Chalcogenide Semiconductor Nanostructures

Labs:
- Photoemission -- PAB B049 (Olmstead Lab)
- Scanning Probe Microscopy -- PAB B009 (Fain Lab)
- High-resolution Photoemission -- Advanced Light Source, Berkeley

Funded Projects:
- Intrinsic Vacancy Chalcogenides for Spintronic Applications
- Phase Change Materials for Nanoelectronics: A combinatorial approach to mechanistic understanding
  - Part 1: Nanotechnology Ph.D. Program
  - Part 2: Research in Olmstead and Fain Groups

Faculty:
- Prof. Marjorie Olmstead
  - olmstd@u.washington.edu
  - Office B433 685-3031
- Prof. Sam Fain
  - fain@u.washington.edu
  - Office B437 543-8444

Graduate Fellowships

Societal Impact

User Facility
- National Infrastructure
- Joint Institutes
- NT Dual PhD Program

Acting Director: Francois Baneyx
Education and Outreach: Ethan Allen
Associate Director: Qiuming Yu
NT PhD Program: Marjorie Olmstead
Founded 1997

www.nano.washington.edu

"Standard" Ph.D.: "Standard Job"
- Take Classes
- Dream New Ideas
- Take Data
- Analyze Data
- Present work
- Publish results

"Standard" Ph.D. Process
- "Standard Job"
  - Basic Research
  - Teaching
  - Preparing to teach
  - Though often not part of training

NT Dual PhD Program
- 85 Faculty
- 5 Centers
- 3 Colleges
- 10 Departments
- 40 PhD Students
- 5 Programs
- 1 National Institute
- 14 Fellowships
- 1 NT Dual PhD Program

UW Center for Nanotechnology
- 85 Faculty
- 5 Centers
- 3 Colleges
- 10 Departments
- 40 PhD Students
- 5 Programs
- 1 National Institute
- 14 Fellowships
- 1 NT Dual PhD Program

Chalcogenide Semiconductors
What Do Nanotechnologists Do?

Inform Public
Policy
Interact Across Disciplines
Teach the Public
Launch New Products
Build life-changing technologies from individual molecules
Compete Globally
Build New Tools

Optional "Essentials"

Dual Degree in Nanotechnology

1. Thesis in Nanoscale Science or Technology
   • Approved in quality by home department
   • Approved as "nano-relevant" by NT Standards Committee
   • Advisor + at least one other committee member in the Center for Nanotechnology
   2. Core Course: Frontiers of Nanotechnology
   • Student joint projects across disciplines
   • Discuss societal impact as well as science & technology
   3. Research Rotation
   • 1 quarter research outside advisor’s home department
   4. Nano-relevant Course Work
   • 3 courses, 2 of which are outside home department
   • 1 quarter research outside advisor’s home department
   • Approved as "nano-relevant" by NT Standards Committee
   5. Fellowship Program
   • Proposal writing experience
   • Bias toward Interdisciplinary Collaborations
   • IGERT, UIF, hopefully more.
Path to a UW Nanotechnology Ph.D.

Optional Degree Program in "Nanomaterials"

Ph.D. in "Home Department" and Nanotechnology

-Doctoral Requirements of Home Department

Non-thesis Option
-Dean's Option
-Graduate Research Project with Co-Tuition

Admission into a "Home Department"

Integrated Graduate Students

Path to UW

Part 2: Olmstead & Fain Group Research

Nanostructures of Dissimilar Materials

Silicon-based Nanoelectronics

Microfabrication + Microelectronics

Spintronics and Optoelectronics

Vacuum Tube

Victrola

Tabletop Turntable

Walkman

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

VacuumTube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet

Vacuum Tube

Tablet
Nanoscale Action

Macroscopic Results

Factors We Can Control --
- Temperature Flux
- Surface Composition
- Average Step Spacing

Factors We Must Deal With --
- Strain (lattice mismatch)
- Surface Structure (steps, defects, symmetry)
- Chemical Reactions (interface compounds)
- Chemical Environments (surface energy, diffusion)

First Monolayer Controls Subsequent Growth

Common Themes in our Research

- Quantify Correlations between Thermodynamics, Kinetics and Nanostructure Properties
- Develop New Materials and Methods to Fabricate Si-
- Establish a Unifying Predictive Framework for Heteroepitaxy of Dissimilar Materials
- Investigate Physics Underlying Nanostructures
- Develop New Materials and Methods to Fabricate Si-
- Establish a Unifying Predictive Framework for Heteroepitaxy of Dissimilar Materials
- Investigate Physics Underlying Nanostructures

Experimental Probes

- High Resolution Microscopy
  - Scanning Tunneling
  - Atomic Force
  - Magnetic Force
- Low Energy Electron Diffraction
- Xray Diffraction
- Photoemission Spectroscopy
  - Scanned Energy & Angle
  - Component-Resolved
- Valence Band Spectroscopy
  - Scanned Energy & Angle
- Photoelectron Diffraction
  - Scanned Energy & Angle
- Ion Scattering Spectroscopy
- SQuID Magnetometry
- Nanoscale Structure
- Average Atomic Structure
- Chemical Environments
- Electronic State Density
- Surface/Bulk
- Surface Elemental Composition
- Electronic State Density
- Surface/Bulk
- Surface Elemental Composition

Theory

UHV

How it’s done …

Substrate

Evaporation cell

Evaporation

Theory

Experimental Probes

Nanoscale Action ⇒ Macroscopic Results
Recent Fain Group Publications


Recent Olmstead Group Publications

- Laser and Electrical Current Induced Phase Transformation of In2Se3: Semiconductor Thin Film on Si(111), Applied Physics A to be published.
- Electronic structure evolution during the growth of ultra-thin insulator films on semiconductors: from interface formation to bulk-like CaF2/Si(111) films, Physical Review B 72, 041302(R) (2005).
**Candidate Materials:**

- **Transition Metal Doped Semiconductors**
  - Mn in GaAs: FM but only below ~100K
  - Co or Cr in TiO₂: Thin films ferromagnetic at RT
  - Mn or Cr in Ga₂Se₃: New material we propose

**Device Requirements**
- Ferromagnetic above room temperature
- Efficient, spin-preserving transport into silicon

**Translation to Materials Requirements**
- Lattice matched to silicon
- Impedance matched
- Semiconductor
- Large exchange interaction

**Si-compatible III-VI Semiconductors**

- Al₃S₅, Ga₃S₅ or In₃S₅ = Conventional Semiconductor + e⁻
- Wide band gap semiconductor
- Lattice matched with Si
- Vacancies plus sp³ bonding
- Reactive dangling bonds
- Unique growth morphologies
- Non-linear optical properties

**III-VI Semiconductors Crystal Structure**

- Hexagonal GaSe
- Cubic GaSe₃
- Hexagonal Al₃S₅ or In₃S₅
- Zinkblend
- Wurtzite
- Hexagonal Al₃S₅ or In₃S₅

**Flexible Bonding Configuration: Vacancies and Lone Pairs**

- Planes
- Lines
- Helices

**III-VI Semiconductor Crystal Structure**

- Al₃S₅, Ga₃S₅ or In₃S₅ = Conventional Semiconductor + e⁻

**Flexible Bonding Configuration: Vacancies and Lone Pairs**

- Flexible bonding configuration: Vacancies and Lone Pairs
- Reactive dangling bonds

**Cubic Substrate: Si(001)**

- Case on As-terminated Si(001) 2x1
- As remains at interface
- 2x1 LEED Pattern
- Strong Photoelectron Diffraction
- Reactive dangling bonds

- Case on pristine Si(001) 2x1
- Crystalline GaSe₃
- No LEED Pattern
- No Photoelectron Diffraction Structure

**Si-compatible III-VI Semiconductors**

- Al₃S₅, Ga₃S₅ or In₃S₅ = Conventional Semiconductor + e⁻
- Wide band gap semiconductor
- Lattice matched with Si
- Vacancies plus sp³ bonding
- Reactive dangling bonds
- Unique growth morphologies
- Non-linear optical properties

**Flexible Bonding Configuration: Vacancies and Lone Pairs**

- Flexible bonding configuration: Vacancies and Lone Pairs
- Reactive dangling bonds

**Cubic Substrate: Si(001)**

- Case on As-terminated Si(001) 2x1
- As remains at interface
- 2x1 LEED Pattern
- Strong Photoelectron Diffraction
- Reactive dangling bonds

- Case on pristine Si(001) 2x1
- Crystalline GaSe₃
- No LEED Pattern
- No Photoelectron Diffraction Structure

**Si-compatible III-VI Semiconductors**

- Al₃S₅, Ga₃S₅ or In₃S₅ = Conventional Semiconductor + e⁻
- Wide band gap semiconductor
- Lattice matched with Si
- Vacancies plus sp³ bonding
- Reactive dangling bonds
- Unique growth morphologies
- Non-linear optical properties
Growth on Si(001)

Zinc-blende Ga2Se3 (2.5CBL)

Nanorods

- 1 Ga-Se bilayer high
- Corrugation = Ga-Ga distance
- Rods to As dimer rows
- Lateral shift between layers

Ga2Se3 Nanoridge Structure

Current Research Direction: Dope Ga2Se3

Vacancy       Ga                 Se
Zn
Ga
Ge
As
Se
Ga3As3
Zn3Se3
Ga2Se3

- Zincblende, with Ordered Vacancies
- Eg ~ 2.3 eV
- Lattice Matched to Si (0.1% mismatch)
- Two cation sites available for TM doping
- TM on Ga-site (TMGa)
- TM on Vacancy-site (TMV)

Vacancy Lines [110]

Spin-Polarized Density of States

\[
\text{Mn gap} \sim \text{Ga2Se3 gap}
\]

\[
\text{Cr states fill Ga2Se3 gap}
\]

\[
\text{V states fill Ga2Se3 gap and overlap CB}
\]

\[
\text{SP-DOS}
\]

\[
\text{d-states}
\]

\[
\text{TMV}
\]

\[
\text{TMGa8Se12}
\]

Vacancy Lines

Theoretical Prediction

Theoretical Prediction

Spin-Polarized Density of States

\[
\text{Mn gap} \sim \text{Ga2Se3 gap}
\]

\[
\text{Cr states fill Ga2Se3 gap}
\]

\[
\text{V states fill Ga2Se3 gap and overlap CB}
\]

\[
\text{SP-DOS}
\]

\[
\text{d-states}
\]

\[
\text{TMV}
\]

\[
\text{TMGa8Se12}
\]
Phase Change Chalcogenides

Challenges:
- Uniform stoichiometry
- Controlled nucleation
- Smaller bit size
- Ce\textsubscript{2}S\textsubscript{2}Te\textsubscript{3} (GST)

Collaborations:
- NIMS, Japan
- Micron, Boise
- PNNL, Richland

Phase Change Chalcogenides

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Phase Change Chalcogenides

- Magnetic

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan

Cr-doped = Magnetic

- Ferromagnetism at both 2K and 300 K
- Hysteresis loop
- Apparent Curie Temperature 335 K

Collaborations:
- PNNL, Richland
- Micron, Boise
- NIMS, Japan
Laminar film despite 7.3% lattice mismatch

Indicating the heterointerface is discommensurate

Reverse phase change

Room Temperature Deposit

- Amorphous to Single Crystal Film
- Add Room Temperature Deposit
- Deposit 2 BL at High Temperature
- Amorphous to Polycrystalline Film

Microscopy: real space information.

- Image contrast often reflects surface chemical composition, phase, and surface dipole.

Multi-channel plate+

Lens column

Object chamber

High bias

Equipped with laser for melting and quenching

Photo Electron Emission Microscopy (PEEM)

Laminar film on Si(111)
Part 1: Nanotechnology Ph.D. Program

A combinatorial approach to mechanistic understanding

Funding Projects:
- High-resolution Photoemission - Advanced Light Source Berkeley
- Scanning Probe Microscopy - PAB B09 (Fain lab)

Labs
- Prof. Sam Fain
  Office B435 682-3945
  Web: http://faculty.washington.edu/fain

- Prof. Marjorie Olmstead
  Office B437 682-3931
  Web: http://faculty.washington.edu/olmstd

Future Directions

- Spintronics: Study role of TM impurities
  - Growth kinetics and morphology
  - Electronic structure
  - Magnetic properties (MFM shared with MSE)
- Nanostructure Phase Change Memory
  - Role of via in controlling phase stability and uniformity
  - Role of size in controlling energy budget and phase transformation
- Combinatorial Materials - Novel alloy and processing space for new materials
  - Non-volatile memory applications
  - Develop new and emerging materials
  - Physical properties (X-ray and electron microscopy)
  - Electronic structure
  - Growth kinetics and morphologies
  - Spintronics: Study role of TM impurities

Reverse phase change

Laser spot

Re-amorphized In$_2$Se$_3$

Amorphous  In$_2$Se$_3$

Clean Si(111)

Reverse phase change: PEEM with laser