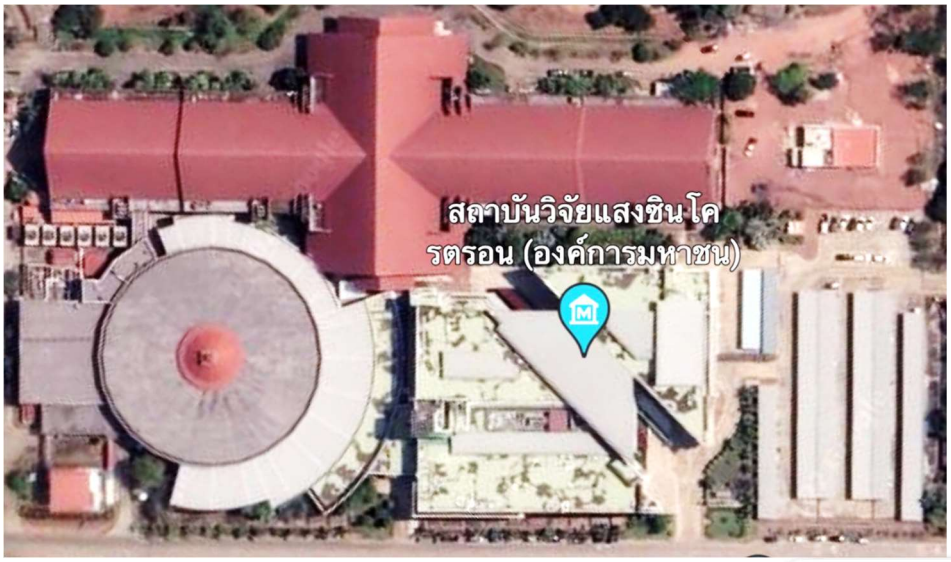
Synchrotron Community

4

Synchrotron Thailand



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Synchrotron Thailand

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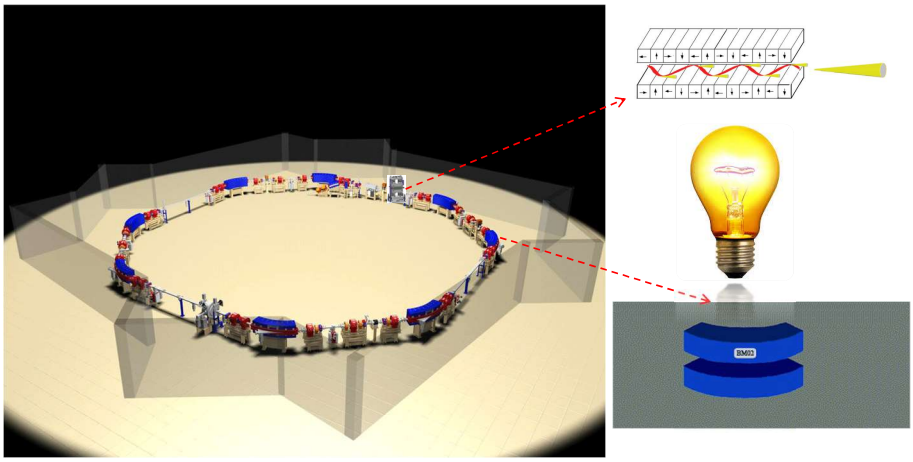
Synchrotron Light Source



วงกักเก็บอิเล็กตรอนเส้นรอบวง 81.3 เมตร

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Synchrotron Light Source

แสงซินโครตรอน คือ แสง หรือ คลื่นแม่เหล็กไฟฟ้าที่ปลดปล่อยออกมาจากการเร่งอนุภาคอิเล็กตรอนที่มีความเร็วใกล้แสงและถูกบังคับให้เคลื่อนที่เป็นแนวโค้งภายใต้สนามแม่เหล็ก เป็นแสงที่มีคุณสมบัติเด่น ดังนี้

1. แสงซินโครตรอน มีความยาวคลื่นต่อเนื่อง ตั้งแต่ย่านอินฟราเรด จนถึงรังสีเอ็กซ์
2. แสงซินโครตรอน มีความสว่างจ้ามากกว่าพระอาทิตย์กว่าล้านเท่า
3. แสงซินโครตรอนสามารถปรับจูนพลังงานตามความต้องการใช้ในการวิเคราะห์ในตัวอย่างแต่ละชนิดได้
4. แสงซินโครตรอน สามารถบีบลำแสงให้มีขนาดเล็กระดับไมโครเมตร เพื่อการวิเคราะห์คุณสมบัติต่างๆ ในเชิงลึกได้

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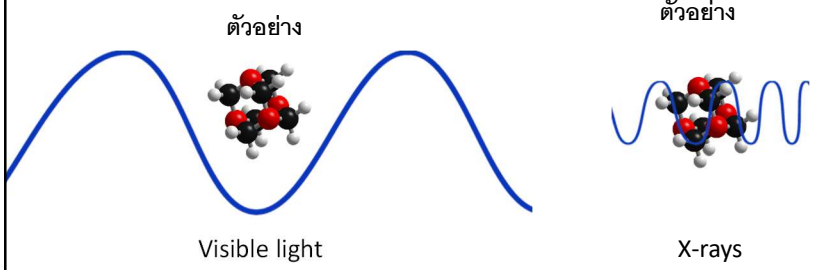
Wavelength

ความยาวคลื่นมีความสำคัญอย่างไร



To penetrate a sample, you need a wavelength of similar, or smaller magnitude.

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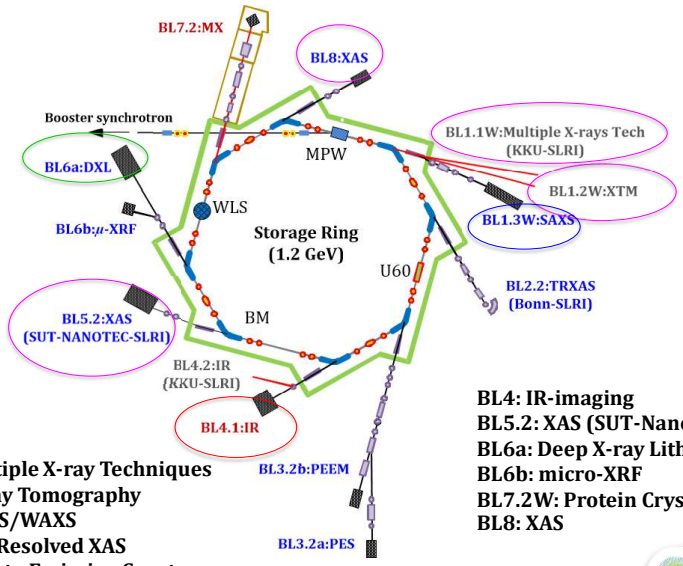
SLRI Beamlines



BL1.1W:Multiple X-ray Techniques
BL1.2W: X-ray Tomography
BL1.3W: SAXS/WAXS
BL2.2: Time Resolved XAS
BL3.2Ua: Photo Emission Spectroscopy
BL3.2Ub: Photo Electron Emission Microscopy

BL4: IR-imaging
BL5.2: XAS (SUT-Nanotec-SLRI)
BL6a: Deep X-ray Lithography
BL6b: micro-XRF
BL7.2W: Protein Crystallography
BL8: XAS

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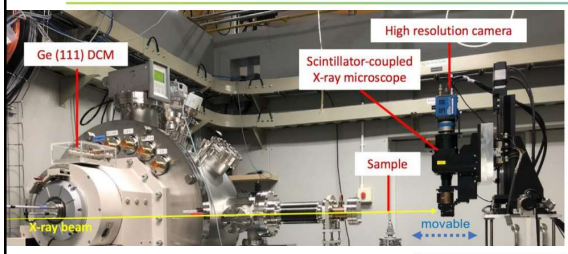
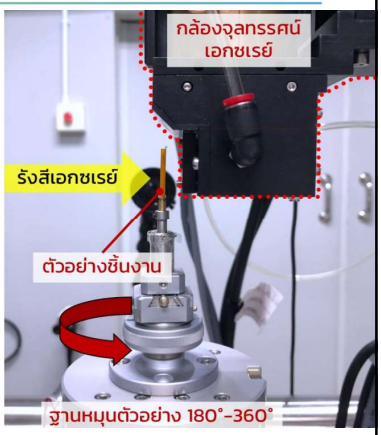
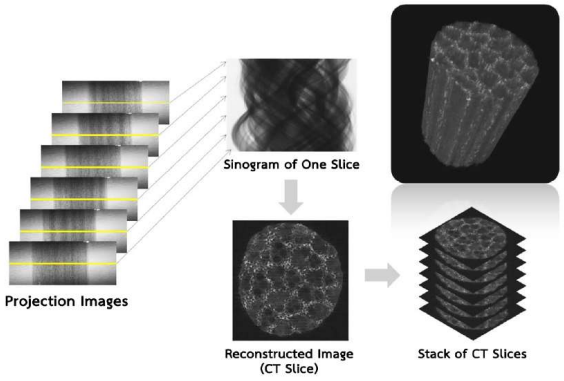
BL1.2W: X-Ray Imaging &Tomographic Microscope







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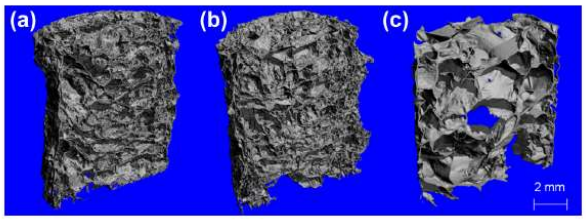
BL1.2W: X-Ray Imaging &Tomographic Microscope

3D cellular microstructure of food products

Extruded refined flour | Extruded refined flour + ~ 25 % wheat bran | Extruded refined flour + ~50 % wheat bran

- Product Development
- Shelf life Analysis



Corn meal extrudates stored for 10 days at different moisture content

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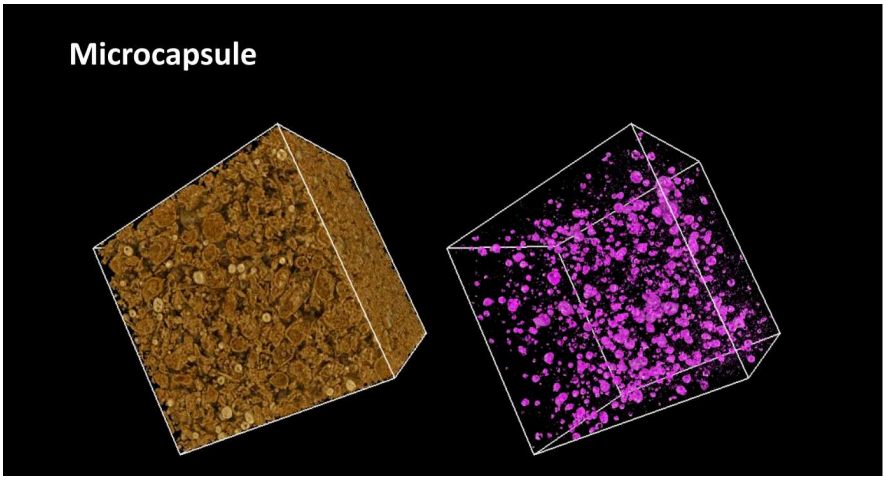
BL1.2W: X-Ray Imaging &Tomographic Microscope



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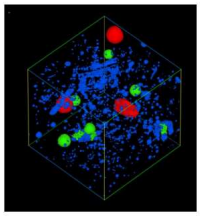
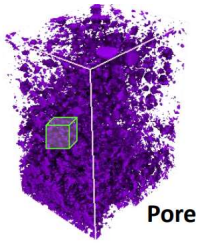
BL1.2W: X-Ray Imaging &Tomographic Microscope

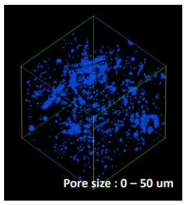
Geopolymer

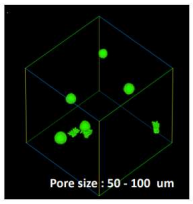


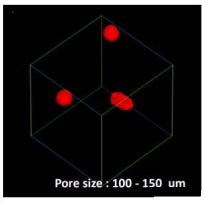
Total volume = 0.373995 mm³
Closed porosity = 3.20828%
Open porosity = 1.08317%
Total porosity = 4.29146%



Pore Classification







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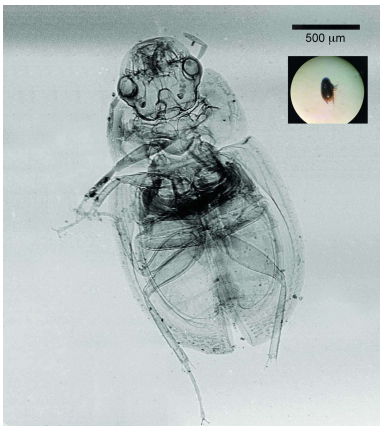
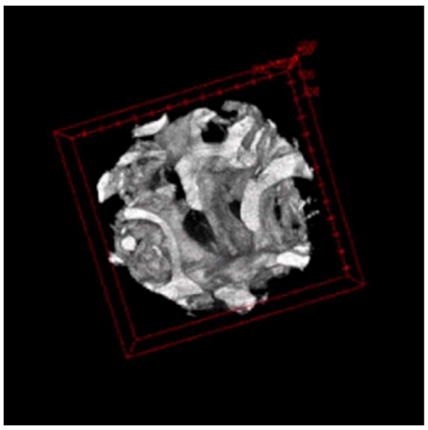
BL1.2W: X-Ray Imaging & Microtomography





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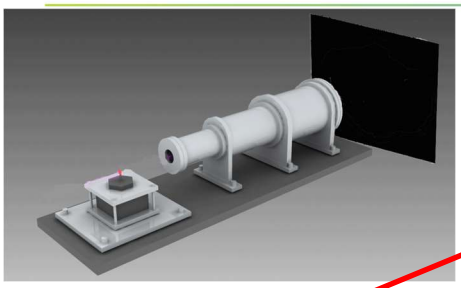
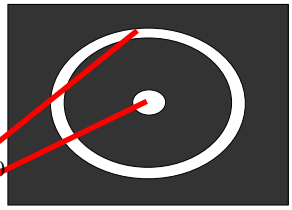
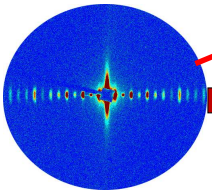
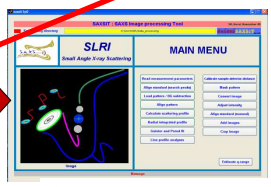
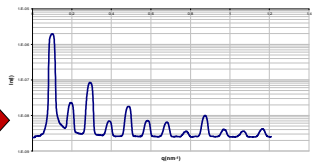
BL1.3W: Small/Wide Angle X-Ray Scattering (SAXS/WAXS)











Specifications

Beamline

Source: Multipole wiggler

Optics: Double Multilayer Monochromator + Toroidal focusing mirror

Photon Energy: 6-9 keV (optimized at 9 keV)

Photon Flux: 2 x 10^9 photons/sec

Beam size at sample: 1 x 2 mm^2 (V x H)

End Station

Detectors: Rayonix SX165 CCD

Maximum sample-detector distance: 4.5 m

q-range (SAXS): 0.08 – 4.6 nm^{-1}

q-range (WAXS): 2.2 – 40 nm^{-1}

2θ-range: 3.0 – 59 degrees in equivalent to Cu K_α source

Sample type: Solid/Liquid/Gel/Powder/Fiber/Film

Sample volume for liquid: 60 µL

Sample environment: In air/Heating-cooling stage/Tensile stage

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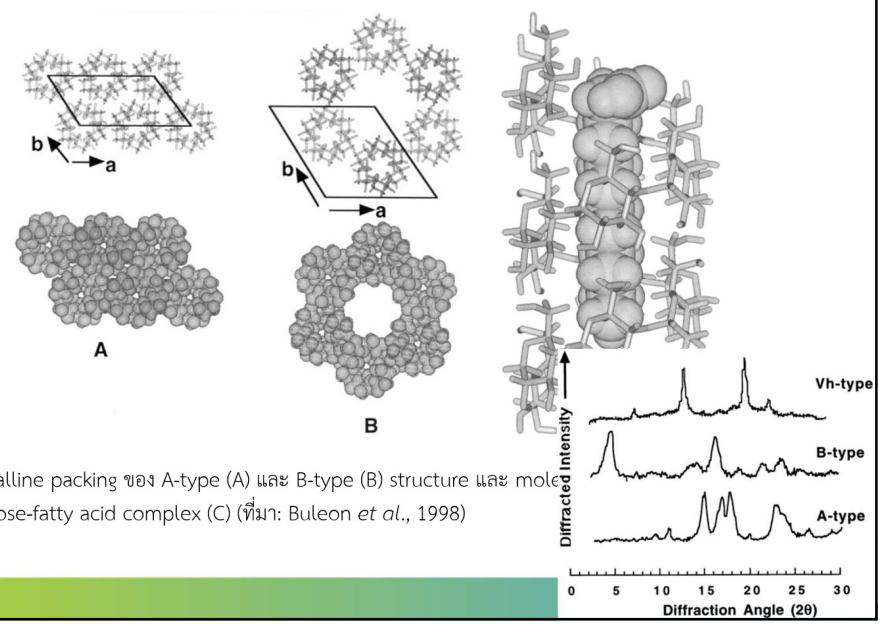
โครงสร้างผลึกของแป้ง



Crystalline packing ของ A-type (A) และ B-type (B) structure และ mole
amylose-fatty acid complex (C) (ที่มา: Buleon *et al.*, 1998)

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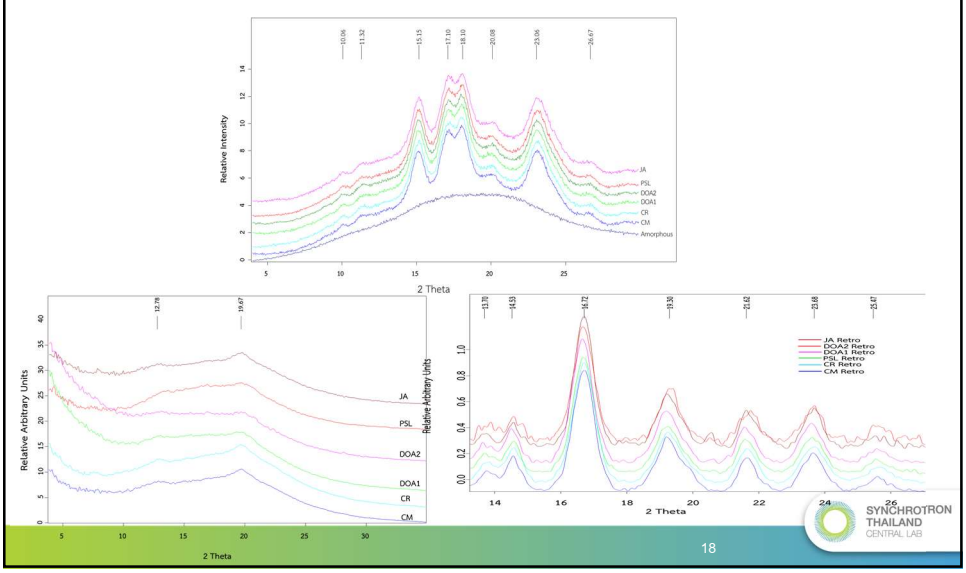
BL1.3W: Small/Wide Angle X-Ray Scattering (SAXS/WAXS)

WAXS can tell you



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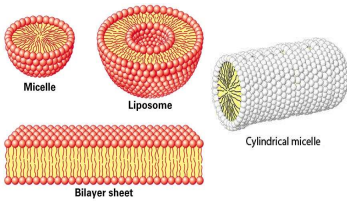
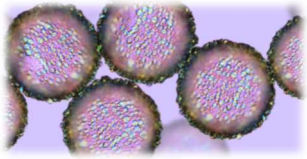
BL1.3W: Small/Wide Angle X-Ray Scattering (SAXS/WAXS)

Self-assembly of surfactant molecules

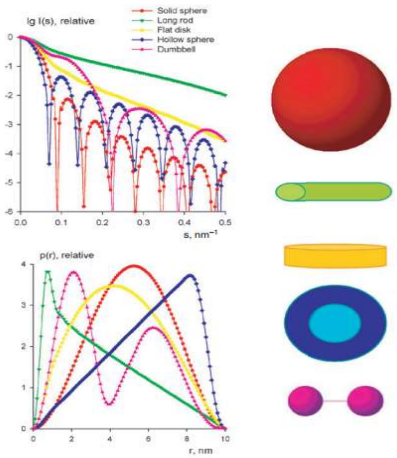


- Nanoparticles
- Colloidal systems
- Surfactant systems: spherical micelles, cylindrical micelles, Liposome (vesicles)



SAXS can tell you

Shape, Size, Size distribution



Svergun, D.I. et. al, Rep. Prog. Phys. 66 (2003) 1735

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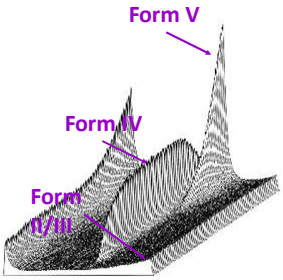
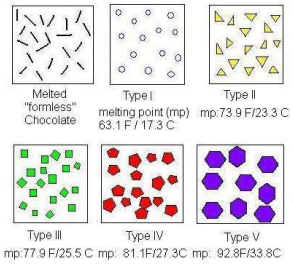
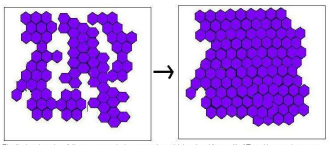
BL1.3W: Small/Wide Angle X-Ray Scattering (SAXS/WAXS)

Small angle X-ray scattering station of the DUBBLE-beamline at the ESRF in Grenoble.

Cadbury UK wanted to produce the most stable, smooth and best- tasting chocolate.







Finally the chocolate fully sets up, and what we end up with is a hard "crystal" of Type V cocoa butter, or Tempered chocolate.

They utilized a synchrotron to investigate the manufacturing process at the molecular level to optimize production conditions.

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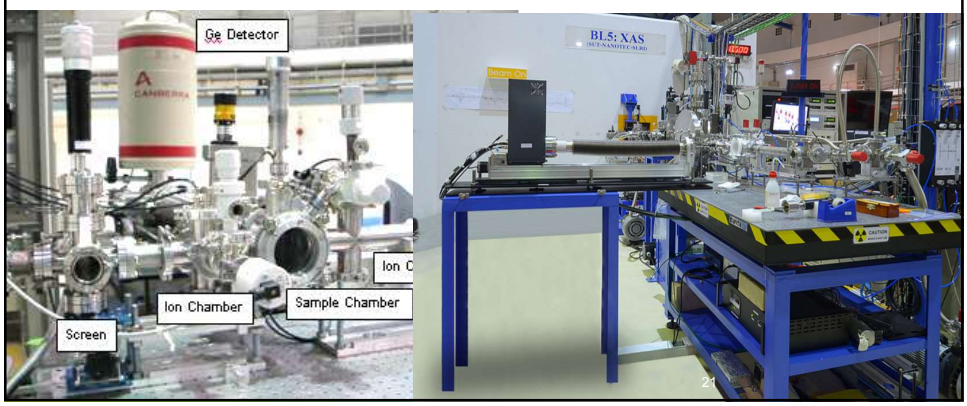
BL1.1W: Multiple X-Ray techniques (MXT)

BL5.1W: micro-X-ray Fluorescence (μ-XRF)
Micro XANES
BL5.2: X-Ray Absorption Spectroscopy (XAS)

BL8: X-Ray Absorption Spectroscopy (XAS)



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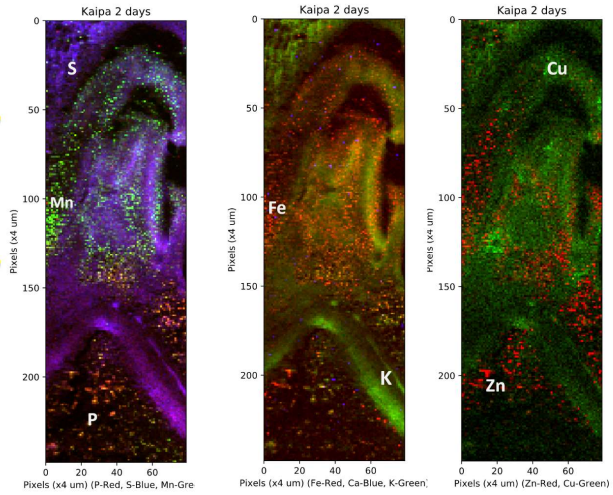
BL6b: micro-X-ray Fluorescence (μ-XRF)

HR7 บือซอมี (ไก่ป่า) 2 วัน



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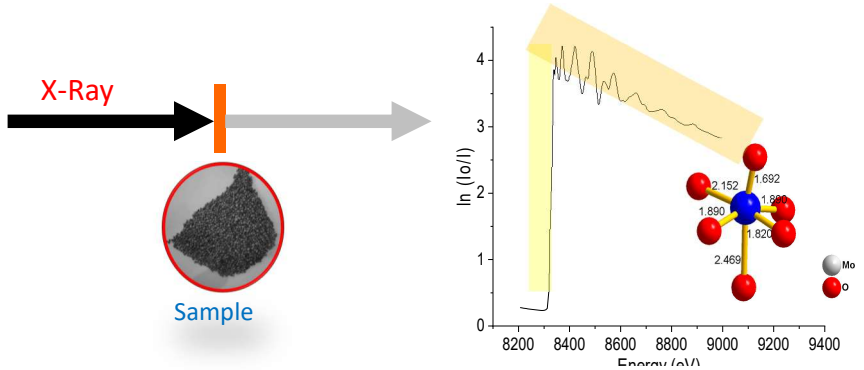
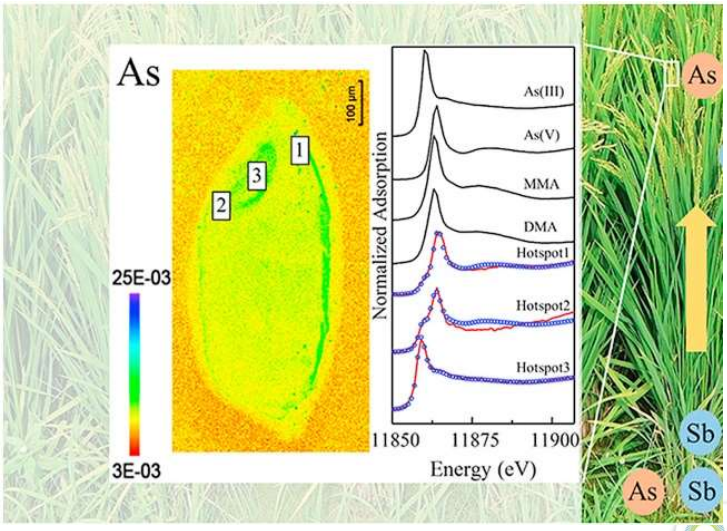
X-Ray Absorption Spectroscopy (XAS)



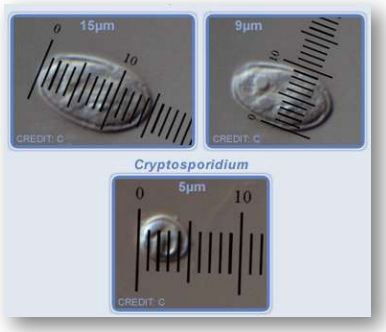
X-Ray Absorption Spectroscopy (XAS)

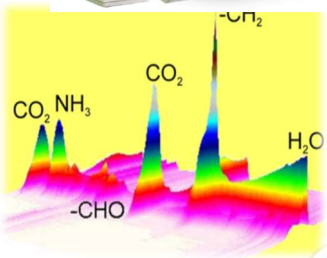
Speciation and location of arsenic in rice samples



Wu *et al.*, 2019

BL4.1 : Infrared Spectroscopy and imaging





Micro-IR

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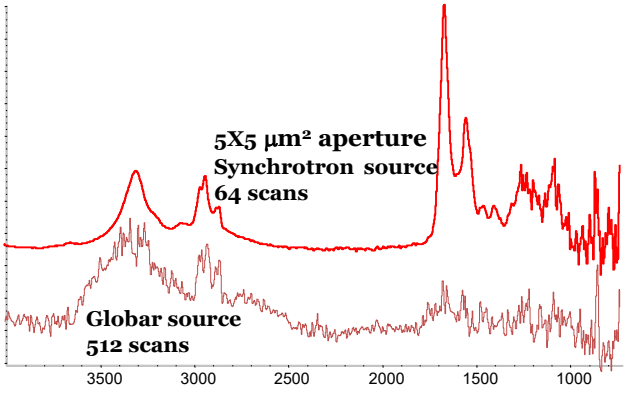
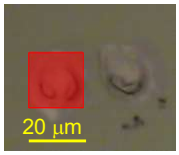
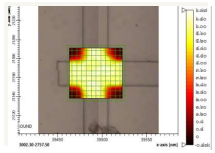
Why synchrotron source ?







Aperture (µm²)	Detectable Signal	
	Globar source	Synchrotron source
30×30	5708	7257
20×20	3168	6223
10×10	986	3712
5×5	271	1127

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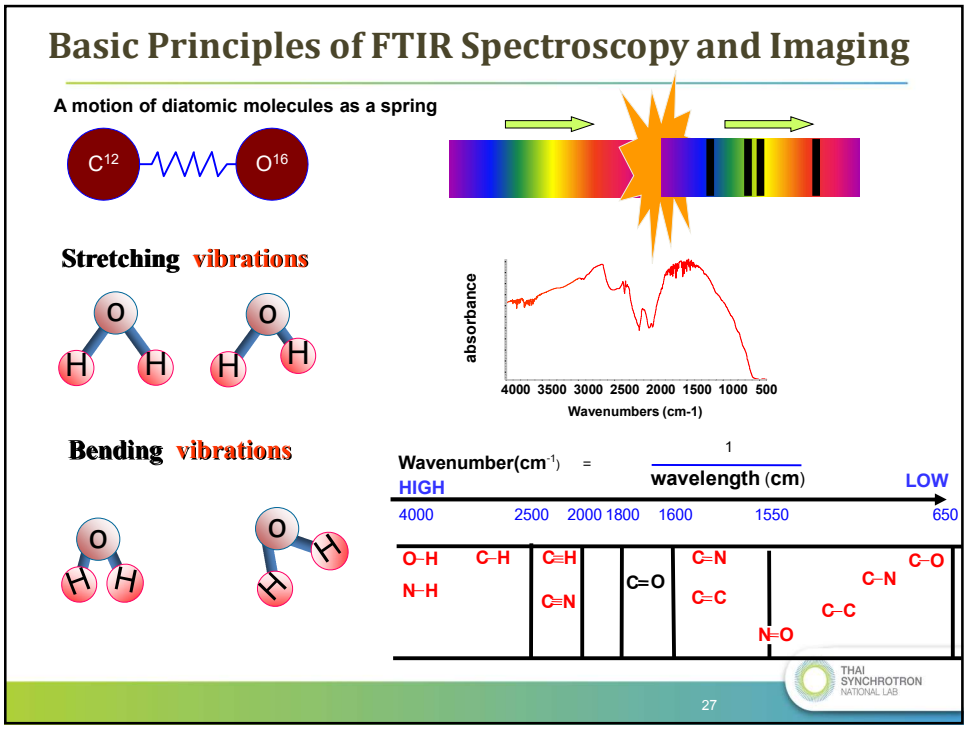
Basic Principles of FTIR Spectroscopy and Imaging
A motion of diatomic molecules as a spring
C12
O16
Stretching vibrations
Bending vibrations
absorbance
4000 3500 3000 2500 2000 1500 1000 500
Wavenumbers (cm-1)
Wavenumber(cm-1) = 1 / wavelength (cm)
HIGH
LOW
4000 2500 2000 1800 1600 1550 650
O–H
N–H
C–H
C≡H
C≡N
C=O
C=N
C=C
N=O
C–C
C–N
C–O
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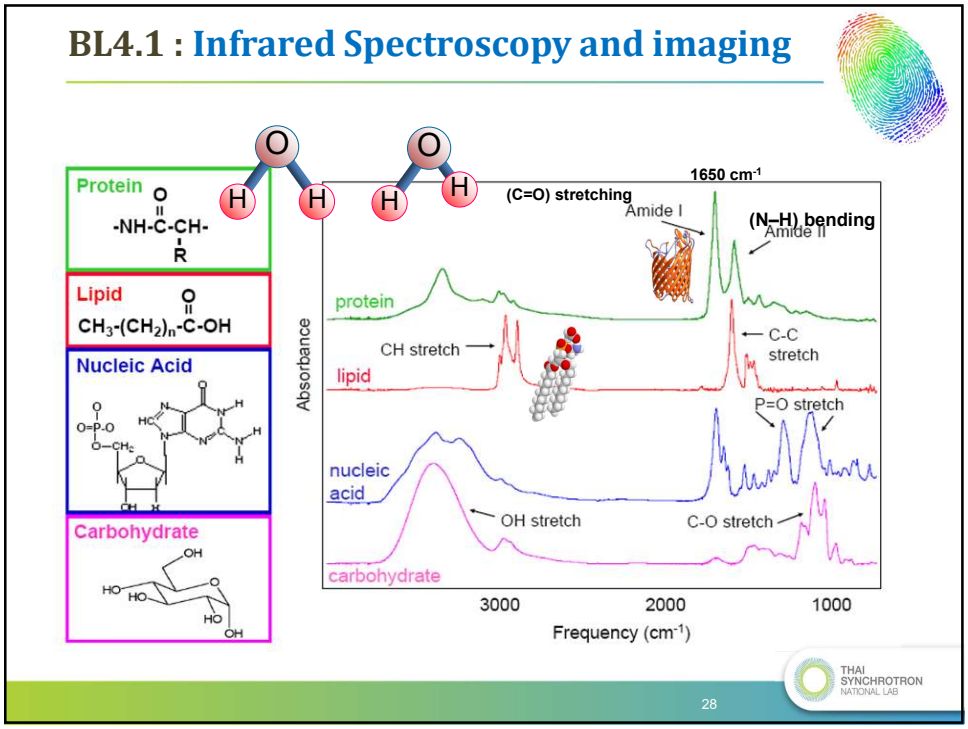
BL4.1 : Infrared Spectroscopy and imaging
Protein
-NH-C-CH-
R
Lipid
CH3-(CH2)n-C-OH
Nucleic Acid
Carbohydrate
1650 cm-1
(C=O) stretching
Amide I
(N–H) bending
Amide II
protein
CH stretch
C-C stretch
lipid
P=O stretch
nucleic acid
OH stretch
C-O stretch
carbohydrate
Absorbance
3000
2000
1000
Frequency (cm-1)
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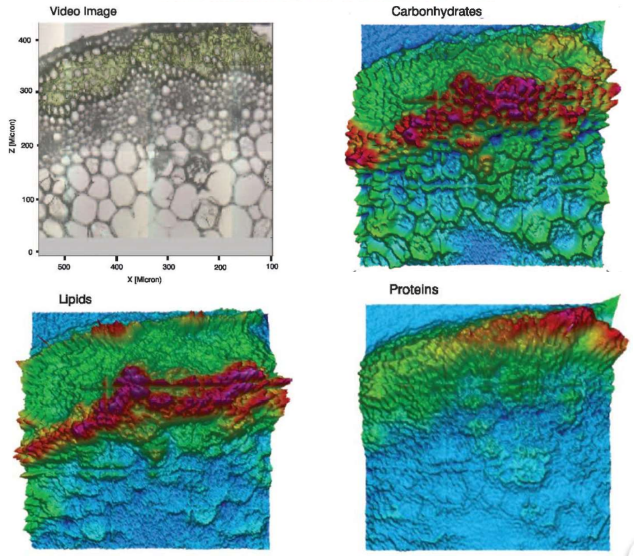
BL4.1 : Infrared Spectroscopy and imaging

FTIR ANALYSIS OF A WHEAT STEM



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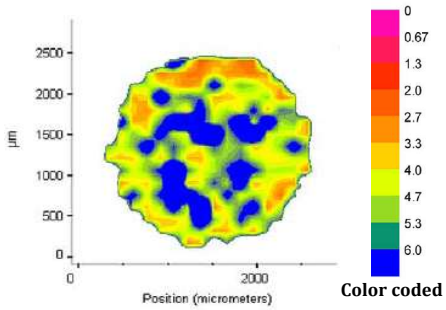
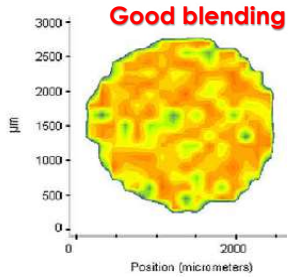
BL4.1 : Infrared Spectroscopy and imaging

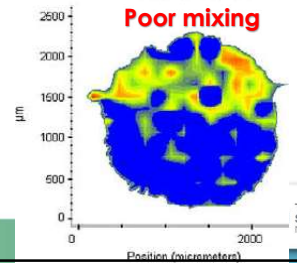
The homogeneity of starch/polyester extruded blends:

Excess of starch is distributed towards the centre of the section



Band Ratio = O–H / C=O





Polymer Testing 25 (2006) 16–21

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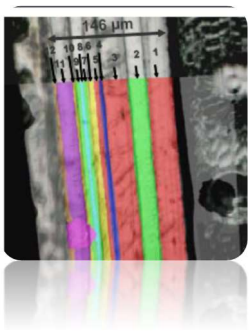
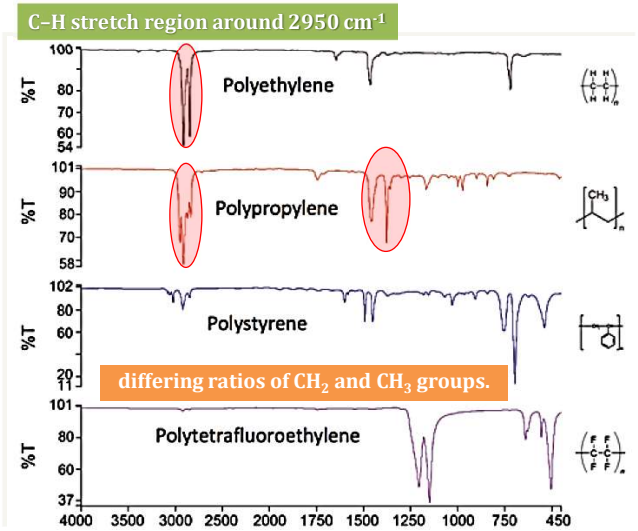
Packaging





The spectrum constitutes a "fingerprint" that can be used to determine the identity of the sample

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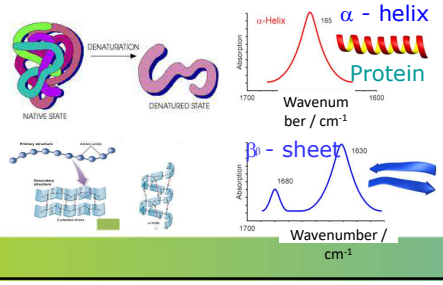
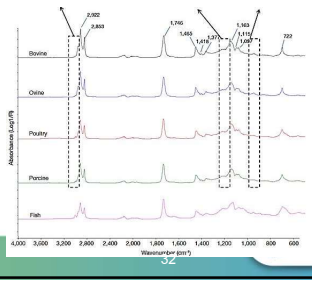
Meat Quality analysis

- ชนิดของเนื้อสัตว์
- ชนิดของสายพันธุ์
- วิธีการหมัก

Protein quality



Lipid quality



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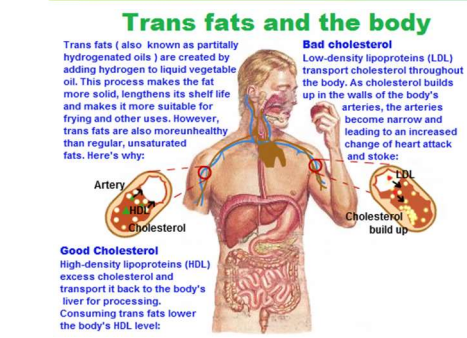
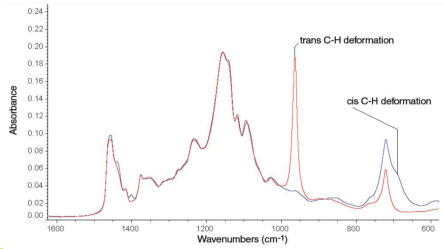
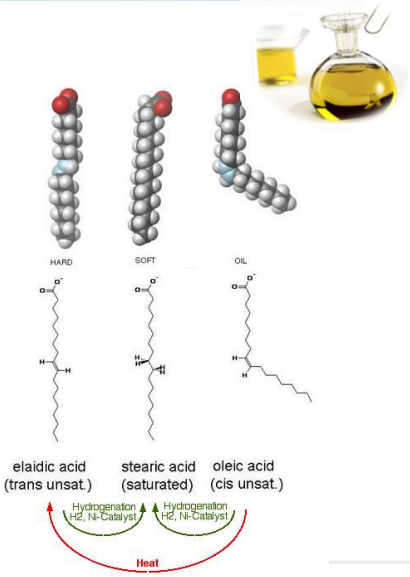
Edible oil / butter Analysis







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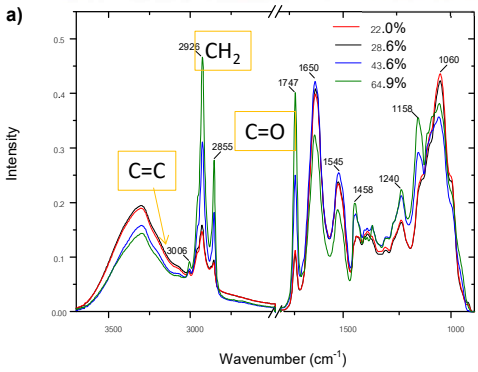
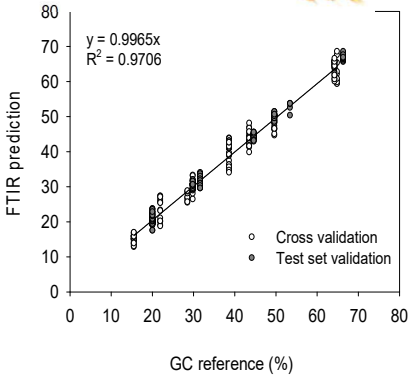
Rapid Chemometric analysis





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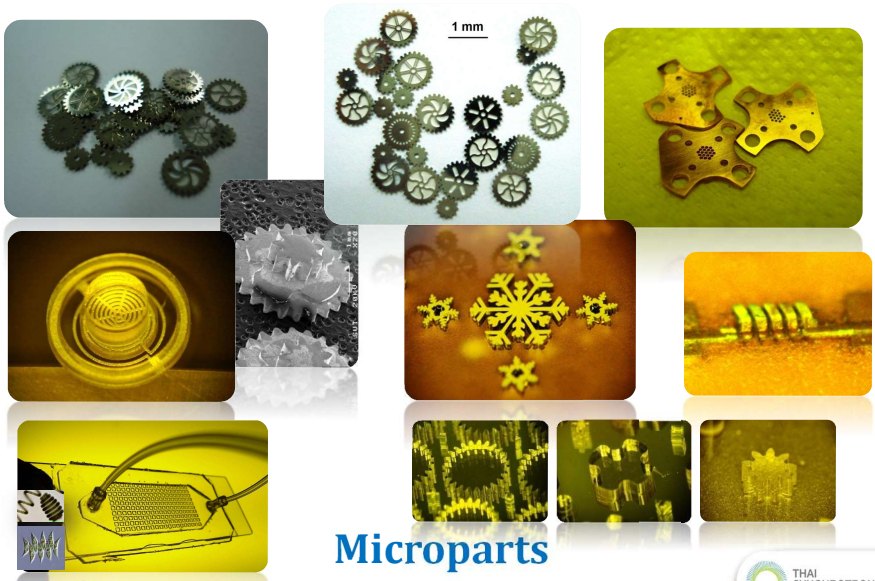
BL6a: Deep X-Ray Lithography



Microparts

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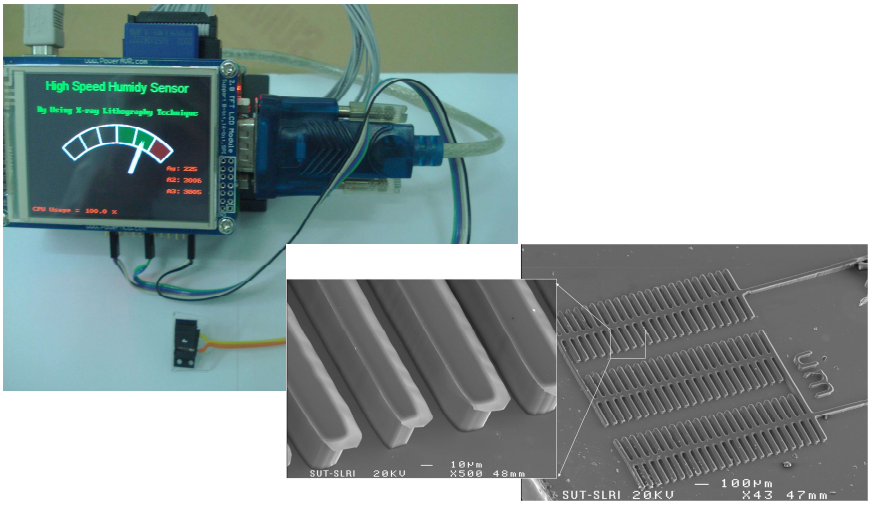
BL6a: Deep X-Ray Lithography



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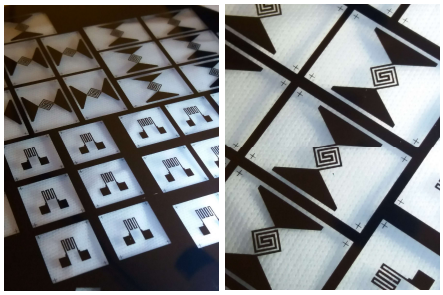
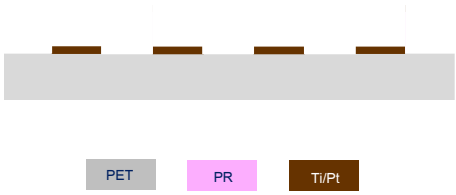
Flexible microhotplate

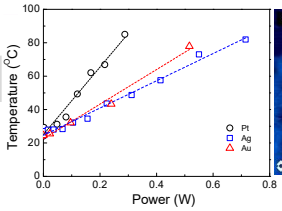
Design of μ-hotplate (temperature sensor)

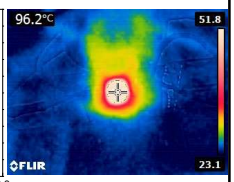
Heat generated when an electric current flows through a resistant path



Flexible microhotplate on PET substrate







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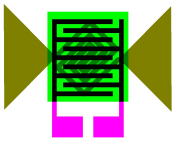
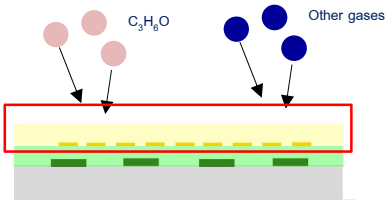
Gas sensors based on metal oxide films

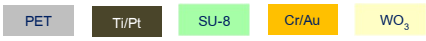
Metal oxide gas sensors on plastic foil platform

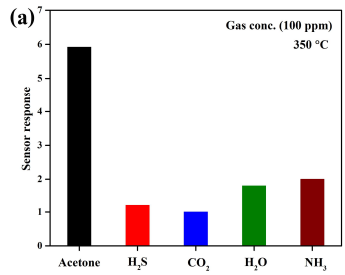


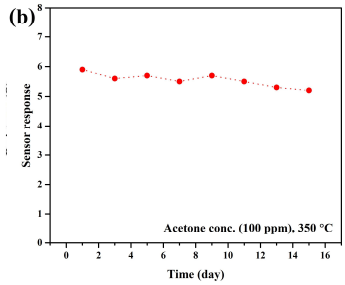
Multilayer devices

Si, SiO_2, Al_2O_3, PI









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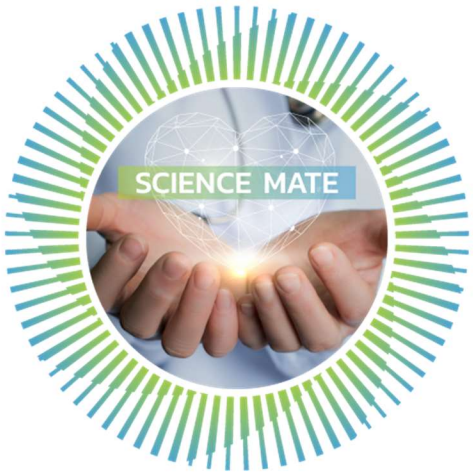

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