Thin-Film and Powder Characterization with X-rays and Polarized Light

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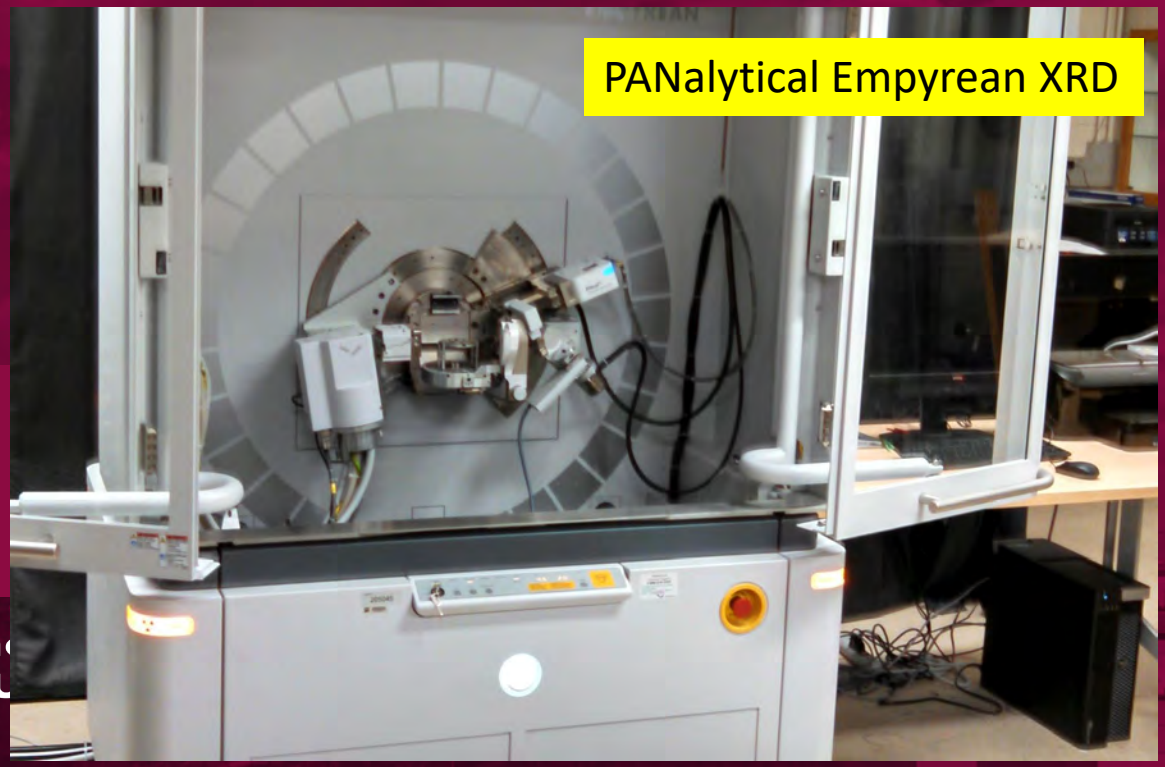
WWW: http://femto.nmsu.edu or http://research.nmsu.edu/ResearchCores/XRAY.html



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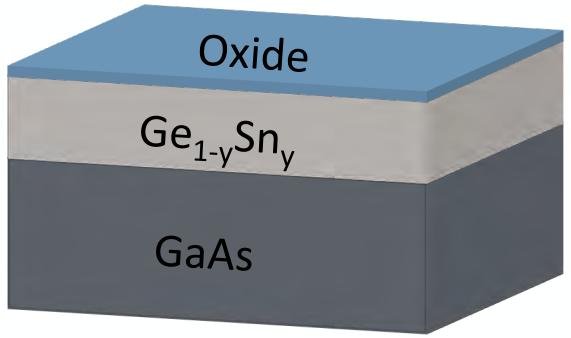
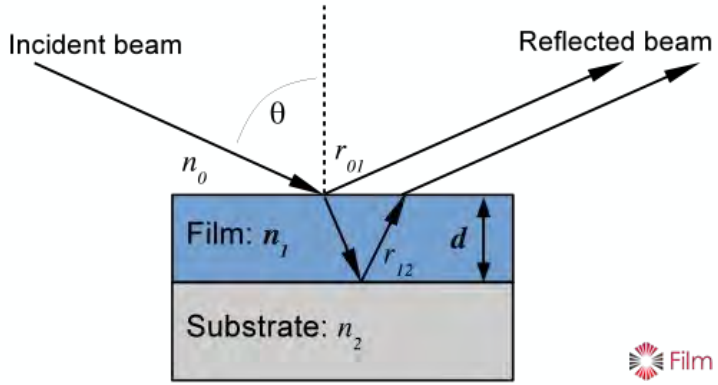
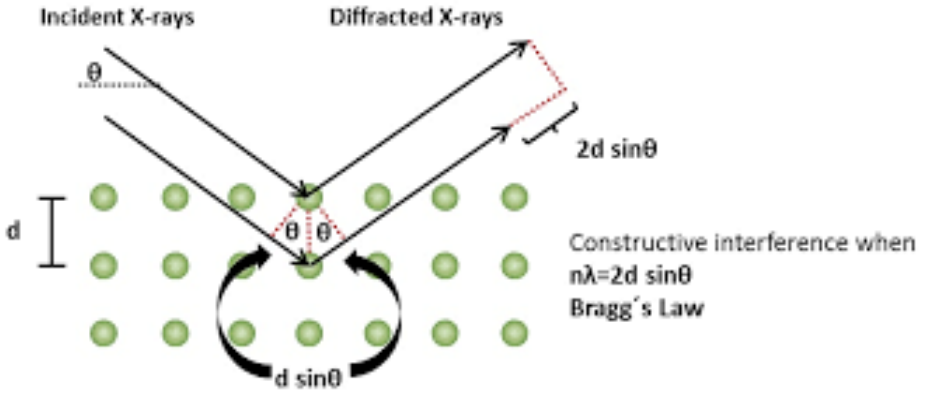
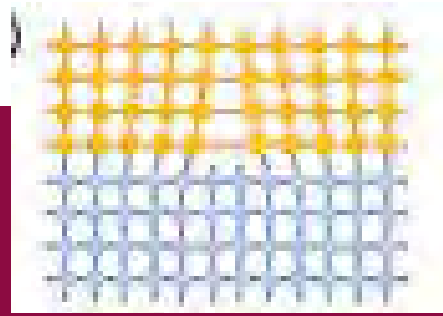
Thin Film and Powder Characterization

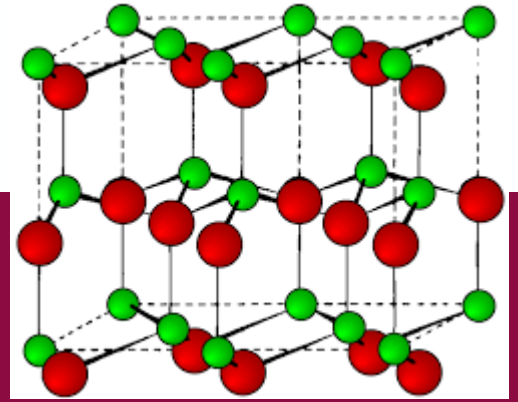
1. **How thick is my film?**
2. **What are the film properties?**
   - Thickness, density, roughness (XRR)
   - Band gap (Ellipsometry)
   - Refractive index and absorption coefficient
   - Infrared vibrations
   - Strain and stress, alloy composition
   - Lattice constants, crystal structure, position of the atoms in the cell
   - Orientation, epitaxial alignment
   - Temperature dependence of properties (10 to 800 K)
3. **Powder and single-crystal characterization:**
   - Chemical identification from diffraction patterns (PDF data base)
   - Lattice constants, crystal structure, position of the atoms in the cell
   - Rietfeld refinement



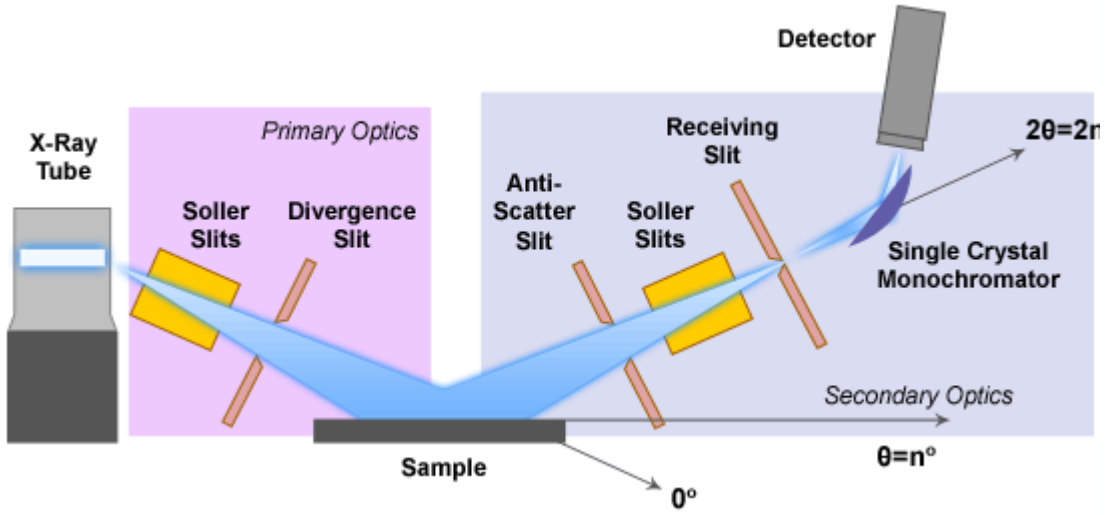


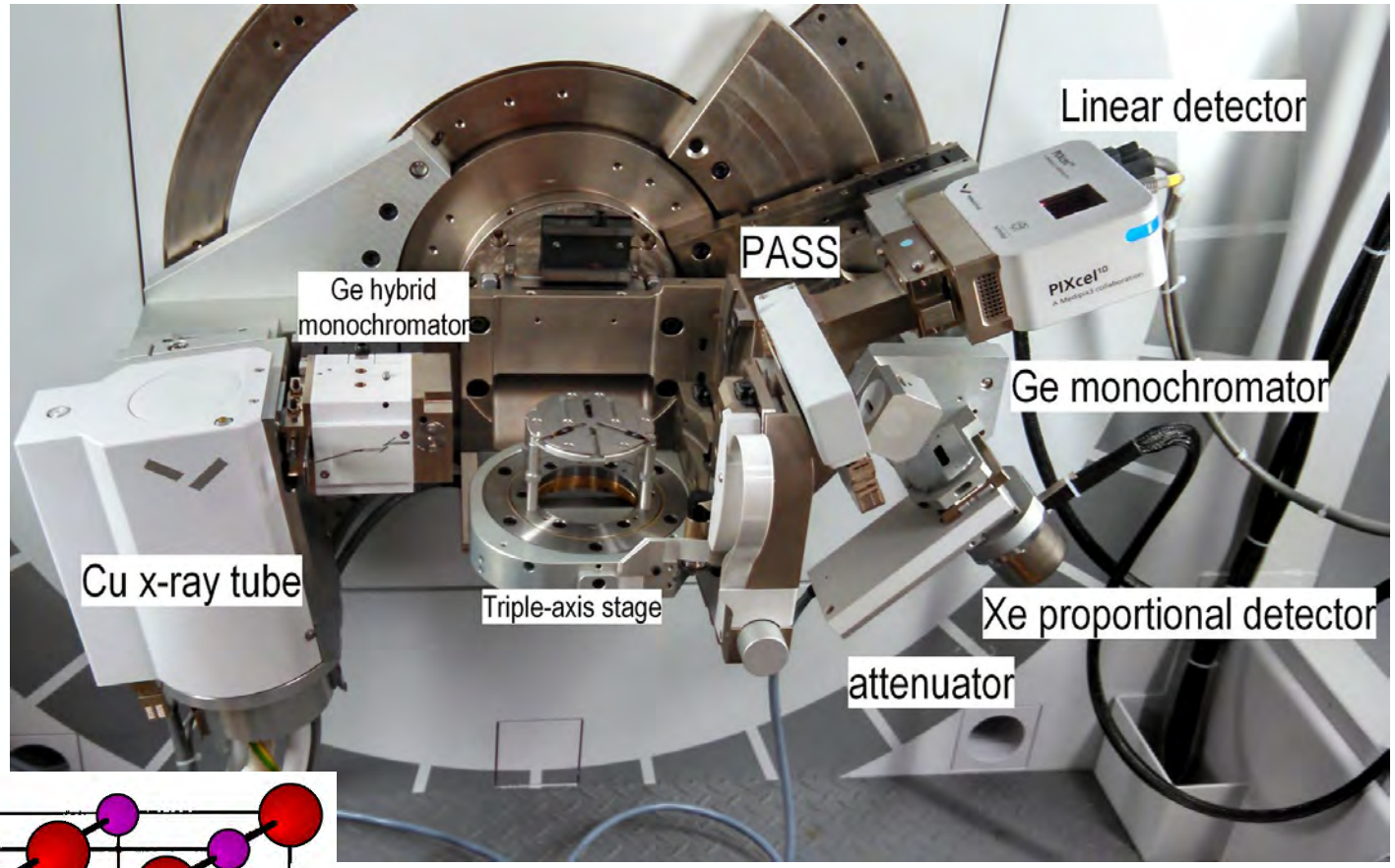


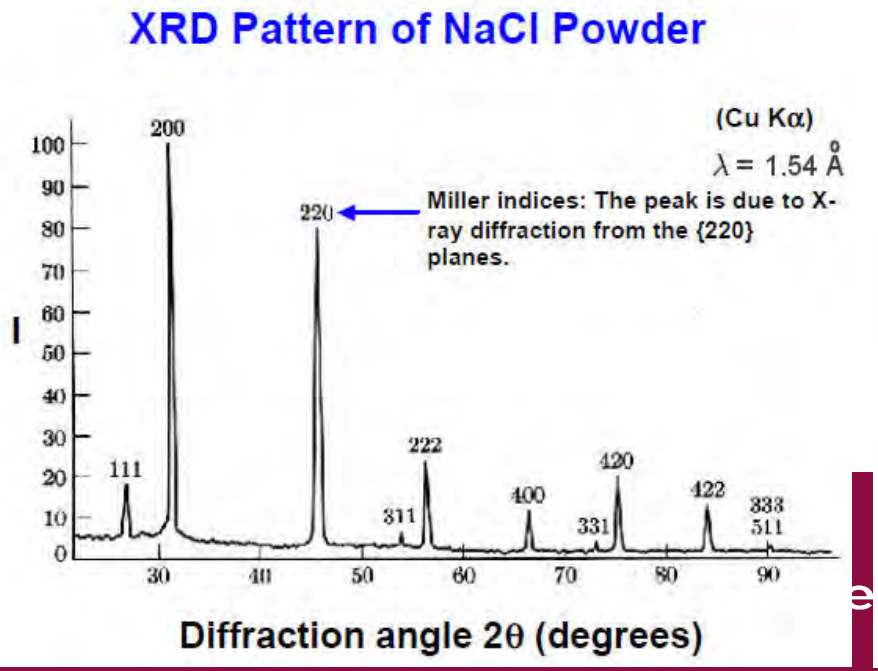


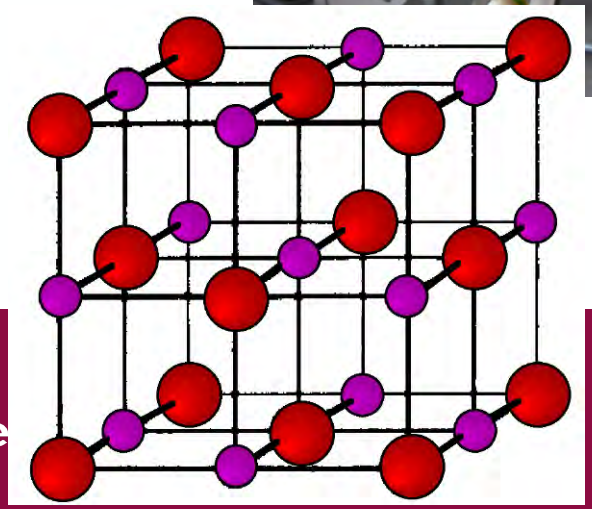


Powder X-ray Diffraction (XRD)





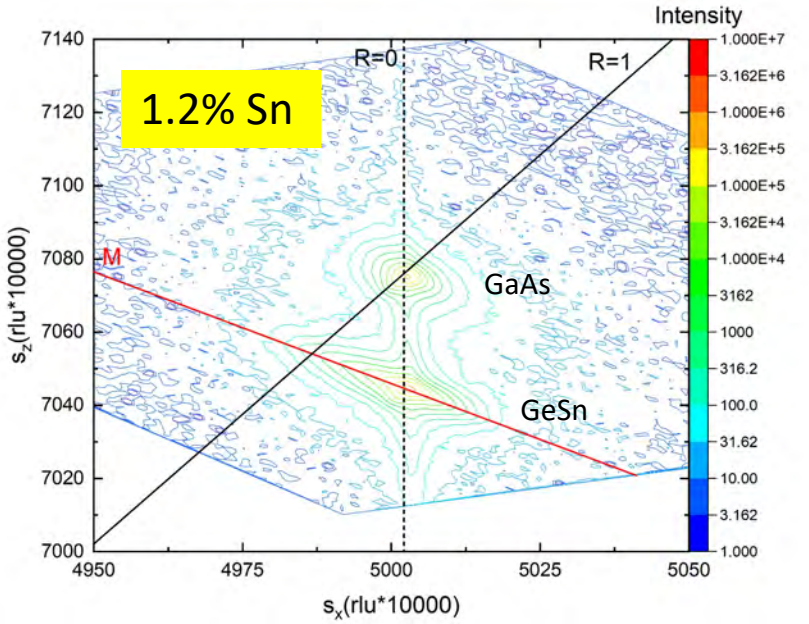


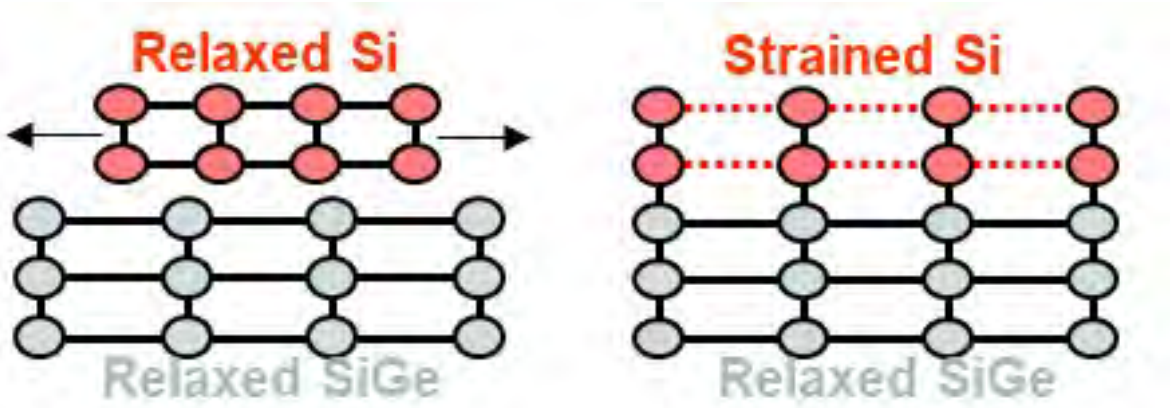


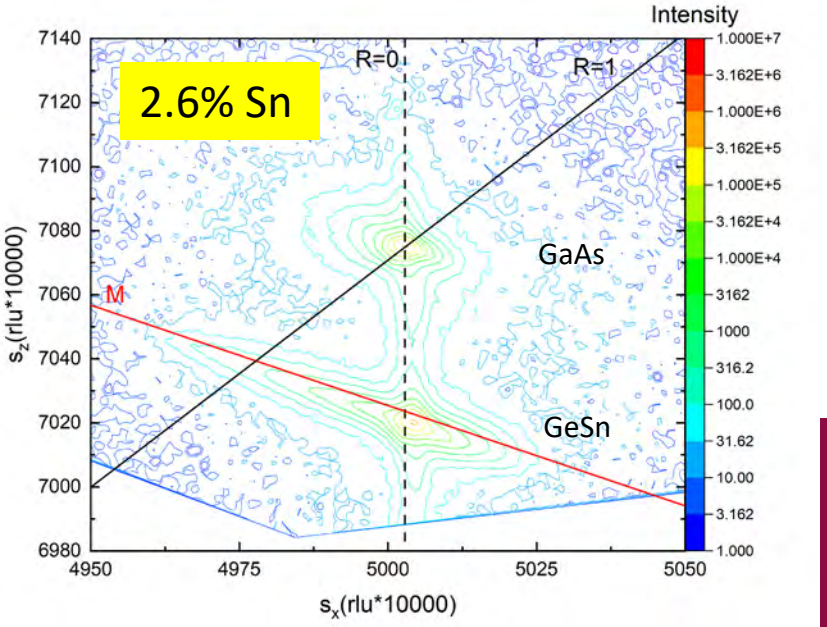
Bragg's Law $2d \sin \vartheta = n\lambda$

High-Resolution and Single-Crystal X-ray Diffraction (HR-XRD)

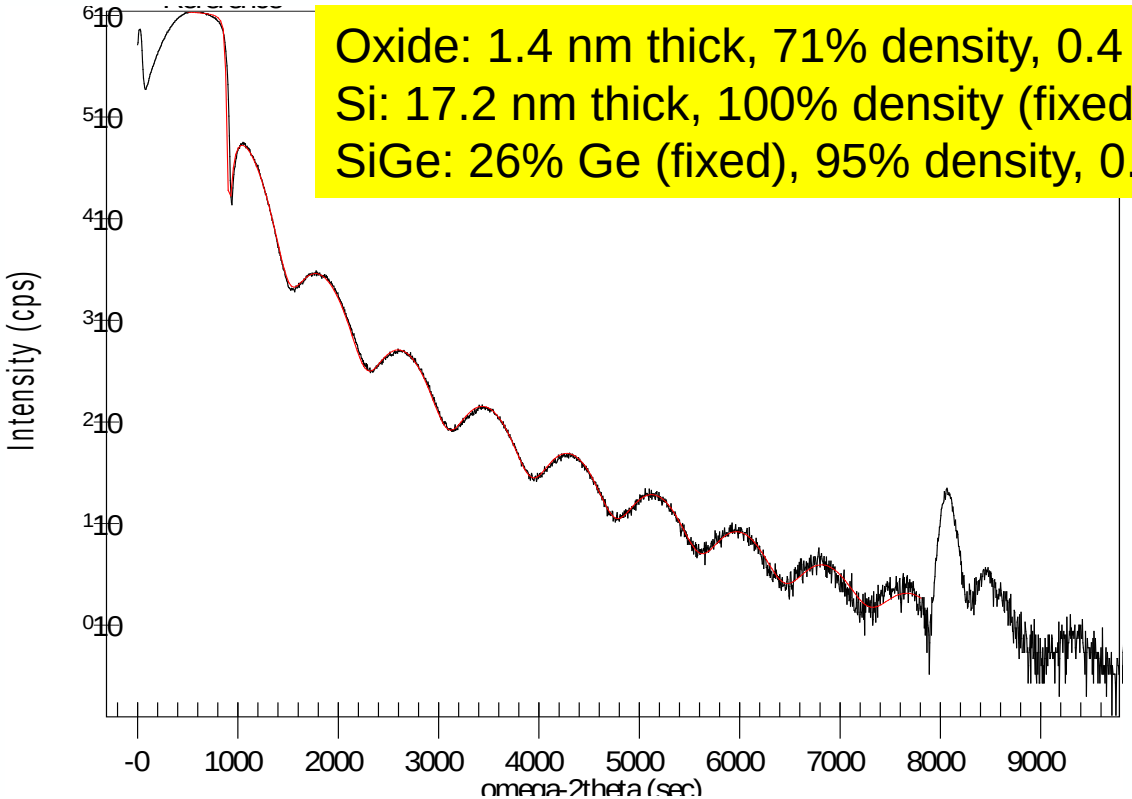
- **High-Resolution Diffraction:**
  Requires monochromatic and parallel x-ray beam
- **Suitable for highly crystalline epitaxial layers.**
- **Symmetric and asymmetric reciprocal space maps**
- **Example: Germanium-tin alloy on GaAs**
- **Measure strain, lattice constant, and composition**



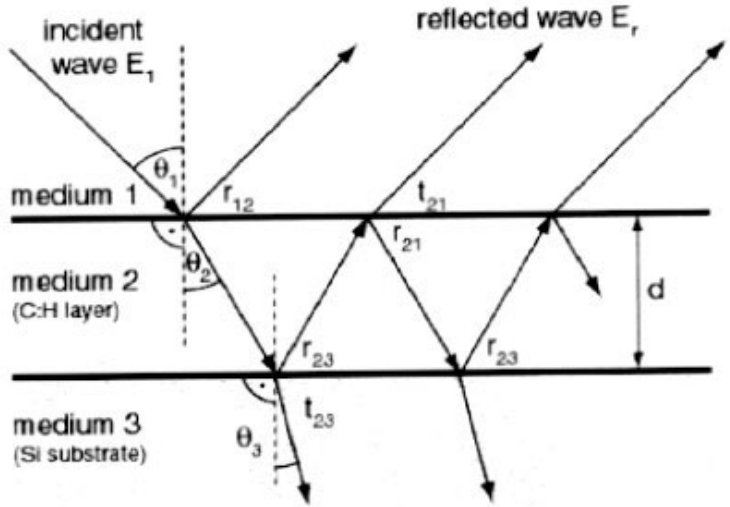




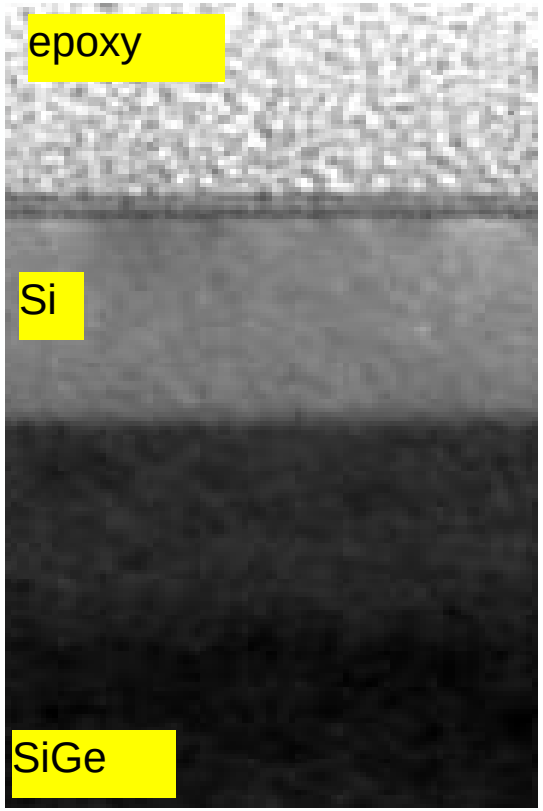
X-ray Reflectivity (XRR): Thickness, density, roughness



Oxide: 1.4 nm thick, 71% density, 0.4 nm rms
Si: 17.2 nm thick, 100% density (fixed), 3 nm rms
SiGe: 26% Ge (fixed), 95% density, 0.5 nm rms



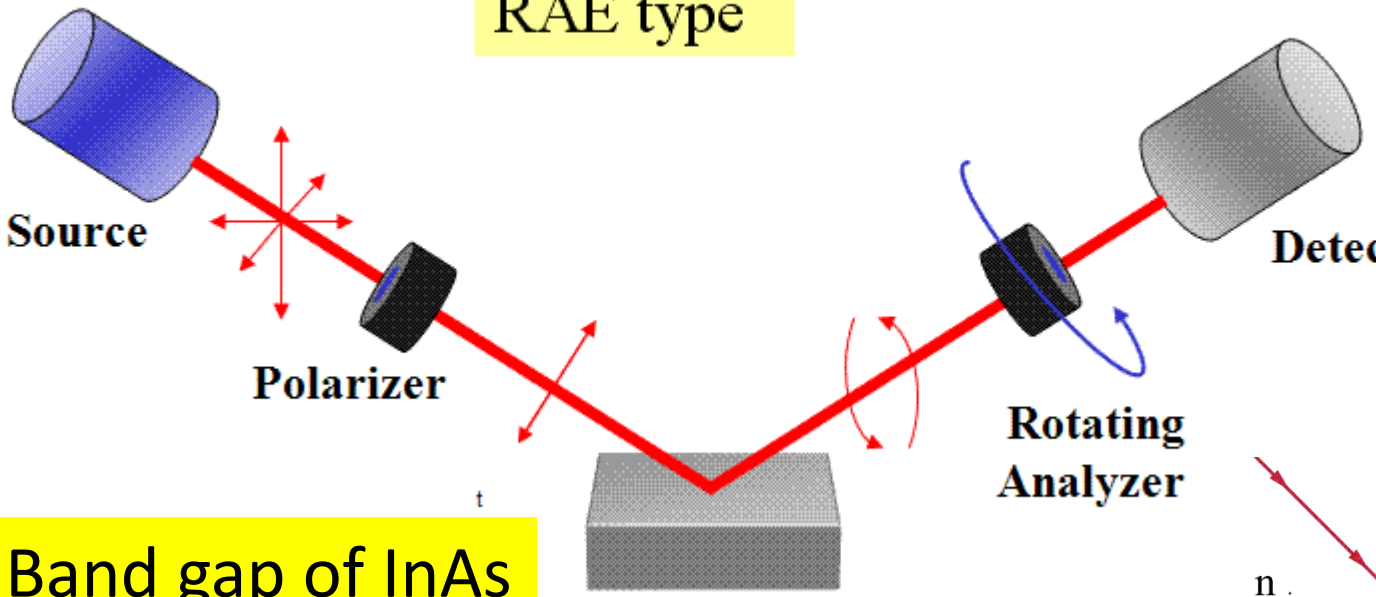
Transmission electron micrograph

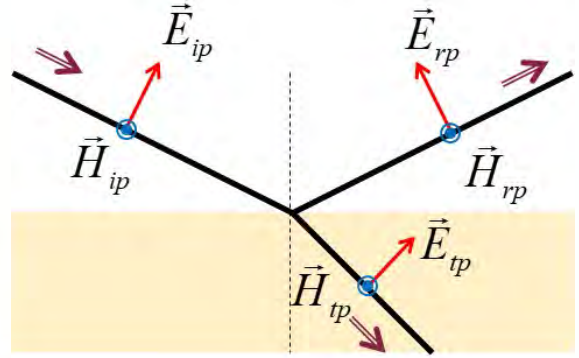


- TEM: 16-17 nm thick. SIMS: 26% Ge. Raman: 75% strained.
- For this smooth sample (0.6 nm rms) XRR gives excellent results.

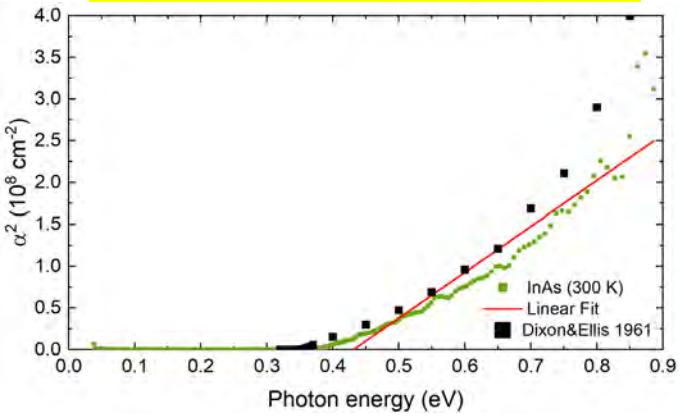
Ellipsometry and Infrared Ellipsometry

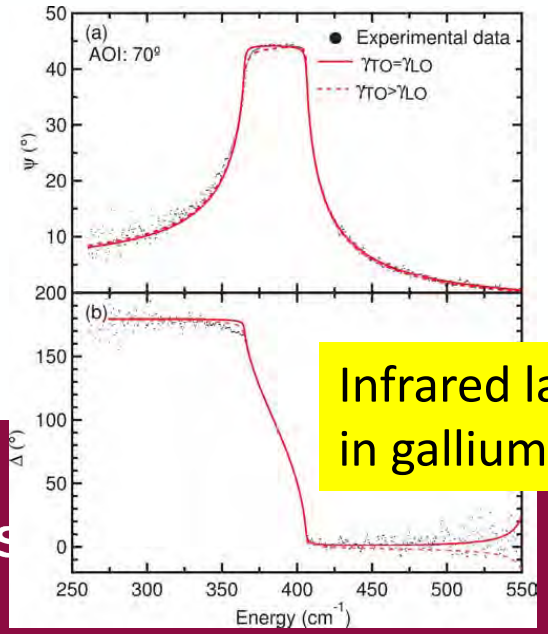
RAE type

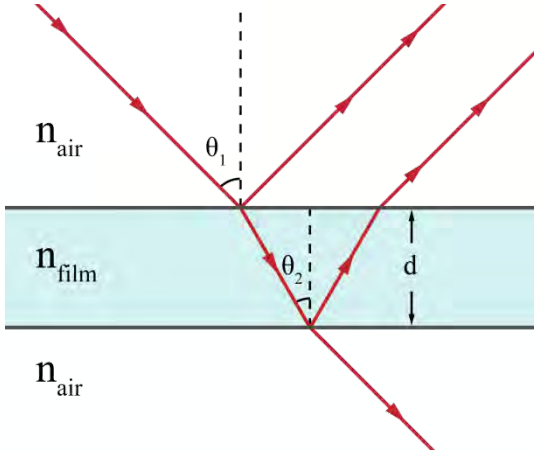




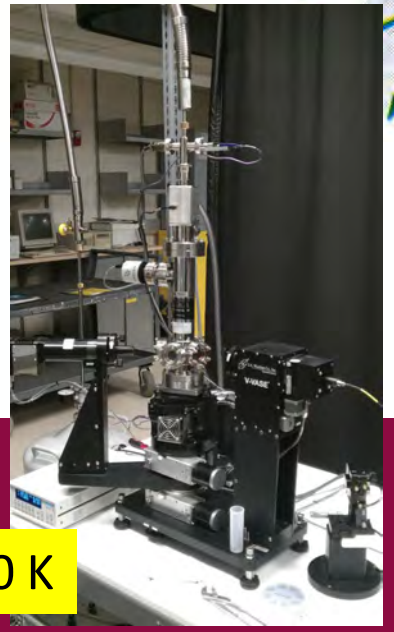
Band gap of InAs







Infrared lattice vibrations in gallium phosphide



Temperature: 4-800 K

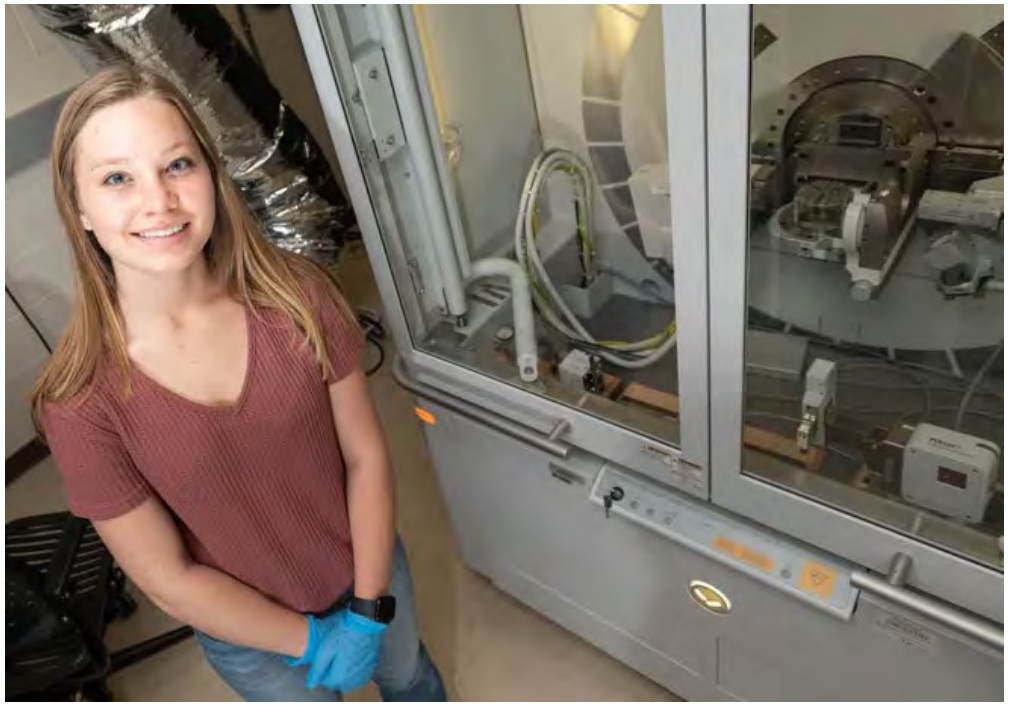
Training and Education

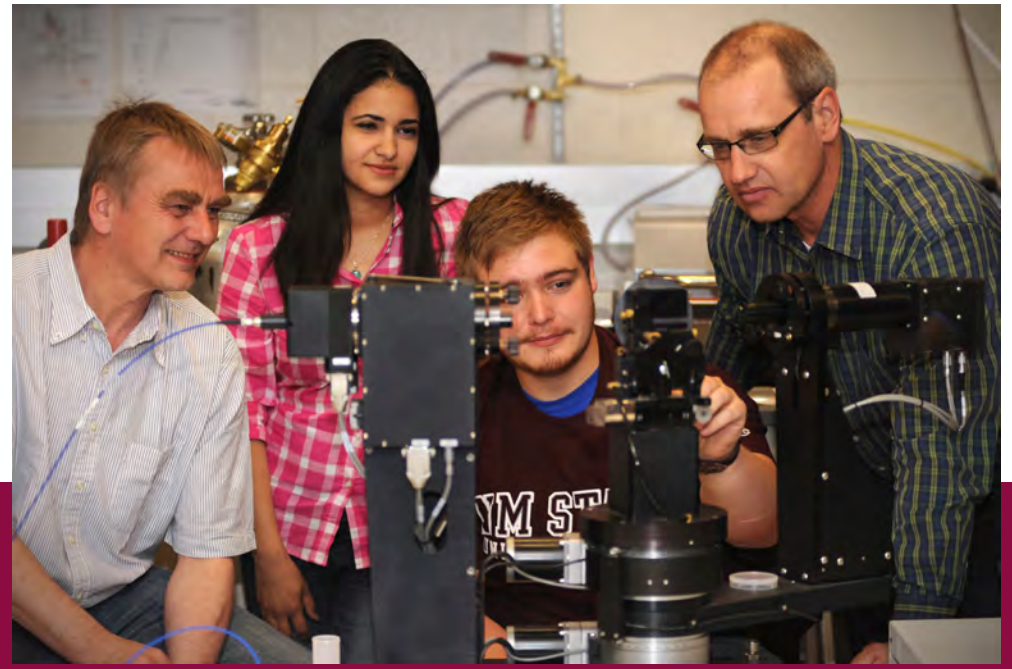
- Is it difficult to learn how to do this?
  No, but it takes practice (like violin or piano).

- Interdisciplinary courses offered at NMSU
  - PHYS 468/568: Elements of XRD
  - PHYS 489/589: Modern Materials
  - PHYS 471/571: Experimental Optics
  - Intended for students from other majors with STEM background (C E, CHME, MAE).

- Safety training by NMSU EHS&RM

- Individual training by **your** research group.





Thank you

QUESTIONS?