Interplay between structure and electrocatalytic activity in flow-engineered three-dimensional porous transport electrodes for alkaline water electrolysis

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The bottleneck challenge consisting in the intensification of alkaline water electrolysis can be narrowed down to two components of the overpotential. Activation losses are the most obvious ones, but it often hides the relevance of ohmic losses, especially at industrially relevant current densities. We recently showed that PEM-like performance can be reached in alkaline water electrolysis by using flow-engineered 3D electrodes [1]. Under forced upstream electrolyte flow, these laterally-graded structures generate a high velocity field normal to and away from the diaphragm, resulting in a significantly enhanced bubble removal efficiency and the lowest ohmic losses reported in the literature.

In the present work, we take the concept further by tuning the structure of these porous transport electrodes (PTEs) and by using highly active coatings. While the electrochemical testing is performed in a home-built setup dedicated to studying the effect of a high forced upstream electrolyte flow, CFD simulations are conducted in parallel, using explicit representations of the porous transport electrodes obtained by micro-computed X-ray tomography.

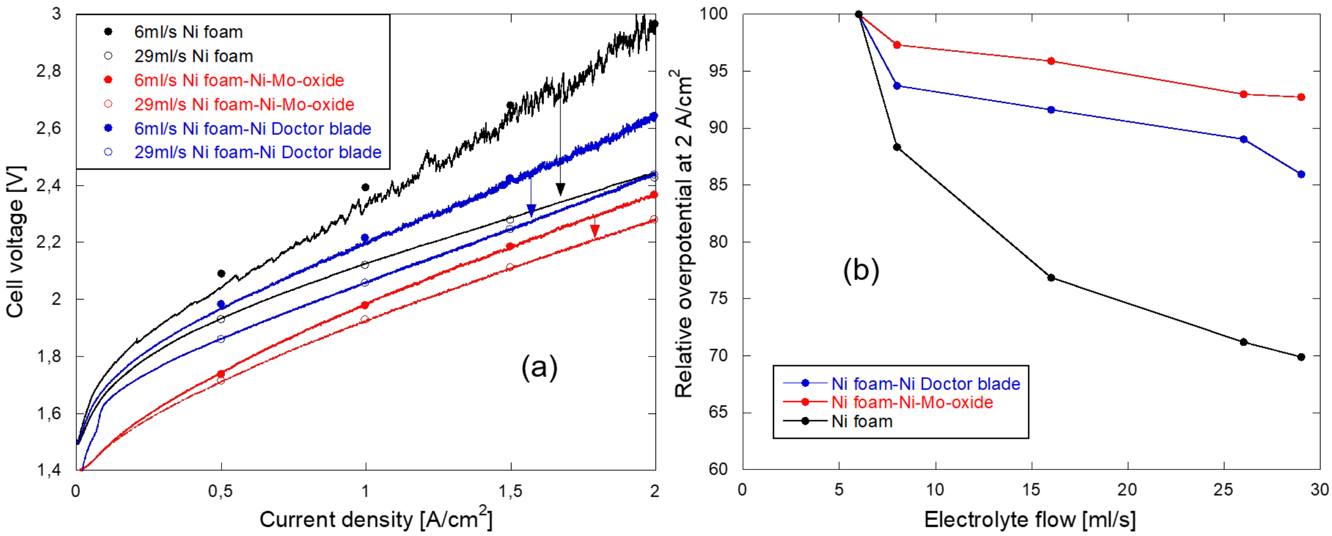

Figure 1 (a) Polarisation curves (lines) and averaged galvanostatic steps (dots) performed on lab-scale cells (4 cm^2 electrodes, 6 mm thickness, 30 wt.% KOH, 80°C) and (b) corresponding relative overpotential decrease with flow (with respect to cell voltage at minimum flow). Black dataset: Ni foam, 3 mm pore size (2 layers). Blue dataset: Ni foam, 3 mm pore size (2 layers, one being coated). Red dataset: Ni foam, 3 mm pore size (1 layer) and Ni foam, 450 µm pore size (1 coated layer)

The interplay between structure and activity is illustrated in Fig. 1, where 3D foam Ni electrodes show very different behaviours under forced electrolyte flow with and without the addition of catalytic coatings. The flow sensitivity of the bare foam is the highest (Fig. 1b), but this is mostly because at low flow and high current, bubble entrapment in this case becomes more critical. The coated foams, on the other hand, show lower cell voltages at all flows (Fig. 1a), still combined with substantial flow sensitivities. Therefore, a performance breakthrough is to be obtained by improving both PTE structure and activity at the same time.

[1] F. Rocha, C. Georgiadis, K. Van Droogenbroek, R. Delmelle, X. Pinon, G. Pyka, G. Kerckhofs, F. Egert, F. Razmjooei, S.A. Ansar, S. Mitsushima and J. Proost (2024), Nature Communications 15 7444, DOI 10.1038/s41467-024-51704-z.