

Introduction

We apply drop-on-demand inkjet printing to fabricate proton exchange membranes for polymer electrolyte fuel cells.^[1] A Nafion® dispersion is directly deposited onto the catalyst layers of anode and cathode gas diffusion electrodes (DDM). This approach completely substitutes the use of a conventional membrane foil, as used in state-of-the-art CCMs.

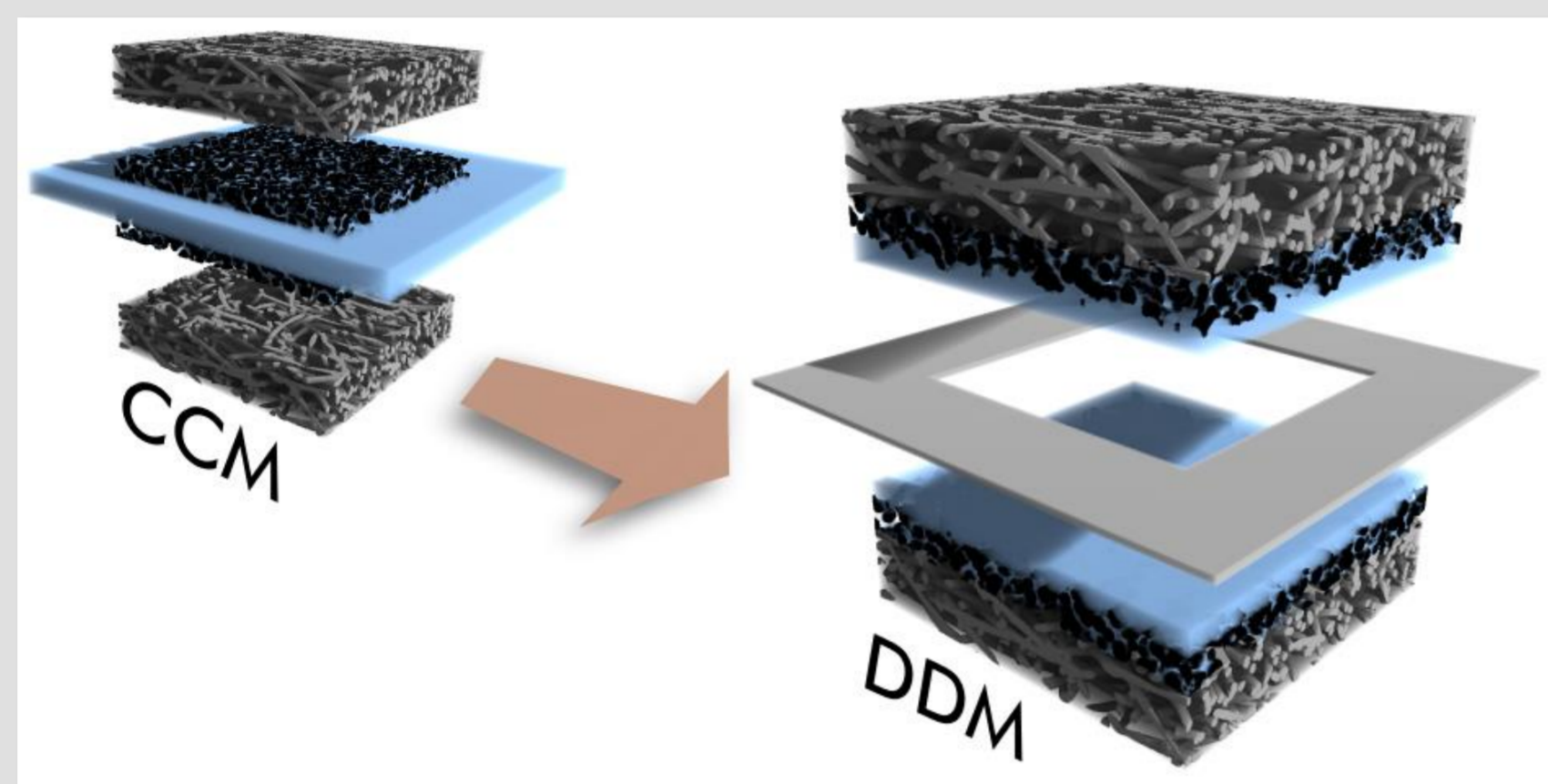


Figure 1: Gas diffusion electrodes are directly coated with a Nafion® dispersion to form the membrane layer. This completely substitutes a conventional membrane foil, as used in CCMs.

Fuel cells constructed this way reveal thin and stable membrane layers (9-12 μm), without compromising fuel crossover, and an optimized interfacial proton resistance. This enables a high and robust cell performance under various operation conditions.

Results & Discussion

Low platinum loading

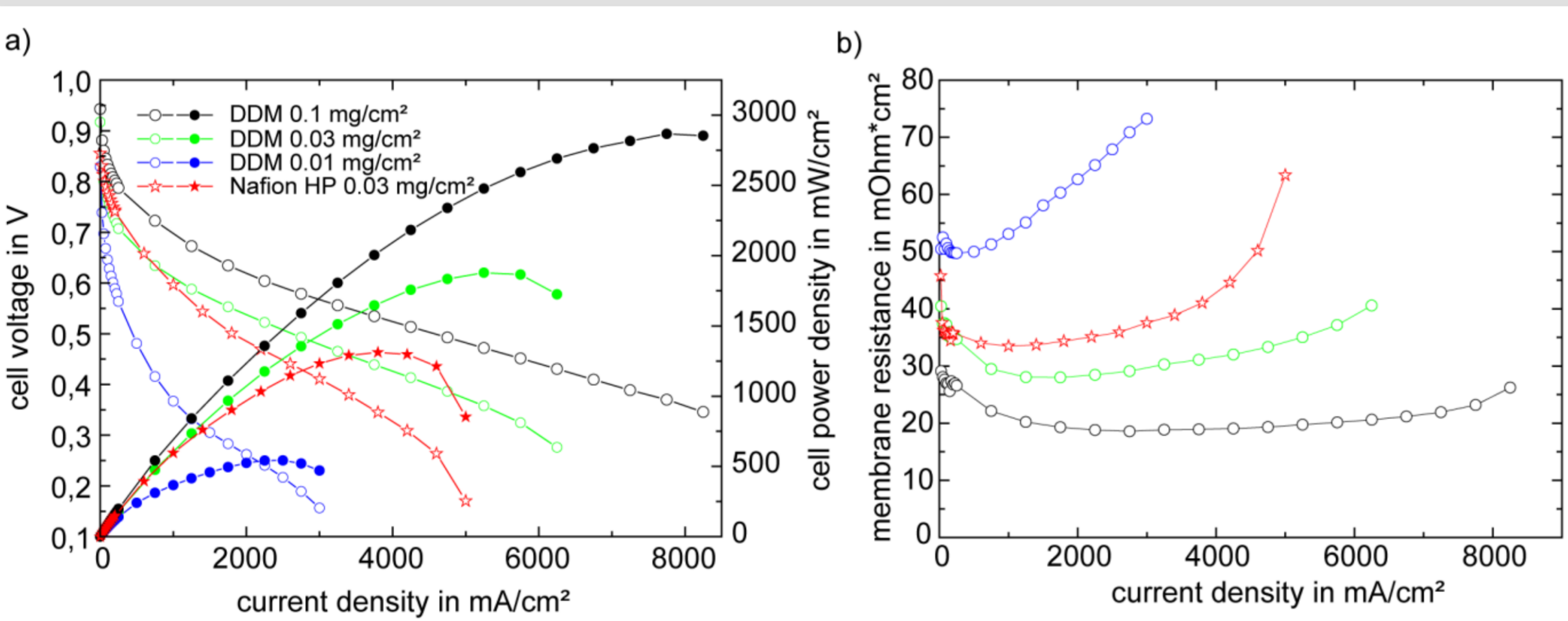


Figure 2: DDM fuel cells are able to compensate for higher kinetic losses originating from lower platinum loadings.^[2] An optimized platinum utilization is reached at 0.03 mgPt/cm² on each anode and cathode electrode, reaching up to a power density of 60 kW/gPt. (0.5/0.5 l/min, H₂/O₂, 80 °C, 95 % RH, 300/300 kPa_{abs}.)

Low reactant gas humidification

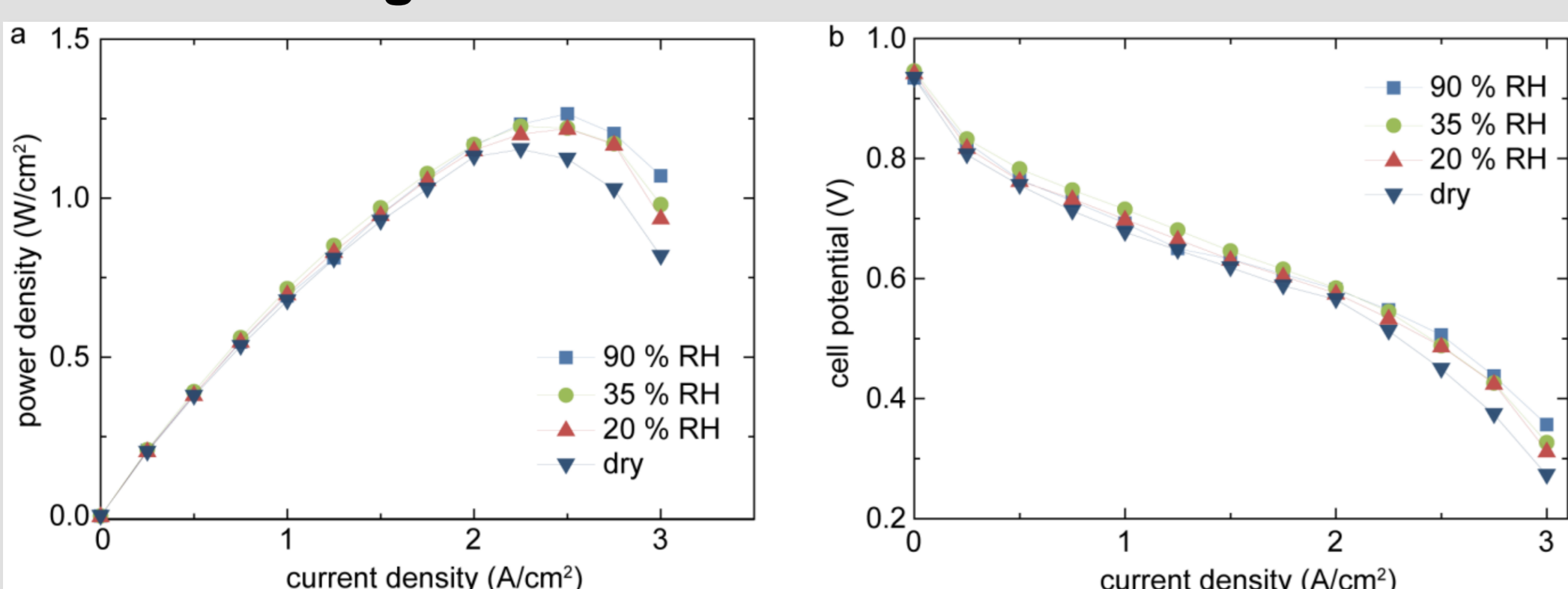


Figure 3: The lower membrane thickness of a DDM fuel cell in comparison to conventional membranes promotes a stronger back-diffusion of cathode water and therefore sufficient membrane humidification even without external feed gas humidification.^[1] (1.2/2.0 stoichiometric ratio, H₂/air, 70 °C, 300/300 kPa_{abs}.)

Elevated operation temperatures – MT PEMFC

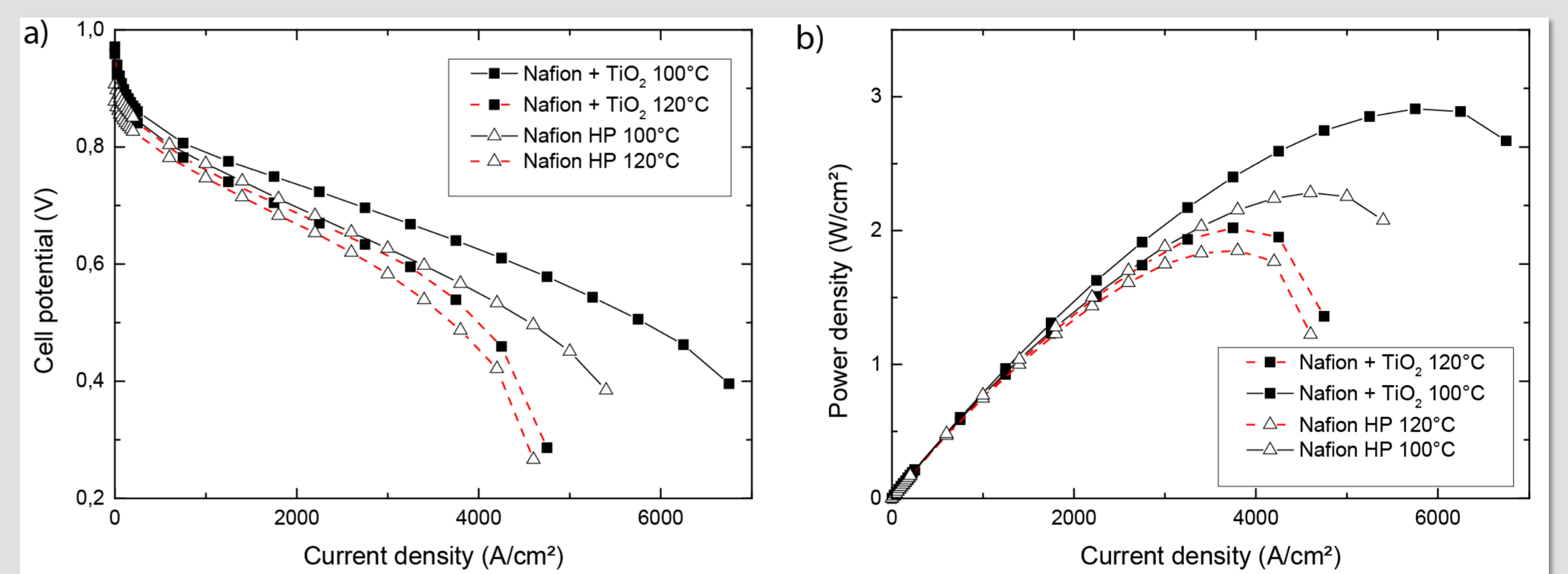


Figure 4: By adding TiO₂ nanoparticles to the membrane ink formulation, the membrane layer of a DDM fuel cell is stabilized for elevated operation conditions up to 120 °C, and outperforms the power density of a CCM fuel cell on Nafion® HP basis.^[3] (0.5/0.5 l/min, H₂/O₂, 90% RH, 300/300 kPa_{abs}.)

Chemical and mechanical stress

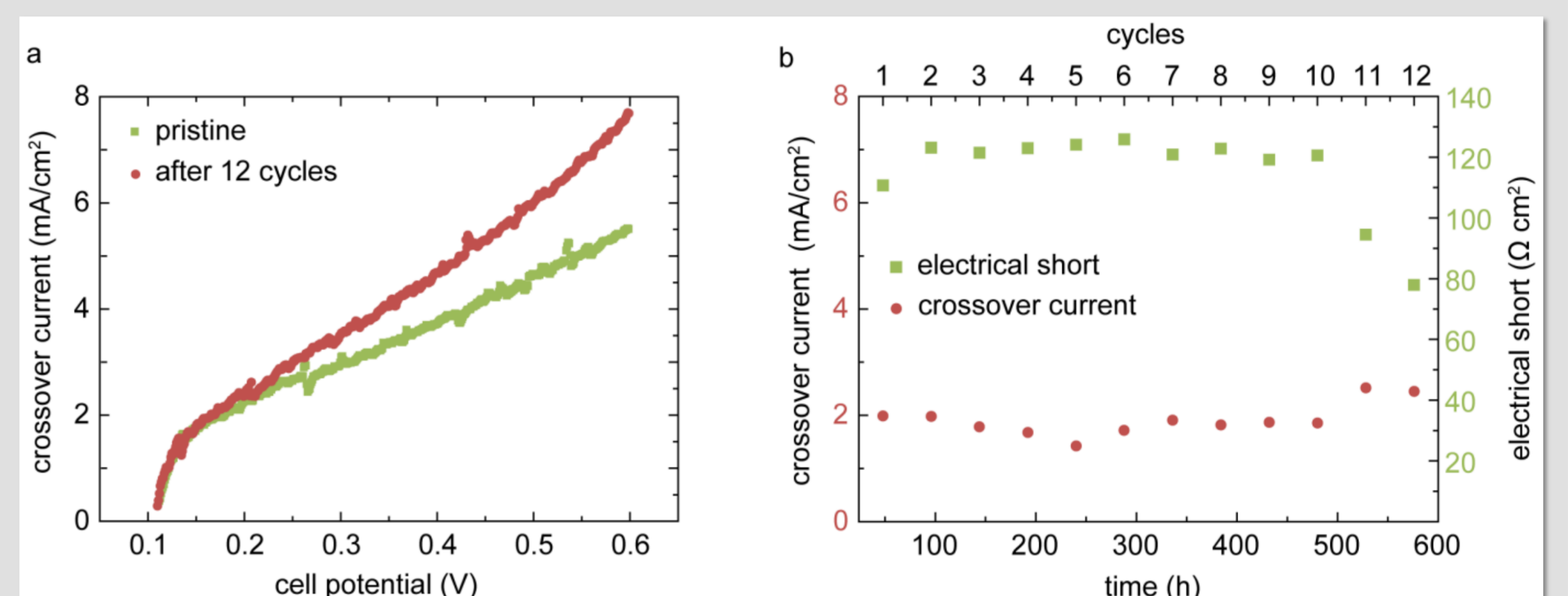


Figure 5: To show the robustness of the directly deposited membrane, a combined chemical and mechanical AST was performed. One AST cycle consisted of 24h load cycling and 24 RH cycling. After 12 cycles the membrane shows first effects of internal shorting but still provides good gas impermeability.^[1] This indicates a promising long-term stability of directly deposited membranes.

Conclusion

In previous work we have shown that fuel cells constructed with direct membrane deposition outperform conventional catalyst coated membranes in terms of power density.^[1] This is mainly due to a thinner membrane and improved interfacial resistance of membrane and catalyst layer. Furthermore, we show that fuel cells with directly deposited membranes are robust in performance under low reactant gas humidification, sluggish kinetics or elevated operation temperatures

Acknowledgements

This work was funded within the project “GECKO” (grant number: 03SF0454C). The authors want to thank Lukas Zielke for help with the graphical artwork.

References

- [1] Klingele, M., Breitwieser, M., Zengerle, R., & Thiele, S. (2015), *Journal of Materials Chemistry A*, 3(21), 11239-11245.
- [2] Breitwieser, M., Klingele, M., Zengerle, R., & Thiele, S. (2015), *Submitted and to be published*.
- [3] Wehkamp, N., Breitwieser, M., Büchler, A., Klingele, M., Zengerle, R., & Thiele, S. (2015), *Submitted and to be published*.