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BUBBLE DETACHMENT FROM THE SURFACE OF A (PHOTO)ELECTRODE

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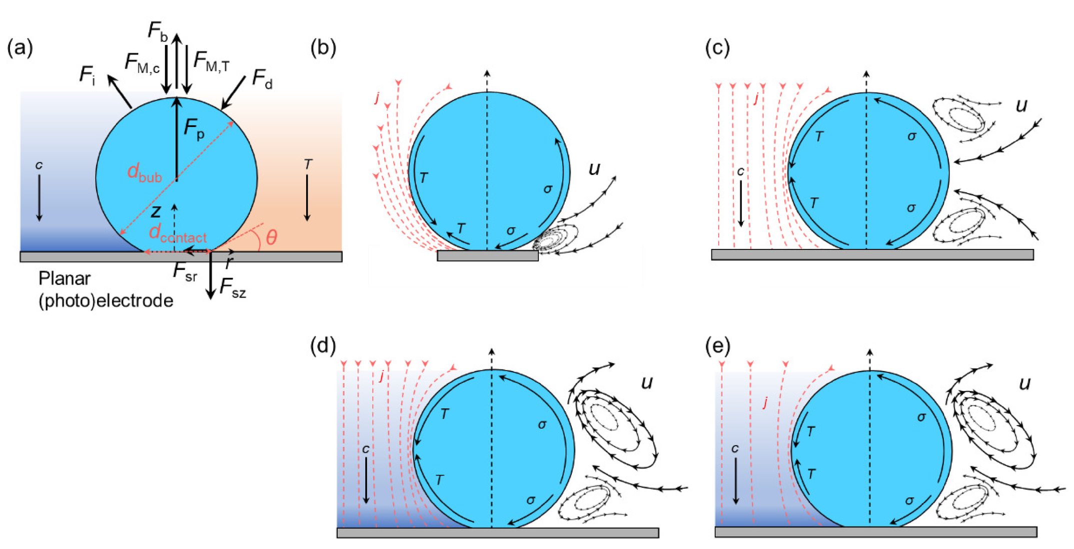
Introduction: Many (photo)electrolytic devices involve the generation of bubbles (e.g., hydrogen, oxygen). In these devices, bubble coverage on the surface of the electrode not only decreases the active area,[1] but also induces product crossover loss[2,3] and optical loss.[4] Effort in understanding the bubble detachment process and the influencing parameters are therefore important in minimizing the losses. We numerically studied the impact of the super-saturated bounary layer of dissolved oxygen on bubble detachment. Results show that the presence of the super-saturated boundary layer of dissolved gas facilitates bubble departure, due to the decreased surface tension force component. Overall, the findings from this work not only elucidate the mechanisms of how the super-saturated boundary layer affects (photo)electrolytic bubble detachment but also provide practical suggestions for cell/electrolyte engineering.

Motivations

Q1: How does the super-saturated boundary layer of dissolved gas affect bubble departure from the surface of a (photo)electrode?

Q2: How do different parameters, e.g., contact angle, thickness of the super-saturated boundary layer, concentration, contribute to the bubble detachment process?

Q3: What suggestions can we give regarding the cell/electrolyte engineering, to mitigate the bubble adhesion induced losses?



(a) Schematic illustration of the forces acting on a bubble adhered on the (photo)electrode, illustrations of the bubble detachment from a **(b)** microelectrode, **(c)** planar electrode, in absence of super-saturated boundary layer of dissolved product, **(d)** planar electrode, in presence of super-saturated boundary layer, **(e)** planar photo-electrode, in presence of the super-saturated boundary layer of dissolved product.

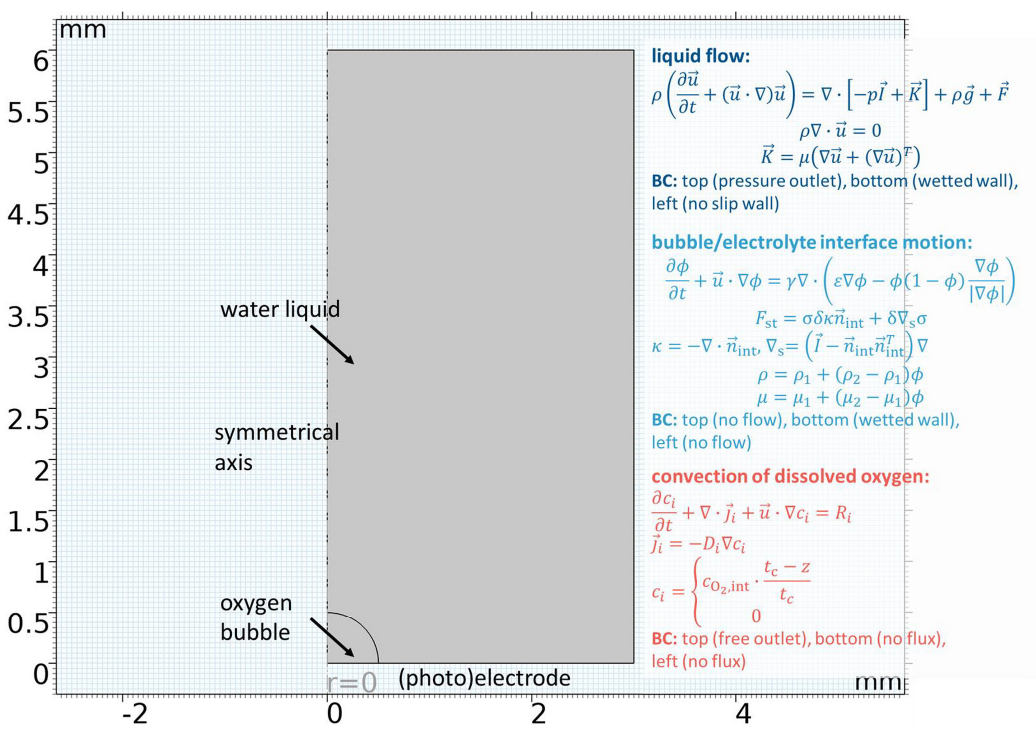
Method

Multiphysics modeling:

liquid flow: Navier-Stokes equation,

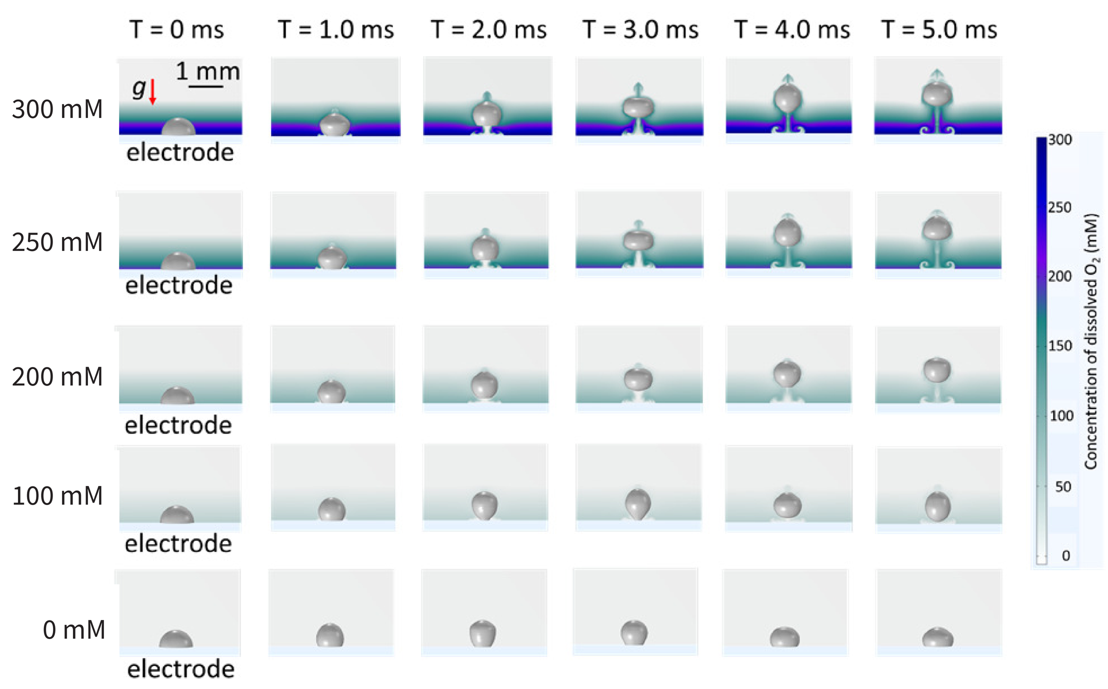
motion of bubble/electrolyte interface: level set method,

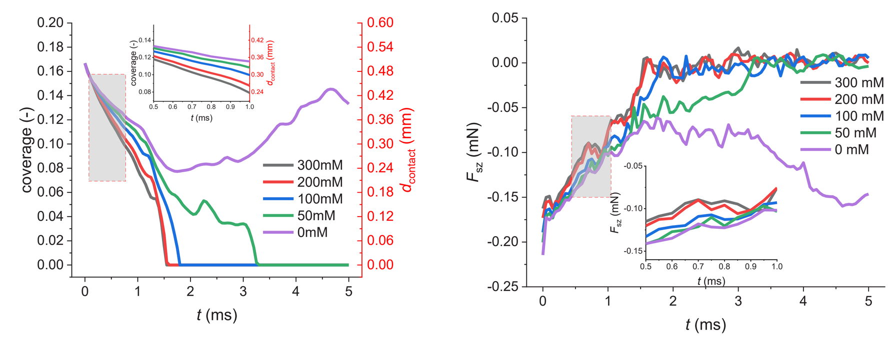
mass transport of dissolved oxygen: convection.



Results

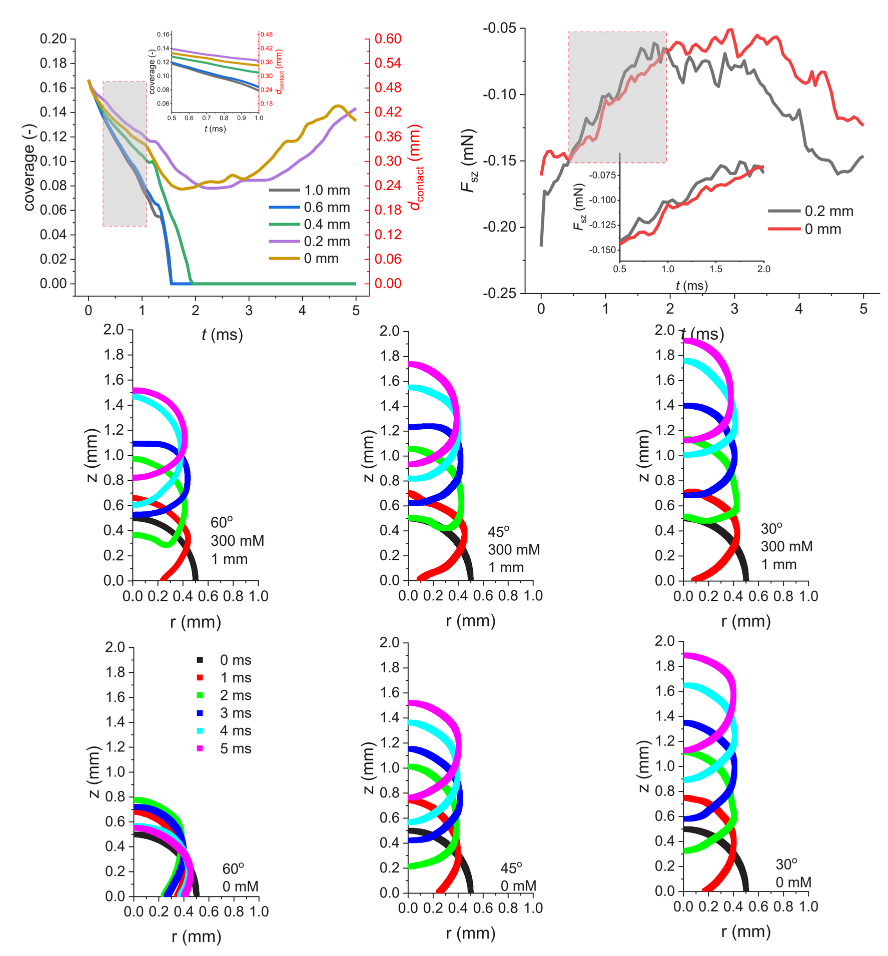
Effect of the super-saturated boundary layer of dissolved gas on bubble detachment





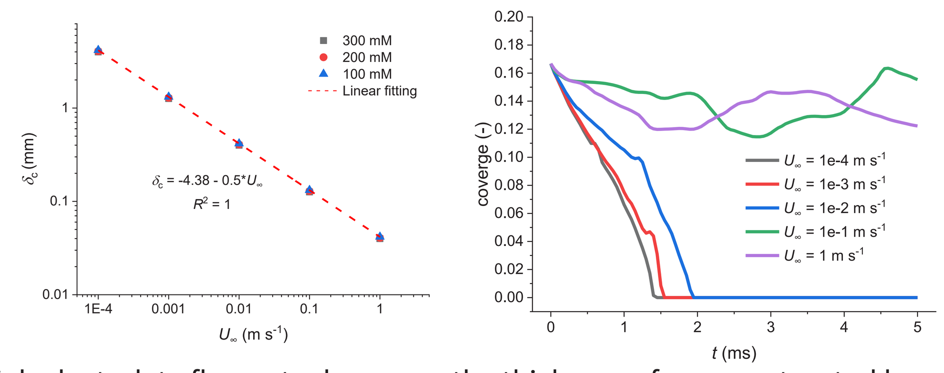
- the super-saturated boundary layer of dissolved gas facilitates bubble detachment
- the surface tension force component F_{sz} is the determining force which hinders bubble detachment
- the concentration gradient induced Marangoni effect facilitates bubble departure by decreasing F_{sz}

Effect of different parameters on bubble detachment

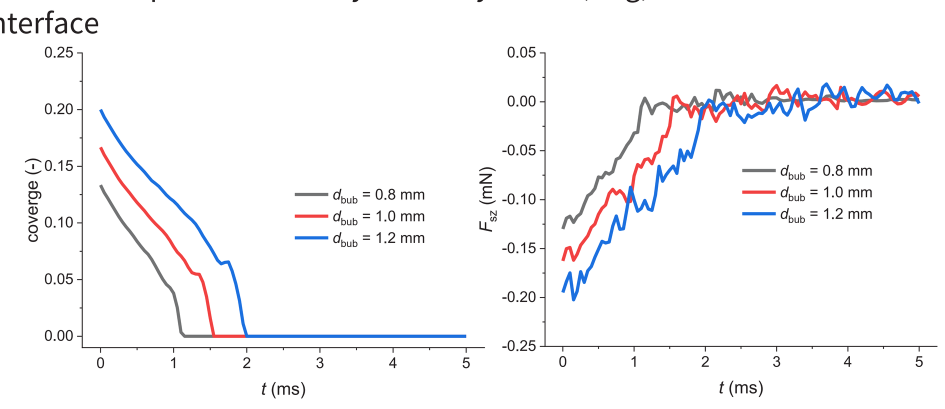


- thick super-saturated boundary layer and large concnetration lead to earlier bubble departure, due to enhanced Marangoni effect
- small contact angle, i.e., a more hydrophilic surface of the (photo)electrode, leads to earlier bubble departure
- at low contact angles, e.g., 30°, super-saturated dissolved oxygen has minor impact on bubble detachment, due to smaller surface tentison force component F_{sz}

Suggestions in cell/electrolyte engineering



- high electrolyte flow rate decreases the thickness of super-saturated boundary layer, thus prevent bubble departure (surprisingly), in the premise of ignoring the other impact induced by electrolyte flow, e.g, shear stress on the bubble interface



- under the same super-saturated bounary layer of dissolved O_2 and contact angle, smaller bubble detaches earlier, representing a potential benefit of operating (photo)electrochemical reactors at high pressure

CONCLUSIONS

A multiphysics model was developed to elucidate the effect of the super-saturated boundary layer of dissolved gas on bubble detachment.

- The presence of the super-saturated boundary layer of dissolved gas facilitates bubble detachment from the (photo)electrode due to the decreased surface tension force components in z direction, F_{sz}.
- Thicker super-saturated boundary layer, higher concentration level, and smaller contact angle lead to earlier bubble departure.
- High electrolyte flow rate decreases the thickness of the super-sautrated boundary layer, thus delays bubble detachment. Note, such conclusion is derived on the basis of ignoring the other effect induced by the forced electrolyte flow, e.g., shear stress on the interface.
- Under the same super-saturated boundary layer of dissolved O_2, smaller bubble detaches ealier, representing a potential benefit of operating (photo)electrochemical reactors at high pressure.

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