Colloidal Drop Spreading, Evaporation and Particle Deposition – A Lattice Boltzmann Study

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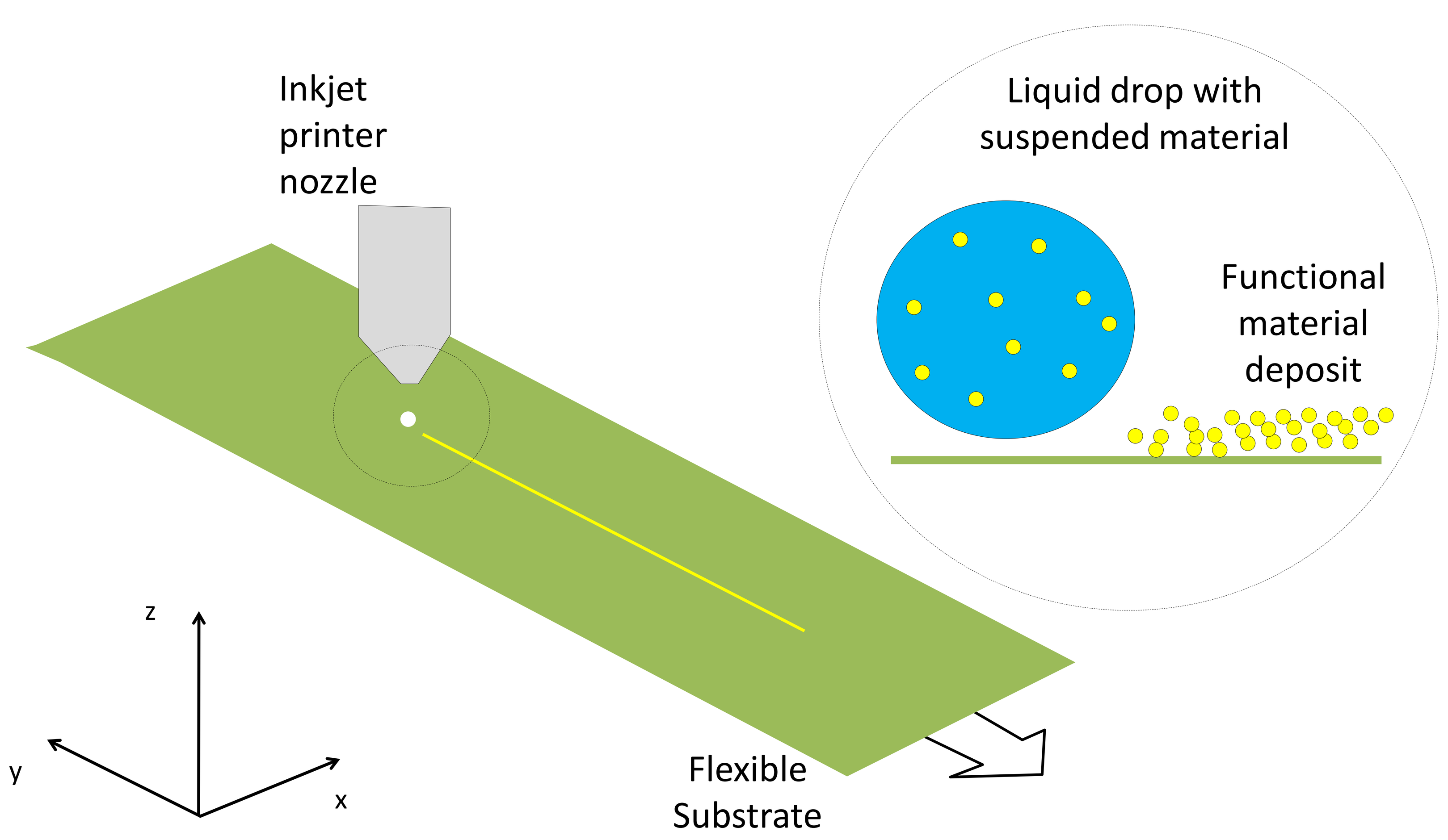
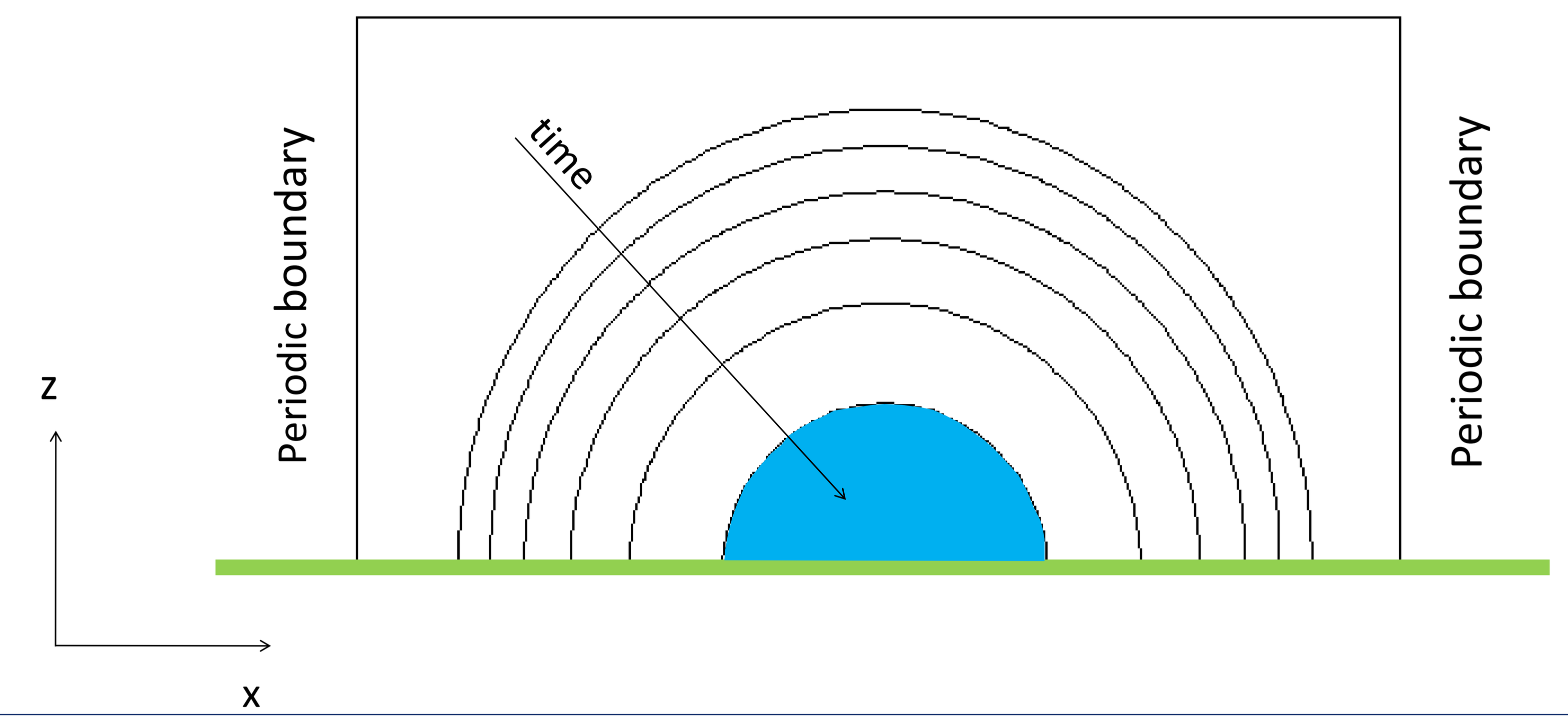
Motivation: Functional Material Deposition using Inkjet Printing

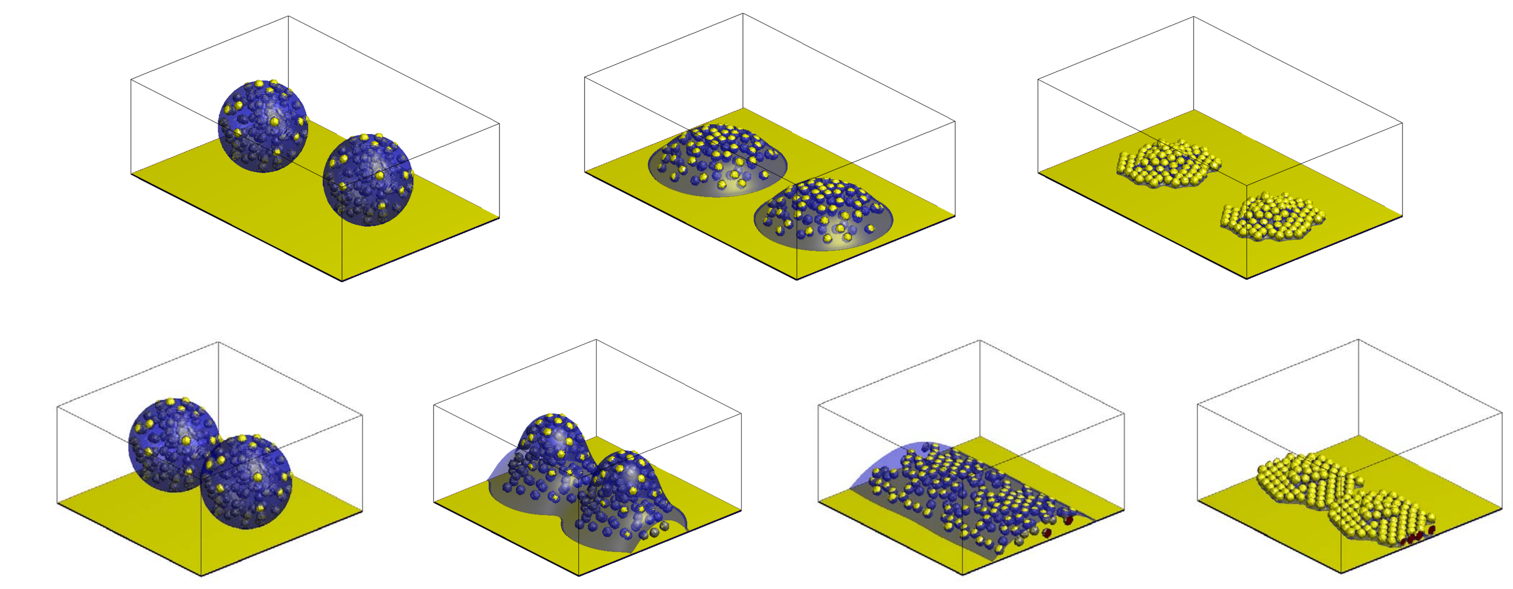


Self-Similar Evaporation (Moving Contact Line)

This type of evaporation is observed for smooth substrates with no physical or chemical heterogeneities. Most of our results so far have been obtained for such an "ideal" substrate. The contact angle remains unchanged throughout the evaporation process.



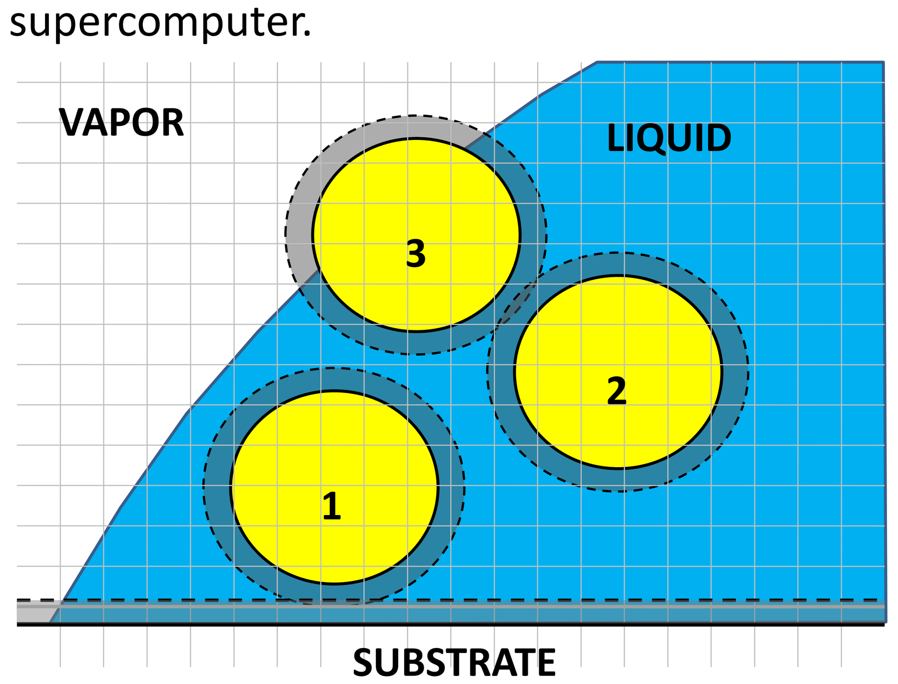
Effect of Drop Spacing on Deposit Morphology



A large spacing between successive drops (top row) leads to isolated deposits. When the spacing between the drops is reduced (bottom row), the spreading contact lines of adjacent drops connect with each other and the final deposit shows continuity. Reducing spacing between drops can lead to line deposits.

Lattice Boltzmann Method

A three-dimensional (3D), multi-phase (liquid + vapor) particle suspension model has been developed based on the 2D model of Joshi and Sun (2009)*. The computer code has been developed using FORTRAN 90 and runs on a parallel supercomputer.



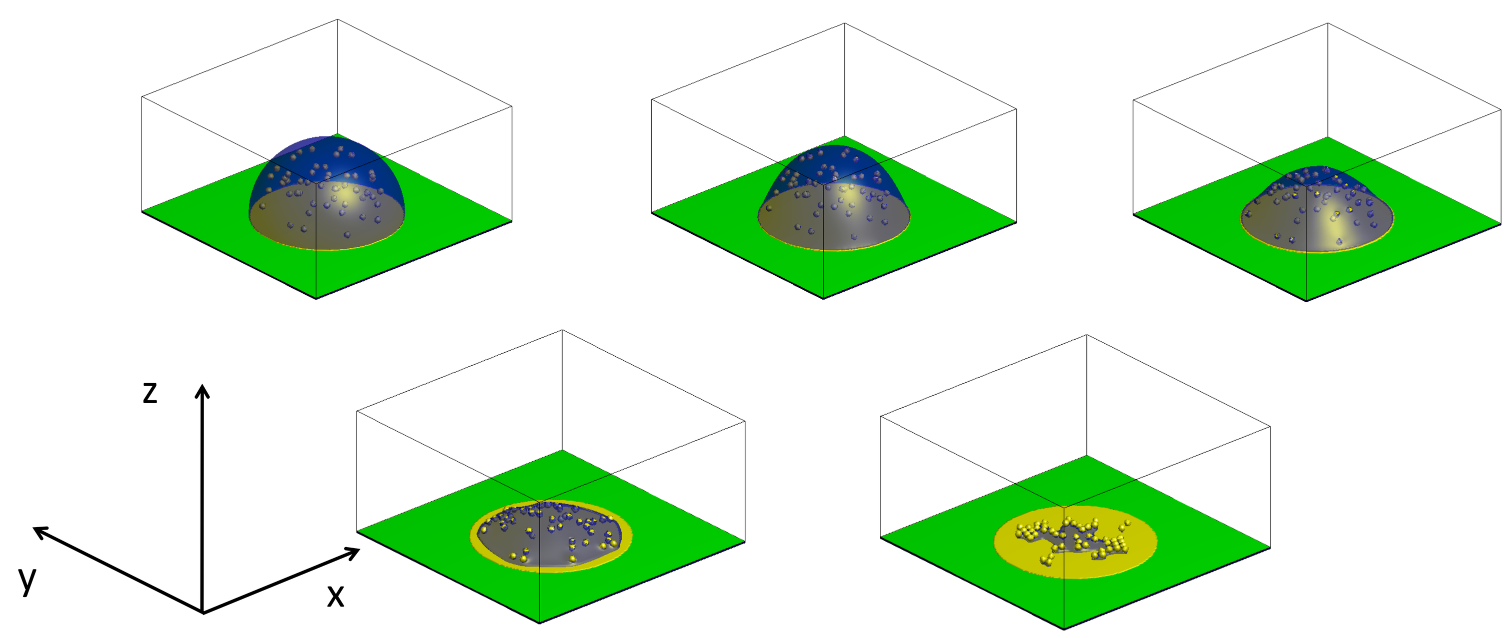
Suspended particles are spherical in shape and their motion is coupled to the fluid flow.

Inter-particle forces prevent particles from overlapping with each other, or with the solid substrate at the bottom.

Particles can be trapped by the liquid-vapor interface.

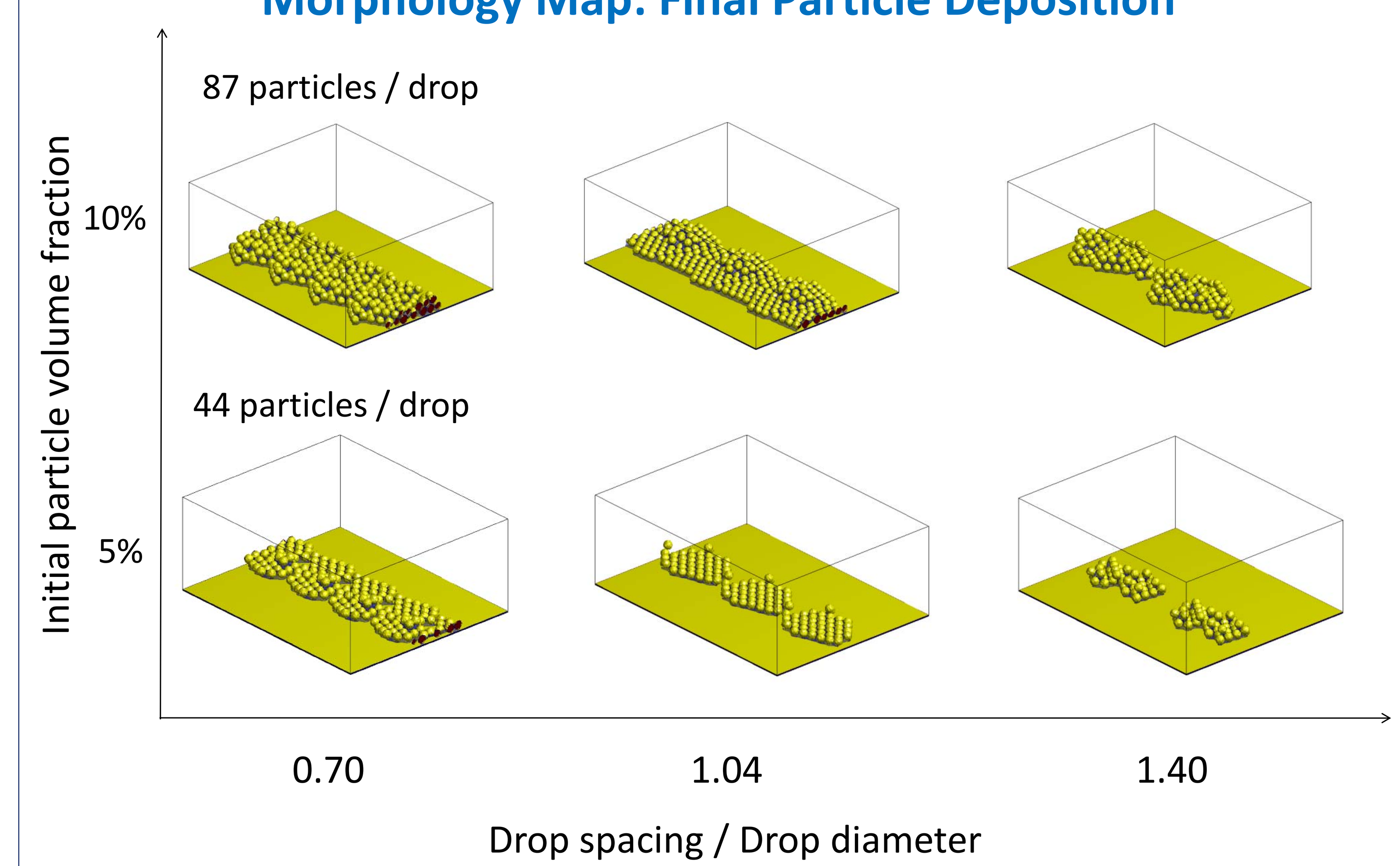
* Joshi A. S. and Sun Y. (2009) *Physical Review E*, **79**, 066703

Evaporation with a "Pinned" Contact Line

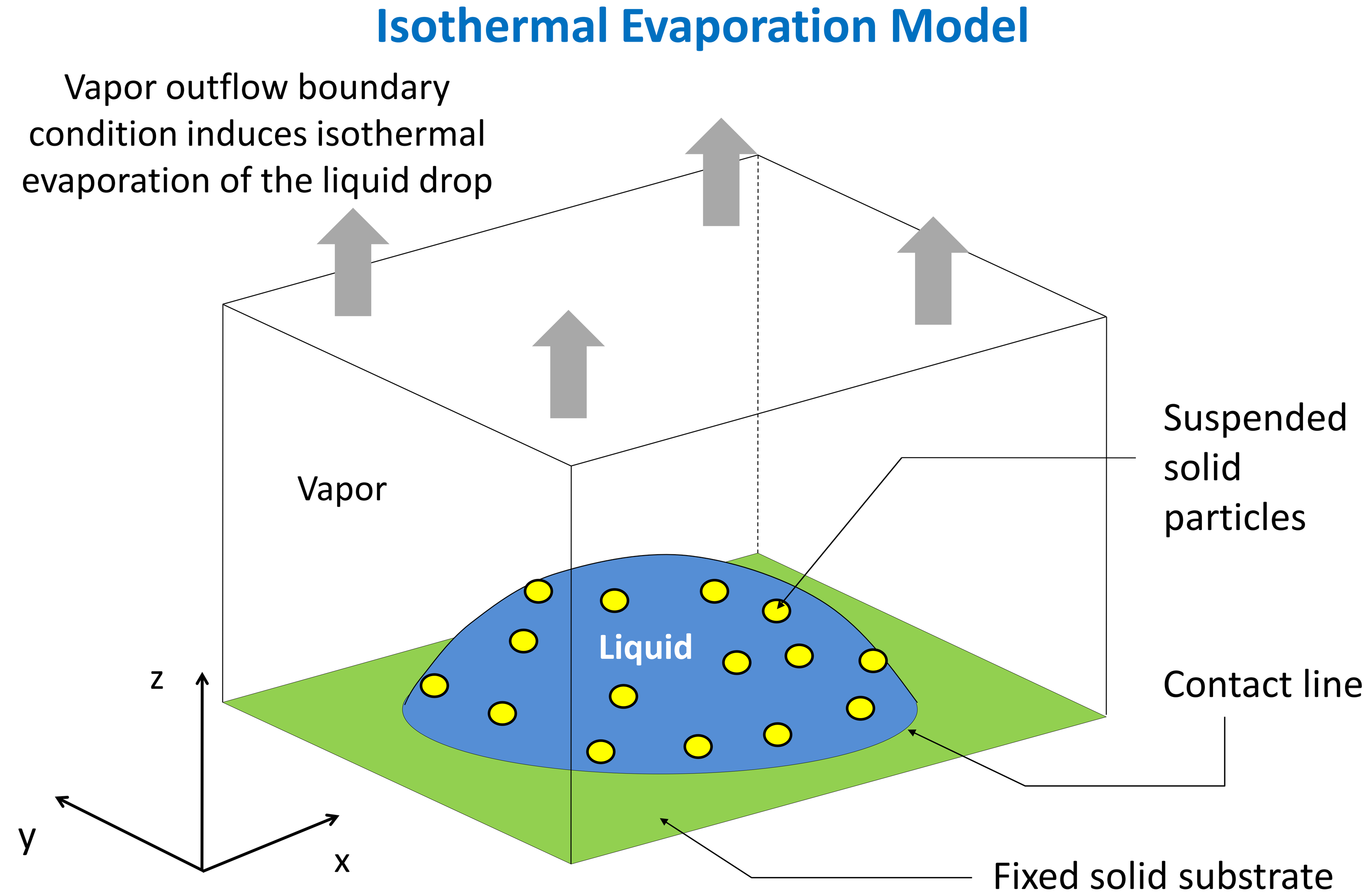


For rough surfaces, experiments reveal that the contact line can remain pinned during drop evaporation until the receding contact angle is reached. The LBM simulation above demonstrates this effect for a receding contact angle of 15°. Like experiments, suspended particles inside the liquid are observed to flow towards the contact line in the LBM.

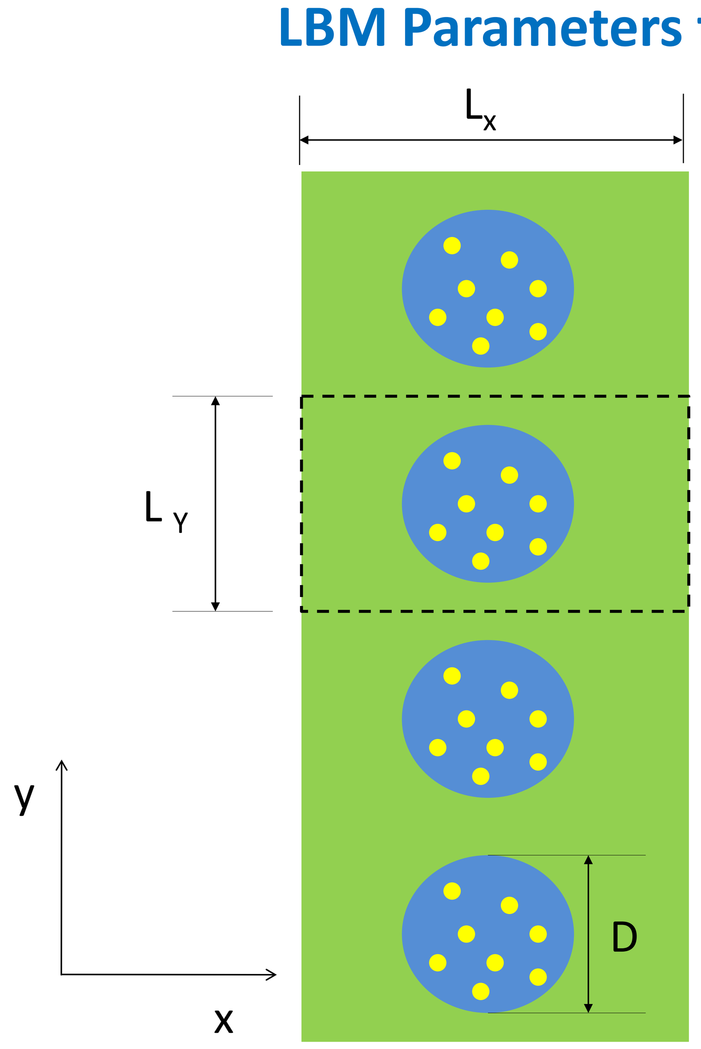
Morphology Map: Final Particle Deposition



Isothermal Evaporation Model



LBM Parameters for Obtaining Line Deposits



Number of suspended particles	N_P
Suspended particle radius	R_P
Initial liquid drop diameter	D
Initial spacing between adjacent (periodic) liquid drops	L_Y
Evaporation rate (suction velocity at the top of the domain)	U_Z
Equilibrium contact angle	θ_{eq}

Conclusions & Future Work

The lattice Boltzmann method (LBM) is a useful computational tool to investigate the fundamental physical processes during deposition of functional materials using inkjet printing.

Experimentally observed processes like contact line pinning can be modeled with ease.

The final particle deposits can be studied as a function of process parameters in order to optimize the process and obtain repeatable results.

Future work will consist of experimental validation of the model and extension to simulate deposition of non-spherical (ellipsoidal) particles.

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