Permeation Properties of Polyurethanes for Continuous Glucose Monitors

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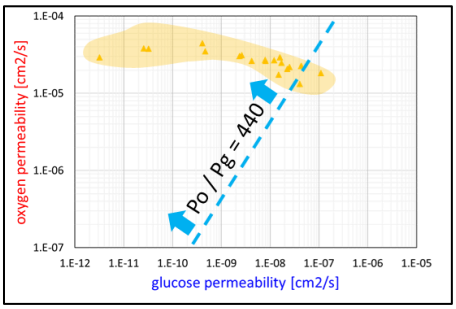
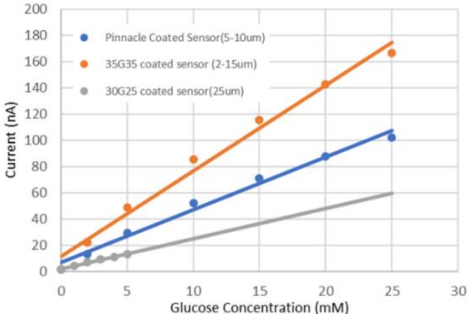
Statement of Purpose: Continuous glucose monitors (CGMs) are dependent on the selectivity of permeation through a membrane enveloping the electro-chemical sensor [1]. The membrane must be glucose limiting, resulting in a permeability ratio allowing more oxygen than glucose to move from the physiological environment to the sensing layer. Often the membrane is formulated as a physical blend of a hydrophilic polymer enabling glucose transport and a hydrophobic polymer enabling oxygen transport. In this study, a single, amphiphilic thermoplastic polyurethane (TPU) was formulated having a soft segment composed of both hydrophobic and hydrophilic polyols. Combining both units into a single polymer chain avoids the challenge of formulating physical blends of dissimilar polymers to achieve the correct chemical and physical properties, and microphase morphology for selective permeation. Formulations were varied to determine trends in permeation properties. Variations included the mass ratio of hydrophobic and hydrophilic polyols, polyol molecular weights, and the hard segment weight percentage (%HS). Functionality was demonstrated by monitoring the performance of a glucose sensor coated by these materials.

Methods: All materials include a soft segment comprised of a hydrophobic and a hydrophilic polyol, and a hard segment comprised of a diisocyanate and small molecule diol. Test films were generated by solvent casting. Water uptake was determined gravimetrically by weighing films before and after holding in water for one week. Glucose permeability (P_G) was determined via a Franz cell experiment performed at 37°C wherein TPU films were positioned between a donor chamber of aqueous glucose solution and an acceptor chamber of pure water. The acceptor chamber was sampled periodically and samples were analyzed using an enzymatic assay and UV/Vis spectrophotometry. Oxygen permeability (P_O) was determined using a Mocon OX-TRAN 2/12 OTR Analyzer. For best comparison with P_G results, films were prehydrated and the test was performed at 37°C and 90% relative humidity. On-sensor measurements were performed using the Pinnacle Desktop Potentiostat and glucose specific biosensors. Pinnacle provided sensors lacking an outer membrane and our formulations were applied via dip coating. Sensor testing was performed in phosphate buffered saline and glucose was spiked at various concentrations to demonstrate equilibration time and linearity.

Results: Increasing the hydrophilic content of the TPU increased both water uptake and P_G. Increasing the hydrophobic content increased P_O. Increasing %HS reduced water uptake and P_G but did not demonstrate a significant effect on P_O. Increasing the molecular weight of the hydrophilic polyol increased P_O and strongly reduced P_G.



Glucose sensors coated with TPUs demonstrated a linear response over the physiological concentration range. Equilibration times were similar to those observed using a sensor with the commercial coating.



Conclusions: Oxygen permeability (P_O), glucose permeability (P_G) and water uptake can be controlled through the hydrophobic/hydrophilic polyol ratio, %HS, and polyol molecular weight. Taking advantage of the observed trends, it is possible to tailor materials to target specific P_O and P_G or ratios of the two.

References: [1] Kulkarni, T., & Slaughter, G. (2016). Application of semipermeable membranes in glucose biosensing. *Membranes*, *6*(4), 55.

[2] Wang, Y., Gupta, M., & Schiraldi, D. A. (2012). Oxygen permeability in thermoplastic polyurethanes. *Journal of Polymer Science Part B: Polymer Physics*, *50*(10), 681–693.