Dynamics of Capillary Imbibition of Poly(ethylene oxide) Melts in Nanoporous Alumina

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Understanding the behavior of polymer fluids through nanochannels is not only of fundamental interest but also important for applications in nanotechnology. Nearly hundred years ago, Lucas and Washburn derived Lucas-Washburn Equation (LWE) for Newtonian liquids penetrating a cylindrical capillary with radius R. The penetrating length is proportional to $t^{1/2}$, t is the wetting time. Herein, we investigate the penetration of a series of entangled poly(ethylene oxide) melts within nanopores of self-ordered alumina. In general, the penetration follows ~ $t^{1/2}$ behavior according to LWE. However, LWE breaks-down because of differences in the prefactor. We observe a reversal in dynamics of capillary rise with polymer molecular weight. Chains with 244 entanglements or more display a faster capillary rise than theoretically predicted. Moreover, it is the first time to our knowledge that a slower capillary rise is observed for chains with 50 or less entanglements. The reversal in imbibition can be interpreted by the competition between a polymer dead zone next to the nanopore surface and the reptation of polymer chains under a pressure gradient. Lastly, we discuss the imbibition of PEO mixtures composed from long and short chains and show that it can result to the fractionation of short/long chains.

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