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Editorial

Special Issue: New Challenges in Thin-Film Nanocomposite Membranes

Jochen Meier-Haack *

Department Processing Technology, Leibniz-Institut für Polymerforschung Dresden e. V., 01069 Dresden, Germany

Rapid population growth and the associated rise in industrialization and food production have resulted in a tremendously increased demand for clean water. Thin-film composite (TFC) membranes have become an important technique in producing and supplying clean water from different resources, such as sea water, brackish water or contaminated fresh water, by reverse osmosis (RO) or nanofiltration (NF). Additionally, forward osmosis (FO) is an emerging technology for water and food processing wherein TFC membranes are used. While RO and NF are pressure-driven separation processes, a salinity gradient is the driving force for water flux in forward osmosis. FO has great potential as a pretreatment step in RO by diluting the feed water and thus reducing the osmotic pressure and consequently the energy demand of the whole process. The active separation layer of these types of membranes, which typically consists of a highly cross-linked polyamide prepared via interfacial polymerization, is susceptible to fouling and degradation by chlorine [1]. The latter is periodically used for cleaning purposes. Furthermore, TFC membranes show a relatively low productivity and trade-off between water permeability and selectivity. To overcome these drawbacks, the special properties of nanomaterials (NMs)/nanoparticles (NPs) have stimulated significant research on membrane modification in recent decades. A broad variety of NMs/NPs, either inorganic, e.g., carbon-based carbon nanotubes (CNTs), graphene oxide (GO), metal–organic frameworks (MOFs) and metal oxides, metallic (e.g., Ag, Cu) or organic NMs/NPs, such as cellulose or covalent organic frameworks (COFs), have been extensively employed and are the focus of several review articles in the literature [2–5]. These nanomaterials can be incorporated into TFC membranes via several modes, such as (a) incorporation of NMs into the PA layer during the interfacial polymerization step, (b) coating of the PA layer with NMs, (c) modifying the substrate with NMs and (d) preparation of an interlayer from NMs between the substrate and the PA layer [2].

The incorporation of nanoparticles or nanomaterials into the surface of TFC membranes aims to enhance permeate (water) flux, increase the rejection of solutes and mitigate fouling. In particular, CNTs [6] and graphene oxide [7,8] confer higher hydrophilicity on the membrane surface, therefore lowering the fouling tendency accompanied by an increase in water permeability [9]. A similar effect is observed when nanoparticles with a defined pore size, such as silica [10], zeolites [11], MOFs [12], COFs [13], titanate nanotubes (TNTs) [14] or halloysite nanotubes (HNTs) [15], a naturally occurring mineral clay, are used for membrane modification.

While the nanomaterials mentioned above can be considered passive in terms of bactericidal properties, the bactericidal activity of metals such as silver or metal oxides, including TiO_2 [16], CuO [17] and ZnO [18], arises from the formation of reactive oxygen species upon irradiation with light (TiO_2), the application of mechanical disruptive stress to the cell walls of bacteria or by releasing metal ions (Ag, Cu) [19,20]. In addition, the incorporation of nanomaterials into the active separation layer may affect the polymerization process and the polymer network arrangement, thus impacting the permeate flux and solute rejection [21].

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To achieve high efficacy, on the one hand, the right nanoparticles must be chosen. On the other hand, such nanoparticles must be properly incorporated into the active layer or on the surface of the active separation layer. In addition, the stability of the composites and environmental aspects such as toxicity must be considered when preparing new thin-film nanocomposite membranes [22–24].

Although remarkable progress in the development of thin-film nanocomposite membranes has been achieved in the past, as outlined by a huge number of publications, there are still open questions and new developments in this field of research. This Special Issue on "New Challenges in Thin-Film Nanocomposite Membranes" offers researchers the opportunity to publish their latest research results as well as reviews. Topics covered by this Special Issue include, but are not limited to:

- The preparation of stable nanocomposite TFC membranes.
- The effect of nanoparticles on membrane properties such as water permeability, selectivity and fouling behavior.
- The description of the mechanism of action of nanoparticles in view of transport, selectivity and antifouling properties.
- Theoretical aspects and simulation of water–salt transport in nanoparticle-modified TFC membranes.

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