Alginic acid-silica hydrogel coatings for the protection of osmotic distillation membranes against wet-out by surface-active agents

J.B. Xu1, D.A. Spiller2, J.P. Bartley1, R.A. Johnson1

1School of Physical and Chemical Sciences, Queensland University of Technology, 2 George St, Brisbane 4001, Australia
2Department of Material Sciences and Chemical Engineering, University of Applied Sciences Offenbach, Germany

Introduction

Previous work in our laboratory has shown that crosslinked sodium alginate and 4:1 sodium alginate-carboxymethylcellulose blend coatings on TFE/PD membrane surfaces provide effective protection against wet-out by surface-active agents [1,2]. However, these coatings have several limitations that may reduce their effectiveness in an industrial plant. These include susceptibility of the biological polymers to microbial attack, low melting points with softening when contaminated by hot cleaning solutions, and poor mechanical strength with possible damage during membrane stretching under pressure.

The objective of the present work was to produce protective alginic acid-siliconized silica and silica gel blends with suitable properties for coating TFE/PD membranes. Silica gel is chemically inert and resistant to microbial attack [3]. It is also known for its good water sorption capability and high melting point (1610 °C). A blend of the hydrophilic coating to the hydrophobic membrane surface was achieved using a calcium surfactant, methyltrimethylammonium bromide (MTMA) as an interfacial bonding agent. In order to create a homogeneous dispersion of silica in the alginic acid matrix and thereby control the degree of silica polymerisation, films were also prepared with the addition of glycerol (10 wt %) to the sodium alginate-sodium silicate mixture because it dispersing [4], plasticising [5] and moisturising [6] properties.

Blend films were characterized using SEM, XRD, DSC, swelling measurements, mechanical strength measurements and duration testing. Coated films were tested for CO performance and resistance to surface-active agents using pure water, lime/rice oil mixtures and sodium dodecylbenzenesulfonate (DBS) detergent solutions.

Experimental

A sodium alginate solution (2.0 wt % as SAG) was prepared by the addition of 13 g NaOH and 8.5 g SAG to 400 mL water. Aliquots (1.5, 3.0, 4.5 or 6.0 mL) of solution were diluted to 30 mL with water, with and without the prior addition of 3 mL glycerol. The diluted solutions were then heated at 45 °C and added to sodium alginate powder (0.5 g). The solution was then transferred to a Femto dish (4 cm diameter) and air-dried for two days. The silica content of the blend films corresponding to the above alginate was 2, 10, 12 and 20 wt % (as SAG) respectively. The film was then immersed for 10 min in a 1:1 ethanol-water solution adjusted to pH 1.5 by HCl addition to form the water-insoluble alginic acid-silica hydrogel.

Membrane coating was affected by the method described above. In this case, however, the blend solution was cast directly onto a TFE/PD membrane (4.5 cm x 4.5 cm) that had been cured by 0.25 mL of 0.33 M MTMA solution.

Results and discussion

SEM images of blend films prepared without glycerol addition showed bumps of aggregated crystalline material (mainly silica) on a continuous background. This was consistent with the occurrence of non-modified sodium acid polymerisation. SEM images of films prepared with glycerol addition generally showed uniform, almost rough surfaces.

The XRD of an alginic acid film and films prepared without glycerol addition showed a sharp peak at 2θ of 13.6° attributable to anhydrous alkali silicate with the intensity of this peak decreasing with increasing silica content. A second, broad peak at about 23° attributable to the polymerization of sodium and was present in all diffractograms. The XRD of alginic acid film and the blend films prepared with glycerol addition showed a sharp peak at 2θ of 13.6° for the alginic acid and a broad peak at 22.5° for the blend films. The marked intensity reduction at absence of the 13.6° peak in the blend films and the presence of a single peak indicated a uniform crystalline structure at all silica concentrations used.

DSC showed a major endothermic peak attributable to the melting point, Tm, at 85 °C for alginic acid. This increased steadily with increasing silica content to 90 °C for the 20 wt % silica film. The heats of fusion of alginic acid and the 5 and 10 wt % silica films were similar, while the 15 and 20 wt % silica films were significantly large. These larger values may have reflected increased silica polymerisation within the alginic acid matrix. DSC curves of films prepared with glycerol addition showed no peaks at temperatures below 250 °C. This observation indicated the presence of glycerol remained in a uniform, more thermally stable structure at all silica concentrations.

Swelling measurements on an alginic acid and blend films prepared without glycerol addition showed that the blend films had similar water sorption characteristics (43-49 wt %) to alginic acid (44-45 wt %). However, those prepared with glycerol addition had markedly larger values (83-92 wt %).

Young's modulus for alginic acid and was shown to be about 3600 times greater than that of the blend film. The alginic acid film could only withstand 7.75 % displacement before breaking compared with greater than 100 % for the blend films. The 10 wt % silica coating gave good protection against membrane wet-out during three six-hour trials using the same membrane. Rapid membrane wet-out occurred when an uncoated membrane was contaminated by 0.2 wt % orange oil feed. The film for feed-solvent mix using a coated membrane was approximately one-half that for pure water. This was attributed to concentration polarization and fouling by hydrophilic and amphiphilic ink components.

Conclusions

Alginic acid-silica hydrogel composite coatings on TFE/PD membranes have been shown to have the properties required of OD membranes and provide protection against wet-out by surface-active materials.

References