BAPVC Annual Project Report

Project Title: Advanced Evaporation Source Design
PI: Gregory M. Hanket
E-mail: hanket@udel.edu

Summary:

The past year has focused on the demonstration of stable Cu effusion rates for various levels of melt depletion. The system has been converted to the evaporation of mixed Ga-In vapor, which will now be the full focus of the program until temporally stable vapor composition has been demonstrated. An invention disclosure has been submitted describing the incorporation of an internal centrifugal separator at the entrance to the effusion nozzle as an additional layer of redundancy against spitting. The insulation in the vicinity of the nozzle has been identified as a likely source of condensation and subsequent spits observed on the substrate – this aspect of the source design will be revisited if time permits after demonstration of a stable Ga-In mixed vapor.

Key Accomplishments:

The evaporation rates and deposition profiles for Cu evaporated at varying melt depletion levels have been characterized and have met the program goal of less than 50% variation in effusion rate. Results are shown in Figure 1.

Consideration of the evaporation and flow processes within the source have identified possible mechanisms for the production of spits within the source: 1) melt boiling since the vapor pressure above the melt must necessarily be less than the saturation pressure (this is a necessary but not necessarily sufficient condition for boiling) for any net evaporation to occur and; 2) wall cooling due to gas expansion as the vapor flows through various internal rate restricting orifices. While theoretical analysis is ongoing to further clarify whether either of these mechanisms may be occurring, the possibility of these mechanisms led to a fundamental change in source design approach: instead designing with the goal of preventing spit formation, a more robust approach is to assume the presence of droplets in the flowing vapor, and then to remove these droplets. This motivation let to the concept of incorporating centrifugal separation into the design. The design concept and predicted spit trajectories are shown in Figure 2.

Future Work:

The system has been reconfigured for the evaporation of a mixed Ga-In vapor, which was delayed due to the onset of Cu spitting (see the following paragraph). The demonstration of a stable Ga-In vapor composition for progressive melt depletion will be the primary focus for the remainder of the program.

The issue with Cu spitting is most likely due to condensation on the felt insulation about the nozzle due to vapor backscattering. This issue will most likely be addressed in the short term by the use of replaceable shielding around the nozzle to prevent run-to-run accumulation of condensation. In the longer term, however, the issue of vapor backscattering, particularly when considering real world operation in the presence of an ambient Se pressure which will further amplify backscattering, may require more careful design of the nozzle exit or may prove to be a fundamental limit on effusion rate.

Modeling efforts are ongoing regarding temperature and pressure profiles within the source, as well as calculations of droplet drag in a flowing vapor. These modeling efforts will be consolidated into a comprehensive design approach.

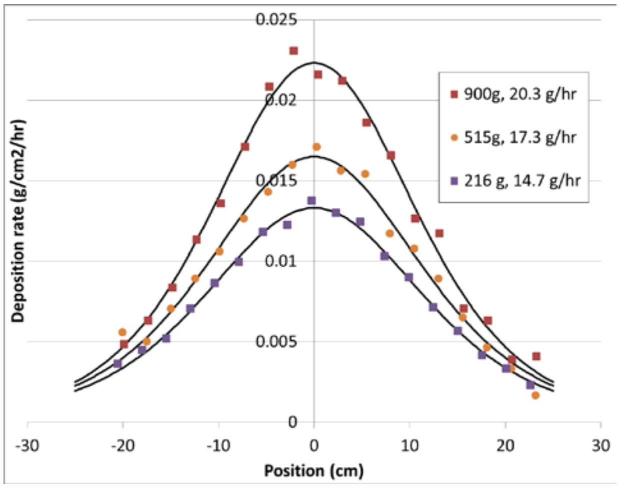

Figure 1. Cu deposition profiles for varying melt depletion levels. The design volume of the crucible accommodates 1 kg of Cu.

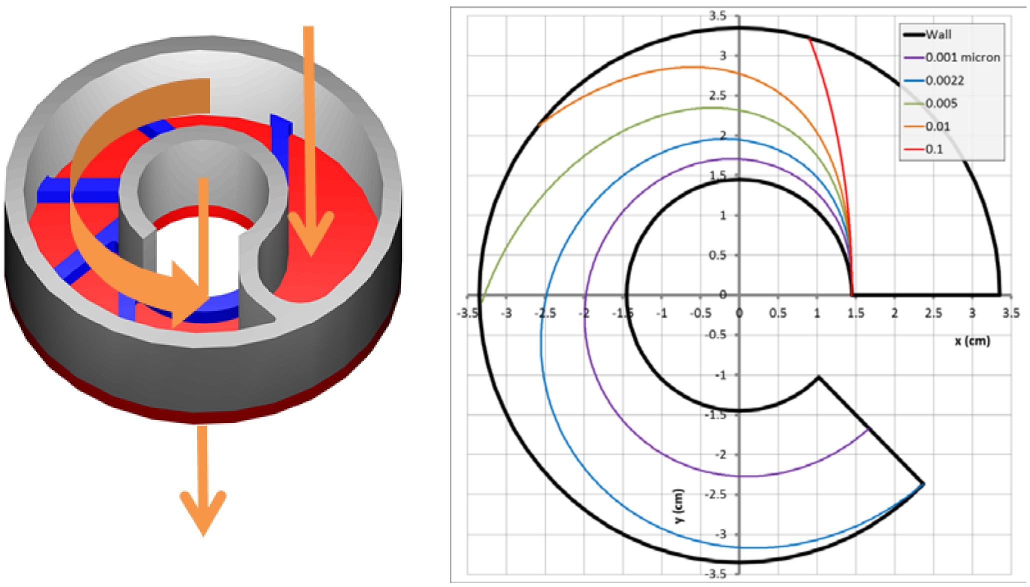

Figure 2. (Left) Conceptual design of a centrifugal separator for incorporation into vacuum evaporation sources. (Right) Predicted trajectories of Cu droplets from 1 nm up to 0.1 micron diameter for a vapor flow rate of 15 g/hr through the separator.