Thermomechanical Responses of Porous Polymer Membranes During the Nanoimprint Process and Their Influences on the Permselectivity of the Membranes

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Recent studies have shown that sub-micron surface patterns can be directly imprinted onto the surface of porous polymeric membranes under compression at a temperature below the glass transition temperature (Tg) of the polymer. Initial results demonstrated that the presence of these patterns improves the antifouling characteristics of the membranes during separations with feed solutions containing colloidal particles or proteins. A more comprehensive understanding of the influence of the imprinting process on thermomechanical deformation is essential since deformation at various combinations of temperature and pressure dictates the characteristics of the final porous structure and thus membrane performance (permselectivity). In this study, we present results from systematic measurements obtained from conventional mechanical testing (tensile and dynamic loading) as well as nanoscale thermoanalysis (nano-TA) of ultrafiltration (UF) membranes before and after nanoimprinting. This work compares data from two commercial polyethersulfone (PES) UF membranes: one of which consists of a small-pore thin layer atop a larger-pore support layer and the other adds both macrovoids as well as a backing layer. Each membrane was plastically deformed at various combinations of pressure (P) and temperature with $P < 4$ MPa and $T < Tg$, and the results show that the temperature dependence of the yield strength agrees well with that predicted for open-cell foams. Pore-size measurements determined by electron microscopy and evapoporometry indicate that the pore-size distribution becomes narrower due to the elimination of the largest pores during compression. Thus the imprinting process effectively reduces the structural hierarchy. Moreover, the relationship between PSD and membrane performance as a function of pressure and temperature indicate that systematic effects are surprisingly modest.