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The Application of Polypropylene Membranes for Membrane Distillation

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Abstract

Microporous hydrophobic membranes are applied in membrane distillation. During a long-term of module exploitation, a part of the pores is filled by water, and the membrane wetting causes that the industrial implementation of this process is hindered. Several investigators achieved promising results using the polypropylene membranes formed via TIPS method for various applications of membrane distillation.

Keywords: Membrane distillation; Polypropylene membrane; Hydrophobic membrane

Abbreviations: MD: Membrane Distillation; PTFE: Polytetrafluoroethylene; PP: Polypropylene PE: Polyethylene; TIPS: Thermally Induced Phase Separation

Introduction

Membrane distillation (MD) is an evaporation process of water through non-wetted porous membranes. In this process the salts and other non-volatile compounds present in the feed water are retained and the quality of produced distillate is close to distilled water [1-4]. The results of studies presented in the literature indicate that the MD process is not only an effective method for water desalination [1-3, 5], but also can be applied for wastewater treatment, especially when the salts concentration is high [3,6,7].

A huge amount of energy is required for water evaporation; thus, a good thermal efficiency is important for industrial implementation of the MD process [7,8]. The capillary MD modules allowed to obtain the thermal efficiency at a level of 70-80% [9]. Moreover, as MD can be operated with low-grade heat, the coupling of MD with waste energy makes the MD process very attractive [8,10].

The porous hydrophobic membranes are assembled in the membrane modules and the membrane wetting is the major problem of MD process [1-3]. The membrane wettability may be accelerated by scaling and fouling [2,3]. The possibility of NaCl solutions concentration in the MD process up to the saturation state has been already demonstrated many times for different types of the hydrophobic membranes [3,10,11]. However, during the separation of actual brines, which contain besides NaCl also hardly soluble salts, a serious problem is scaling (precipitation e.g. $CaCO_3$ and $CaSO_4$) [2,12,13]. Therefore, the high salt concentrations in the feed water (scaling) may restrict e.g. the fresh water production from brines [2,3,12]. For this reason, the number of works presenting the preparation of MD membranes with enhanced resistance to wetting has significantly grown [7,11,14-16]. However, the performance and durability of these membranes is most often tested over a period of below 10-50h, hence, the MD process has been used so far on the pilot scale for desalination with utilization of the traditional membranes made of polytetrafluoroethylene (PTFE), polypropylene (PP) and polyethylene (PE) [1,5,9,17].

A promising method to mitigate fouling and scaling intensity is the application of low feed temperature [12], however, a large membrane area should be used in order to achieve a high efficiency of the installation [18]. Thus, the realization of industrial implementation requires the membranes as cheap as possible, namely, manufactured by a simple method from inexpensive raw materials [11,19]. Such conditions are fulfilled by the capillary membranes produced from polypropylene by a TIPS method [3,20]. The TIPS process parameters and the diluents type and its concentration in the initial polymer/diluents system affected considerably the phase separation behaviors and the final membrane microstructure for PP membranes [21,22]. The PP membranes manufactured in the industrial

installation were presented in Figure 1. The small increase (from 30 to 35wt%) of PP concentration in the casting solution caused significant changes in the pores structures. This showed while such a different membrane morphology is obtaining during the PP membranes preparation via TIPS method [20-22]. For this reason, only a few kinds of membranes produced from PP are appropriate for the MD process (e.g. Accurel PP [2,9,16,23]).

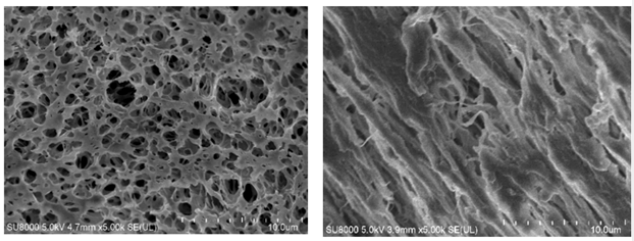

Figure 1: SEM mages surface of PP membrane formed via TIPS method. Effect of the polymer concentration in the casting solution.

The promising results were achieved using PP membranes for various applications of MD process [2,9,24]. A disadvantage of the PP membranes is a formation of the hydrophilic groups on their surface during MD [22]; as a result, the membrane surface was wetted after 40-50h of MD process operation [2]. However, in spite of a rapid wetting of the surface, the pores were not wetted over the entire membrane cross-section during long-term MD studies, which confirmed that the capillary PP membranes exhibit the excellent resistance to wetting over a period of 2-4 years of MD module exploitation [9,25].

Conclusion

The polypropylene membranes formed via TIPS method can be applied for MD process. However, the membrane morphology is strongly affected by the TIPS conditions. Therefore, not all hydrophobic PP membranes produced for microfiltration process are appropriate for MD. The good results were obtained applying the Accrual PP membranes for MD process.

In the pilot scale studies of seawater desalination, an intensive scaling caused the need to replace the membrane modules after several months of operation [21]. Although the scaling can be limited by lowering the feed temperature below 50 ˚C, but the operational efficiency will be several times lower [12]. In this case it is necessary to increase the membrane area in the installation, hence, the application of cheap membranes such as the proposed capillary PP membranes allows to reduce the production costs.

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