Electrochemical process intensification of hydrogen production using 3-D electrodes

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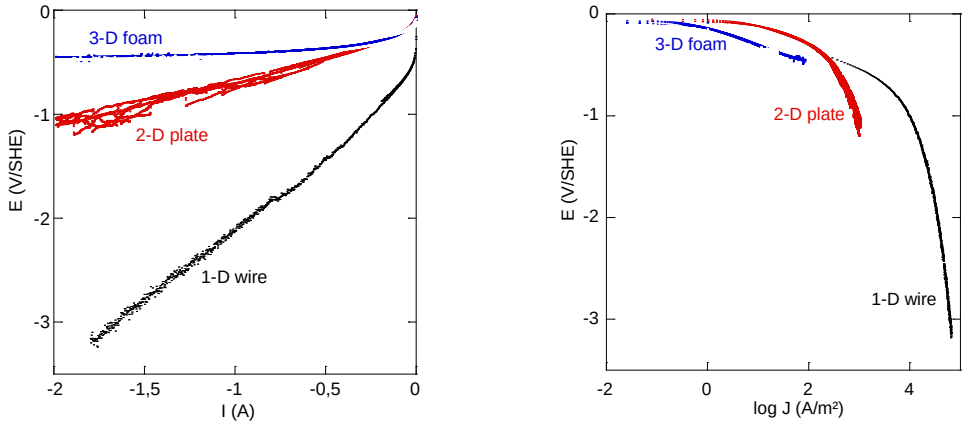
Hydrogen has become now a well-accepted energy vector to store electricity produced by intermittent sources, such as solar panels and wind turbines. The current work focuses on a most simple way to increase the efficiency of conventional water electrolysers by the use of porous, 3-D electrodes. These have been shown to allow for a reduction in cathodic overpotential, while at the same improving the intrinsic mass transfer characteristics of a conventional 2-D electrochemical cell [1]. As a result, both the energy requirement and the technological cost of water electrolysers can be significantly reduced.
Water electrolysis was performed in both acid and alcaline electrolytes, using a commercial filter-press cell in flow-by mode. Commercial Ni cathodes with different geometries were compared, including 1-D wires, 2-D plates and 3-D foams (30, 60 and 100 ppi).
A typical result is shown in the figure below, both in linear coordinates (a, left) as on a semi-logarithmic scale (right). First of all, according to the electrokinetic Butler-Volmer equation, a higher current density requires a higher overpotential. Therefore, since for the same applied current the current density decreases with increasing electrode area, it can be seen in Fig. (a) that the required overpotential to drive the macroscopic current is lowest for the 3-D electrode. Moreover, Fig. (b) also shows a sharp increase (in absolute value) of the measured potential for the wire and plate electrodes. This is indicative of the appearance of a limiting current, associated with mass transfer limitations for the hydrogen evolution reaction at these 1-D and 2-D electrodes. No such limitation is observed for the 3-D foam electrodes, meaning that mass transfert becomes only an issue at still higher current densities.



Recorded cathode potential as a function of imposed current in linear coordinates (a, left), and as a function of current density on a semi-logarithmic scale (b, right).

[1] Q. de Radiguès, P.-Y. Sévar, R. Santoro, F. Van Wonterghem and J. Proost, *Industrial & Engineering Chemistry Research* 51 (2012) 14229–14235.