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Modified GDL for Improved Water Management in PEFC

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Objectives

- In polymer electrolyte fuel cells (PEFC), water is a product of the cathode oxygen reduction reaction.
- Liquid water accumulates in the porous gas diffusion layers (GDL) ➡ efficiency loss due to mass transport limitations.
- New GDL design[1]:
  - Improved water removal from the electrode towards flow field.
  - Improved gas access to the electrode in wet conditions.
- New GDL design based on patterned hydrophobic/hydrophilic regions.
- Design evaluation using X-ray tomographic microscopy[2,3] to image water during ex-situ imbibition/drainage of the modified GDL.

Synthesis

- The synthetic method is based on radiation grafting of the hydrophobic coating (fluoroethylen propylene, FEP) using blocking masks.

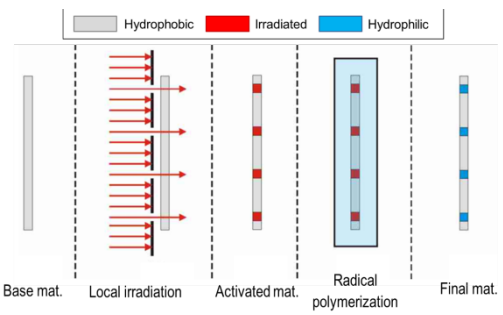

Figure 1: Schematics of the synthetic process steps.

- Electron beams with an energy higher than 200 keV permit modification throughout the complete material thickness.
- The choice of chemical copolymer and the reaction conditions (temperature, monomer concentration and time) determine the contact angle in the modified region.
- Two hydrophilic systems are being considered: the graft copolymer of FEP with polyacrylic acid (FEP-g-pAA) and the copolymer of FEP with poly N-vinylformamide (FEP-g-pNVF).

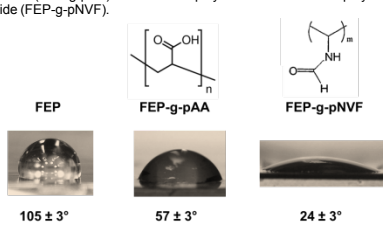

Figure 2: External contact angle of water (2µL) on: left: unmodified FEP film; center: FEP-g-pAA film; right: FEP-g-pNVF film.

Characterization

- Two GDL materials investigated: Toray TGP-H060 (10%PTFE) and modified Toray TGP-H060 (sample size = 6 mm diameter).
- Injection/withdrawal of liquid water from the bottom of the GDL using a syringe pump.
- Capillary pressure $p_c = p_{liquide} - p_{air}$ across the static liquid/air interface.
- Capillary pressure controlled by a relative pressure sensor.

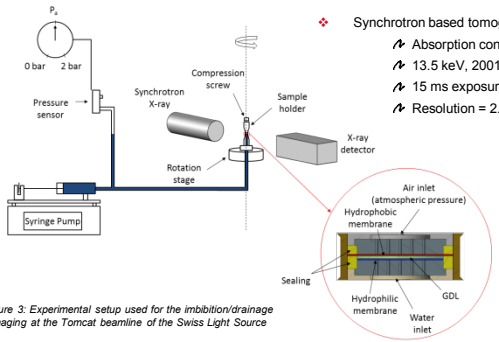

Figure 3: Experimental setup used for the imbibition/drainage imaging at the Tomcat beamline of the Swiss Light Source

- Synchrotron based tomographic imaging at the Swiss Light Source:
  - Absorption contrast
  - 13.5 keV, 2001 exposures
  - 15 ms exposure time
  - Resolution = 2.2 - 2.5 µm/pixel
- Elemental chemical mapping
  - Energy dispersive xray spectroscopy (EDX)
  - 10 keV, 256 frames

Results

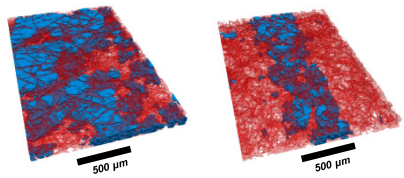

Figure 4: Surface renderings of X-ray tomographic microscopy images of water imbibition into Toray TGP-H060 gas diffusion layers; left: standard material (capillary pressure 30 mbar, saturation 58%); right: modified material (capillary pressure 50 mbar, saturation 58%).

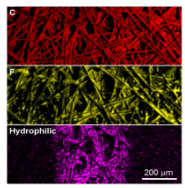

Figure 5: Elemental EDX mapping of the modified GDL. Carbon is representative of the carbon fibers and coating; Fluorine is representative of the coating; An ionic replacement allows for identification of the grafted region corresponding to hydrophilic stripe.

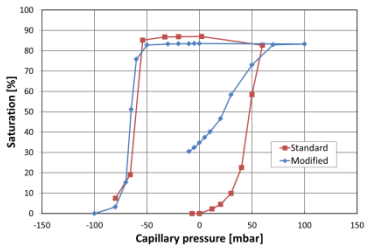

Figure 6: Capillary pressure – saturation curves for the standard (red) and modified Toray TGP-H060 (blue).

- Positive capillary pressure is required to fill the standard GDL while the saturation of the modified GDL already starts at negative capillary pressure (self imbibition).
- Water in the modified GDL flows through sharply defined hydrophilic regions (lines of about 600 µm in width).
- No water pattern observed in the standard GDL during imbibition.
- Plateau between the end of the imbibition and the beginning of the drainage ➡ inversion of the contact angle of water on solid.
- Water is removed from the GDLs when p_c is decreased.

Conclusions

- GDL material properties have been modified: hydrophilic lines patterned in an hydrophobic support.
- Imbibitions in standard and modified GDL were performed.
- The hydrophilic lines of the modified GDL channel water through the entire GDL thickness.
- In comparison, no water pattern can be observed in the standard GDL.

Outlook

- Influence of the modified GDL on the performance and durability in operando fuel cell to be assessed.
- Investigation of the ideal hydrophilic/hydrophobic pattern for optimal performance and durability to be conducted.

Acknowledgement

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