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Electrokinetic characterization of the Al_2O_3 ceramic MF membrane by streaming potential measurements

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Abstract

The alumina microfiltration(MF) membrane was modified with nanocrystalline TiO_2 in the pore wall. The electrokinetic properties of unmodified and modified alumina membranes were characterized by streaming potential measurements during tangential filtration at various conditions of pH, ionic concentration and ionic species in solutions. The modified membrane reveals a more acidic characteristic. The influence of pH value on the streaming potential of both membranes is explained by the shifting of the proton equilibrium that occurs at the surface of the membrane. The modification of the alumina membrane with TiO_2 leads to the decrease of its isoelectric point (IEP) from 6.1 to 4.0 when filtered with NaCl solution. The ionic concentration and electrolyte species also have influence on the streaming potential of both membranes. The reversal of the streaming potential sign and the change of the isoelectric point of the membrane when filtered with $CaCl_2$ and Na_2SO_4 solutions show specific adsorption of Ca^{2+} and SO_4^{2-} ions onto the surface.

Keywords: Alumina; Ceramic membrane; Streaming potential; Isoelectric point; Titania

1. Introduction

Ceramic membranes are known to be superior to organic ones in respect of thermal, chemical, and mechanical stability and resistance to microbial degradation [1], and are suitable for application in many fields such as the textile, food and pharmaceutical industries and wastewater recycling [2,3]. The electrokinetic properties of oxide ceramic membranes play a significant role in their separation performances and fouling tendency, since they can exert profound influence on the

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nature and magnitude of the interactions between the membrane and the liquid feed, thus affecting the permeating fluxes of solvent and solute through the membranes pores [4].

The electrokinetic phenomena which occur at the mineral oxide–solution interface are due to the electric charge distribution in the electrochemical double layer. A mineral oxide in contact with an aqueous solution develops an electrical charge on its surface due to amphoteric behavior. The properties of filtration membranes depend on the surface charge and the filtered solutions. The electrokinetic properties of ceramic membranes are commonly studied by electrophoretic mobility [5,6], electroosmosis flow rate [7] and streaming potential measurements [6–10], and the most convenient method to determine the surface charge linked to the zeta potential is the streaming potential (SP) measurements. When an electrolyte solution passes through a porous material by means of applied hydraulic pressure, a streaming potential is created: it is dependent on the pressure difference ΔP. It was measured when the potential difference ΔE reached at the equilibrium. Streaming potential is the slope of the straight line given by $\Delta E = f(\Delta P)$ curves [7,10].

Alumina is one of the most important materials for ceramic membranes and also for membrane supports, and the alumina MF membrane presently is the most widely used ceramic membrane in various separation processes. In our previous work [11], nanocrystalline TiO_2 coating was used for the modification of a disk Al_2O_3 MF membrane with a probable pore size of 0.35 μm, since TiO_2 is an important semiconducting material, and possesses potocatalysis, antibacterial properties and relatively good corrosion resistance in caustic environments [12], which are beneficial to some of the separation applications, such as wastewater treatment, food and pharmaceutical industries. The increment of water permeate flux by more than 19% after being modified with TiO_2 for alumina membranes was observed in dead-end filtration, in spite of the decreasing in pore size and porosity, as is supposed to have resulted from the change of the surface charge of the membrane.

The aim of this work is to characterize the electrokinetic properties of tubular alumina ceramic membranes by streaming potential measurements under different conditions of pH, ionic strength and solution compositions. The influence of modification with nanocrystalline TiO_2 coating on the electrokinetic properties of the membrane is studied.

2. Experimental

2.1. Membranes and preparation of TiO_2 modifying coating

The MF membrane selected is commercially available three-layered α-Al_2O_3 tubes (15 cm length and 10 mm outer diameter for 7 mm inner diameter) which were produced by Pall Exekia, France. The top MF layer of 0.2 μm pore size is deposited in the inner part of the support, giving a 26 cm^2 filtration area.

The TiO_2 coating was deposited on the pore wall of the membrane for modification by the homogeneous co-precipitation method. The process for preparing TiO_2 coating is the same as describe in [10]. The reagents for the preparation of TiO_2 coating were hydrated titanium sulfate ($Ti(SO_4)_2 \cdot 4H_2O$) and urea ($CO(NH_2)_2$) supplied by Shanghai Chemical Reagents Company, China. Titanium sulfate and urea with a mol ratio of 1:4 were mixed in deionized water to obtain a solution containing 0.2 M Ti^{4+}, and then the alumina membrane was fully dipped into this solution for 5 min. After that, the membrane was taken out from the solution and placed in a closed container with saturated water vapor pressure at 85°C and 1 atm. for co-precipitation reaction. Finally, the membrane was dried and heated up to 900°C to form the TiO_2 coating in the pore wall, and thus the alumina membrane modified for once was obtained. Multiple modifying could be done by