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Improvement of Cell Power of a µDMFC by Means of Additional Geometrical Obstacles in the Anode Channel

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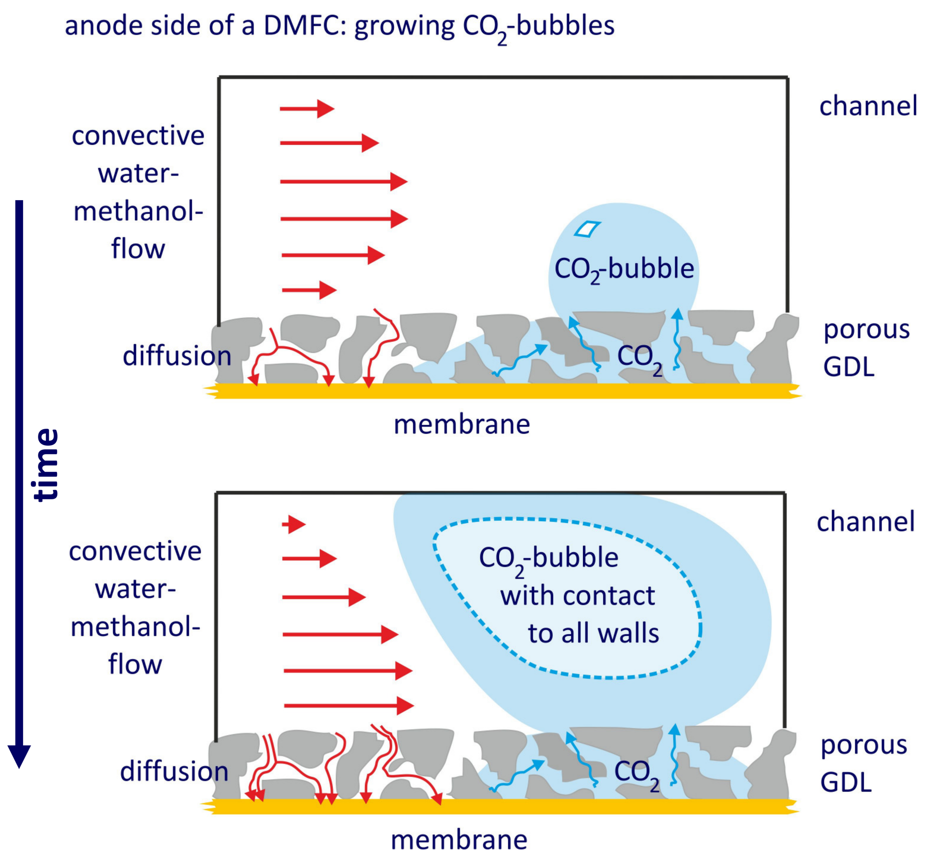
Introduction:



- CO_2-bubbles grow inside the anode channel of a Direct Methanol Fuel Cell (DMFC)
- Given hydrophobic channel walls, CO_2-bubbles stick to the walls and keep growing.
- Strong displacement effect by channel-filling bubbles on the water-methanol-flow toward the GDL.

→ Temporal improvement of the cell power while bubble is present.

- Fluid mechanical effects of sticking CO_2-bubbles numerically predicted in:

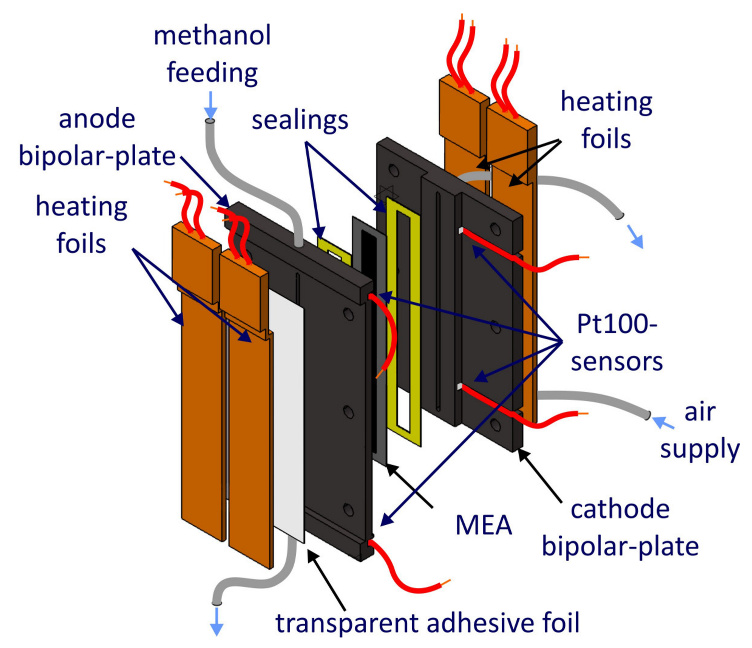
  Hutzenlaub, T, Paust, N, Zengerle, R, Ziegler, C: *The effect of wetting properties on bubble dynamics and fuel distribution in the flow field of direct methanol fuel cells*, Journal of Power Sources, 196: 8048– 8056, 2011
- Displacement effect proven by laser-optical flow measurements in an operating DMFC with synchronous cell-power-logging by ZBT, published in:

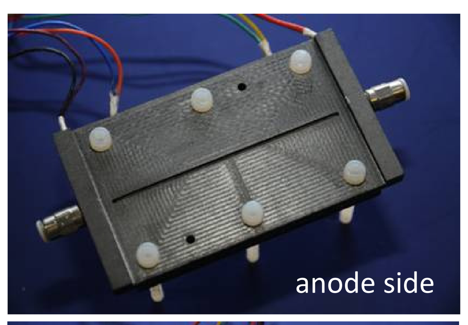
  Burgmann S, Blank M, Wartmann J, Heinzel, A: *Investigation of the effect of CO_2-bubbles and slugs on the performance of a DMFC by means of laser-optical flow measurements*, Energy Procedia, 28: 88-101, 2012

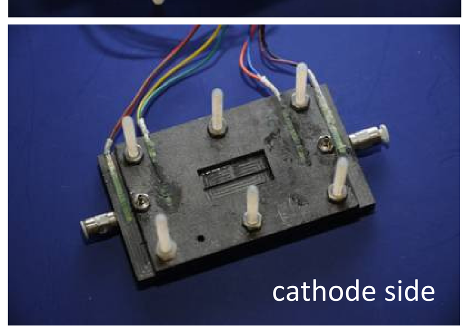
  Burgmann, S, Blank, M, Panchenko, O, Wartmann, J: *µPIV measurements of two-phase flows of an operated direct methanol fuel cell*, Exp Fluids, 54:1513, 2013

→ Can the fuel cell power be permanently increased by artificial bubbles that lead to a similar displacement effect on the water-methanol flow?

Single-Channel-DMFC:

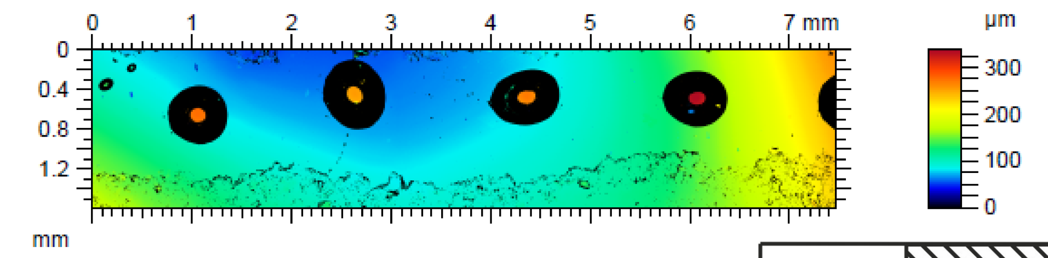


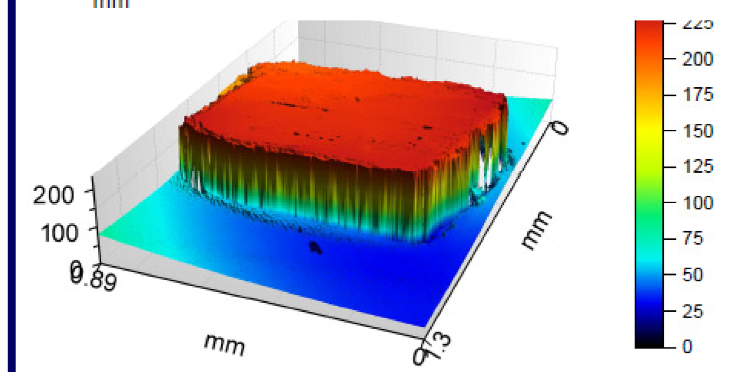


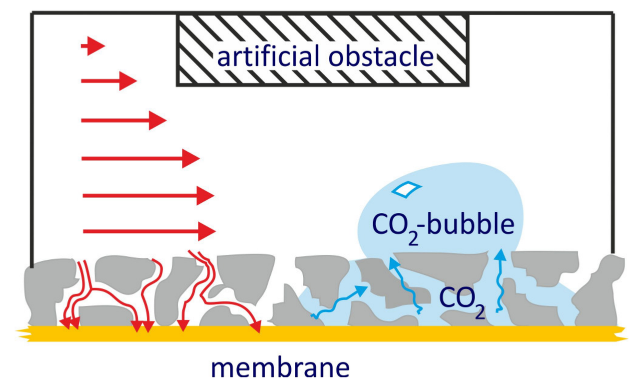


- Single channel DMFC made of Eisenhuth Sigracet BMA5 compound material with optical access to the anode and the cathode side via transparent foil and glass window, respectively.
- 55 mm long channel with a cross-section of 1 × 0.67 mm² on the anode and the cathode side, respectively.
- Active area of the cell is 5 x 55 mm² (2.75 cm²), SolviCore Nafion 115 membrane with carbon paper GDL (contact angle 140° at the anode side)
- Temperature control via heating foils and PT100 sensors.
- Flow control via syringe-pump on the anode side and flow meter on the cathode side.

Artificial Obstacles:



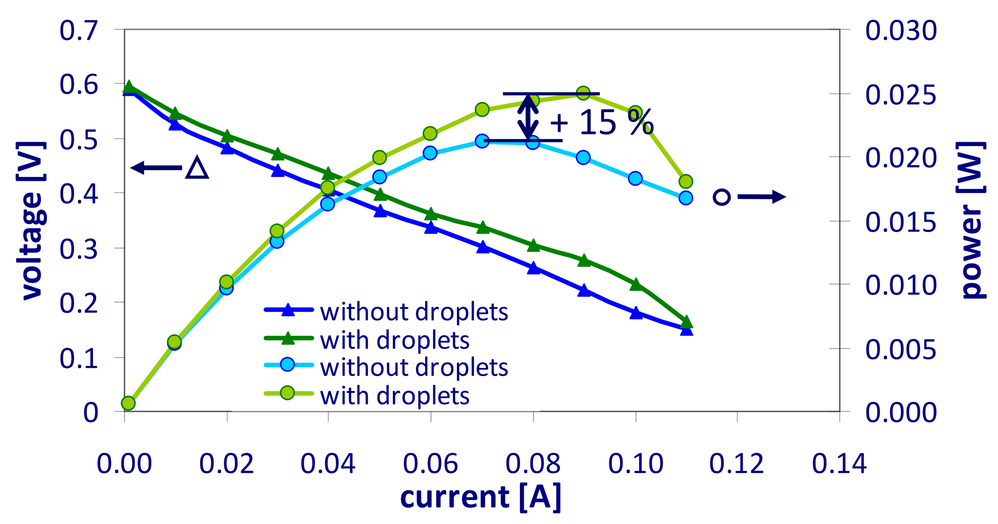




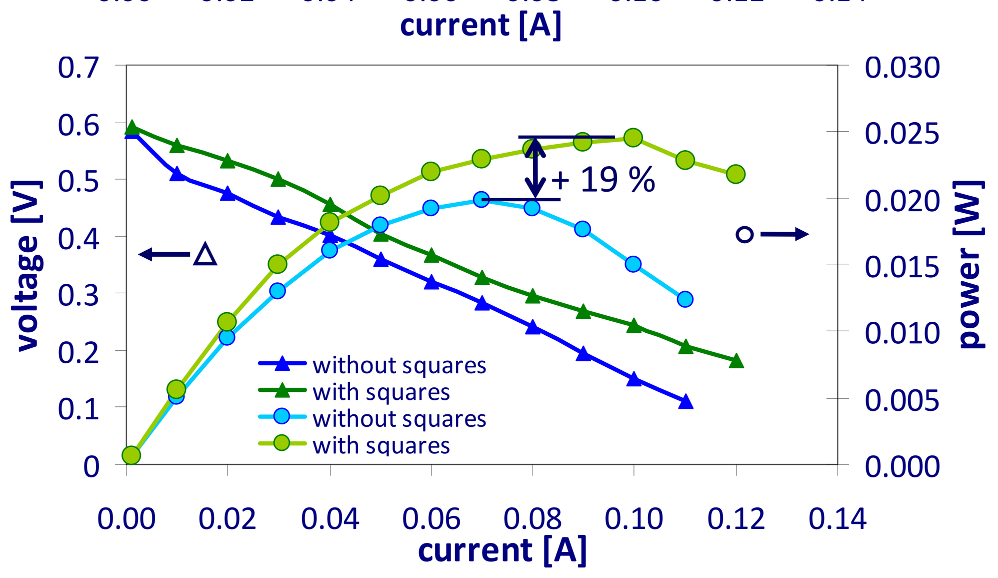
- All thickness and size values are measured using a NanoFocus ''µSurf Custom'' Confocal-Multi-Pinhole sensor; resolution of 1 µm in lateral and 10 nm in vertical direction, respectively.
- Transparent foil is covering the anode side → artificial obstacles are applied to that foil such that they reach into the anode channel.
- Transparent anode-side cover-foils are easy and fast to remove; they are applied to the anode side with and without artificial obstacles glued to the foil.
- First tests with glue-droplets on the inner side of the transparent foil of the anode side: 250 µm high and 500 µm wide → blockage ratio: ≈ 15 %.
- Ongoing tests with square-size obstacles on the inner side of the transparent foil of the anode side (contact angle similar to the transparent foil, i.e., 111°): 200 µm high and 650 µm wide → blockage ratio: ≈ 20 %.

Results:

- Cell operated at 70 °C with 1M methanol solution @ 0.5 ml/min and air @ 100 ml/min, with and without artificial obstacles; repeated load cycle.



- 5 almost half-sphere-droplets along the anode channel lead to an power increase of ≈ 15 %



- 5 square-sized obstacles along the anode channel lead to an power increase of ≈ 19 %

→ Artificial geometrical obstacles at the anode channel wall may increase the fuel cell power; scaling with blockage ratio and obstacle distance needs to be investigated.

Outlook:

- Further investigation on pressure drop, two-phase-flow behaviour / contact angles and flow distribution, the latter one by laser-optical flow measurements (µPIV).
- Analysis of global channel design modifications, e.g., converging channel-height in combination with diverging channel width.