CROSS-LINKED SILICONE POLYMERS, FAST CURING SILICONE PRECURSOR COMPOSITIONS, AND INJECTABLE INTRAOCULAR LENSES

This application is a division of application Ser. No. 07/885,136, filed May 18, 1992, now U.S. Pat. No. 5,278,258.

BACKGROUND OF THE INVENTION

The present invention relates to optically clear, cross-linked silicone polymers, to fast curing precursor compositions useful for producing such polymers, to intraocular lenses (IOLs), for example, injectable IOLs, and to methods of forming such IOLs. More particularly, the invention relates to such silicone polymers, fast curing precursor compositions, injectable IOLs and methods which provide substantial benefits, for example, silicone polymers and injectable IOLs which have reduced discoloration susceptibility.

Silicone polymers are known materials and many are known to be produced using platinum group metal-containing catalysts, which catalysts become an integral part of the final product. For example, certain silicone polymers are known to be useful in the production of IOLs. Also, certain curable liquid compositions comprising monomers which can be cured in the presence of platinum group metal-containing catalysts to form silicone polymers have been suggested for use in forming a solid, transparent synthetic lens upon being injected into the lens capsule of an eye from which the natural lens has been removed. Such solid, transparent synthetic lenses formed in the eye may be considered or termed "injectable IOLs". See, for example, Wright et al U.S. Pat. No. 4,608,050, which is incorporated in its entirety herein by reference.

Injectable IOLs which comprise cross-linked silicone polymers are cured or cross-linked in the eye, at physiological temperature, for example, about 35°–37° C. In order to obtain a desirably fast cure rate, relatively high levels of catalyst, in particular platinum group metal-containing catalyst, are used.

One problem that presents itself in the use of such fast curing liquid precursor compositions is that over time the resulting polymer tends to discolor. Such discoloration, which is believed to be associated with the relatively high platinum group metal-containing catalyst levels in the precursor compositions, is disadvantageous. Therefore, it would be advantageous to provide fast curing precursor compositions which yield polymers having a reduced susceptibility to discoloration.

Sierawski U.S. Pat. No. 4,122,246 discloses a silicone gel which discolors less on aging than other platinum catalyzed silicone gels. The disclosed silicone gel is prepared by mixing vinyl-containing polyorganosiloxane, a silicon-bonded hydrogen containing organosiloxane compound, a platinum catalyst, a polysiloxane having at least two vinyl radicals and at least one silicon-bonded hydroxyl radical, and an epoxy-containing alkoxy silane. The mol ratio of silicon-bonded vinyl groups to silicon-bonded hydrogen atoms in the vinyl-containing polyorganosiloxane plus silicon-bonded hydrogen containing organosiloxane compound is greater than 1, preferably greater than 1.1, while the mol ratio of silicon-bonded vinyl radicals to silicon-bonded hydrogen atoms in the entire mixture is preferably from 1.2 to 3.3. The presence of epoxy silanes in the polymerization mixture can result in quality control problems. For example, the epoxy silanes can provide large numbers of crosslinks which can result in products not having the desired characteristics. Also, injecting a mixture containing such epoxy silanes into the eye may have detrimental effects on the eye. Therefore, it would be advantageous to provide fast curing precursor compositions, e.g., useful for injection into the eye, yielding silicone polymers which have reduced susceptibility to discoloration without the need to include epoxy silanes.

SUMMARY OF THE INVENTION

New cross-linked silicone polymers, fast curing precursor compositions useful for providing cross-linked silicone polymers, IOLs, preferably injectable IOLs, and methods of forming such IOLs have been discovered. The present precursors have compositions which reduce the discoloration susceptibility of the resulting cured polymer even if the polymerization is catalyzed with a relatively high concentration of platinum group metal component, and which preferably do not include epoxy silanes, in particular epoxy-containing alkoxy silanes. Moreover, such cured polymers are optically clear. The present curable compositions are very effective when injected into the lens capsule of an eye and caused to form an injectable IOL, or when used to produce IOL optics. The present polymers and compositions can be produced using materials which are commercially available and processing techniques which are well known in the art.

In one broad aspect, the present invention is directed to compositions which comprise an optically clear, cross-linked polymer derived from the polymerization, e.g., cross-linking, of a mixture of (A) a vinyl-containing polyorganosiloxane component, and (B) an organosilicon component including silicon-bonded hydride groups which react with vinyl groups included in (A) during the polymerization, and (C) an effective amount of a platinum group metal-containing catalyst component. It is important that the mol ratio of vinyl groups to silicon-bonded hydride groups in the mixture is greater than 1.2, preferably greater than about 4 and more preferably greater than about 5. In one embodiment, the present precursor mixtures are substantially free of epoxy silanes. Particularly useful precursor mixtures consist essentially of (A), (B) and (C). It has been found that cross-linked polymers produced from such precursor mixtures or compositions, for example, fast curing precursor mixtures containing at least about 10 ppm by weight of platinum group metal catalyst component (calculated as elemental platinum group metal), have a reduced discoloration susceptibility relative to a substantially identical polymer derived from a precursor mixture having a mol ratio of vinyl groups to silicon-bonded hydride groups equal to 1.2.

Both the cross-linked or cured polymers and the precursor compositions, as described herein, are included within the scope of the present invention.

In a further aspect of the present invention, methods of forming an IOL, for example, an injectable IOL, are provided. Such methods comprise forming a mixture of (A) a vinyl-containing polyorganosiloxane component, (B) an organosilicon component including silicon-bonded hydride groups which react with vinyl groups included in (A) when (A) and (B) are polymerized and (C) a platinum group metal-containing catalyst component in an amount effective to promote the polymerization of (A) and (B). The mol ratio of vinyl groups to