

## Characterizing precursor delivery from a vapor draw ampoule

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Models that have been validated against experimental data can be used for both optimizing ALD processes and evaluating ampoule designs. The figure below shows the results from a computational fluid dynamics (CFD) simulation of water in a 1.5 L vapor draw ampoule at 5 °C (water vapor pressure of 6.5 Torr) with a carrier gas of nitrogen at 100 sccm and a 50 Torr ampoule pressure. The lines represent gas flow streamlines while the color gradient represents the water density distribution. These results are consistent with a complex mixing process that involves a gas vortex under some, if not all, flow conditions of interest. The physical-chemical properties of water and nitrogen are well established, making this a particularly useful system with which to evaluate CFD models using experimental data. The results from simulations such as these indicate that mass transfer processes in the ampoule contribute to a decrease in precursor output with time from vapor draw ampoules, with the magnitude of the contribution depending on precursor, ampoule design, and process conditions.

