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Experimental analysis of Gas—liquid flow in PEM water electrolysis micro-channels using a permeable wall

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Introduction

One means of reducing the cost of PEM electrolyser is to increase production from the existing cells by increasing the current density from 1 (A/cm2) (at the existing conventional cells) to more than 5 (A/cm2). At high current densities, due to high rate of oxygen generation and concentrated heat generation in the cell, issues related to heat and bubble management come up which must get managed.

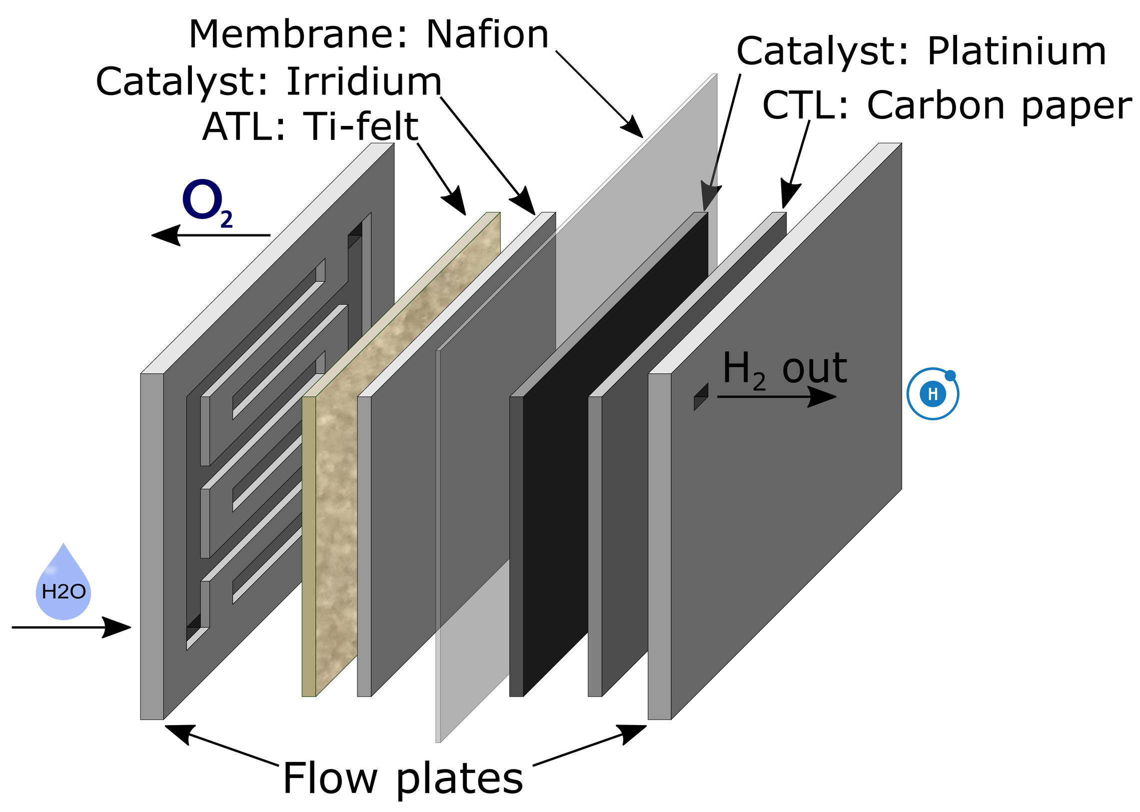

Fig. 1: PEM water electrolysis components

The following figure shows five different flow regimes encounters in micro-channels. According to the literature, channel size, phase superficial velocities, liquid phase surface tension, wall wettability and inlet conditions affect flow pattern. Meanwhile, the channel cross sectional geometry, liquid viscosity and flow orientation respecting the gravity has a lower degree of importance.

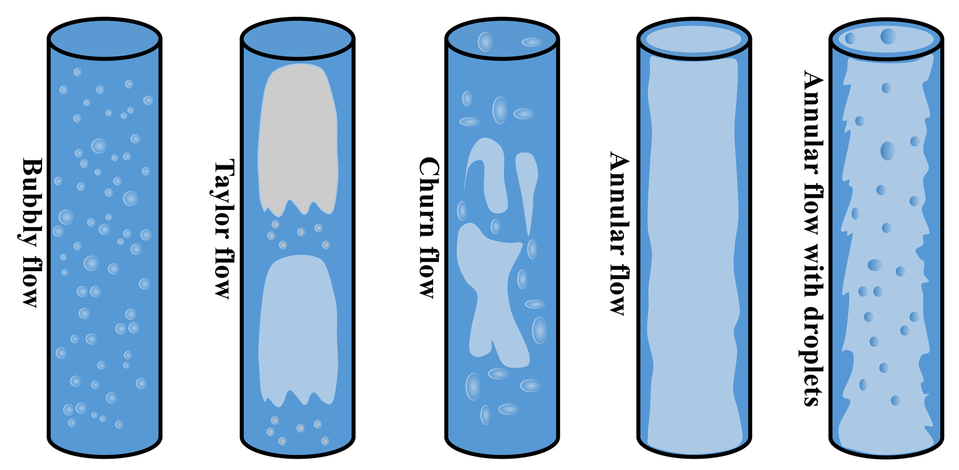

Fig. 2: Gas—Liquid flow regimes in a channel.

Experimental Setup

In this study, an experimental setup is made of Plexiglas, Titanium-felt and micro-porous ceramic. The setup demonstrates a similar gas-liquid flow encounters in PEM water electrolysis channels and anode porous media.

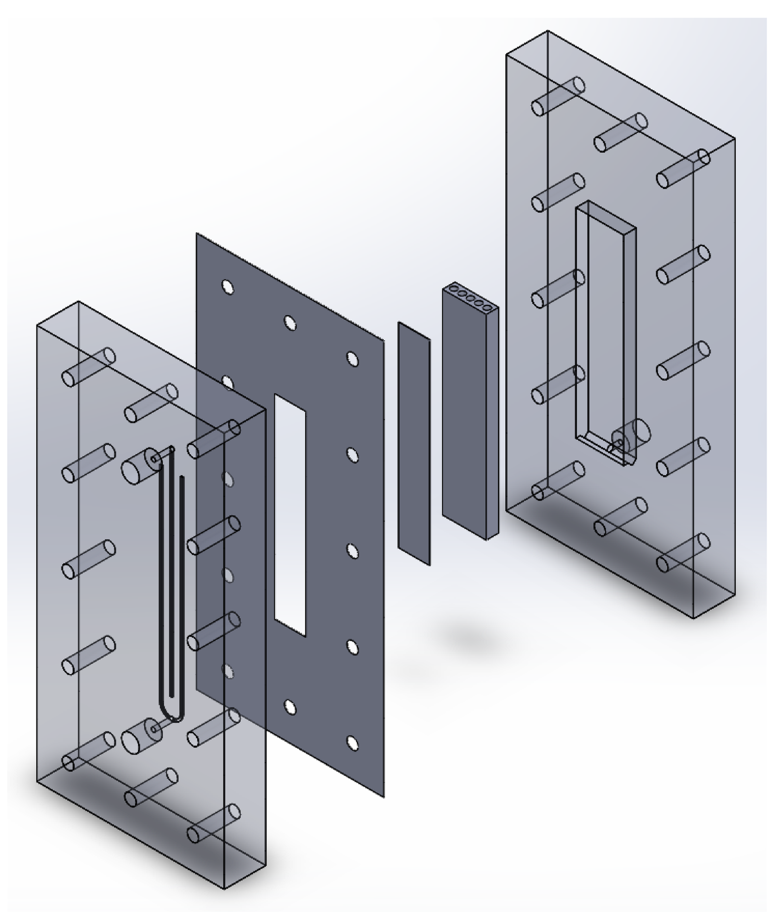

Fig. 3: Experimental setup

Experimental Setup

The micro-porous ceramic plate simulates generates tiny bubbles simulating the real membrane electrode assembly (MEA). The movement of bubbles upward in the micro-channel at a specific stoichiometric number is analysed and its multiphase flow regime is identified. The channels size is 0.5 x 1 mm.
To take images of the gas—liquid flow, a high-speed AOS camera is set in front of the setup. Two high power LED is used on besides of the camera to bright the view.
The bubbles forms in the channels aren't clearly visible in the raw images. Therefore, a code is written in MATLAB to emphasize the bubble borders based on their movement.

```
vid = VideoReader('exp-1.avi');
mov = read(vid);
implay(mov);
mov2 = diff(mov,1,4);
mov3 = mov2*10;
implay(mov3);
```

Results

The following figure shows bubbly flow in the entrance channels and annular flow in the outlet channel. Large bubbles in the entrance channel are aligned in a column. They are very close to each other with a film of water in between. However, they don't merge to make a Taylor bubble.

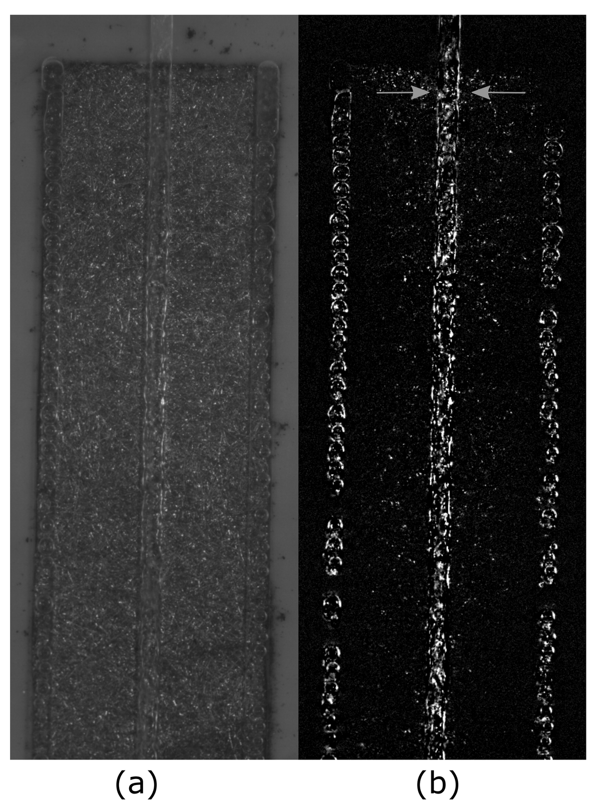

Fig. 4: Bubbly flow in the entrance channels and Annular flow in the outlet channel (I=16A/cm2, St=25).

The following figure shows Taylor flow in the outlet channel. Opposite to the previous figure, as the gas flow rate increases, bubbles merge together, accumulate the whole sectional area and make a Taylor bubble.

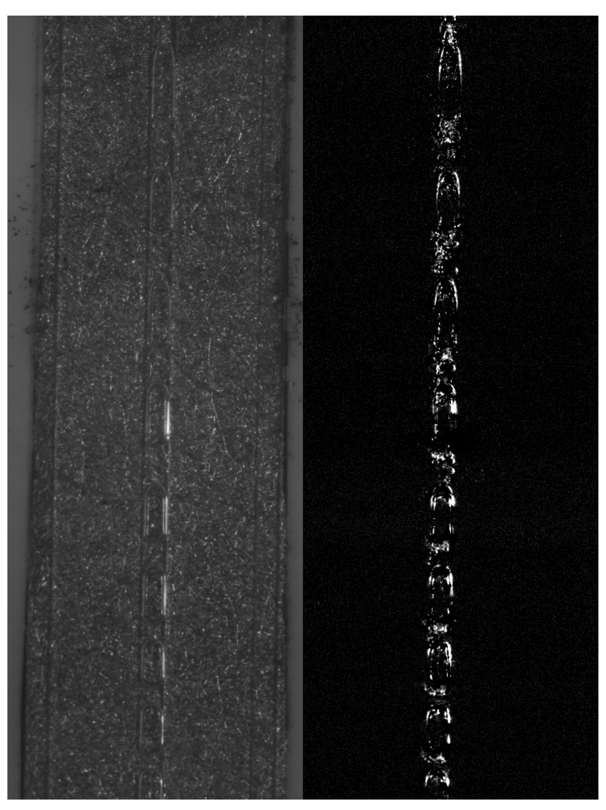

Fig. 5: Taylor flow in the outlet channel. (Current density=2, St.No.=100)

Results

The following figure shows Taylor bubbles along the outlet channel. In most of the figures shown in this study, there are 4 parallel vertical lines along the outlet channel. The two outer lines are the edges of the channel and the two inner lines are borders of the gas touches the channel wall. Here, about 0.6 mm of the channel width is in touch with the gas. On the other hand it's dry (zero wall film).

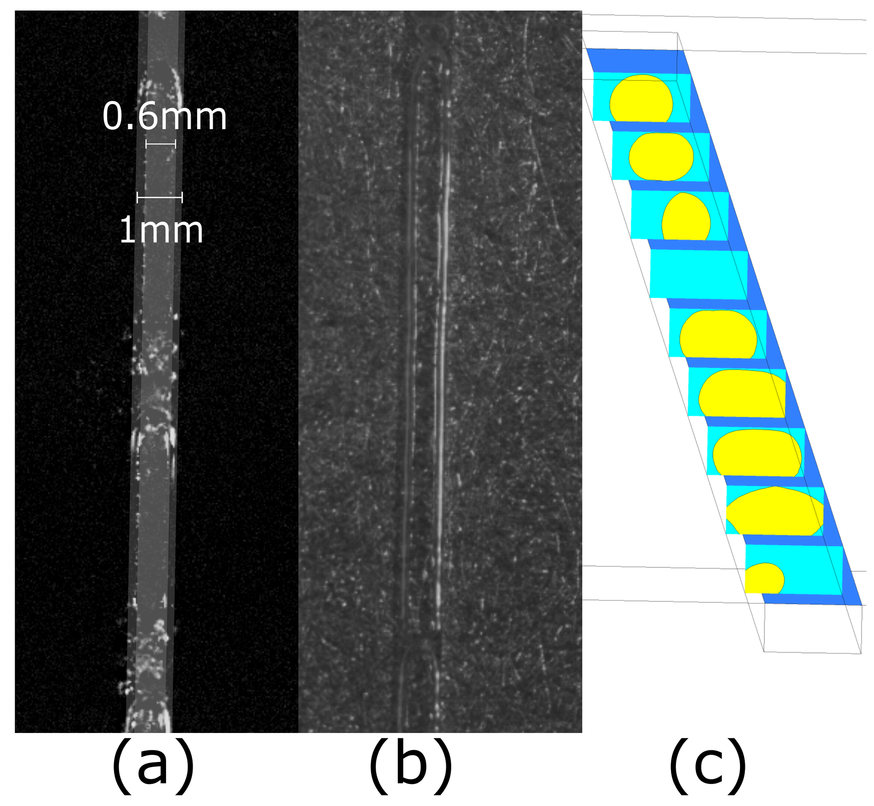

Fig. 6: Taylor bubbles in the outlet channel. About 0.6 mm of the Taylor bubbles are in contact with the micro-channel wall.

The aim of the following figure is to show accumulation of tiny bubbles in the upper section of the Ti-felt.

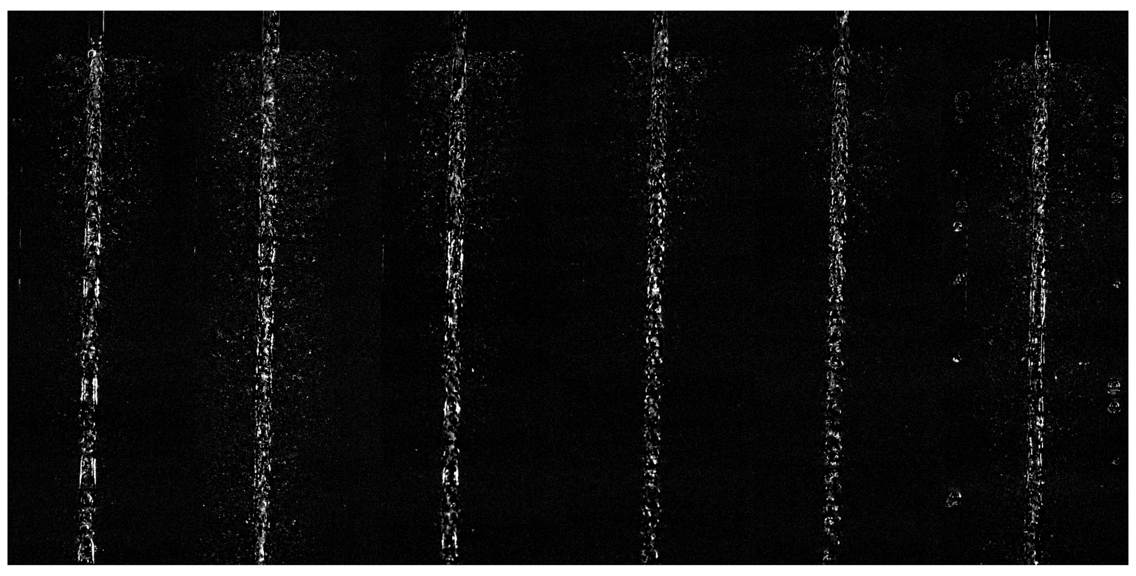

Fig. 7: Accumulation of bubbles in the top section of the Ti-felt in different current densities and stoichiometric numbers.

Conclusion

Gas—liquid flow in micro-channels of electrolyser independent of the electro-chemical complexities was demonstrated. Different gas-liquid flow regimes was seen by different gas flow that corresponds to the current density and water flow rate was successfully demonstrated using a micro-porous ceramic as a permeable wall.

Similar papers

[1] Lafmejani S., Olesen, A., Kær, S.,: *VOF modelling of gas—liquid flow in PEM water electrolysis cell micro-channels*, Int. J. of Hydrogen Energy, 2017.

[2] Lafmejani, S., Olesen, A., and Kaer, S.,: *Analysing Gas-Liquid Flow in PEM Electrolyser Micro-Channels*, ECS Trans., 2016.

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