# SOFT X-RAY SPECTROSCOPY AND POLARIZATION (CSX-2)

BROOKHAVEN NATIONAL LABORATORY

NATIONAL SYNCHROTRON LIGHT SOURCE II

## SCIENTIFIC SCOPE

The CSX-2 beamline focuses on core-level spectroscopy in the soft x-ray range (250 - 2000 eV). Two complementary endstations are positioned at the beamline: (1) ambient pressure photoelectron spectroscopy (AP-PES) chamber which enables investigation of catalysts under realistic operating environments; and (2) an x-ray absorption spectroscopy (XAS) endstation that will be equipped with custom-designed experimental cells for XAS of catalysts, electrochemistry, liquids.

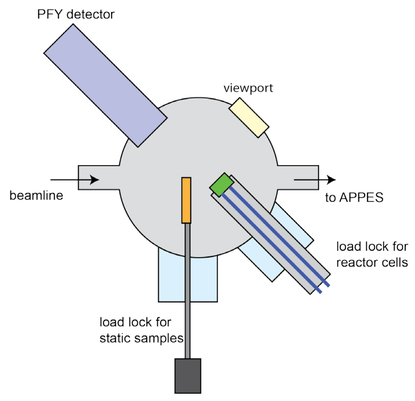
## BEAMLINE CHARACTERISTICS

**TECHNIQUES:**

- X-ray absorption spectroscopy (TEY and PFY)
- Ambient pressure x-ray photoelectron spectroscopy (AP-XPS)

**ENDSTATION DETAILS:**

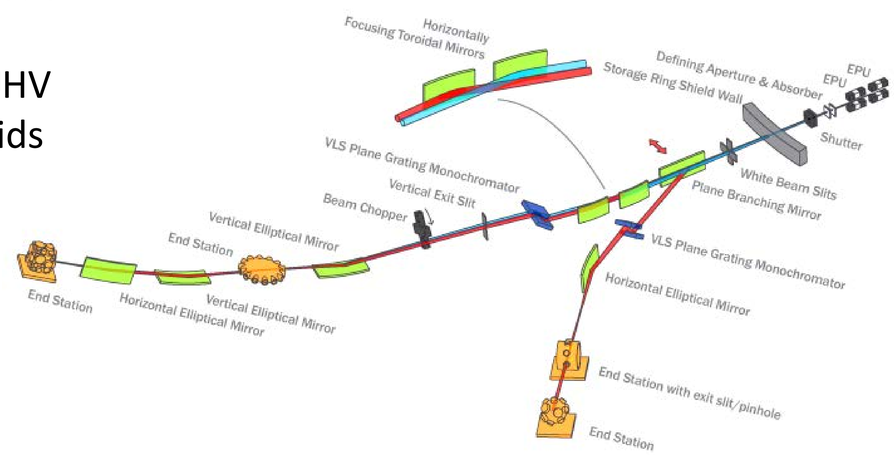
- **XAS Endstation**
  - ✧ Partnership with BNL Chemistry Dept.
  - ✧ Fluorescence and electron yield detection for bulk and surface sensitivities
  - ✧ Currently open for solid samples in UHV
  - ✧ Reactor cells in development for liquids and gas environments

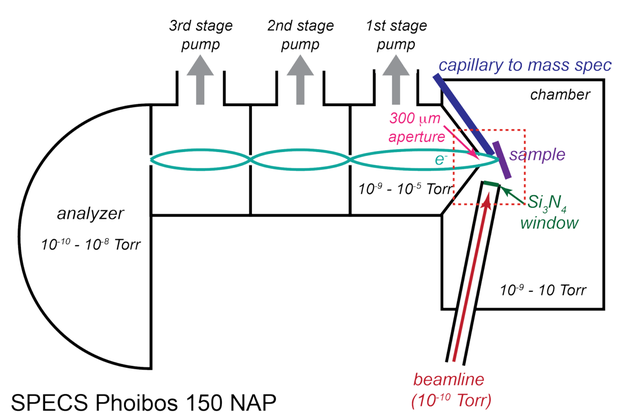



- **AP-PES Endstation:**
  - ✧ Partnership with the CFN
  - ✧ Mechanistic study of catalysis under up to 10 Torr of gases
  - ✧ Heating up to 900 C
  - ✧ Surface prep. tools: sputter gun, e-beam evaporator
  - ✧ Mass spectrometer for correlating surface chemistry with reactivity

**CSX-2 at NSLS-II:**

- In situ spectroscopy of surface processes relevant in energy materials under realistic conditions
- Surface and bulk sensitive x-ray absorption spectroscopy of energy materials




SPECS Phoibos 150 NAP analyzer

## Overview

**PORT**: 23-ID

**SOURCE**: Undulator (EPU49)

**ENERGY RANGE**: 250 – 2000 eV

**ENERGY RESOLUTION**: $\Delta E/E = 10^{-4}$

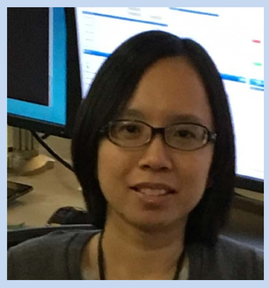
**SPOT SIZE**: 16 µm (V) x 40 µm (H)

**BEAMLINE STATUS:** Open to users

**BEAMLINE PHONE:** 631.344.1623

**BEAMLINE WEBSITE:** www.bnl.gov/nsls2/beamline/23-ID-2

## Beamline Team



**Ira Waluyo**
Lead Beamline Scientist

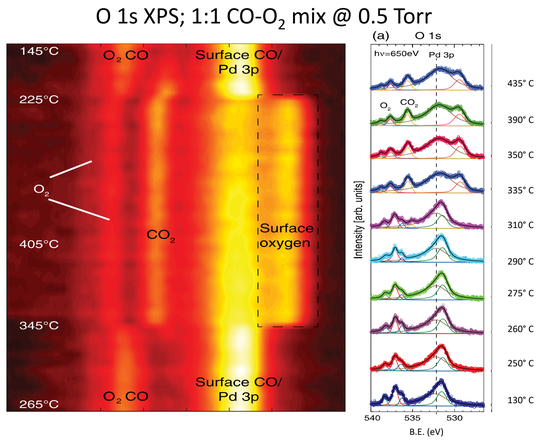
**Anibal Boscoboinik**
Partner Beamline Scientist

## Apply for Beam Time

Beamlines at NSLS-II are available to all scientific researchers through a peer-review proposal process. For more information, see the NSLS-II Users' Guide at:

**www.bnl.gov/ps/userguide/**

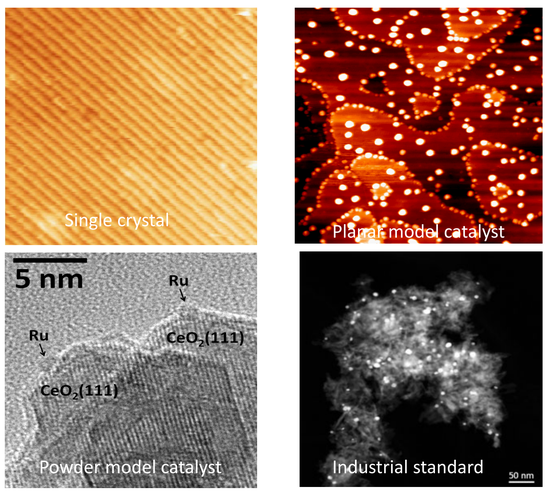
## SCIENTIFIC APPLICATIONS




Source: Blomberg *et al.,* PRL (2013); ALS BL 9.3.2

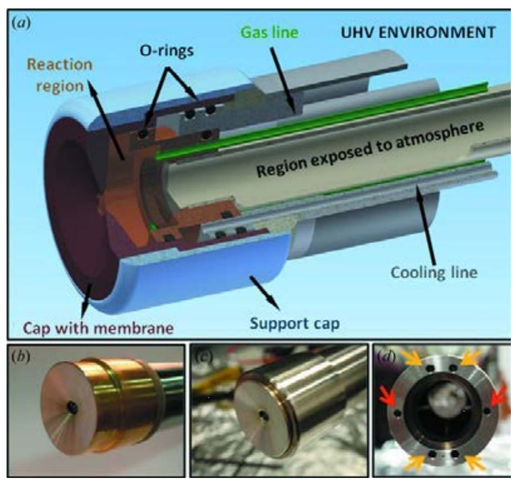
### Bridging the Pressure Gap in Catalysis

The design of better catalysts requires the thorough understanding of the reaction mechanism. Due to its surface and chemical sensitivity as well as elemental selectivity, x-ray photoelectron spectroscopy (XPS) is a powerful tool in the mechanistic study of catalytic reactions. Ambient pressure photoemission spectroscopy (AP-PES) is a game-changer as it greatly expands the applicability of XPS beyond ultra-high vacuum conditions to more realistic operating pressures. The exceptional brightness of NSLS-II enables the development of an AP-PES endstation that pushes the limits of photoemission spectroscopy up to the long-sought goal of operation at atmospheric pressure.




### Bridging the Materials Gap: From Single Crystals to Real Catalysts

The complexity of real catalysts used in industrial processes cannot be replicated by simplified model systems such as single crystals. The characterization of complex systems in realistic conditions (in high pressures of gases or in solution) is made possible by the high brightness and high resolution photons from NSLS-II. The electronic structure of the active components of the catalyst as well as their interaction with reactants can be studied using in situ x-ray absorption spectroscopy. Coupling this technique with mass spectrometry will make this a true operando technique.




### Versatile Spectroscopy for Catalysis and Electrochemistry

Soft x-rays offer many potential benefits for chemical spectroscopy (elemental resolution, valence state & charge transfer identification, ligand field symmetry, *etc.*) but at a price. Typically experiments are performed under ultra-high vacuum conditions. Custom-designed experimental cells can position the surface of interest near a transparent membrane (typically silicon nitride) for innovative photon-in / photon-out measurements. The many benefits of soft x-ray spectroscopy can then be applied to many issues such as hydrogen production from water-gas shift (WGS) reaction or methanol synthesis (MS) by $CO_2$ hydrogenation.