Thin Films and *In Situ* Characterization

The thin film facility focuses on transition metal dichalcogenides (TMDs), topological insulators, monochalcogenides, and *in situ* growth analysis.

Chalcogenide MOCVD

- H_2Se and H_2S gas sources
- W, Mo, In, and Nb sources
- Residual 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 (210-1690 nm)
- Reflection High-Energy Electron Diffraction
- Residual Gas Analysis

Multi-Module UHV MBE Growth and Characterization System

- 6-pocket e-beam (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

- 8 bubbler stations and 4 gas sources including H_2Se and H_2S
- *In situ* spectroscopic ellipsometry (210-1690 nm) laser reflectometry, Raman/PL

Bulk Crystal Growth

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

Vertical Bridgman

- Three zones
- Temperatures up to 1250 °C
- Ampoule diameter up to 2"
- Crucible rotation

Chemical Vapor Transport (CVT)

- Two four-zones (up to 1100 °C)
- Two two-zones (up to 1200 °C)
- Ampoule diameter up to 2"

Compounding and Ampoule Preparation

- Rocking Compounding Furnace – powder melting and mixing up to 1250 °C
- Glove Box – powder preparation in Ar atmosphere
- Quartz Sealing – up to 2" diameter

Theory and Simulation

Combines the expertise of the 2DCC theory team, the technical capabilities of the Materials Computation Center (MCC), and the Institute for CyberScience – Advanced Cyberinfrastructure (ICS-ACI) at Penn State.

Unique expertise to overcome experimental obstacles, aid in interpreting *in situ* characterization and post-synthesis sample measurement and predict new synthesis targets.

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

Related Facilities

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.