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Water Content of Soft-Contact-Lens-Material Hydrogels

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Abstract

Purpose

SCL wear comfort is dictated, in part, by hydrogel mechanical and transport properties that depend strongly on water uptake (e.g., lubricity, elasticity, and oxygen/ion/water permeability). Accordingly, an essential feature of SCLs is their equilibrium water volume fraction,φ_1. We present a method to predict φ_1 of both HEMA-based and silicone-based SCL hydrogels that compares well with experiment.

Methods

Water uptake of HEMA/MAA, Si/HEMA, and Si/MAA hydrogels was determined gravimetrically for varying copolymer composition. Prior to measurement, hydrogels were swollen for a minimum of 3 d in pH = 7.4 0.02 M phosphate buffer saline solutions (0.15 M NaCl). Water content was predicted using a multicomponent Flory-Rehner-Donnan theory modified to account for specific complexation of water with charged carboxylic groups of MAA, along with charge-dependent binding of salt counterions.

Results

Fig. 1 graphs water volume fraction, denoted $\varphi_{1,hyphil}$, against MAA-copolymer volume fraction during synthesis, ν_{MAA}, for HEMA/MAA hydrogels. The solid line is drawn using theory with no adjustable constants. At pH = 7.4, addition of MAA to the hydrogel increases water content primarily through hydration of charged MAA carboxylic groups. Small MAA amounts increase water uptake dramatically, but less so as MAA copolymer fraction increases. Fig. 2 displays water volume fraction, φ_1, for Si/MAA and Si/HEMA hydrogels with varying copolymer composition (i.e., MAA or HEMA volume fraction, denoted ν_{hyphil}). φ_1 increases monotonically with increasing ν_{hyphil}, as expected. Hydrophobic silicone moieties uptake negligible water. Consequently, we propose

that φ_1 for silicone-based hydrogels is simply the volume-fraction-weighted water content of the hydrophilic domains, or $\varphi_1 = \nu_{hyphil}\ \varphi_{1,hyphil}$ (solid lines). In both cases, agreement between experiment and theory is excellent.

Conclusions

We developed a new procedure to quantify equilibrium water uptake of SCL-material hydrogels. Our procedure permits estimation of SCL water content without resort to experiment. To our knowledge, this study is the first attempt to predict water uptake of silicone-based hydrogels.

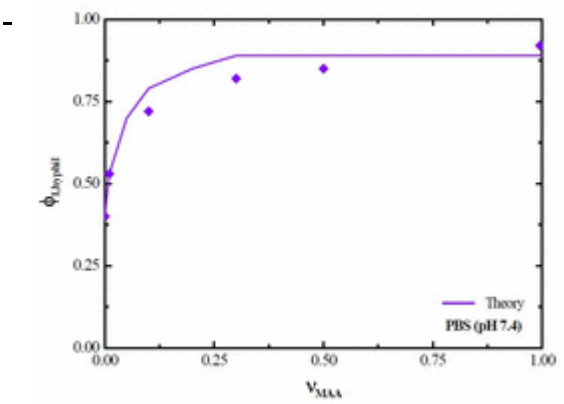

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Fig. 1. Water volume fraction, $\varphi_{1,hyphil}$, versus MAA-copolymer volume fraction, ν_{MAA}, for the HEMA/MAA hydrogels.

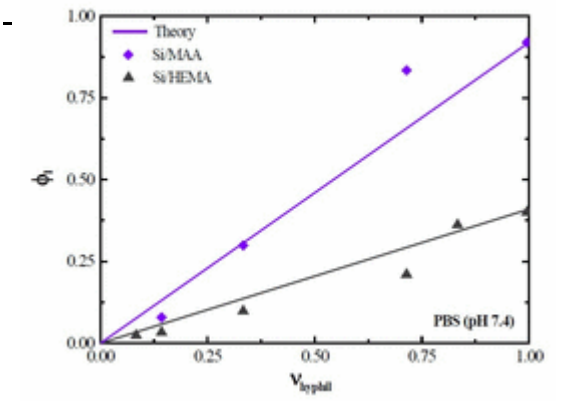

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Fig. 2. Water volume fraction, φ_1, versus hydrophilic-phase volume fraction (i.e., HEMA or MAA), ν_{hyphil}, for the silicone-based hydrogels.