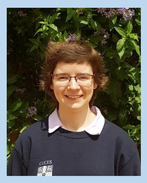
The role of diffusiophoresis in the drying of thin coatings



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1. Introduction

Small particles at the top surface – why?

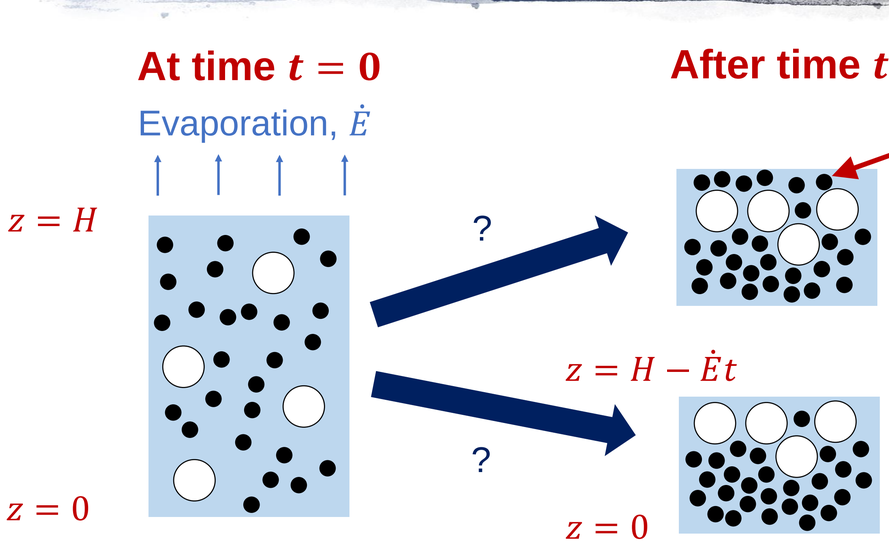


Figure 1: *Schematic of the drying of a film containing two types of particles.*

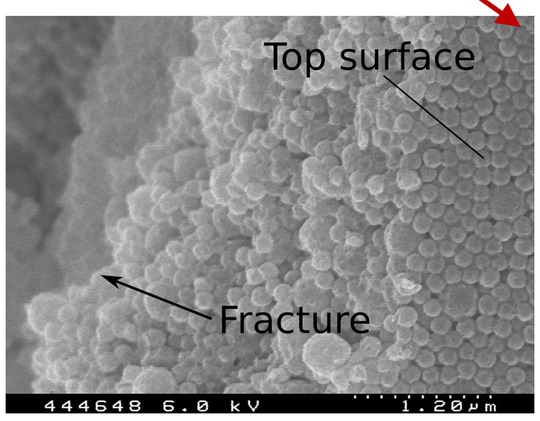


Figure 2: *Cryo-SEM image showing an accumulation of small particles at the top surface (Atmuri et al., 2012).*

2. Diffusiophoresis

Diffusiophoresis has been suggested as an explanation.

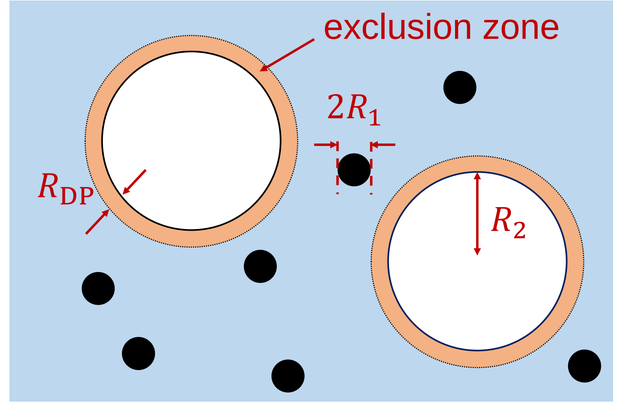


Figure 3: *Schematic of the exclusion zones around the larger particles, which give rise to diffusiophoresis.*

3. Model validation

Derive partial differential equations → Non-dimensionalise and transform coordinate system

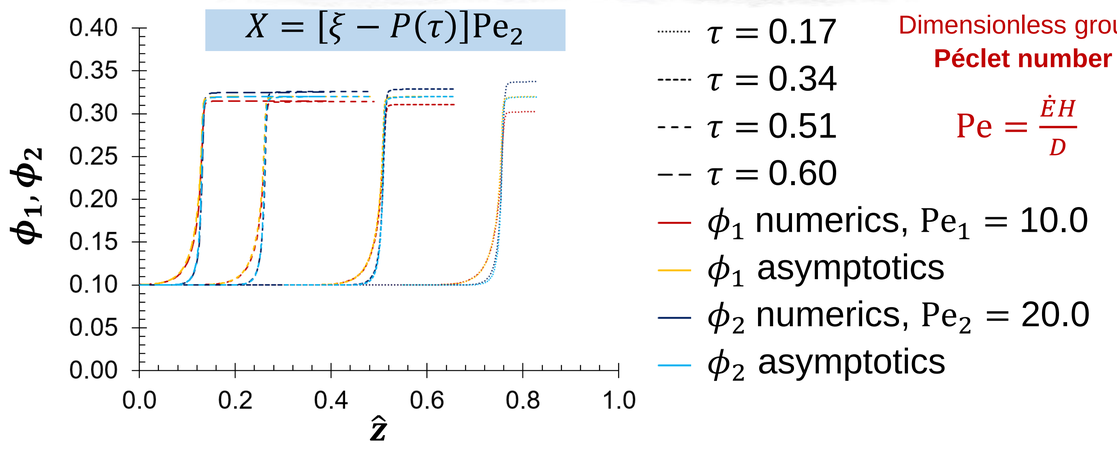
Solve numerically using finite volume method → Verify code with asymptotic solutions

Quasi-advection

$$\frac{\partial \phi_2}{\partial \tau} + \frac{\xi}{1-\tau}\frac{\partial \phi_2}{\partial \xi} = \frac{1}{\mathrm{Pe}_2(1-\tau)^2}\frac{\partial}{\partial \xi}\left[(1-\phi_1-\phi_2)\right.$$

Diffusion Diffusiophoresis

$$\left.\left(\frac{\mathrm{Pe}_1}{\mathrm{Pe}_2}\right)^3\left[\frac{\phi_1\phi_2 K_{21}(\phi_1,\phi_2)+\frac{9}{4}\left(\frac{\mathrm{Pe}_2}{\mathrm{Pe}_1}\right)\phi_1\phi_2(1-\phi_2)K_P(\phi_1,\phi_2)}{\left(\phi_1+\left(\frac{\mathrm{Pe}_1}{\mathrm{Pe}_2}\right)^3\phi_2\frac{\partial\mu_2/\partial\xi}{\partial\mu_1/\partial\xi}\right)}\right]+\frac{\phi_2 K_{22}(\phi_1,\phi_2)}{\left(\left(\frac{\mathrm{Pe}_2}{\mathrm{Pe}_1}\right)^3\phi_1\frac{\partial\mu_1/\partial\xi}{\partial\mu_2/\partial\xi}+\phi_2\right)}\right]\frac{\partial}{\partial\xi}\left[\left(\left(\frac{\mathrm{Pe}_2}{\mathrm{Pe}_1}\right)^3\phi_1+\phi_2\right)Z(\phi_1,\phi_2)\right]\Bigg]$$



Dimensionless group: **Péclet number**

$$\mathrm{Pe} = \frac{\dot{E}H}{D}$$

Figure 4: *Excellent agreement between the numerical and asymptotic diffusion only solutions at high Péclet number.*

4. Model results

Diffusion only → **With diffusiophoresis** → **Increased diffusiophoresis**

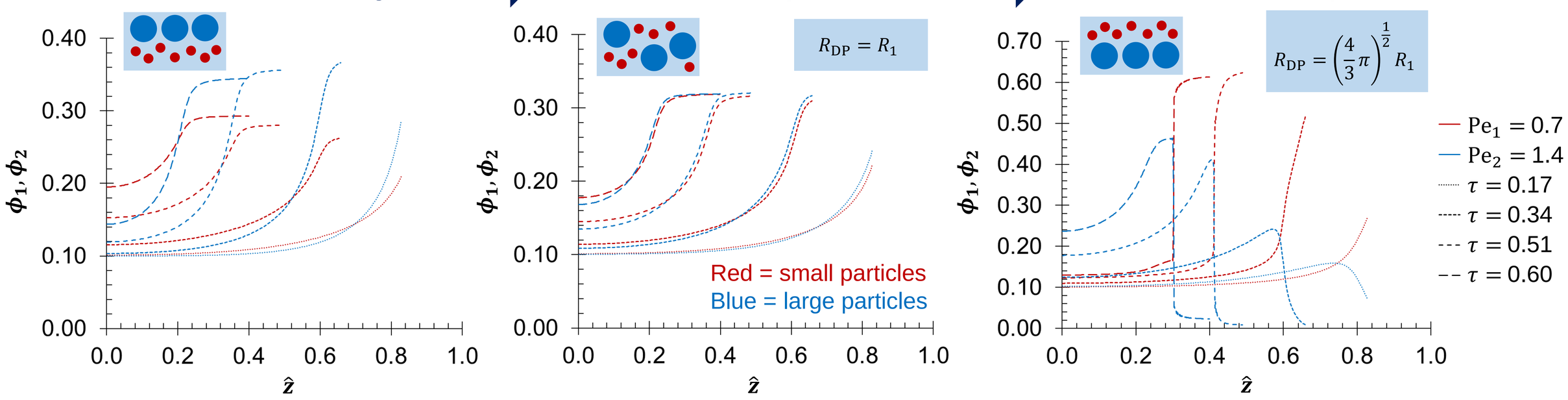
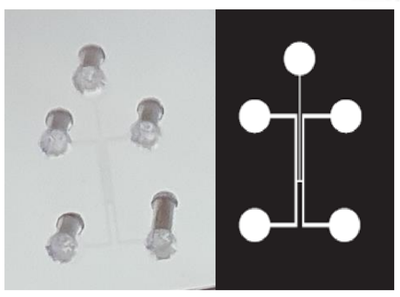


Figure 5: *Model results without (left) and with (centre and right) diffusiophoresis at different values of R_{DP}.*

5. Conclusions

With diffusiophoresis: Increasing the strength of diffusiophoresis results in more **small particles at the top surface**.

Next steps: Microfluidics experiment to verify the importance of diffusiophoresis



Acknowledgement

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Figure 6: *Microfluidic device (left) and drawing (right).*