IN-SITU CHARACTERIZATION
STM/AFM
ARPS
4-Probe Testing
Raman Spectroscopy
Photoluminescence

THEORY / SIMULATION
DFT
Monte Carlo
Molecular Dynamics
Reactive Force Field
Phase Field

Research Focus
Close loop iterative collaboration of synthesis, characterization, and predictive modeling to accelerate discovery in 2D chalcogenides materials for next generation electronics.

Focus
Single crystal chalcogenides in monolayer, few layer, and bulk form.

Become A User
The 2DCC user facilities are accessed through user proposals. Facility use is free to user PIs from U.S. academic and government institutions. Industry and international user PIs are charged a fee.

Two Proposal Types
Research projects - Synthesis, characterization, and/or theory efforts that are performed by users who come onsite or by 2DCC staff. Three-page description, plus bios.

Sample-only - Requests for standard materials routinely synthesized at the 2DCC. One-page description of the research to be performed on the sample, plus bios.

The 2DCC aims to inspire a broad range of high-quality submissions from a diverse user base. Potential users are encouraged to contact the 2DCC to discuss their ideas before preparing a proposal.

User Program Questions?

Director of Operations and User Facilities
Kevin Dressler
kxd13@psu.edu • 814-863-2867

Director of User Programs
Joshua Robinson
jar403@psu.edu • 814-863-8567

Educational, Outreach, and Diversity
Focused activities directly related to MIP research:
- Monthly Webinars – including tutorials, research, diversity, and inclusion
- Annual Graphene and Beyond Workshop
- Instrument Training
- Focus on broadening access to the facility and its products

Contact
Director of Education, Outreach and Diversity
Eric Hudson
ewh10@psu.edu • 814-863-5345

mip.psu.edu
2DCC@psu.edu
The thin film facility focuses on transition metal dichalcogenides (TMDs), topological insulators, monochalcogenides, and in situ growth analysis.

**Chalcogenide MOCVD**
- H₂Se and H₂S gas sources
- W, Mo, In, and Nb sources
- RGA for real-time gas analysis

**Hybrid MBE**
- 3” diameter wafer
- 4-pocket e-beam (W, Mo)
- Effusion cells for Bi, In, Fe, Se, and Te
- **In situ** spectroscopic ellipsometer (210-1690nm)
- Reflection High-energy Diffraction (RHEED)
- RGA for real-time gas analysis

**Multi-Module UHV MBE Growth and Characterization System**
Available in early 2018.
- 6-pocket e-gun source (Fe, Nb, V, W, Mo EuS)
- Se cracker, effusion cells for Te, Bi, Cr, Sb, Fe
- **In vacuo** STM and ARPES

**Chalcogenide MOCVD System with In situ Optical Characterization**
Available in summer 2018.
- 8 bubbler stations and 4 gas sources including H₂Se and H₂S
- **In situ** spectroscopic ellipsometry (210-1690nm)
- laser reflectometry, Raman/PL

**Contact**
Joan Redwing / Director, Synthesis Lead  
email: jmr31@psu.edu  
Nitin Samarth / Assoc. Dir., Characterization Lead  
email: nxs16@psu.edu

The bulk crystal growth effort is focused on binary TMDs, TMD alloys and dopants, and chalcogenide-based topological insulators.

**Bridgman**
- Vertical Bridgman for melt growth of bulk crystals:
  - Crucible rotation
  - Three zones
  - Temperatures up to 1250°C
  - Ampoule diameter up to 2”

**Chemical Vapor Transport (CVT)**
- Two identical CVT systems are available.
  - Four zones
  - Temperatures up to 1100°C
  - Ampoule diameter up to 2”

**Support Equipment**
- Do all of your powder and ampoule preparation in-house.
  - Compounding Furnace – powder melting and mixing up to 1250°C
  - Glove Box – powder preparation
  - Quartz Sealing Station – up to 2” diameter
  - Ampoule Loading Station – wide variety of transport agents (Br, I, and Cl)

**Contact**
Joan Redwing / Director, Synthesis Lead  
email: jmr31@psu.edu  
Tom Mallouk / Bulk Synthesis & Exfoliation  
email: tem5@psu.edu

**Unique Capabilities**
Combined expertise of the 2DCC theory team and technical capabilities of the Materials Computation Center (MCC) and the Institute for CyberScience – Advanced Cyberinfrastructure (ICS-ACI) at Penn State.
- Overcome experimental obstacles
- Aid in interpreting in situ characterization and post-synthesis sample measurement
- Predict new synthesis targets

**Access to MCC Software Tools**
- First-principles (Quantum Espresso, VASP, etc.)
- Empirical methods capable of long time scales and length scales at both atomistic (ReaxFF) and phase-field levels

**Contact**
Vincent Crespi / Theory Lead  
email: vhc2@psu.edu

All MIP users have access to extensive related facilities for characterization and device fabrication.

**Materials Characterization Lab**
web: mri.psu.edu/mcl

**Nanofabrication Lab**
web: mri.psu.edu/nanofab

Both labs are conveniently located adjacent to MIP facilities in the Millennium Science Complex.