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On The Modelling of Electrowetting in COMSOL MultiPhysics

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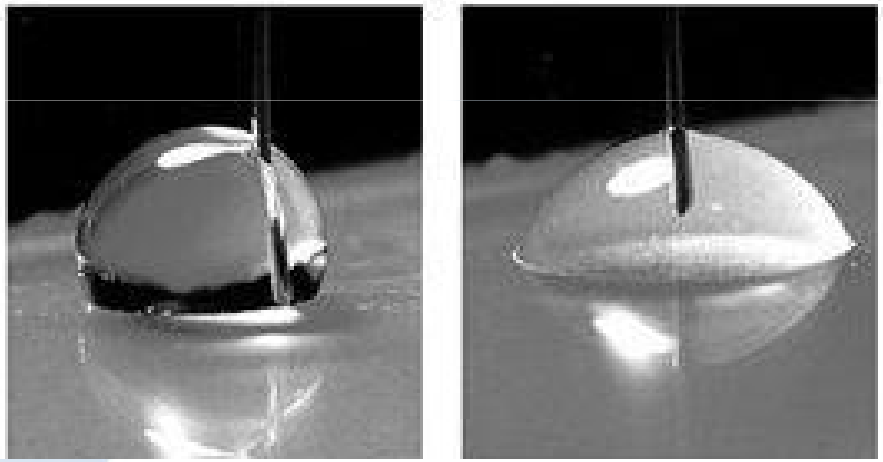
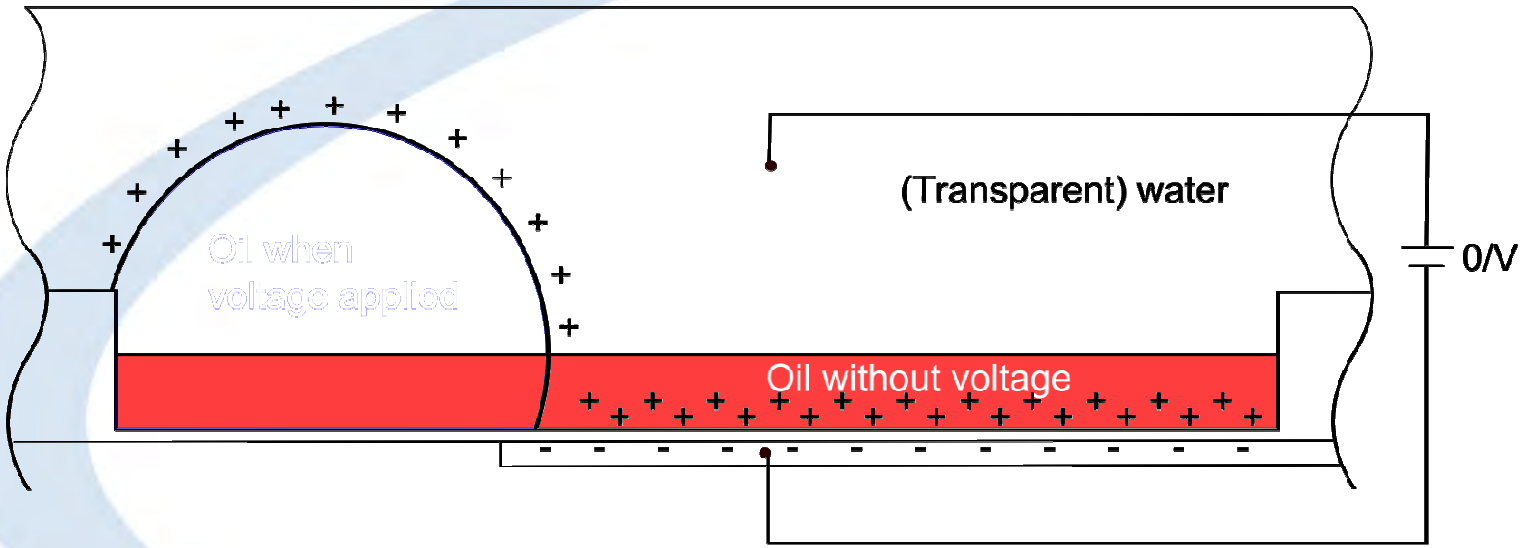
Introduction

- Electrowetting:
  - Applying a voltage, leading to a change in contact angle.



Introduction
Electrowetted displays

- The water is not in contact yet; the oil layer has to break first



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Physics

- Main physics
  - Electric force
  - Surface tension

Use the *two phase level set* and the *electrostatic* module

- Maxwell stress tensor:

$$T_{ik} = \epsilon_0 \epsilon_r \left(E_i E_k - \frac{1}{2} \delta_{ik} E^2 \right), \text{where} \quad i = 1, 2, 3 \text{ and } \quad k = 1, 2, 3$$

- -> Volume force

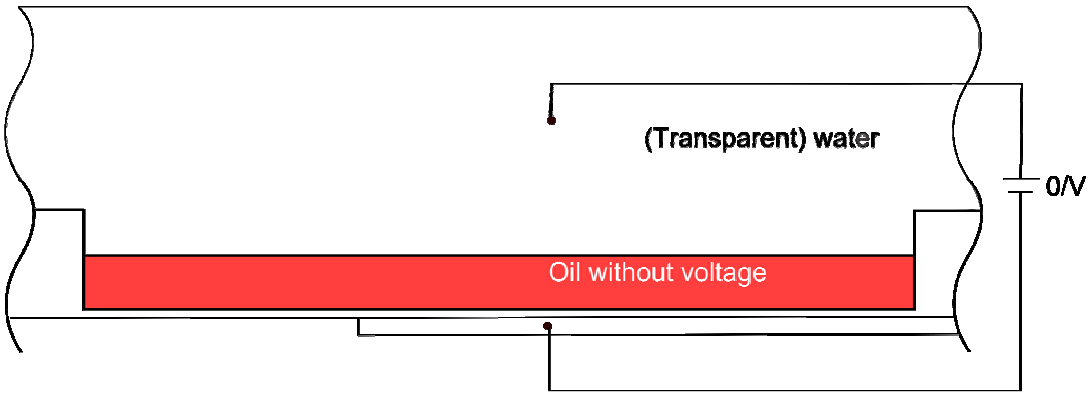
$$f = \nabla \cdot T_{ik}$$

- Permittivity

$$\epsilon_r = \epsilon_{r1} + (\epsilon_{r2} - \epsilon_{r1})\, \phi$$

- Contact angle

$$\cos\theta = \cos\theta_0 + \frac{\epsilon_0 \epsilon_r}{2 d \sigma} V^2$$

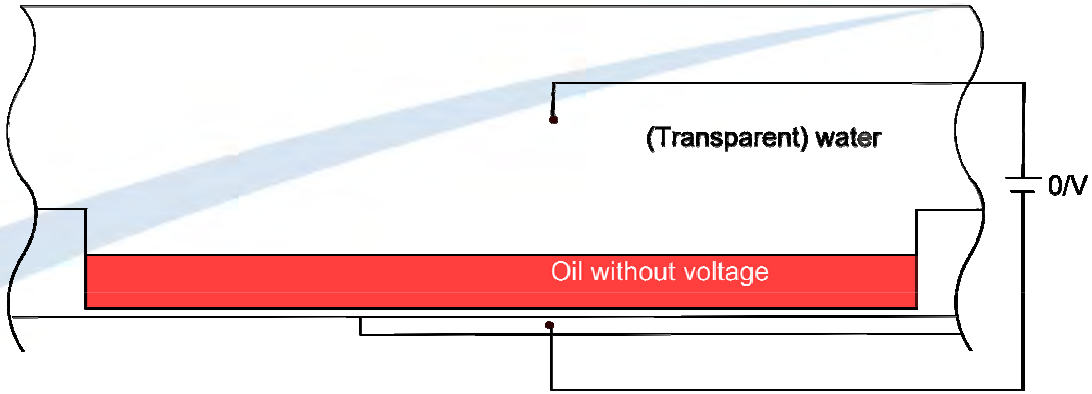


Physics Analytically

- Analytical

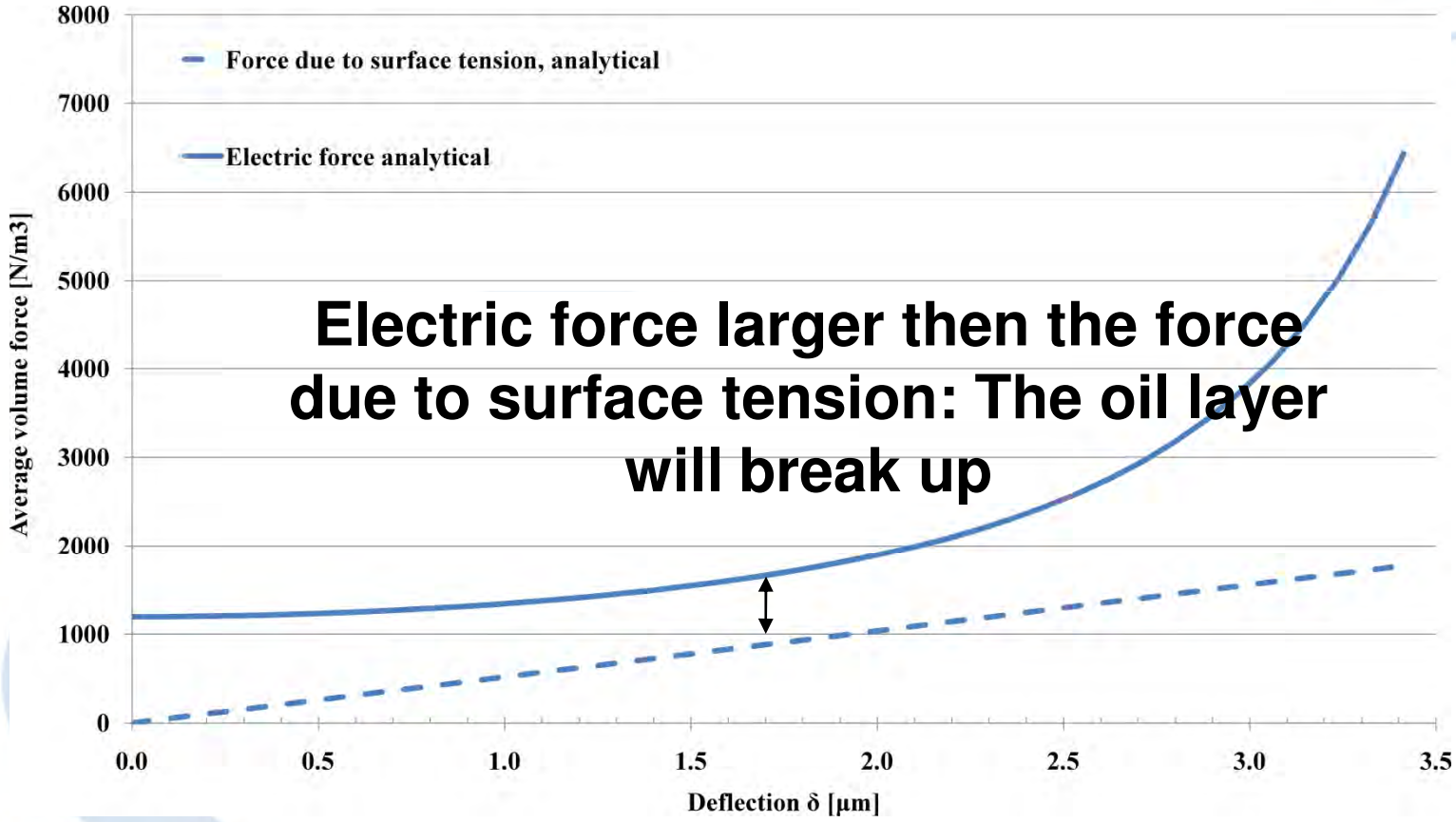
$$P_{\text{elec}} = \frac{1}{2}\epsilon_0 \epsilon_r E^2$$

$$P_{\text{surf}} = \sigma\left(\frac{1}{R}\right) = \sigma\kappa$$



- Assumed:
  - Cylindrical shaped interface with curvature κ.
  - Only pressure due to electric field in y-direction (normal on the initial interface).
  - Volume of the oil is constant.

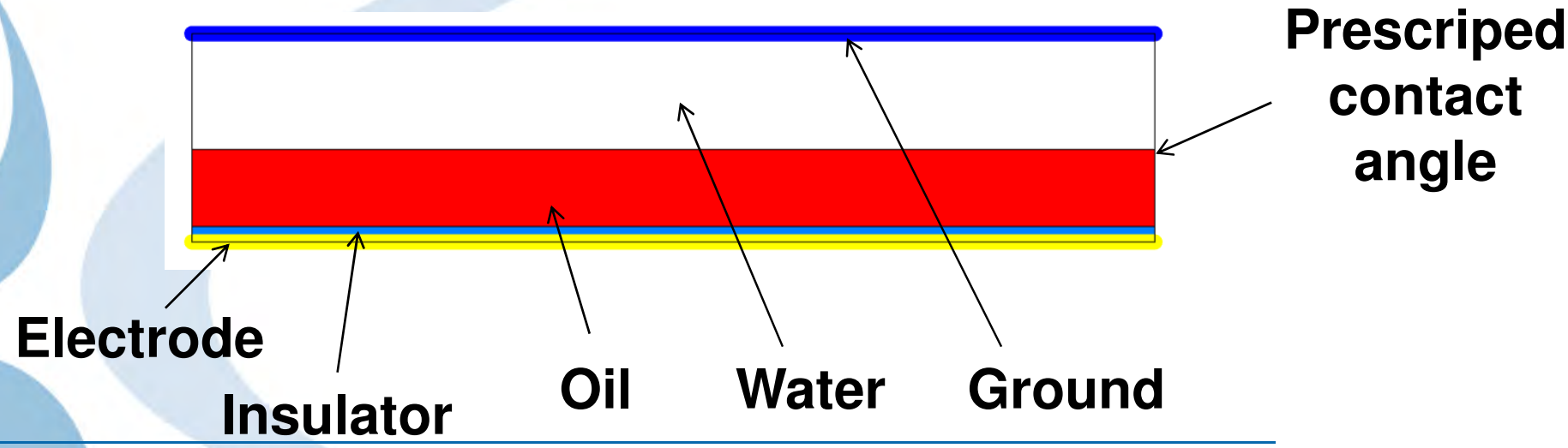
Results
Analytically



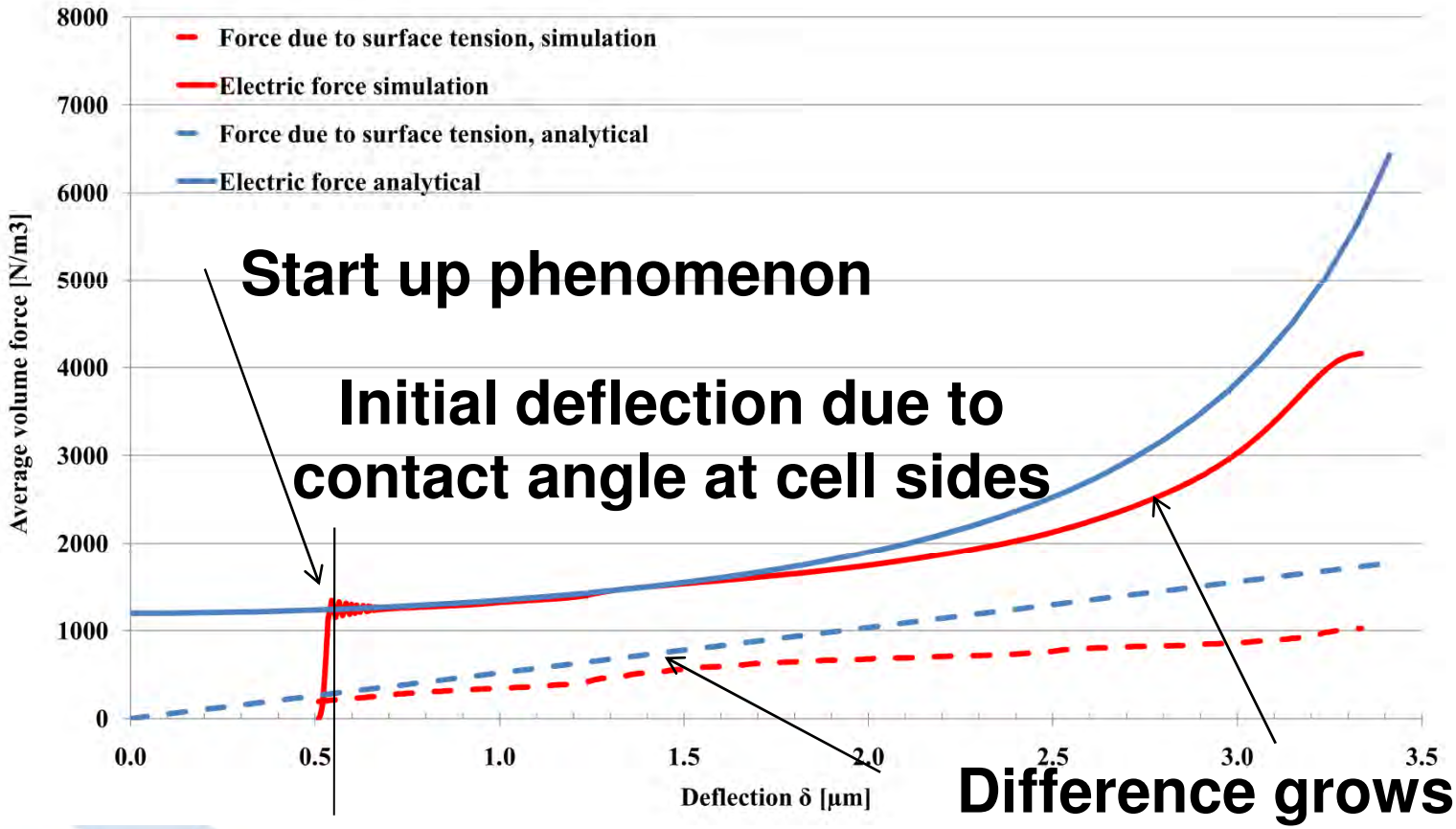
Electric force larger then the force due to surface tension: The oil layer will break up

Results Geometry

- Simulation
  - 2D:
    - Using the input as used in the analytical (viscosity, surface tension and voltage).
    - Forces should be equal to the analytical.

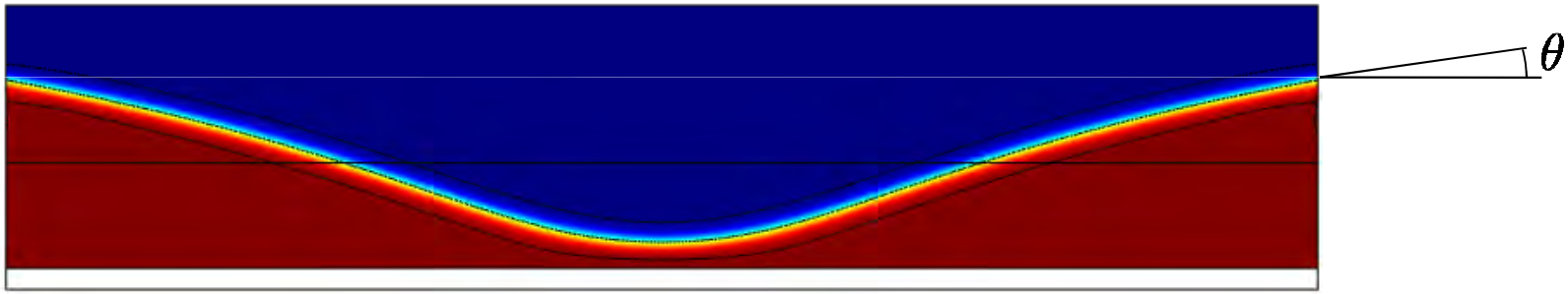


Results
Comparison simulation - analytical



Results

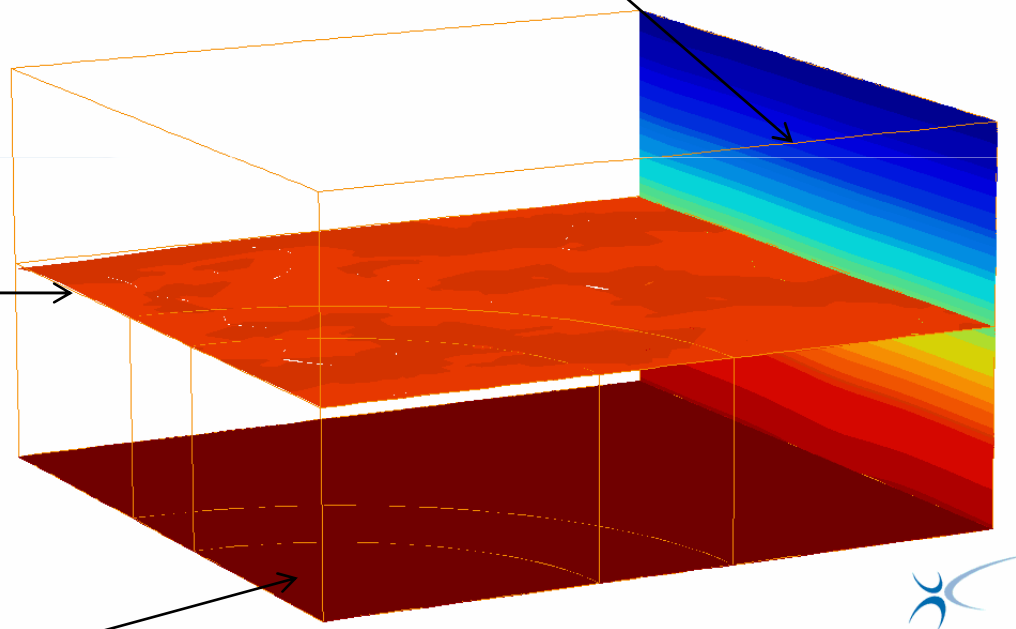
- Simulation:
  - Interface not cylindrical, due to the prescribed contact angle.



Results

- First 3D model

The level set function; blue is water, red is oil



Interface Oil/Water

Shows the surface force due to the electric field

The voltage on the bottom of the cell

Conclusions and recommendations

- Coupling between electric force and volume forces in the Navier-Stokes has been made.
- Good agreement analytical and simulation
- No 3D validation yet, however results are promising
- Still large simulation times due to the large amount of degrees of freedom.

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Thank you for your attention!!

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