Development and modification of hollow fiber polymer membranes for ultrafiltration

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The main advantage of hollow fiber membranes is a high surface to volume ratio which yields in a higher packing density of the membranes per unit volume in a membrane module and smaller size of the membrane equipment in comparison with flat sheet or tubular membranes. Hollow fiber membranes are fabricated using the dry (evaporation induced phase inversion) or the wet (diffusion induced phase inversion) spinning method, or their combination (dry–jet wet process). Hollow fiber spinning is a complex process that depends on a great number of parameters. In principle, the hollow fiber manufacturing process is determined by the thermodynamics of the spinning polymer solution, the phase inversion process, the rheological properties of the polymer solution inside the spinneret and in the air gap, and other spinning operating conditions. Hollow-fiber formation conditions (for example, spinneret design, dope extrusion rate, fiber drawing, air gap length, solvent concentration in the bore fluid, polymer solidification kinetics, etc.) are largely defined by a particular “polymer–solvent–non-solvent–coagulant” system.

The basic principles of the spinning of polysulfone hollow fiber membranes by the dry-jet wet spinning process, where the polymer solution is extruded through an air gap between the spinneret and coagulation bath by the free fall spinning method are discussed within the lecture [1]. The main factors affecting the spinneret drawing and dimensions of the hollow fiber membranes formed by free fall spinning have been experimentally revealed using polysulfones of different molecular weights. The factors are the dope composition, approaching ratio and viscosity, the air gap length, the temperature and the feed rate of the dope and the bore fluid, coagulation power of the bore fluid with respect to the dope [1].

Different modification techniques for hollow fiber membranes are discussed: introduction of polymer additives [2] and nanofillers [3] to the dope, using the systems with upper and lower critical solution temperatures, introduction of hydrophilic polymers [4] and polyelectrolytes to the bore fluid upon hollow fiber formation.

The novel method of modification of hollow fiber membranes from polysulfone have been proposed. The method involves the use of aqueous solutions of hydrophilic polymers (polyvinylpyrrolidone, PVP) and polyelectrolytes as a bore fluid in the dry-jet wet spinning process (Figure). Increasing PVP concentration (1-5 wt.%) in the bore fluid was found to yield in
the efficient hydrophilization of the inner skin layer of the hollow fiber membrane and significant improvement of antifouling characteristics of the modified polysulfone membranes [4].

Hollow fiber polysulfone membranes for ultrafiltration with the addition of multiwalled carbon nanotubes (MWCNT), silica and tin (II) chloride bihydrate were obtained by phase inversion technique. It was shown that addition of 0.00084–0.0048% of MWCNT in the spinning solution makes it possible to change membrane performance in a broad range [3]. The maximum flux and the lowest rejection coefficient of the membrane at 0.0033% MWCNTs in the dope correspond to the highest porosity and a greater pore width of the skin layer. The minimum value of the water flux and the highest value of the rejection coefficient for the membrane with 0.0048% MWCNTs in the dope can be explained in terms of a low porosity of the transition and skin membrane layers and the smallest pore size of the skin layer. Polymer-inorganic hollow fiber ultrafiltration membranes from polysulfone and fumed silica were prepared via phase-inversion process. It was found, that an increase in fumed silica loading results in the enhancement of membrane’s rejection properties. Fumed silica was observed to change pore size distribution of the selective layer, increasing the fraction of small pores.

References
