Impact of Operating Parameters on Precursor Separation in "Air Hockey" Spatial Atomic Layer Deposition Reactor

J. Grasso, B. Willis
Department of Chemical and Biomolecular Engineering, University of Connecticut, Storrs, CT, United States

UCONN SCHOOL OF ENGINEERING

INTRODUCTION

What is atomic layer deposition (ALD)?

- ALD is a vapor-based thin film deposition technique achieved by sequential exposure of reactant gases

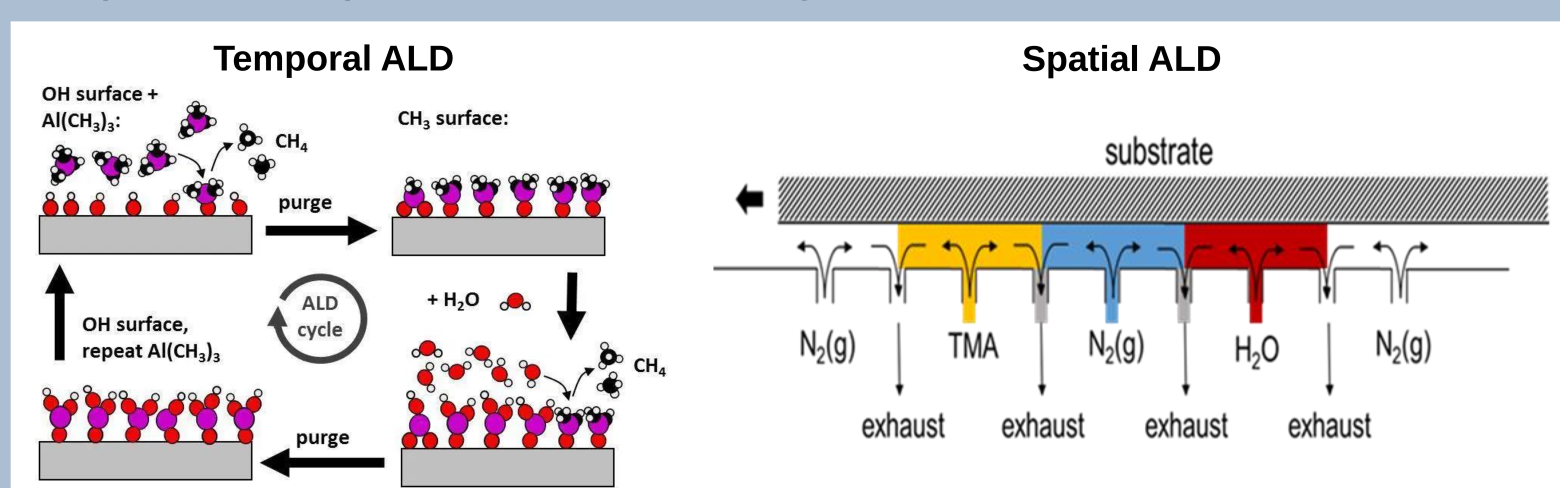

Figure 1: Overview of atomic layer deposition: temporal and spatial.

Film Characteristics: pinhole free, conformal, atomic level thickness
Applications: solar cell, nanolaminates, MOSFETs, CMOS

Project Objective:
Develop a computation model to predict the flotation height of substrate for various operating parameters in an "air hockey" spatial ALD (SALD) reactor

Analytical Solution – Lubrication Theory

Pressure Distribution:

$$p = p_R - (p_R - p_a)\frac{I_0(\alpha r)}{I_{0(\alpha)}}$$

Force Balance:

$$Mg = \pi R^2 (p_R - p_a)\left[1 - \frac{2I_0'(\alpha)}{\alpha I_0(\alpha)}\right]$$

where, $\alpha = \left(\frac{12k}{d^3}\right)^{\frac{1}{2}} R$

$k \equiv permiability\ constant\ (m)$
$I_0(x) \equiv Modified\ Bessel\ Function$

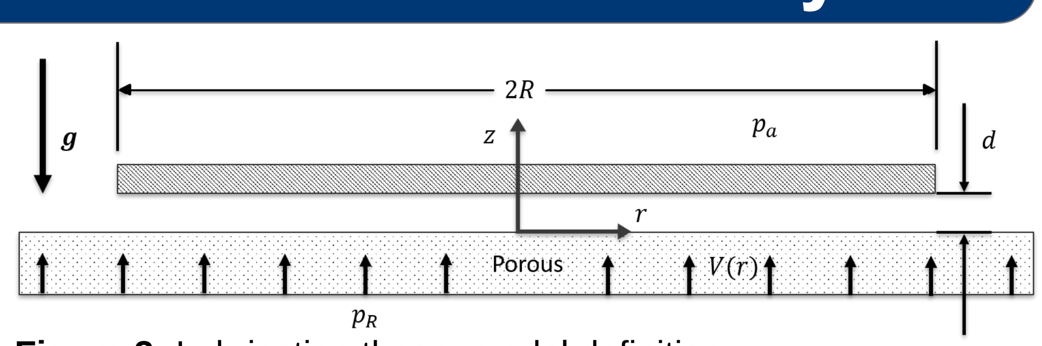

Figure 2: Lubrication theory model definition

Assumptions:

- $\varepsilon \ll 1$: *Thin Gap Parameter* (d/R)
- $\widetilde{Re} \ll 1$: *Characteristic Reynold's Number*

Limitations:

- Assumptions weaken as the gap increases
- Only valid for porous table

COMPUTATIONAL METHOD

Inverse Modeling

- Gap height is set → reservoir pressure computed

Force Balance

- Global Constraint in laminar flow interface

$$Mg = \int_0^R 2\pi r(\boldsymbol{p} - p_a)dr$$

Porous Table– 2D Axisymmetric

- Porous media interface
- Atmospheric pressure at edge of disk

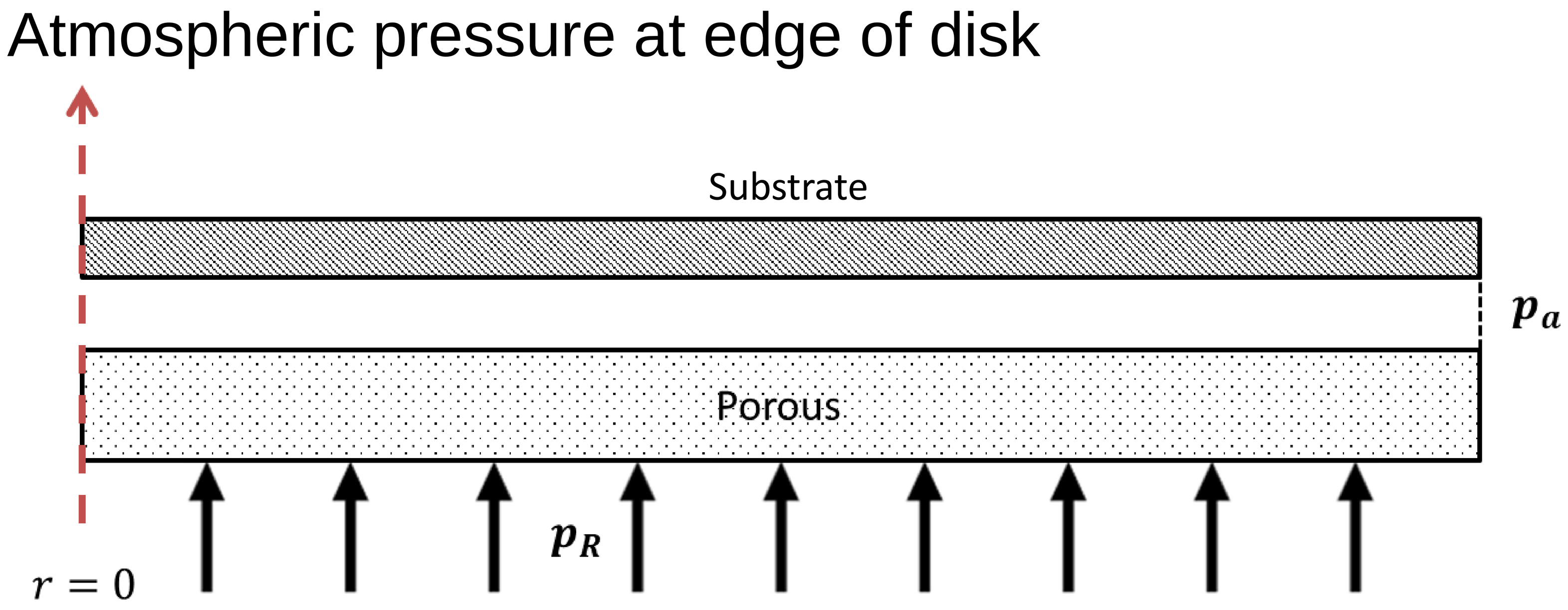

Figure 3: Porous table model geometry

Air Hockey Table – 3D

- Periodic Boundary Conditions
- One reservoir pressure for all jets
- No pressure constraint at disk edge

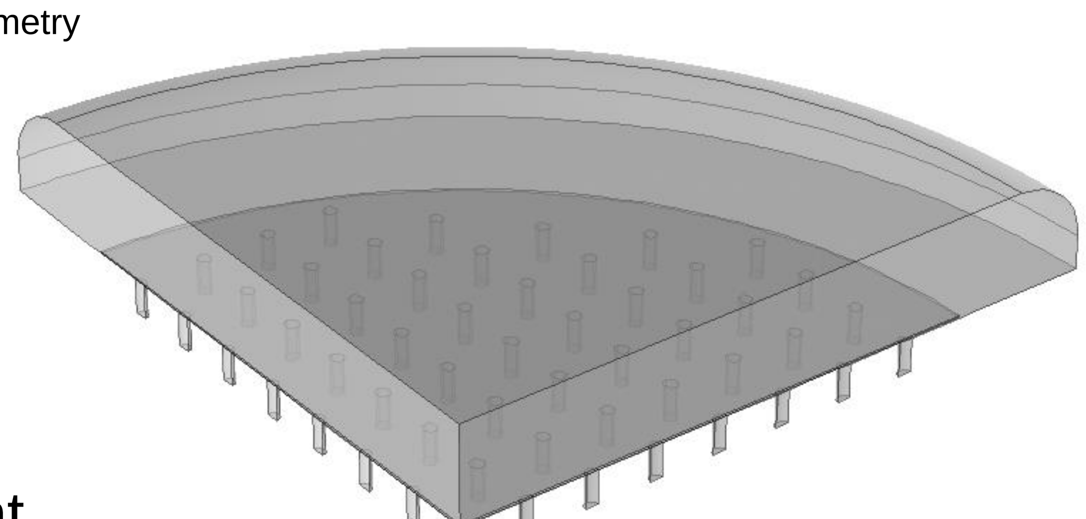

Figure 4: Air hockey table model geometry

RESULTS

- Analytical solution diverges from experiment as flotation height increases
- COMSOL model aligns well with experimental data

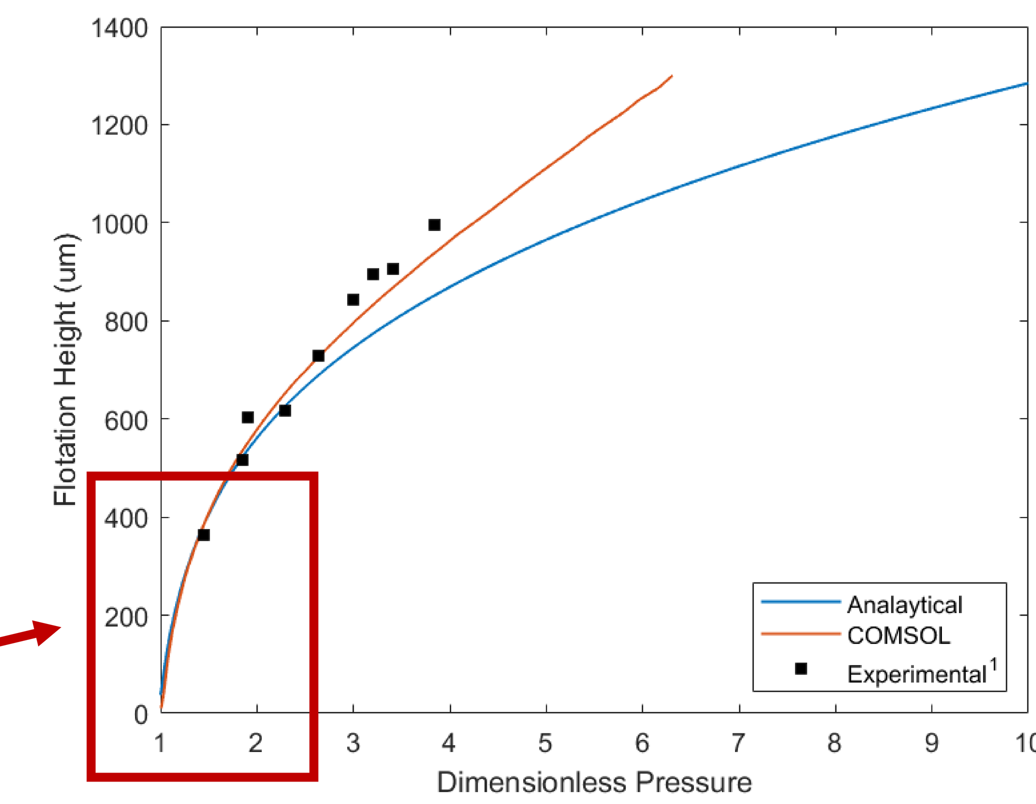

Figure 5: Flotation height computation comparison

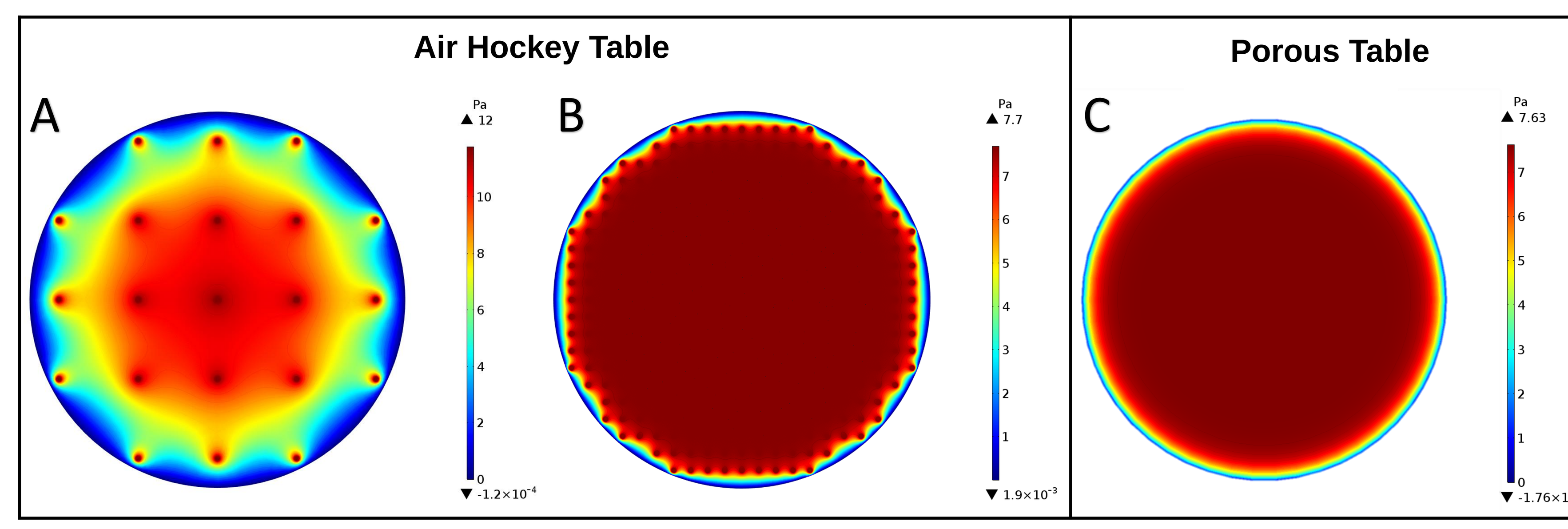

Figure 6: Disk surface pressure comparison for air hockey and porous table designs. A) Air hockey design with low jet density. B) Air hockey design with high jet density. C) Porous table design

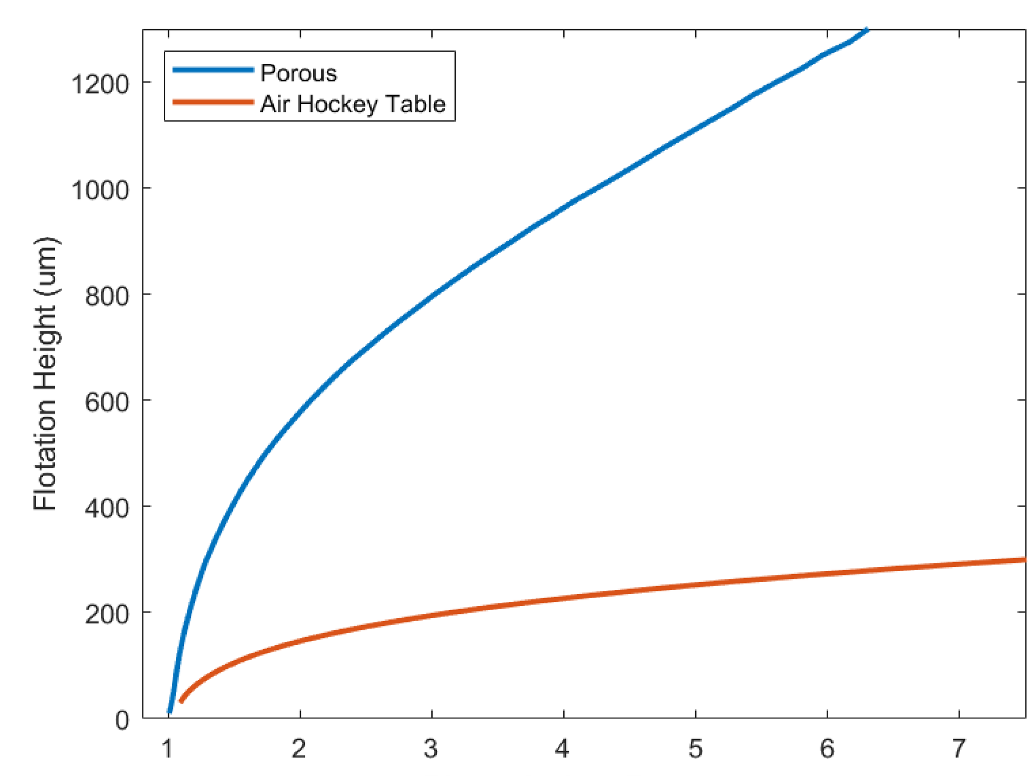

Figure 7: Flotation height curve geometric comparison

- Uniform pressure distribution yields high stability and film stiffness
- Air hockey table approaches porous table solution as jet density increases
- Air hockey table design decreases flotation height sensitivity to pressure at low deposition gaps

CONCLUSION/FUTURE WORK

- Inverse computational modeling is sufficient to predict disk flotation height
- Air hockey table behaves similarly to porous table with improved sensitivity

Future Work

- Investigate if the **Thin Film Flow Interface** can be used
- Integrate flotation model into SALD diffusion model
- Examine methods to increase the stability of the substrate in the low deposition gap region
- Explore additional computational methods to analyze aerostatic bearings

REFERENCES

1. E.J. Hinch and J. Lemaitre. "The Effect of Viscosity on the Height of Disks Floating Above an Air Table," *J. Fluid Mech.*, vol. 273, pp. 313-322. 1994.
2. N. Parsons, Gregory & George, S.M. & Knez, Mato. (2011). Progress and future directions for atomic layer deposition and ALD-based chemistry. MRS bulletin / Materials Research Society. 36. 865.10.1557/mrs.2011.238

ACKNOWLEDGEMENTS

- Mastraccio Fellowship & NSF