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(54) **DENTAL COMPOSITIONS**
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Reissue of:

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(57) **ABSTRACT**

(58) **Field of Classification Search** **424/49**
See application file for complete search history.

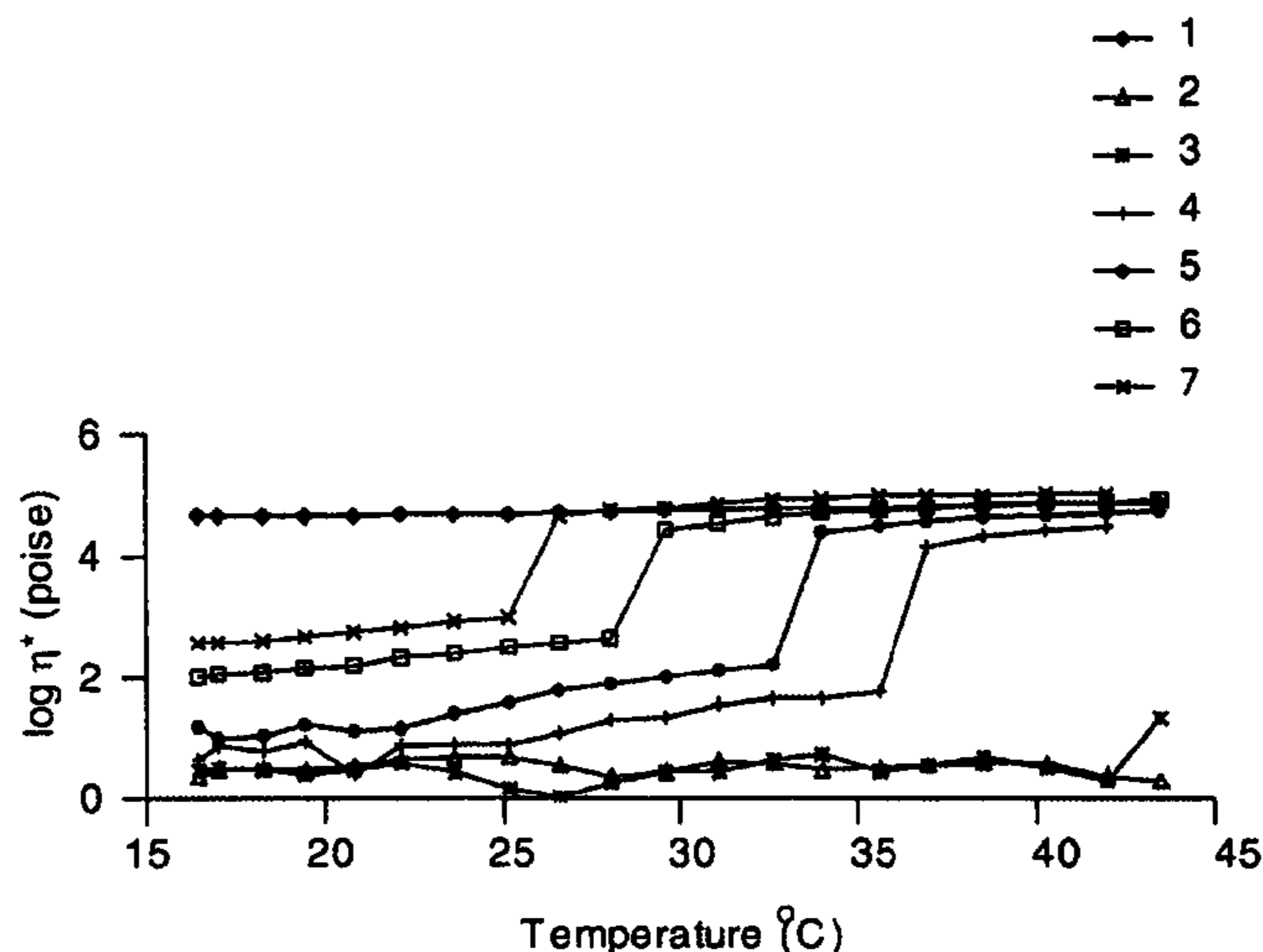
Dental compositions containing adjuvants are provided that have the capability of undergoing an increase in viscosity in response to an increase in temperature. In a preferred embodiment, the compositions also have the ability to reverse their viscosity in response to a decrease in temperature.

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35 Claims, 2 Drawing Sheets



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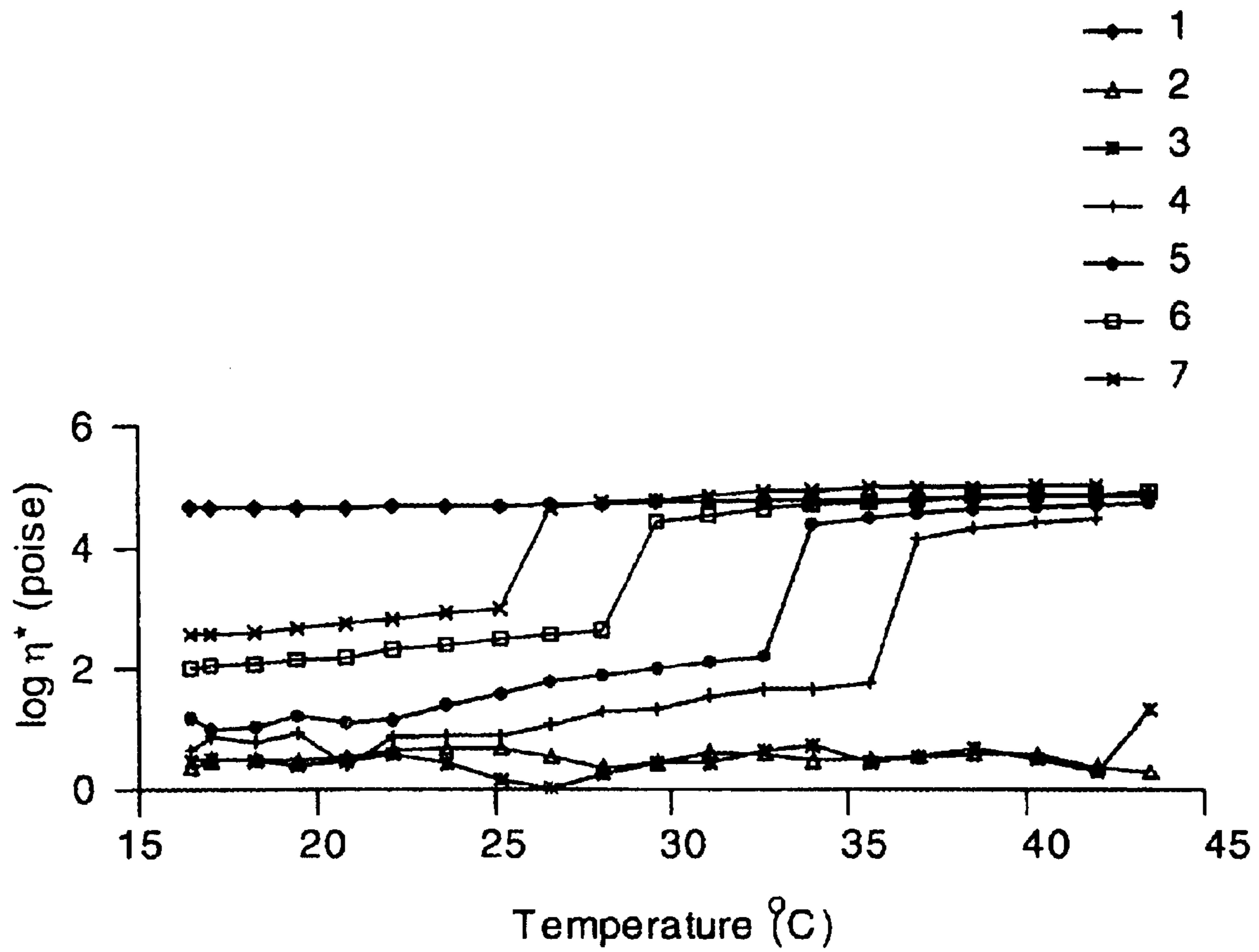


FIG. 1

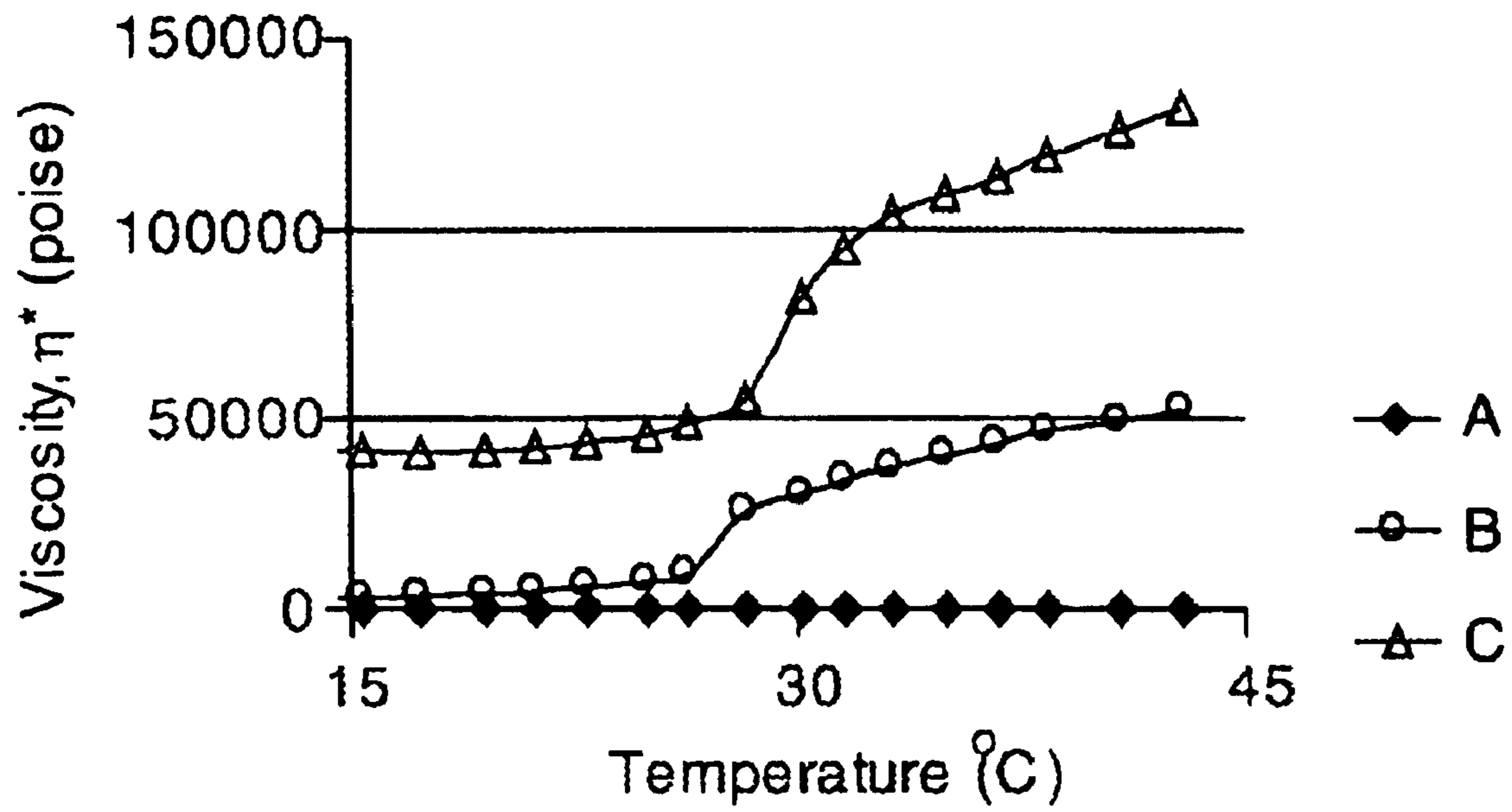


FIG. 2

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DENTAL COMPOSITIONS

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application Ser. Nos. 09/190,541 now U.S. Pat. No. 6,312,666 and 09/190,717, now U.S. Pat. No. 6,312,667 both filed Nov. 12, 1998, and both of which are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

This invention relates to dental compositions having viscosities capable of responding to a change in temperature. The invention also relates to methods of applying the composition directly onto a target area of the substrate.

BACKGROUND

In the dental art, the use of a dental coating composition is generally desirable for a wide variety of applications, such as etching or bleaching. To attain proper application at the desired location, it is desirable that the composition be controllable and slow to flow away from the target site. Thus a high viscosity dental composition in the oral environment would be quite useful.

Currently available dental compositions are provided in seemingly extreme viscosity states. That is, there exist compositions that have very low viscosities as well as compositions that are highly thickened and therefore possess high viscosity. Those with low viscosities are difficult to control and have tendencies to flow away from the target site once they are applied. Compositions with high viscosities are difficult to extrude through a small orifice.

Certain dental compositions may use thickeners such as fumed silica and polyvinyl alcohols. Problems encountered in using these thickeners include aging, which results in non-homogenous gels which make handling difficult, and shear thinning, which reduces the viscosity of a gel when extruded through an orifice and thinning at elevated temperatures. Thinning can result in a material that drips from the orifice and that may fail to remain localized at the desired point of application.

SUMMARY OF THE INVENTION

The present invention provides a dental composition suitable for application in the oral environment comprising a thermally responsive viscosity modifier that is capable of undergoing an increase in viscosity in response to an increase in temperature. These compositions also preferably have the ability to reverse their viscosity upon the lowering of temperature.

Compositions of the invention work very well in the oral environment where temperature is generally higher than ambient or the pre-treatment temperature of a composition. This differential in temperature thickens the composition and thus provides a thickened, semi-solid or gel-like composition in the oral environment.

A preferred method of use of the invention comprises applying the composition directly onto the oral surface. Upon exposure of the composition to the oral temperature, the composition thickens to a semi-solid or gel-like state.

In one aspect, the present invention provides a method of applying a dental composition in the oral environment using

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a dental composition comprising about 10% by weight to about 50% by weight of a thermally responsive viscosity modifier and an adjuvant, wherein the composition is in a low viscosity state at a pre-treatment temperature and a highly viscous state at a treatment temperature that is higher than the pre-treatment temperature. The method includes applying the composition through an orifice, preferably the orifice of a syringe, onto a surface, wherein the composition is at the pretreatment temperature and in the low viscosity state prior to being applied onto the surface, allowing the composition to warm to the treatment temperature and increase in viscosity to the highly viscous state wherein the viscosity of the composition at the treatment temperature is at least about 10 times the viscosity of the composition at the pre-treatment temperature, and allowing the composition to remain on the surface. Preferably the pre-treatment temperature is at most about room temperature and the treatment temperature is about body temperature. Preferred adjuvants include acids, whitening agents, fluoride, anti-microbial agents, and medicaments.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a graphic illustration of the viscosity versus temperature data as described in Example 1.

FIG. 2 is a graphic illustration of the viscosity versus temperature data as described in Example 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a dental composition in a low viscosity state prior to application onto an oral surface, but which also is highly viscous, thick and controllable at the target site. These compositions are easily dispensed, applied, and manipulated when handled by the user, and are easily controlled upon application to the target site. Because the composition has a low viscosity initially at a pre-treatment temperature, it requires lower syringe extrusion forces to deliver the compositions to the intended site. In turn, this would allow a user the alternative of using a brush or other applicator to apply the composition. In addition, production of low viscosity compositions may provide easier processing and greater uniformity and consistency.

Compositions of this invention are particularly suitable for use in the intraoral environment where a composition having a pre-treatment temperature at or lower than ambient (room temperature) is applied to a user's oral surface that is near or at oral temperature of about 30° C. to about 39° C. For certain dental applications, it is preferred that the composition be thermally reversible. In that application, the composition not only has the ability to increase its viscosity at an elevated intra-oral temperature, but also reverses or decreases its viscosity upon a decrease in temperature.

The capacity of the dental composition to thicken at oral temperatures is a critical feature of the invention, for it is in this property that many of the disadvantages of previous approaches are overcome. The dissipative characteristic of liquid solutions is avoided since the compositions herein experience thickening at the site of treatment. Moreover, the problems of formulation, handling, delivery and application of viscous compositions are overcome since the present compositions may be free-flowing liquids prior to treatment.

For example, the art of etching hard tissue typically requires etching a target site or controlled areas of several teeth at one time. Current etchant liquids are easy to dispense and apply, but these tend to flow away from the target area of application. Consequently, an etch patch could be

larger than desired or, more undesirably, contact with the soft tissue could occur, which can cause sensitivity or irritation. A large etch patch unnecessarily increases the risk of decalcification during treatment. Some compositions have been provided in thickened states to provide less flow and mobility; however, they are often difficult to dispense.

Furthermore, other applications, such as dental whitening, suffer when the dental whitening compositions decrease in viscosity due to the increase in temperature from the intraoral environment. This thinning and viscosity decrease creates a tendency for the whitening composition to flow from the target location, resulting in a reduced amount of whitening composition available for treatment at the target location for the desired length of time.

A "semi-solid," as used herein, is a material whose physical state is between the solid and liquid state, in which pure or mixed solvent or solution is entrained within a network, and can alternatively be considered a gel. By "pure or mixed solvent and/or solution," as stated herein, it is recognized that a mixture of solvents may be absorbed by the network. Additionally, the solvent may include salts or other additives so as to form a solution, which may also be absorbed or entrained within the network.

"Thickening" as used herein, is where a composition undergoes a substantial increase in the viscosity of the composition. The degree of thickening is dependent on the initial viscosity of the composition.

In a preferred embodiment of the invention, the initial viscosity of the composition may be low enough such that the composition is in a liquid state. Subsequently, upon exposure to a temperature of about near or at oral temperature, the viscosity increases to result in a thickened composition. A viscosity increase in the range of about 10- to about 100-fold can be experienced when the initial viscosity is such that the composition is a liquid. Thus, for example, a composition in a liquid state may have a viscosity of about 0 to about 7000 poise. In response to an increase in temperature, the viscosity of the composition can increase to at least about 10,000 poise. Upon the lowering of the temperature, the composition preferably has the ability to reverse its viscosity and return to flow properties of a liquid.

Yet another preferred embodiment of the invention is when the initial viscosity of the composition is at a level at which the composition is in a semi-solid state at pre-treatment temperature (viscosity is at least about 5000 poise), and upon exposure to a higher treatment temperature, the composition transforms into an "ultra-thick" composition or one with a substantially higher viscosity and very low flow characteristics. For compositions having initially high viscosities, the degree of thickening is typically about 2- to about 5-fold.

The pre-treatment temperature is the temperature at which the composition is subjected to prior to application or treatment. The range for the pre-treatment temperature can be about 5° C. to about 29° C., although there may be certain instances where the temperature may be outside this range. Having a pre-treatment temperature at about 20° C. to about 25° C. allows the composition to be easily stored at ambient or room temperature. Alternatively, the compositions of the invention can also be advantageously stored at lower, refrigeration pre-treatment temperatures of about 5° C. to about 10° C. to provide improved stability and shelf life.

The treatment temperature is the temperature at which the composition is exposed during intraoral application. This can be at or near body temperature, or about 30° C. to about 39° C.

In accordance with the invention, the dental composition consists of a water-miscible, physiologically compatible medium that is liquid at ambient temperature below about 30° C. and experiences thickening at oral temperatures above about 30° C. It has been found that a composition having a thickening transition temperature in the range of from about 25° C. to about 40° C. is useful in the practice of the present invention. Preferably, the thickening occurs in a temperature range of from about 25° C. to about 39° C., and more preferably from about 30° C. to about 35° C.

Compositions of this invention are comprised of a solvent and one or more polymeric substances that provide the desired viscosity increase at the desired elevated temperature range in the said composition. Optionally, adjuvants may be added to the composition. Preferably, the composition of this invention should be physiologically compatible so that no adverse reaction occurs if the dental composition comes in contact with human tissue or fluids.

As used herein, a "thermally responsive viscosity modifier" is one or more polymeric substances that provide the composition or polymeric system the capability of substantially changing its viscosity in response to a change in temperature. Suitable polymeric substances useful as thermally responsive viscosity modifiers include polyoxyalkylene polymers, particularly the polymeric surfactants available under the tradename PLURONIC. This class of polymers is available commercially from BASF Wyandotte Corporation. Other polyoxyalkylene polymers may also be useful as a thermally-responsive composition material.

A preferred dental composition in accordance with this invention comprises an aqueous solution of a selected polyoxyethylene-polyoxypropylene block copolymer. A composition comprising polyoxyethylene-polyoxypropylene block copolymers in which the number of polyoxyethylene units is at least about 50% of the number of units in the total molecule, and the block copolymer having an average molecular weight of from about 1100 to about 15,500 has been found to be particularly useful. It is more preferable that a composition comprises about 70% polyoxyethylene units of the total number of monomeric units in the copolymer and the copolymer has an average molecular weight of about 11,500. PLURONIC F-127 is a material that meets these criteria.

The PLURONIC polymers are closely related block copolymers that may be generically classified as polyoxypropylene-polyoxyethylene condensates that terminate in primary hydroxyl groups. These polymers are formed by the condensation of propylene oxide into a propylene glycol nucleus followed by the condensation of ethylene oxide onto both ends of the polyoxypropylene base. The polyoxyethylene hydrophilic groups on the ends of the base pre-polymer are controlled in length to constitute from about 10% to about 80% by weight of the final polymer.

The PLURONIC polymer series of products may be represented empirically by the formula: $\text{HO}(\text{C}_2\text{H}_4\text{O})_a(\text{C}_3\text{H}_6\text{O})_b(\text{C}_2\text{H}_4\text{O})_c\text{H}$ where a and c are statistically equal.

The concentration of the block copolymers is an important parameter and can be formulated in such a manner corresponding to the other components' concentrations. By adjusting the concentration of the copolymer to accommodate other solutes present in the composition, any desired liquid to semi-solid transition temperature in the critical range of above ambient temperature and below body temperature can be achieved. Thus, the principal consideration is the selection of a concentration that, in conjunction with all of the constituents of the total composition, will provide a liquid to semi-solid transition temperature in the required range.

It has been found that a useful block copolymer concentration is from about 5% to about 40% by weight (wt. %) of the composition, particularly from about 15 wt. % to about 26 wt. % of the composition. Excellent results have been obtained using aqueous solutions having from about 17 wt. % to about 29 wt. % of PLURONIC F-127. Increased polymer concentrations may be required in highly acidic systems to affect the same results as in a less acidic system so that, in optimizing the thickening or gelation characteristics for a system, the pH of the solution must be taken into account.

Particularly preferred polymers for the present invention are the PLURONIC F-127 and F-108. These viscosity modifiers are block copolymers of ethylene oxide and propylene oxide. Thickening tendencies of block copolymers increase as ethylene oxide content and total molecular weight increase. Thermally responsive block copolymers have been disclosed in U.S. Pat. Nos. 4,474,751; 4,474,752; 5,441,732; and 5,252,318, as well as the Product Catalog, "BASF Performance Chemicals," all the teachings of which are incorporated by reference herein. These block copolymers offer extremely low toxicity and a high degree of mildness for applications involving human contact.

A preferred solvent for the composition of this invention is water. The concentration of water in the composition can be in the range of from about 30 wt. % to about 90 wt. % of the composition. Preferably, water can exist in the range of about 40 wt. % to about 80 wt. % of the composition. The water used in forming the aqueous solution is preferably purified, as by distillation, filtration, ion-exchange, or the like.

Co-solvents may be used, including anhydrous solutions comprising a polyol component such as propylene glycol or polyethylene glycol. Glycerin may also be used as a constituent of the composition.

Adjuvants can be added to the composition for various purposes (e.g., acids for dental etchants and whitening agents for dental whiteners). For example, a preferred embodiment of the invention can contain fluoride, a desirable additive in the oral composition. Additives may also be included in the composition to promote the stability of the formulation. Anti-microbial agents, anti-fungal agents, and preservatives may be added to the composition to improve shelf-life. The compositions may further include other adjuvants such as medicaments, indicators, dyes, wetting agents, buffering agents, thixotropes, polyols and the like, contingent upon attainment of the desired degree of etching performance and suitability for use on the desired hard tissue. For example, a composition may contain indicators that communicate to the user the degree of etching that has been performed on the hard tissue. The compositions may further include other adjuvants such as fillers, cariostatic agents and flavorings.

When the dental composition is a dental etchant, acids may be added to the composition as an adjuvant. Acids for use in the present invention can be inorganic or organic acids, and if organic can be monomeric, oligomeric or polymeric. If desired, a precursor to the acid such as an acid anhydride, e.g., 4-Methacryloxyethyl Trimellitate Anhydride (4-META), acid halide (including inorganic acid halides such as Lewis acids, e.g., ferric chloride, and organic acid halides), or ester can be used in place of the acid itself, e.g., to generate the desired acid in situ. Suitable acids include mineral acids, carboxylic acids, sulfonic acids, and phenols, with carboxylic acids, alkylsulfonic acids, arylsulfonic acids, and phosphonic acids being preferred.

The acid has a pKa in water that is less than or equal to that of phenol. Preferably, the pKa of the acid is between

about -20 and about +10, more preferably between about -10 and about +5.

The acid can be liquid or a solid; if a solid it should be dissolved in a suitable solvent to enable the acid to wet the hard tissue. Liquid acids can also be dissolved in a suitable solvent, e.g., in order to facilitate wetting. Preferred solvents for the acid are the film former cosolvents discussed in more detail below.

Suitable inorganic acids include hydrobromic acid, hydrochloric acid, nitric acid, phosphoric acid, and sulfuric acid. Suitable organic acids include acetic acid, α -chloropropionic acid, 2-acrylamido-2-methylpropane sulfonic acid, acrylic acid, benzenesulfonic acid, benzoic acid, bromoacetic acid, 10-camphorquinone-sulfonic acid, 10-camphorsulfonic acid, chloroacetic acid, citraconic acid, citric acid, dibromoacetic acid, dichloroacetic acid, di-Hema ester of 1,2,4,5 benzenetetracarboxylic acid, 2,4-dinitrophenol, ethylenediaminetetraacetic acid (EDTA), the mono-, di- and trivalent salts of EDTA, formic acid, fumaric acid, 2-hydroxy-4-methoxybenzophenone-5-sulfonic acid, maleic acid, methacrylic acid, 2-naphthalene sulfonic acid, oxalic acid, p-nitrophenol, phenol, phosphorous acid esters (such as 2,2'-bis(a-methacryloxy-b-hydroxypropoxyphenyl) propane diphosphonate (Bis-GMA diphosphonate), dibutyl phosphite, di-2-ethyl-hexyl phosphate, di-2-ethyl-hexyl phosphite, hydroxyethyl methacrylate monophosphate, glyceryl dimethacrylate phosphate, glyceryl-2-phosphate, glycerylphosphoric acid, methacryloxyethyl phosphate, pentaerythritol triacrylate monophosphate, pentaerythritol trimethacrylate monophosphate, dipentaerythritol pentaacrylate monophosphate, and dipentaerythritol pentamethacrylate monophosphate), pivalic acid, propionic acid, toluene sulfonic acid, tribromoacetic acid, trichloroacetic acid, trifluoroacetic acid, trifluoromethanesulfonic acid, and trihydroxybenzoic acid. Mixtures of such acids can be used if desired.

In the practice of the present invention, the hard tissues that can be etched include human and animal tissues such as teeth, including the component parts which are enamel, dentin, and cementum. The invention has particular utility for etching dentin, sclerotic dentin, enamel, and cervical enamel. In a preferred method of the invention, the etchant is permitted to stand on the hard tissue for a desired period of time, readily volatile cosolvents are removed therefrom (e.g., by air-drying) to modify the surface of the hard tissue. Delivery of the etching composition of the invention may be performed in various methods. One method of delivery of the etching composition is the direct application of the composition onto the hard tissue. This may be done directly from the composition's container or dispenser such as a bottle, vial, syringe, or tube. Alternatively, it can be applied by using a brush to paint or coat the composition onto the hard tissue. The composition is kept on the hard tissue for a desired period to effectuate etching. The length of time the composition is in contact with the hard tissue would depend on the amount of etching desired.

A preferred method of use comprises first etching with the composition of the present invention, followed by an application of a dental material on the tissue such as a sealant or coating, restorative material, adhesive, cement, dental primer or film former. Yet another preferred method is first etching with the composition of the present invention, then followed by an application of a bonding agent for purposes of bonding an orthodontic appliance onto a tooth. The invention enables etching of hard tissue in order to improve the bond strength or durability of a restorative or coating applied thereto.

Hard tissue to which the etchant is applied preferably is first cleaned using conventional methods (e.g., by abrading it with a bur), rinsed (e.g., using water) and dried (e.g., using air). If desired, deep excavations in teeth can be lined with a conventional basing material, (e.g., calcium hydroxide or a glass ionomer cement).

The acid should be allowed to stand on the surface of the hard tissue long enough to provide the desired degree of etching. The standing time will depend upon the particular acid employed, the type of hard tissue and its intended use, and the time available for carrying out the etching procedure. For etching dentin and enamel, standing times less than about 5 minutes, and preferably about 5 seconds to one minute provide very effective etching, although shorter or longer times can be used if desired.

When the dental composition is a dental whitener, whitening agents may be added to the composition as an adjuvant. The whitening agent used in the present invention may be any material that has the effect of whitening teeth. Whitening agents are preferably selected from hydrogen peroxide and its urea complex: carbamide peroxide ($\text{CO}(\text{NH}_2)_2\text{H}_2\text{O}_2$). These whitening agents are also known by alternative names, including urea hydrogen peroxide, hydrogen peroxide carbamide, or perhydrol-urea. Alternatively, sodium hypochlorite may be suitable for use as the whitening agent. The concentration of a whitening agent in the composition can vary depending upon its reactivity. With carbamide peroxide, for example, the currently preferred concentration range is from about 3% to about 40%, with a range from about 4% to about 21% being most preferred. In the case of hydrogen peroxide, which is more reactive than carbamide peroxide, the currently preferred concentration range is from about 2% to about 10%.

Various methods can be employed in using the whitening composition of this invention. One method of use of these whitening compositions entails application of the composition to the tooth structure directly from the composition's container or dispenser such as a bottle, syringe, or tube. Alternatively, the whitening composition can be applied by using a brush to paint it onto the tooth surface. The composition is kept on the user's tooth surface(s) for a desired time period to effectuate whitening. The length of time the composition is in contact with the tooth surface(s) would depend on the amount of discoloration the user prefers to remove.

In a preferred method, the whitening composition is loaded into a dental tray. Such dental trays can be custom fitted to a user's dentition and be made with or without reservoirs. A preferred reservoir is described in U.S. Pat. No. 6,126,443. Dental trays can be made from varying thicknesses and softness of pliable thermo-formable plastic materials. Typically, these materials are 0.02–0.08 inches thick. After dispensing or loading the whitening composition into the dental tray, the user then places the loaded tray into the mouth and initiates thickening of the composition. The thickening occurs when the composition is exposed to the elevated treatment temperature of the oral environment. The tray is retained in the mouth to effectuate whitening of the tooth surface(s) for a sufficient period of time to remove discoloration.

An alternative method of use incorporates a pre-warmed dental tray into which the whitening composition is loaded. Upon contact of the composition having a pre-treatment temperature, with the tray having a higher temperature, the composition experiences thickening. This method provides easy handling of a loaded tray into a user's mouth, with minimal fear of the composition moving to an undesired

section of the tray or having the composition flow out of the tray. Where the dental compositions are thermally reversible, the composition can be readily removed from the hard tissue by cooling the material below the liquid to semi-solid transition temperature, thus reversing the thickening effect. This can be accomplished with cool water or other physiologically compatible liquid. Alternatively, the concentrations of the components in the composition may be adjusted and diluted by adding water or other liquid solution. By adjusting the concentrations of the components, the transition temperature is correspondingly adjusted, and thus provides the user the ability to remove the composition even with warm solutions. Water or other liquid solutions may be administered through a rinsing cup, squirt bottle, a liquid dispensing dental tool, or any other liquid dispensing device that can provide solution to the oral environment. Preferably, administering cool or cold water provides a significant decrease in viscosity. Alternatively, the composition may be brushed, wiped, or blown off.

These and other aspects of the invention are illustrated by the following examples that should not be viewed as limiting in scope. Unless otherwise indicated, all molecular weights are number average molecular weights and all ratios, parts and percentages are by weight.

EXAMPLES

Example 1

Etching compositions were made in which the acid used was 3M Etchant Liquid manufactured by 3M Dental Products Division. Sample compositions 2 through 7 were mixed such that the compositions contained 15–30% by weight of PLURONIC F127 (BASF) in 3M Etchant Liquid (3M Co., St. Paul, Minn.).

Complex viscosity versus temperature data were obtained using a controlled strain rheometer ("RDA2", Rheometrics Scientific, Piscataway, N.J.). A parallel plate geometry was used with a plate diameter of 25 mm and a gap of approximately 1 mm. Samples were subjected to an oscillatory strain of 10% applied at a frequency of 1 rad/sec while the temperature was ramped from 15° to 45° C. (3° C./min). The resulting data is shown in FIG. 1.

The compositions 1–7 are phosphoric acid gels of the following types:

Composition #

Comparative 1 3M Dental Etchant Gel containing fumed silica (3M Co.)

Comparative 2 Contains 15.3% PLURONIC F127+84.7% 3M Etchant Liquid

Comparative 3 Contains 18.4% PLURONIC F127+81.6% 3M Etchant Liquid

Comparative 4 Contains 21.3% PLURONIC F127+78.7% 3M Etchant Liquid

Comparative 5 Contains 24.0% PLURONIC F127+76% 3M Etchant Liquid

Comparative 6 Contains 26.5% PLURONIC F127+73.5% 3M Etchant Liquid

Comparative 7 Contains 28.8% PLURONIC F127+71.2% 3M Etchant Liquid

FIG. 1 illustrates the viscosity of each composition in response to temperature. As seen in the Figure, the liquid to gel transition temperature for the compositions containing PLURONIC, as shown by the substantial increase in viscosity in response to temperature increases, is dependent on the concentration of the PLURONIC block copolymer. The silica filled etchant (Comparative Composition 1) maintained a high, consistent viscosity throughout the temperature range.

Example 2

Compositions 2 and 7 were further tested using a laboratory convection oven, heated to a temperature of approximately 45° C.

The concentration of PLURONIC F127 had significant impact on the initial viscosity of the acid etchant gel as well as the temperature at which the acid formed an "immobile gel." An "immobile gel" indicates that the gel did not flow readily under its own weight in small volumes but was still able to be easily manipulated into new positions using hand-held dental instruments. The composition that contained 15.3% PLURONIC F127 had a low initial viscosity similar to that of 3M Etchant Liquid and did not form an immobile gel at approximately body temperature but did form an immobile gel at approximately 45° C. The composition containing 28.8% PLURONIC F127 was a thick liquid when cooled in a refrigerator at approximately 5° C., but was an immobile gel at room temperature of approximately 24° C.

Example 3

An acid composition (gel) containing 24% PLURONIC F127 and 76% 3M Etchant Liquid was placed on a bovine tooth heated to 37° C. The gel was extruded from a syringe as a liquid but formed an immobile gel on contact with the tooth. The gel was left in place for 30 seconds, washed with cold water and dried in the air. There was an obvious difference between the etched and unetched surfaces indicating that the acid gel was effective.

Example 4

An acid gel containing 19.4% PLURONIC F127, 8.1% citric acid (Aldrich, Milwaukee, Wis.) and 72.5% DI water was placed on a bovine tooth heated to 37° C. The gel was extruded from a bottle as a liquid but formed an immobile gel on contact with the tooth. The gel was left in place for 45 seconds, washed with cold water and air dried. There was an obvious difference between the etched and unetched surfaces indicating that the acid gel was effective.

The citric acid and phosphoric acid gels had similar initial viscosity and gel characteristics with significantly different levels of PLURONIC F127. More PLURONIC F127 is required in highly acidic systems to affect the same results as in a less acidic system so that, in optimizing the gelation characteristics for a system, pH of the stock etchant solution must be taken into account.

Preparation of Stock Solution 1

An aqueous stock solution containing approximately 15% hydrogen peroxide (H₂O₂) was prepared by transferring 5 grams of a 30% H₂O₂ (J. T. Baker) and 5 grams of distilled water to a glass vial. The stock solution was mixed thoroughly.

Preparation of Stock Solution 2

An aqueous stock solution containing approximately 20% urea hydrogen peroxide (carbamide peroxide) was prepared by transferring 4 grams of 97% urea hydrogen peroxide (Sigma) and 16 grams of distilled water to a glass vial. The stock solution was mixed thoroughly. (The hydrogen peroxide content of the urea hydrogen peroxide was about 35%). Stock solution contained about 7% H₂O₂.

Example 5

A thermally-reversible hydrogen peroxide composition was prepared by transferring the ingredients below to a glass vial and mixing thoroughly until a colorless and transparent liquid solution was obtained.

Stock Solution 1	1.60 grams
PLURONIC F127 (BASF)	0.40 grams
	2.00 grams

The above solution contained approximately 12% hydrogen peroxide, 68% water and 20% PLURONIC F127. The glass vial containing the liquid peroxide solution was warmed to body temperature by holding the vial in a human hand. Following about one to two minutes, the liquid was transformed into a colorless, transparent composition that did not flow upon inverting the vial. The vial was allowed to cool to room temperature wherein the composition was transformed back to the low viscosity state. This cycle was repeated several times with the same outcome.

The liquid and semi-solid (gel) states were both semi-quantitatively evaluated for hydrogen peroxide utilizing hydrogen peroxide analysis strips. The analysis utilized "EM Quant Peroxide Test Strips" (EM Science Gibbstown, N.J., Catalog No. 10011-1). The compositions were evaluated according to the manufacturer's directions.

Results of the tests indicated that both the liquid and semi-solid states contained significant amounts of available peroxide.

The same sample was re-evaluated 2 months later and found to still exhibit thermally-reversible characteristics and comparable hydrogen peroxide levels based on the semi-quantitative analysis.

Example 6

A thermally reversible composition containing urea hydrogen peroxide was prepared by transferring the ingredients below to a glass vial and mixing thoroughly until a colorless and transparent liquid solution was obtained.

Stock Solution 2	4.00 grams
PLURONIC F127 (BASF)	1.00 grams
	5.00 grams

The above solution contained approximately 16% urea hydrogen peroxide (or about 5.6% hydrogen peroxide), 64% water and 20% PLURONIC F127. The glass vial containing the liquid peroxide solution was warmed to body temperature by holding the vial in a human hand. After about 1 minute, the liquid transformed to a colorless, transparent composition that did not flow upon inverting the vial. The vial was allowed to cool to room temperature wherein the semi-solid composition was transformed back to the low viscosity state. This cycle was repeated several times with the same outcome.

The liquid and semi-solid states were both semi-quantitatively evaluated for hydrogen peroxide utilizing hydrogen peroxide analysis strips, EM Quant Peroxide Test Strips (EM Science; Gibbstown, N.J., Catalog No. 10011-1), according to the manufacturer's directions. Both the liquid and semi-solid states indicated the presence of significant amounts of available peroxide.

The same sample was re-evaluated 9 days later and found to still exhibit thermally-reversible characteristics and comparable hydrogen peroxide levels based on the semi-quantitative analysis.

Table 1 summarizes the results of the two previous examples. The "+" indicates an increase in the viscosity. The

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indicates a decrease in the viscosity. The presence of hydrogen peroxide as indicated in the table are the results obtained from the semi-quantitative test using the EM Quant Peroxide Test Strips and test method.

TABLE 1

	% Peroxide	35° C. viscosity	35° C. viscosity @ 9 days	25° C. viscosity	25° C. viscosity @ 9 days	H ₂ O ₂ Present	H ₂ O ₂ Present @ 9 days
Example 5	12	+	+	-	-	Yes	Yes
Example 6	16	+	+	-	-	Yes	Yes

Example 7

Several compositions have been evaluated for viscosity as a function of temperature. The compositions are described below:

TABLE 2

Comparative Sample A				
Component	parts by weight (g)	% by weight	Physical Appearance at 23° C.	Physical Appearance at body temp
Urea	20	20	Low viscosity, colorless liquid	Low viscosity, Colorless liquid
hydrogen peroxide				
Water	80	80		

TABLE 3

Sample B				
Component	Parts by weight (g)	% by weight	Physical Appearance at 23° C.	Physical Appearance at Body temp
Urea	20	16	Low viscosity, Colorless liquid	non-flowing, colorless gel
hydrogen peroxide				
Water	80	64		
PLURONIC F-127	25	20		

TABLE 4

Sample C				
Component	Parts by weight (g)	% by weight	Physical Appearance at 23° C.	Physical Appearance at Body temp
Urea	1.6	14.7	Non-flowing, colorless gel	Non-flowing, colorless gel
hydrogen peroxide				
Water	6.4	58.7		
PLURONIC F-127	2.0	18.3		
CAB-O-SIL M-5* (fumed silica)	0.9	8.3		

*available from Cabot Corp. (Boston, MA)

Samples were further evaluated for viscosity as a function of temperature between 15° C. and 45° C. utilizing a Rheometrics RDA II Rheometer. Complex viscosity, η^* (units of measure is in Poise), versus temperature data were obtained

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using a controlled strain rheometer ("RDA2", Rheometrics Scientific, Piscataway, N.J.). A parallel plate geometry was used with a plate diameter of 25 mm and a gap of approximately 1 mm. Samples were subjected to an oscillatory

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strain of 10% applied at a frequency of 1 rad/sec while the temperature was ramped from 15° C. and 45° C. (3° C./min).

Set out below is the RDA viscosity data. FIG. 2 illustrates that aqueous compositions containing PLURONIC F127 polymer exhibit a relatively sharp increase in viscosity upon warming from room temperature to about 45° C. Sample C, which exhibited semi-solid-like characteristics at room temperature (due to the incorporation of a fumed silica), also increased substantially upon an increase in temperature.

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TABLE 5

A		B		C	
Temp ° C.	η° P	Temp ° C.	η° P	Temp ° C.	η° P
14.02	9.75424	17.88	2308.56	18.5	52951.1
14.28	3.35258	17.88	2379.72	18.3	42757.9
15.36	7.33292	18.54	2587.46	18.79	41559.9
17.28	3.46242	19.42	3111.41	19.64	41144.7
19.46	5.85152	20.91	3711.59	20.76	41347.4
21.12	5.79953	22.36	4580.71	22.09	42047
22.89	7.09599	23.72	5661.42	23.51	43615.7
24.91	4.19887	25.46	7221.65	24.04	45494.3
26.31	0.87001	26.85	8940.38	26.03	48768.7
28.23	3.13629	28.73	25375.6	27.94	55250.6
30.12	4.57411	30.7	29698.2	29.57	82062.6
31.6	4.7215	32.07	33651.8	31.31	94988.5
33.2	9.01765	33.57	37181.2	32.83	1.04E + 05
35.02	8.0025	35.22	40557.8	34.36	1.09E + 05
36.75	2.94618	36.89	43766.3	36.09	1.13E + 05
38.44	4.24626	38.43	46677.4	37.49	1.20E + 05
40.85	1.08273	40.01	49322.7	38.95	1.26E + 05
42.92	5.04081	41.84	52296.6	40.7	1.32E + 05
		43.52	54490.4	42.2	1.36E + 05
				43.9	1.39E + 05

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We claim:

1. A method of applying a dental composition [in the oral environment] to a tooth structure using an aqueous dental composition comprising about 10% by weight to about 50% by weight of [a thermally responsive viscosity modifier] one or more polymers, water, and [an] one or more adjuvants, wherein the [composition is in] one or more polymers is a polyoxyalkylene polymer, which provides the composition with a lower viscosity state at a pre-treatment temperature and a [highly viscous] higher viscosity state at a treatment temperature that is higher than the pre-treatment temperature, comprising:

applying the composition through an orifice onto a surface of the tooth structure, wherein the composition is at the pretreatment temperature and in the lower viscosity state prior to being applied onto the surface of the tooth structure,

allowing the composition to warm to the treatment temperature and increase in viscosity to the [highly vis-

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cous] *higher viscosity* state wherein the viscosity of the composition at the treatment temperature is at least about 10 times the viscosity of the composition at the pre-treatment temperature, and

allowing the composition to remain on the surface of the tooth structure.

2. The method of claim 1 wherein the pre-treatment temperature is at most about room temperature.

3. The method of claim 1 wherein the treatment temperature is about body temperature.

[4. The method of claim 1 wherein the thermally responsive viscosity modifier is a polyoxyalkylene polymer.]

5. The method of claim 1 wherein the composition further comprises a solvent.

6. The method of claim 1 wherein the viscosity of the composition at the treatment temperature is about 10 times to about 100 times the viscosity of the composition at the pre-treatment temperature.

7. The method of claim 1 wherein the composition decreases in viscosity upon cooling from the treatment temperature.

8. The method of claim 7 further comprising removing the composition from the surface by cooling the composition from the treatment temperature.

9. The method of claim 8 wherein the composition is cooled by application of a cool liquid.

10. The method of claim 9 wherein the liquid comprises water.

[11. The method of claim 1 wherein applying the composition onto a surface comprises applying the composition onto hard tissue.]

12. The method of claim 1 wherein applying the composition through an orifice comprises applying the composition through an orifice of a syringe.

13. The method of claim 1, wherein the dental composition comprises about 17% by weight to about 40% by weight of [a thermally responsive viscosity modifier] *the one or more polymers*.

14. The method of claim 1, wherein the adjuvant is selected from [the group consisting of] acids and medicaments.

15. The method of claim 1, wherein the adjuvant is selected from [the group consisting of] whitening agents and medicaments.

16. A method of applying a dental composition [in the oral environment] *to a tooth structure* using an aqueous dental composition comprising about 10% by weight to about 50% by weight of [a thermally responsive viscosity modifier] *one or more polymers*, water, and [an] *one or more* adjuvants selected from [the group consisting of] fluoride, antimicrobial agents, anti-fungal agents, and cariostatic agents, wherein the [composition is in] *one or more polymers is a polyoxyalkylene polymer, which provides the composition with a lower viscosity state at a pre-treatment temperature and a [highly viscous] higher viscosity state at a treatment temperature that is higher than the pre-treatment temperature, comprising:*

applying the composition through an orifice onto a surface of the tooth structure, wherein the composition is at the pretreatment temperature and in the lower viscosity state prior to being applied onto the surface of the tooth structure,

allowing the composition to warm to the treatment temperature and increase in viscosity to the [highly viscous] *higher viscosity* state wherein the viscosity of the composition at the treatment temperature is at least about 10 times the viscosity of the composition at the pre-treatment temperature, and

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allowing the composition to remain on the surface of the tooth structure.

17. The method of claim 1, wherein the aqueous composition includes a salt.

18. A method of applying a dental composition to a tooth structure using an aqueous dental composition comprising about 10% by weight to about 50% by weight of one or more polymers, water, and one or more adjuvants, wherein the one or more polymers is a polyoxyalkylene polymer, which provides the composition with a lower viscosity state at a pre-treatment temperature and a higher viscosity state at a treatment temperature that is higher than the pre-treatment temperature, comprising:

applying the composition through an orifice onto a surface of the tooth structure, wherein the composition is at the pretreatment temperature and in the lower viscosity state prior to being applied to the surface of the tooth structure,

allowing the composition to warm to the treatment temperature and increase in viscosity to the higher viscosity state wherein the viscosity of the composition at the treatment temperature is at least about 2 times the viscosity of the composition at the pre-treatment temperature, and

allowing the composition to remain on the surface of the tooth structure.

19. A method of applying a dental composition to a tooth structure using an aqueous dental composition comprising about 10% by weight to about 50% by weight of one or more polymers, water, and one or more adjuvants, wherein the one or more polymers is a polyoxyalkylene polymer, which provides the composition with a viscosity of about 0 to about 7000 poise at a pre-treatment temperature and a viscosity of at least about 10,000 poise at a treatment temperature that is higher than the pre-treatment temperature, comprising:

applying the composition through an orifice onto a surface of the tooth structure, wherein the composition is at the pretreatment temperature and has a viscosity of about 0 to about 7000 poise prior to being applied to the surface of the tooth structure,

allowing the composition to warm to the treatment temperature and increase in viscosity to at least about 10,000 poise, and

allowing the composition to remain on the surface of the tooth structure.

20. A method of applying a dental composition to a tooth structure using an aqueous dental composition comprising about 10% by weight to about 50% by weight of one or more polymers, water, and one or more adjuvants, wherein the one or more polymers is a polyoxyalkylene polymer, which provides the composition with a liquid and lower viscosity state at a pre-treatment temperature and a higher viscosity state at a treatment temperature that is higher than the pre-treatment temperature, comprising:

applying the composition through an orifice onto a surface of the tooth structure, wherein the composition is at the pretreatment temperature and in the liquid and lower viscosity state prior to being applied to the surface of the tooth structure,

allowing the composition to warm to the treatment temperature and increase in viscosity to the higher viscosity state such that the composition forms an immobile gel, and

allowing the composition to remain on the surface of the tooth structure.

21. The method of claims 18, 19, or 20 wherein the pre-treatment temperature is at most about room temperature.

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22. The method of claims 18, 19, or 20 wherein the treatment temperature is about body temperature.

23. The method of claims 18, 19, or 20 wherein the composition further comprises a solvent.

24. The method of claims 18, 19, or 20 wherein the viscosity of the composition at the treatment temperature is about 10 times to about 100 times the viscosity of the composition at the pre-treatment temperature.

25. The method of claims 18, 19, or 20 wherein the viscosity of the composition at the treatment temperature is about 2 times to about 5 times the viscosity of the composition at the pre-treatment temperature.

26. The method of claims 18, 19, or 20 wherein the composition decreases in viscosity upon cooling the composition from the treatment temperature.

27. The method of claim 26 further comprising removing the composition from the surface by cooling the composition from the treatment temperature.

28. The method of claim 27 wherein the composition is cooled by application of a cool liquid.

29. The method of claim 28 wherein the liquid comprises water.

30. The method of claims 18, 19, or 20 wherein applying the composition through an orifice comprises applying the composition through an orifice of a syringe.

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31. The method of claims 18, 19, or 20, wherein the dental composition comprises about 17% by weight to about 40% by weight of the one or more polymers.

32. The method of claims 18, 19, or 20, wherein the adjuvant is selected from acids and medicaments.

33. The method of claims 18, 19, or 20 wherein the adjuvant is selected from whitening agents and medicaments.

34. The method of claims 18, 19, or 20 wherein the adjuvant is selected from fluoride, anti-microbial agents, anti-fungal agents, and cariostatic agents.

35. The method of claims 18, 19, or 20, wherein the aqueous composition includes a salt.

36. The method of claims 18, 19, or 20 wherein the viscosity of the composition at the pre-treatment temperature is at least about 5000 poise.

37. The method of claims 18 or 20 wherein the viscosity of the composition at the treatment temperature is at least about 10,000 poise.

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