USE OF METALLIC FOAMS IN ELECTROCHEMICAL REACTORS
OF FILTER-PRESS TYPE: MASS TRANSFER AND FLOW
VISUALIZATION

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ABSTRACT

This article deals with the study of a filter-press type electrolyser (ElectroSynCell of ElectroCell AB) with an undivided configuration obtained by replacing, for the working electrode, the usual inert turbulence promoter by a three-dimensional nickel foam electrode. The mass transfer rates are investigated at the working electrode and at the counter-electrode, which consists of a plane plate covered by a plastic net. The measured mass transfer coefficients are discussed with respect to the available literature data.

The different residence time distribution (R.T.D.) behaviours of the tested configurations (empty channel, channel with plastic nets, channel filled with metallic foam) are explained by use of a visualization technique in the reaction zone.

INTRODUCTION

Optimising filter-press type electrolysers is of major importance in electrochemistry. Electrolytic treatment of dilute solutions or recycling of ionic mediators used in indirect electrosynthesis requires cells characterized by high mass transfer rates, large specific surface areas and small pressure losses¹,². Recently, three-dimensional electrodes such as reticulated media, expanded metals or fine mesh grids have been widely tested and used in filter-press type cells. The knowledge of structure of, flow in, and mass transfer to three-dimensional electrodes is insufficient to predict their performances in electrolysers. Previous work has outlined the importance of cell design, i.e. electrode dimensions, inlet and outlet areas. Then, experiment is a necessary step. The main purpose of the present study is to test an undivided configuration, consisting of a three-dimensional electrode coupled with a plane plate electrode, in the ElectroSyncell of Electrocell AB.
Membrane-partitioned configurations are generally preferred to undivided ones because they allow a large range of applications including electrodialysis. Working in the undivided mode is, for the instance, limited to simple ionic reactions involved in recycling operations; its advantage consists in using a single hydraulic circuit. This paper focuses on mass transfer and flow visualization in the reaction zone.

MASS TRANSFER

Scope of the study

This work aims at quantifying mass transfer to the two electrodes of a representative unit cell (R.U.C.) without a membrane. Its principle is based on the imbalance between the surface areas of the electrodes. The working electrode consists of a plane plate with a sheet of foam and the counter-electrode consists of a plane plate with a plastic net turbulence promoter. The ratio of their surface areas is equal to 15.

In the reaction zone, the flow is limited to a single channel. As shown previously\(^3\), the residence time distribution in a R.U.C. consisting of plane plates with sheets of foam is radically different from that occurring in a R.U.C. consisting of plane plates with classical turbulence promoters.

In the literature dealing with mass transfer in filter-press type electrochemical cells, two groups of studies can be distinguished:
- those concerning mass transfer to plane plates with turbulence promoters or mass transfer to three-dimensional electrodes made of turbulence promoter type materials (expanded metals, fine mesh grids...),
- those concerning mass transfer to reticulated media: metallic foams, reticulated vitreous carbon (R.V.C.) foams, graphite foams.

Advantages and drawbacks of using turbulence promoter type materials or reticulated media have already been discussed\(^2,4,5\). The best ratio of specific surface area to generated pressure losses is given by reticulated media whereas turbulence promoters are reputed to enhance mass transfer coefficient and to give a uniform current distribution. To our knowledge, only one study deals with current distribution in metallic foams\(^6\), but the undivided mode was not tested. With the presently studied configuration, a comparison of mass transfer correlations obtained at each electrode with previous data from the literature may indicate a possible interaction between the turbulence promoter and the three-dimensional electrode.

Experimental details

The Electrosyncell is provided with a single R.U.C.. The working electrode consists of a 2.5 mm thickness sheet of foam (grade: 60 pores per pouce, porosity \(\varepsilon = 0.98\), specific surface area per volume of electrode \(A = 6400 \text{ m}^{-1}\)) bonded to a plane plate. The counter-electrode is a nickel plate covered with a polymeric net from Electrocell AB (diamond mesh, \(\varepsilon = 0.89\)). The length of the reaction zone is 0.28 m, the cross sectional area for the electrolyte flow is 5x140 mm.

The mass transfer coefficient between the liquid and the electrode is obtained using the cathodic reduction of ferricyanide ions to ferrocyanide ions. The limiting diffusion current, \(I\), is measured as a function of the flow rate \(Q_V\). The procedure consists in cleaning the electrodes in situ with a 0.1 M solution of sulphuric acid and in cathodically activating the working electrode in a 0.5 M solution of sodium hydroxide (a current of 5 A is applied for one hour). Then, the electrolyte, a mixture of \(10^{-3} \text{ M K}_3\text{Fe(CN)}_6\) and \(0.1 \text{ M K}_4\text{Fe(Cn)}_6\) in 0.5 M NaOH, is introduced to the cell and continuously recirculated at 30\(^\circ\)C.