Molecular Beam Epitaxy:
Improving the Operating Program

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Abstract

Molecular Beam Epitaxy (MBE) creates layered synthetic crystals out of individual elements. The layering process is controlled by a hierarchy of programs written in LabView. This project updated all the programs to increase the total capabilities of the MBE System. This program was successfully used to create a complex synthetic crystal, as well as identify and correct an issue that was not previously recognized.

Introduction

MBE uses molecular beams to create layered synthetic crystals. It starts by heating an elemental source until it evaporates. The vapor is emitted into a larger chamber, where it creates a plume of that element. This plume will evenly deposit very thin layers onto a prepared substrate. These layers can be as thin as individual atoms, and by depositing multiple elements, complex structures can be created that do not appear in nature.

MBE System

Shutters are placed between the source and the main chamber, which controls when the vapor can enter the chamber and deposit onto the substrate. This allows for very precise control of the thickness of the element deposited – down to individual atomic layers. Additionally, two masks are used to control where deposition occurs on the substrate. Together, these two elements allow the creation of multiple stacks of an arrangement of elements. Lastly, the deposition is monitor by Atomic Absorption Spectrometers. A lamp, tuned to a spectra line for a specific element, shines a beam of light into the main chamber. If it is present, the specific element will absorb some of that light.

This causes a drop in the Atomic Absorption, which can be used to determine the thickness deposited onto the substrate. A diagram is provided below that details the system.

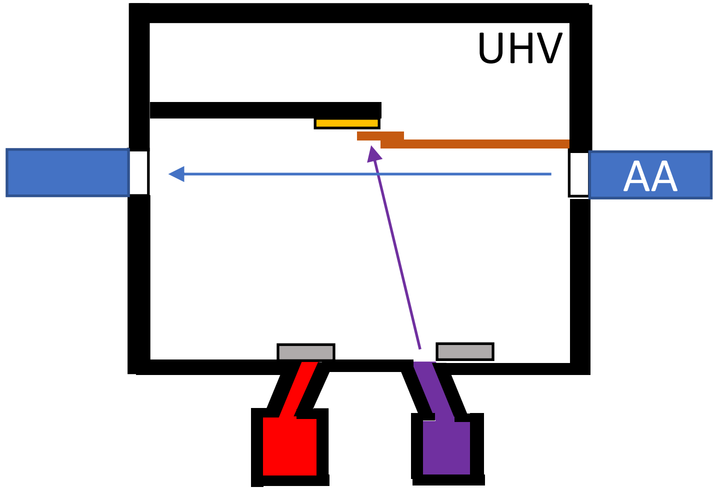


Fig. 1 – A simplified description of the MBE device used in the Tsui Lab, displaying sources (Red and Purple) AA spectrometers (Blue), Shutters (Grey), Masks (Orange), the Substrate (Gold) and the walls of the Chamber (Black for Steel, White for Glass)

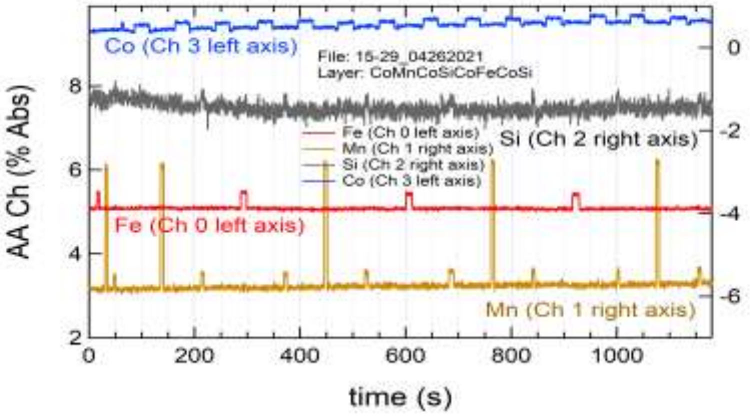
This diagram highlights the only the features that are controlled by the Operating Program. There are many additional features that were not included.

Programmatic Control

The previous operating program that controlled the masks, shutters and AA spectrometers had several problems that required the program to be completely re-designed. The previous iteration of the program ran completely in series, as most programs do.

However, this prevented it from controlling multiple devices at once. It was impossible to monitor the Atomic Absorption spectrometers and control shutters and masks at the same time, or even view multiple AA Channels simultaneously. The new iteration of the program consists of multiple parallel segments that can run independently. This allows simultaneous control and measurement. This vastly increases the capabilities of the programmatic control, allowing for more complex crystalline structures.

Results and Conclusion



Using this program, we were able to create the graph above. This displays a run of one stack with 5 layers of CoMnCoSiCoFeCoSi, repeated. Each spike on the graph corresponds to the deposition of that element – except for the small spikes on the Mn graph, which correspond to the deposition of Si. This problem, which is currently being addressed, was only identified because of the newfound ability to view multiple channels at once.

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