MBE Lab #2

Oxide MBE of Binary Oxides
(IrO$_2$, Co$_3$O$_4$, SrRuO$_3$
depending on your group)

Darrell G. Schlom
Questions for MBE Lab #2

- Substrate to use (material and orientation)?
- Source material(s) to use?
- Temperature(s) of source material(s)?
- Crucible(s) to contain them?
- Deposition strategy (codeposition, shuttered growth, etc.)?
- Substrate temperature during growth?
- Oxidant and its pressure during growth?
- How to calibrate growth rate?
Substrate to Use (material and orientation)

- “Substrate Picker” from Materials Project
  https://www.materialsproject.org

Source Material(s) to Use

• Vapor Pressure of the Elements

• Vapor Pressures of Oxides

• “Material Deposition Chart” from Kurt J. Lesker Co.
  https://www.lesker.com/newweb/deposition_materials/materialdepositionchart.cfm?pgid=0
Source Temperature(s)

- **Vapor Pressure of the Elements**

- **Vapor Pressures of Oxides**

- **“Material Deposition Chart” from Kurt J. Lesker Co.**
  https://www.lesker.com/newweb/deposition_materials/materialdepositionchart.cfm?pgid=0
Crucible(s)

• “Material Deposition Chart” from Kurt J. Lesker Co.
  https://www.lesker.com/newweb/deposition_materials/materialdepositionchart.cfm?pgid=0

• Phase Diagrams

  ACerS—NIST Phase Equilibria Diagrams On-Line
Deposition Strategy
(codeposition, shuttered growth, etc.)

- This is the fun and freedom of MBE!

YBa$_2$Cu$_3$O$_7$

![Diagram of YBa$_2$Cu$_3$O$_7$ structure]

- Codeposition
- Partial Codeposition
- Layer-by-Layer, Including Oxidation
- Layer-by-Layer with Interruptions
Substrate Temperature

Assuming growth rate of 0.1 monolayer/sec

$T_{\text{min}}$ for smooth epitaxial films (growth by step propagation)

$T_{\text{min}}$ for epitaxy

Optimal Growth Temperatures

\[
0.55 \leq \frac{T_{\text{sub}}}{T_{\text{melt}}} < 0.7 \quad \text{for semiconductors}
\]

\[
0.35 \leq \frac{T_{\text{sub}}}{T_{\text{melt}}} < 0.4 \quad \text{for metals}
\]

\[
0.1 \leq \frac{T_{\text{sub}}}{T_{\text{melt}}} < 0.4 \quad \text{for simple ceramics}
\]

M.H. Yang and C.P. Flynn

“Growth of Alkali Halides from Molecular Beams: Global Growth Characteristics”

Oxidant and its Pressure

• Ellingham Diagram

• Thermodynamics of MBE (TOMBE) Diagram

• If Desire Highest Oxidation State of all cations, then higher activity is better (within the limits of MBE, the equipment, and stable fluxes)
How to Calibrate Growth Rate

- Shadow Mask and Surface Profilometer
- Quartz Crystal Microbalance
- Ion Gauge
- RHEED Oscillations
- Shuttered RHEED Oscillations
- Rutherford Backscattering Spectrometry
- Mass Spectrometer
- Atomic Absorption Spectroscopy
- Atomic Emission Spectroscopy
- X-Ray Reflectivity, Ellipsometry, …
If your desired flux of Sr is 30% higher than your measured flux or Sr, by how many °C do you need to increase the temperature of the Sr effusion cell to get the desired flux?