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New separation hybrid membrane cells applied to ultrafiltration processes

S.I.S. Pinto*, J.M. Miranda, J.B.L.M. Campos
University of Porto, Portugal

Membrane separation processes, such as macromolecules separation by ultrafiltration, have been intensively used in diverse fields as food industry and biotechnology. Several techniques have been explored to increase the efficiency of the separation of two macromolecules by ultrafiltration, which is strongly affected by concentration polarization of the layer over the membrane surface. Several methods have been proposed in the literature to reduce this concentration polarization, such as: Dean vortices [1], oscillatory flows [2], flow enhanced by Taylor bubbles [3], turbulence promoters [4] and backflushing [5]. Hybrid Membrane Cell (HMC) is a new type of membrane cell that was conceptualized in our research group (CEFT), having in mind similar effects. The starting point was the separation of one solute from its solvent through a HMC [6] – cell with two types of membranes, i.e. different porosities, alternating in juxtaposition along the cell; semi-permeable membranes only permeable to the solvent and fully permeable membranes permeable to the solute and to the solvent – Figure 1. With this configuration of the hybrid cell, it was observed a reduction of the concentration polarization phenomena and an increase of the separation [6].

The present work reports all the numerical (CFD) study done by the research group concerning HMC. Four types of HMC were explored: Type A - HMC combined with differential diffusion of the components [7]; Type B - selective HMC [8]; Type C - HMC with electric interactions membrane-components and, simultaneously, with differential diffusion of the components [9]; and Type D - selective HMC with electric interactions membrane-components.

Firstly, the potential of a HMC combined with differential diffusion of two macromolecules (Type A) was studied [7]. This type of HMC is composed by several membrane sections where each one has a semi-permeable membrane (only permeable to the solvent) and a fully permeable membrane (permeable to the solutes and to the solvent), alternating along the cell. The feed stream is separated into three streams: a retentate stream, a solvent stream, which crosses the semi-permeable membranes, and a concentrate stream which crosses the fully permeable membranes – Figure 1. The purity and recovery of the solute with lower diffusivity in the fully permeable sub-sections (concentrated stream) show the potential of this new fractionation process. Shortly, the purity increases with the solvent stream velocity, decreases with the concentrate stream velocity and increases with the number of sections of the HMC. The recovery increases with the solvent stream velocity and also with the concentrate stream velocity [7].

Afterwards, the potential of the selective HMC - Type B was explored by CFD [8]. This type of HMC is also composed by several membrane sections in series. Each membrane section has a semi-permeable sub-section selective to the solutes and permeable to the solvent and a fully-permeable sub-section totally permeable to the solutes and to the solvent. The apparent selectivity of the separation of two macromolecules was determined. The results show that the fully permeable membranes contribute to the cleaning of the mass boundary layer over the semi-permeable membranes, reducing concentration polarization and transmission of the components. Consequently, for a range of high transmembrane pressure, where a conventional cell polarizes, the apparent selectivity through the semi-permeable membranes increases when

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a HMC is used. This selectivity increases for increasing velocity of the concentrate stream and number of sections of the HMC [8].

The potential of a HMC with electric interactions membrane-components and, simultaneously, with differential diffusion of the components (Type C) was also analyzed by CFD [9]. This HMC is composed by several membrane sections, where each section has an electrically charged semi-permeable sub-section (permeable to the solvent and impermeable to the solutes) and a neutral fully permeable sub-section (permeable to the solvent and to the solutes). The numerical results were compared with those obtained in a neutral HMC. By selecting semi-permeable membranes with the same charge of the macromolecules with higher diffusivity, these macromolecules move away further from the membrane, while those with lower diffusivity approach, further. However, due to interactions between the electric and concentration fields in the region crossed by the streamlines of the concentrate stream, the separation in the fully permeable membrane is reduced [9].

Lastly, the fourth type of HMC is composed by electrically charged semi-permeable membranes, permeable to the solvent and partially permeable to the solutes, and electrically charged fully permeable membranes (Type D). The apparent selectivity of the new fractionation process combining selective hybrid membrane cells with electric interactions between membrane and components was studied. The results were compared with those using a conventional cell (CC). The apparent selectivity of the separation has a significant increase when electric interactions between membrane and solutes are considered. Moreover, the depolarization phenomenon promoted by the electric interactions is much more pronounced than that due to the specific configuration of the HMC.

Separation of two macromolecules in an ionic solution through a HMC has high potential, unless electric interactions between membrane-components are relevant. When they are relevant, the effect of the electric interactions overlaps the effect of the specific configuration of the HMC, i.e, the depolarization is mainly due to electric effects.

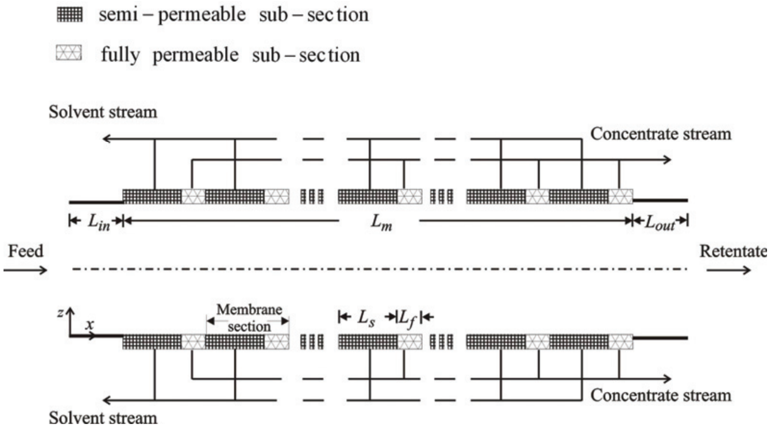

Figure 1 – Hybrid Membrane Cell with semi and fully permeable sub-sections.

References

[1] J. Kaur, G.P. Agarwal, Studies on protein transmission in thin channel flow module: the role of dean vortices for improving mass transfer, Journal of Membrane Science 196 (2002) 1-11.

[2] W. Wang, C.D. Bertram, D.E.Wiley, Effects of collapsible-tube-induced pulsation vigour on membrane filtration performance, Journal of Membrane Science 288 (2007) 298-306.

[3] R. Ghosh, Q. Li, Z. Cui, Fractionation of BSA and lysozyme using ultrafiltration: Effect of gas sparging, AIChE Journal 44 (1998) 61-67.

[4] S. Poyen, F. Quemeneur, B. Baroiu, M. Desille, Improvement of the flux of permeate in ultrafiltration by turbulence promoters, International Chemical Engineering 27 (1987) 441.

[5] J. Levesley, M. Hoare, The effect of high frequency backflushing on the microfiltration of yeast homogenate suspensions for the recovery of soluble proteins, Journal of Membrane Science 158 (1999) 29-39.

[6] J.M. Miranda, J.B.L.M. Campos, Numerical study of a hybrid membrane cell with semi and fully permeable membrane sub-sections, Chemical Engineering Science 62 (2007) 1215-1229.

[7] S.I.S. Pinto, T.M.G.T. Rocha, J.M. Miranda, J.B.L.M. Campos, A new membrane fractionation process based on the combination of hybrid membrane cells and differential diffusion of two solutes, Desalination 241 (2009) 372-387.

[8] S.I.S. Pinto, J.M. Miranda, J.B.L.M. Campos, Use of hybrid membrane cells to improve the apparent selectivity in the fractionation of two components: computational fluid dynamics study, Industrial Engineering Chemistry Research 49 (2010) 9978-9987.

[9] S.I.S. Pinto, J.M. Miranda, J.B.L.M. Campos, Interactions between the electric and concentration fields in the fractionation of two macromolecules using a hybrid membrane cell – CFD study, Desalination and Water Treatment 35 (2011) 209-221.

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