Chair: Physics of Fluids group — Master/Bachelor project proposal

Coalescence driven dynamics of hydrogen bubbles during water electrolysis

Motivation

The evolution of electrogenerated gas bubbles, such as those formed during water electrolysis, significantly hampers the overall efficiency of the process. These gas bubbles act as almost perfect insulators, increasing the Ohmic resistance both close to the electrode surface and in the electrolyte bulk [1] (see Figure 1). Additionally, they block the surface of the electrode, which leads to additional losses [2]. A better understanding and control of the bubble dynamics [3] is crucial to optimize the cell design and operating parameters.

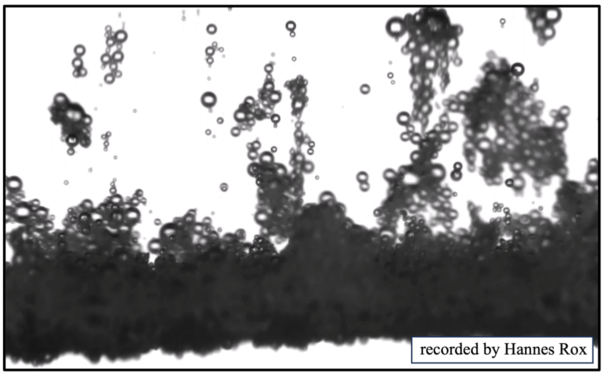

Figure 1: Evolution of the hydrogen bubbles on mesh electrode. Adapted from Rox et al.[1].

The evolution of electrogenerated H_2 bubbles is a multifaceted problem at the intersection of fluid mechanics and electrochemistry. The growth and detachment stages of the evolution are for example interconnected with the gradients of chemical species and/or temperature close to the electrode surface causing Marangoni convection, electrostatic interactions, composite of the electrolyte, wettability of the surface, coalescence events between neighboring bubbles leading to earlier departure, motion reversals as well as to the injection of electrolyte fractions inside the gas phase, etc.

Assignment

In this work, the dynamics of a pair of H_2 bubbles produced during water electrolysis in acidic electrolyte at a dual microelectrode is being to systematically studied by varying the cathodic potential and electrolyte composite. By combining high-speed imaging and electrochemical methods, we will explore the interactions between the pair of bubbles and their impact on the reaction rate. During preliminary experiments, the bubble-bubble coalescence events were shown to on one hand lead to a substantially earlier departure than that defined by the buoyancy (see Figure 2). On the other hand, repeated coalescence events may also reverse the motion direction of the once-departed bubble. The latter leads to a growth resumption near the electrode surface until buoyancy-driven detachment.

What to expect? What will you learn?

We are looking for enthusiastic students with an interest in experimental work. You can expect a readily available setup, state-of-the-art measurement equipment, comprehensive support, interesting discussions, and supervision of the work.

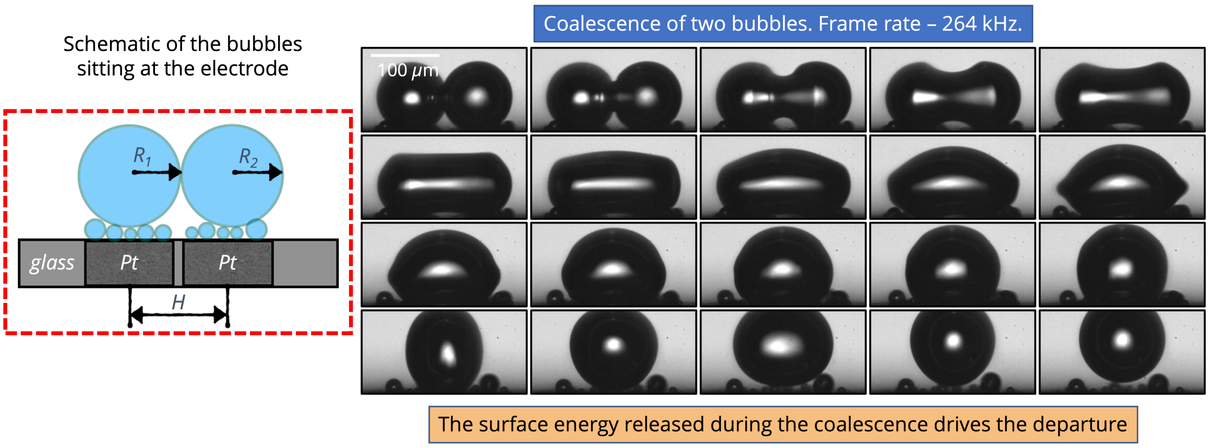

Figure 2: Schematic of two bubbles sitting at Pt microelectrodes and experimental snapshots of coalescence-driven departure process recorded at a frame rate of 264 kHz.

You will learn

- About the dynamics of electrogenerated gas bubbles produced during water electrolysis
- How to perform electrochemical and high-speed optical measurements
- Image processing in Matlab/Python (by your choice)
- Basic and advanced scientific data analysis

Please, feel free to contact Aleksandr in case of any related questions. Contacts below:

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References

[1] Hannes Rox, Aleksandr Bashkatov, Xuegeng Yang, Stefan Loos, Gerd Mutschke, Gunter Gerbeth, and Kerstin Eckert. Bubble size distribution and electrode coverage at porous nickel electrodes in a novel 3-electrode flow-through cell. *International Journal of Hydrogen Energy*, 48(8):2892–2905, 2023.

[2] Andrea Angulo, Peter van der Linde, Han Gardeniers, Miguel Modestino, and David Fernández Rivas. Influence of bubbles on the energy conversion efficiency of electrochemical reactors. *Joule*, 4(3):555–579, 2020.

[3] Aleksandr Bashkatov, Syed Sahil Hossain, Gerd Mutschke, Xuegeng Yang, Hannes Rox, Inez M Weidinger, and Kerstin Eckert. On the growth regimes of hydrogen bubbles at microelectrodes. *Physical Chemistry Chemical Physics*, 24(43):26738–26752, 2022.