The optimal electrode hole size for zero-gap alkaline water electrolysis

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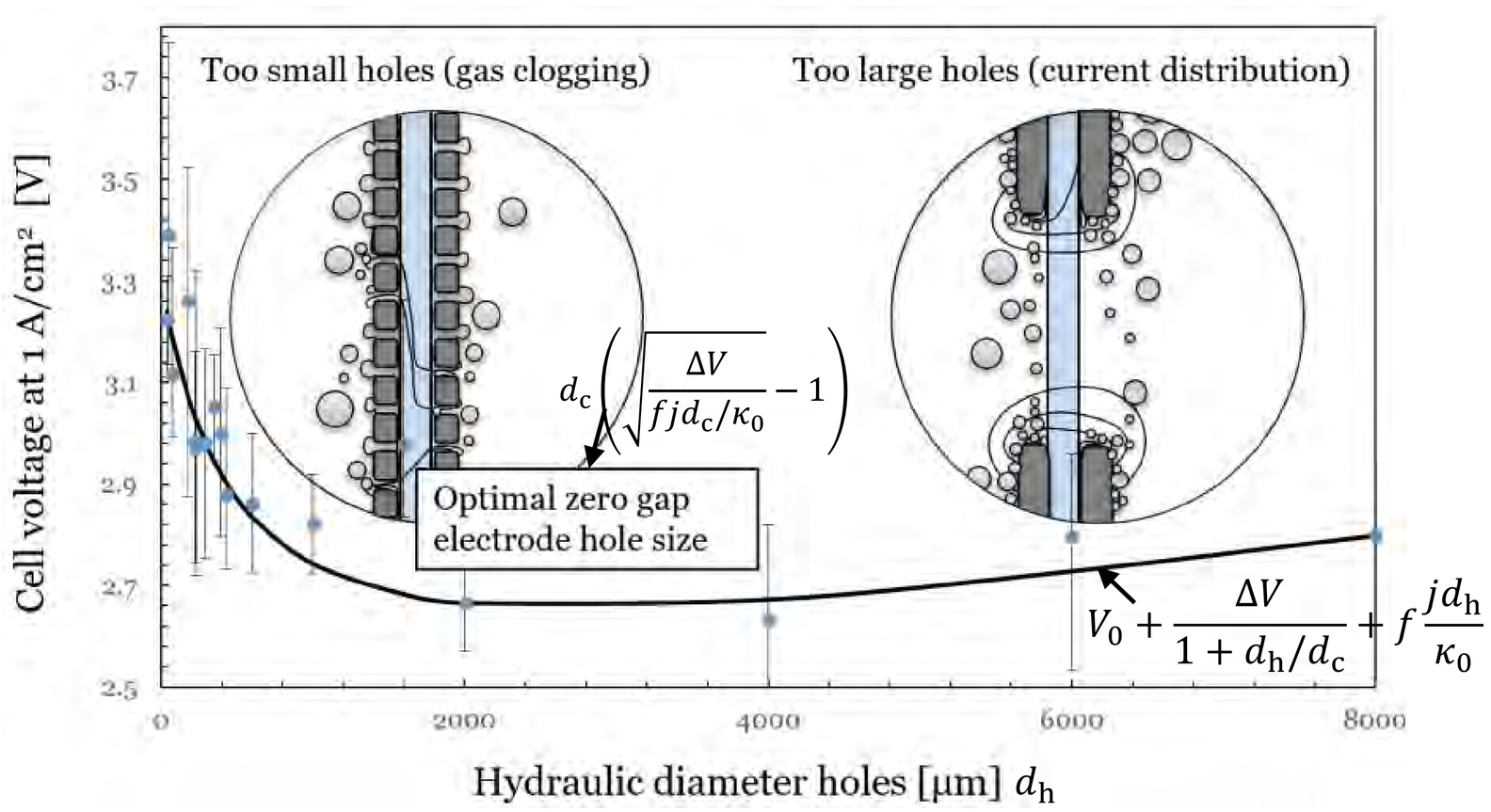
In zero-gap alkaline water electrolysis, electrode holes are needed to evacuate gas bubbles. Despite its extensive use, design criteria for these holes are lacking. We performed an extensive experimental campaign using 18 different hole sizes in various shapes, using Nickel in 30 w% KOH at 80 °C. We find a clear optimum showing that the holes should be neither too small, nor too large.



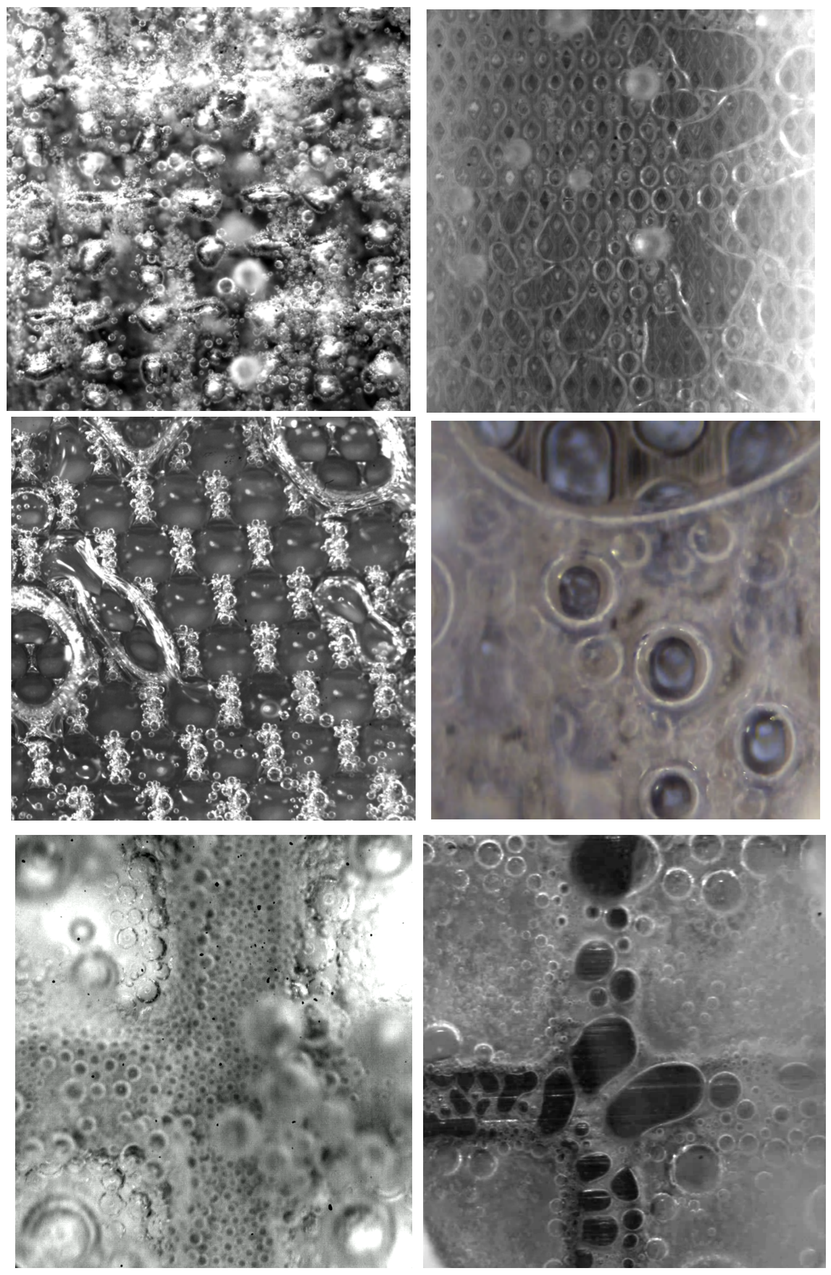
Why not too small?

We found [1] that for hydraulic hole diameters d_h of the order fo, or smaller than, a characteristic size $d_c \approx 0.5$ mm, a large, mostly resistive, overpotential arises ΔV reaching almost 1 V at 1 A/cm^2. In the same range of hole diameters, equal to several bubble diameters, we visually observed a significant fraction of the holes to fully clog with bubbles. By observing *through* a transparent membrane, we see that large parts of the electrode facing the membrane become inactivated by a gas film.

For electrodes with $d_h \sim 1$ mm, we find that the resistance from anode to cathode, as measured by reference electrodes, attains the expected membrane resistance of $\sim 0.1\ \Omega\ \mathrm{cm}^2$. However, for both smaller and larger sizes, a much larger resistance is obtained. Our interpretation of this is that in both cases, the reaction takes place primary inside the electrode holes and the outside of the electrode, instead of at the electrode front. This leads to much larger ion transport paths, explaining the decrease in performance.

back

Front (through membrane!)



Why not too large?

Already in in the 1980s , Nishiki *et al.* performed simulations of a near zero-gap electrode [2], showing that an additional resistive component arises that increases with increasing hole diameter. The reason is a current distribution that becomes increasingly inhomogeneous as the holes are spaced further apart. To agree with these simulations, requires a unrealistically high gas fraction above 80%. However, the partial inactivity of the electrode front, not included in these simulations also leads to an additional increase in resistance.

Finally, to combine a large surface area with good gas evacuation properties, we took the worst performing electrode with very small holes and perforated it with large holes. In this way, by *decreasing* the amount of reactive electrode material, we found that the performance *increased!*

Conclusions

Too large holes give rise to inhomogeneous current distributions, while too small holes tend to clog with bubbles, also leading to an inactive electrode front, and inhomogeneous current distributions. While the optimal hole size is found to be in the millimeter range, such large holes may effectively be combined with smaller holes or porous materials to further increase reactive surface area.

[1] J.W. Haverkort, A.S. Aghdam, E.J.B. Craye, Int. J. Hydrogen Energy, *in press*
2] Y. Nishiki, K. Aoki, K. Tokuda, and H. Matsuda. J. Applied Electrochem., 17:67–76, 198

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