Development of a Biologically Stable Urethane-Silicone Copolymer Gel

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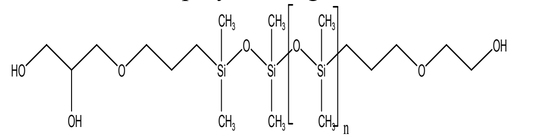
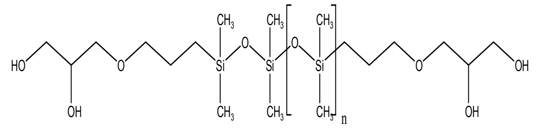
Statement of Purpose: Polymer gels are semi-solid systems that respond in a liquid like fashion under certain circumstances but their molecules do not have motion that is independent of each other, hence they behave like solids in other circumstances. Biologically stable gels find applications several applications such as in breast implants, spinal disc augmentation and urethral bulking. Gels can be synthesized as physical gels where a cross-linked network is swelled by a non reactive liquid. Gels can also exist as chemical gels where a crosslinked network formed by covalent bonding or ionic bonding (first-order bonding) and hydrogen bonding and dipole interaction (second-order bonding). Silicon gels are physical gels with a solvent extractable and heavy metal catalyst compromising biological toxicity. In this study a novel, chemical approach to gel formation is described in order to synthesize a silicone-polyurethane gel that is biological stable, has a shape-memory or form stable property, natural tissue feel, a lower degree of solvent extractables and with no catalyst or additives. The gel chemistry was based on the formulation of the biologically stable Elast-Eon formulation. Elast-Eon is a family silicone-urethane co-polymers that have been successfully tested in several in-vivo and in-vitro trials and their suitability for long term implantation has been confirmed. [1, 2]

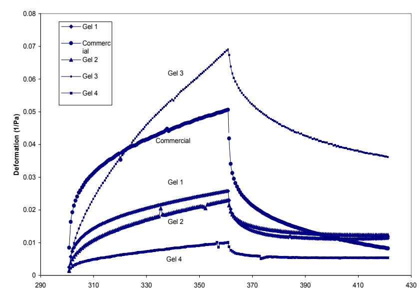
Methods: The materials used for synthesizing the gels include a di-isocyanate in the form of MDI and different hydroxyl terminated polyols of multifunctional, novel, silicon based such as bi, tri & tetra-functional macromers. The synthesized gels were subjected to soxhlet extraction and rheological analyses. The extractables in hexane were measured in the Soxhlet extraction technique over 24 hours. The rheological study[2] relates the both the natural feel and the form stability. A good creep-recovery performance describes the feel or the elasticity. The parameters of storage modulus (G') and loss modulus (G") as measured in frequency sweep measurement on a rheometer describe the form stability.

Results / Discussion The different novel synthesized multifunctional polyols used to prepare the gels are α,ω-bis(hydroxyethoxypropyl) polydimethylsiloxane, α-(hydroxyethoxypropyl)-ω-(6,7- dihydroxyethoxypropyl) polydimethylsiloxane, and α,ω-bis(6,7-dihydroxyethoxypropyl) polydimethylsiloxane, hydroxyethoxypropyl terminated (hydroxyethoxypropyl methyl siloxane)(dimethyl siloxane) copolymer, α,α',α"-(methylsilylidyne)tris-[ω[(hydroxyethoxypropyldimethylsilyl)oxy]poly (dimethylsilyene)]], α,α',α", α'''- tetrakis-[ω[(hydroxyethoxypropyldimethylsilyl) oxy]poly(dimethylsilyene)]]silane and hydroxyethoxypropyl terminated 3.55%-(methylmethacryloxypropyl methyl siloxane)(dimethyl siloxane) copolymer. Representative structures of multifunctional polyols are given below:


(II)


(III)

The soxhlet extraction results show a significant improvement in the extractable percentage which lies in between 20-25 % when compare to commercial silicone gels (avg.50%). The rheological results of gels synthesized from novel multifunctional polyols are on par with the commercial available silicone gels. The synthesized gel show higher storage modulus (G') than loss modulus (G") compared to the commercial gel at low frequencies ($0.01 s^{-1}$ to $1 s^{-1}$) implies form stability and also shows a good elasticity by creep recovery analysis (Fig.1).



Conclusions: A gel, based on a biologically stable chemistry, having a greatly reduced extractable content and containing no heavy metal catalysts has been formulated using novel synthetic routes. The gel possesses good elastic and recovery properties and can be formulated over a range of modulus suitable for a variety of applications.

References: A. Simmons, J. Hyvarinen, R. A. Odell, D. J. Martin, P.A. Gunatillake, et al., *Biomaterials,* **2004**, 25:4887-4900

P.A. Gunatillake, D.J. Martin, G.F. Meijs, et al, *Aust. J. Chem.,* **2003,** 56: 545-557