Kinetics and elasticity of in-situ forming silicone or silicone-g-PEG polymers for lens refilling

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Introduction: The present insertion of rigid or soft IOLs (intraocular lens) to treat a cataract results in the loss of accommodation. Lens filling is a new concept to solve the problem by maintaining the natural ability of accommodation. By this technique, the capsular bag is evacuated through an even smaller capsular opening then refilled with a liquid prepolymer and cured. Silicone compounds are suitable material for lens refilling in terms of refractive index, elasticity, non-toxicity, transparency, and biocompatibility. However, silicones as well as other hydrophobic polymers suffer from the posterior capsule opacification (PCO) which remains the most common cause of vision loss after a cataract surgery. In the present study, silicone prepolymers were modified by grafting with hydrophilic poly(ethylene glycol) to produce silicone-g-PEG polymers whether to prevent PCO. The silicone or silicone-g-PEG polymers were in-situ cured via hydrosilylation reaction. The rate of gelation and mechanical properties were characterized by a rheometer.

Methods: Silicone prepolymers containing Si-H (MHBP023 (KCC, Korea) or HMS-031 (Gelest, Morrisville, PA)) or vinyl group (VEP1000(KCC, Korea)) were cured via hydrosilylation reaction catalyzed by Karstedt's catalyst (KCC, Korea). Silicone-g-PEG was synthesized by a vigorous mixing and sonication of MHBP023 and allyl methoxy PEG (A-PEG-M) in the presence of Speier's catalyst (Sigma-Aldrich). The concentration of Si-H or vinyl groups in the silicone prepolymers was confirmed by ^{1}H-NMR. Rheological experiments were conducted with a rheometer (Gemini, Malvern Instruments, UK) at 37 ℃ in an oscillatory mode. A certain amount of silicone prepolymers containing Si-H or vinyl group and the Karstedt's catalyst were mixed, degassed and applied to the rheometer with a frequency of 1 rad/s and a strain of 0.1%. The storage (G') and loss modulus (G'') were recorded as a function of time.

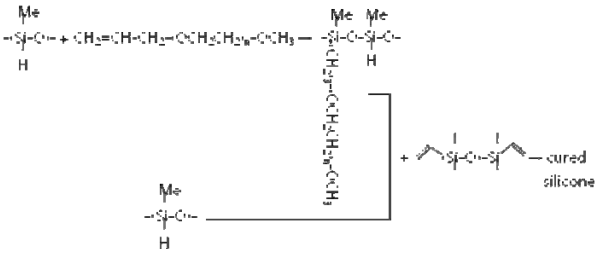

Figure 1. Synthesis of silicone-g-PEG and curing

Results: Various amounts of A-PEG-M were grafted to the silicone prepolymer, MHBP023 (Si-H), via hydro-silylation to yield the silicone-g-PEG after a scheme shown in Fig. 1. The intensity of Si-H peak (b in Fig. 2) at 4.6 ppm was decreased with increasing the A-PEG-M content.

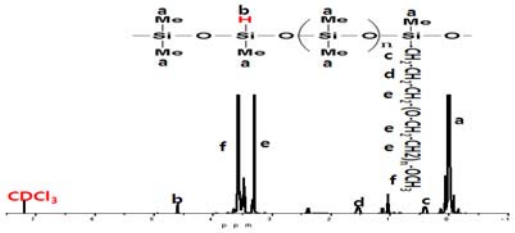

Figure 2. ^{1}H-NMR spectra of a silicone-g-PEG

The silicone-g-PEG, MHBP023 or HMS-031 containing Si-H group was further cured with VEP1000 having vinyl groups. The kinetics of curing was followed by monitoring the G' and G'' on time (Fig. 3). The G' and G'' increased rapidly during the initial 10 min and leveled off after 15 min indicating that the crosslinking reaction was complete. The gelation time was observed around 9 min. The shear modulus (S) and Young's modulus (E) were calculated from the G' and G'' values by using the equation, $G=\{(G')^2 + (G'')^2\}^{0.5}$, $E=2G(1+v)$, v=poisson′s ratio. The Young's modulus of a cured silicone polymer was 1.3 kPa, comparable to a 20-year-old human lens.

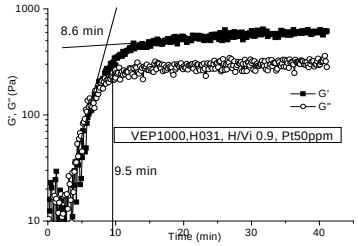

Figure 3. The G' and G'' of silicone polymer made of VEP1000 and HMS-031 at a H/Vi mol ratio of 0.9

Conclusions: The hydrophilic silicone-g-PEG was synthesized to apply for a lens refilling material aiming to reduce PCO. The kinetics of gelation by hydrosilylation reaction of silicone polymers was monitored by a rheometer. The shear and Young's moduli measured also from the G' and G" values were equivalent to the strength of natural lens. The obtained results demonstrate that these in-situ forming silicone gel would have a great potential for lens refilling materials.

References:

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2) Fisher, R.F. J Physiol. 1971:212:147-180

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