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(54) **Title**: STABLE AND STERILE TISSUE ADHESIVE COMPOSITION WITH A CONTROLLED HIGH VISCOSITY

(57) **Abstract**: A stable and sterile adhesive composition with a controlled level of high viscosity is disclosed in the present invention. Adhesive compositions with different ranges of viscosity could be prepared by heating the adhesive monomer composition at mild temperature in the presence of pluronic polymer. The viscosity of the adhesive composition is able to be controlled to any desired level. A method of stabilizing the adhesive composition with a desired level of high viscosity is provided by using the combination of free radical and acid stabilizers. Methods for packaging, sterilizing and applying the adhesive in the medical field are also provided.

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STABLE AND STERILE TISSUE ADHESIVE COMPOSITION WITH A CONTROLLED HIGH VISCOSITY

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STABLE AND STERILE TISSUE ADHESIVE COMPOSITION WITH A CONTROLLED HIGH VISCOSITY

RELATED APPLICATION

This application claims the benefit of priority to U.S. Patent Application Number 12/214,791 titled "STABLE AND STERILE TISSUE ADHESIVE COMPOSITION WITH A CONTROLLED HIGH VISCOSITY," filed on June 20, 2008, the contents of which are incorporated in this application by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to stabilized, sterilized cyanoacrylate adhesive compositions with the controlled level of high viscosity, methods of making these compositions and to their use for medical applications.

2. Description of Related Art

Cyanoacrylate esters are well known to be adhesives and have been used extensively in different fields due to their quick bonding and applicability to a large range of substrates. They are used as industrial and structural adhesives, consumer product for repair of household items and in the hobby sector for assembly and repair. In addition, cyanoacrylate compositions have found application in medicine for closing wounds especially in cases where suturing does not provide satisfactory results. Cyanoacrylate esters are used in protecting surface injuries including abrasions, lacerations, sores, burns and other open surface wounds. In spite of their interesting properties and wide applications in different fields, cyanoacrylate monomers have disadvantages which prevent use of cyanoacrylates in certain fields. For example, the inherent low viscosity of cyanoacrylate monomers in medical applications may result in the spreading of the adhesive into undesired areas as a consequence of the cyanoacrylate adhesive's runniness. In addition, the runniness of the cyanoacrylate

monomer makes it difficult to prevent the adhesive from entering the wound, which will adversely affect the healing of the wound.

In order to obtain a cyanoacrylate adhesive composition with a desired level of higher viscosity, different thickening agents and methods have been employed. Thickening agents, such as polymers have been used to improve the viscosity of the cyanoacrylate adhesive compositions. The polymer additives are soluble in cyanoacrylate compositions either at room or elevated temperature.

Misiak et al., in U.S. Pat. Appl. No. 20070092481, disclose a thickened cyanoacrylate adhesive composition by using poly[butyleneterephthalate-co-poly(ethyleneglycol) terephthalate] as a viscosity modifier. The formulation of cyanoacrylate adhesives as low viscosity emulsions, non-flowable and gels forms can be prepared by adding this polymer component to cyanoacrylate compositions. The viscosity of the composition is dependent upon the nature and level of the polymer material used in the composition.

Kotzey et al., in U.S. Pat. No. 6,797,107, disclose a solid cyanoacrylate adhesive composition which can be applied to a substrate in solid form and which polymerizes into an adhesive polymer upon liquefying. The solid cyanoacrylate composition liquefies at temperatures slightly above room temperature and polymerizes upon liquefication. ε- caprolactones are used as a solidifying polymer with cyanoacrylate monomers and other additives to form the solid cyanoacrylate adhesive composition.

Hickey et al., in U.S. Pat. No. 6,743,858, disclose a method of making a thickened sterile monomeric adhesive composition preparation of the composition includes placing a mixture of a polymerizable monomer and a thickening agent in a container, sealing the container and sterilizing the container and the mixture. The thickening agent is soluble in the monomer at room temperature. Suitable thickeners employed include, for example, polyoxalates, lactic-glycolic acid copolymers, polycaprolactone, lactic acid-caprolactone copolymers, poly (caprolactone + DL-lactide + glycolide),

polyorthoesters, polyalkyl acrylates, copolymers of alkylacrylate and vinyl acetate, polyalkyl methacrylates, and copolymers of alkyl methacrylates and butadiene.

Shalaby, in U.S. Pat. No. 6,299,631, discloses a bioabsorbable adhesive/hemostatic formulation of a 2-alkoxyalkylcyanoacrylate with trimethylene carbonate-based polymers as the viscosity thickener.

Greff et al. disclose in U.S. Pat. No. 5,665,817 alkyl cyanoacrylate compositions suitable for topical application to human skin, which comprise a suitable amount of the thickening agent to increase the viscosity. The thickening agent used is biocompatible materials that increase the viscosity of the alkyl cyanoacrylate composition, which include polymethylmethacrylate (PMMA) or other preformed polymers soluble in the alkyl cyanoacrylate. The thickening agent is added to provide a viscosity of from about 2 to 50,000 centipoises (cp) at 20 °C.

Linden et al., in U.S. Pat. No. 5,350,789, disclose 2-cyanoacrylate-based tissue adhesives employing biocompatible oxalate polymers as reactive plasticizers and thickening agents. The adhesives are capable of being formulated to allow modulus matching of the adhesive and the substrate.

Leung et al., in U.S. Pat. No. 5,328,687, disclose adhesive compositions which contain thickening agents that may be used for bonding tissue. Polymer thickeners employed include polylactic acid, polyglycolic acid, lactic-glycolic acid copolymers, polycaprolactone, lactic acid-caprolactone copolymers, poly-3-hydroxybutyric acid, polyorthoesters, polyalkyl acrylates, copolymers of alkylacrylate and vinyl acetate, polyalkyl methacrylates, and copolymers of alkyl methacrylates and butadiene.

O'Sullivan et al., in U.S. Pat. No. 4,038,345, disclose stable cyanoacrylate adhesive compositions having improved viscosities. The adhesive compositions have viscosities in excess of about 500 centipoises comprising at least one monomeric ester of 2-cyanoacrylic acid, and a polyacrylate thickener which is pretreated to have a reduced viscosity greater than about 5 cp. A free radical polymerization initiator is

used in the amount of less than about one percent by weight. The composition also contains an inhibitor of the anionic polymerization of the monomer. O'Sullivan discloses a process for preparing improved cyanoacrylates which involves heating a conventional polyacrylate thickener at a suitable temperature and for a suitable period of time to reduce its content of free radical polymerization initiators to below about one percent; and dissolving a sufficient amount of polymer thickener in the adhesive monomer to produce a cyanoacrylate adhesive composition with suitable viscosity.

Gleave discloses in U.S. Pat. No. 4,102,945 a cyanoacrylate adhesive composition thickened by a copolymer or terpolymer resin capable of being dissolved or solvated by the cyanoacrylate monomer exhibits significantly improved peel strength. Polymer thickeners are acrylonitrile-butadiene-styrene terpolymers, methacrylate-butadiene-styrene terpolymers, and vinylidene chloride-acrylonitrile copolymers.

Setsuda et al., in U.S. Pat. No. 3,692,752, disclose thickened cyanoacrylate solutions containing certain polyether acrylates/methacrylates, acrylic/methacrylic esters of bis(hydroxyalkyl) phosphonic acid derivatives, and acrylic/methacrylic esters of tris(hydroxyalkyl) cyanuric acid derivatives.

Wicker et al. disclose in U.S. Pat. No. 3,527,841 2-cyanoacrylate adhesive compositions for general and particular for surgical uses containing poly (lactic acid) as a viscosity thickener and an acidic compound such as sulfur dioxide and a free radical stabilizer such as hydroquinone.

Wicker, in U.S. Pat. No. 3,282,773, discloses cyanoacrylate adhesive compositions in which poly (methylmethacrylate) was used as the thickener.

Polymer of cyanoacrylates has also been used to increase the viscosity of the cyanoacrylate adhesive compositions. U.S. Pat. Appl. No. 20060062687 to Morales discloses a method of sterilizing 2-cyanoacrylate compositions with poly-cyanoacrylate as the thickener, including heating the composition in a device at a temperature of from about 70 to about 140 °C for an effective amount of time.

Morales discloses sterilized 2-cyanoacrylate ester compositions for use in medicine or surgery. Morales also discloses a method for assaying the sterilization of cyanoacrylate compositions.

U.S. Pat. No. 3,564,078 discloses the use of poly (ethyl 2-cyanoacrylate) as a component of cyanoacrylate compositions. U.S. Pat. No. 3,527,224 to Rabinowitz discloses a surgical adhesive composition comprising monomeric and polymeric n-pentyl cyanoacrylate obtained by free-radical polymerization. U.S. Pat. No 2,794,788 teaches thickening of cyanoacrylate adhesives by dissolving polymeric alkyl cyanoacrylates, as well as other compounds including methacrylates, polyacrylates and cellulose esters.

Organic or inorganic powders, which are not soluble in cyanoacrylate monomer, have also been used as fillers to adjust the viscosity of cyanoacrylate compositions. Such materials include various inert inorganic materials such as silica, quartz, alumina, calcium and metal salts and organic powders such as polycarbonates, polyvinylidene fluorides, polyethylenes, and other polymeric powders. For example, U.S. Pat. No. 4,533,422 discloses cyanoacrylate compositions which employ fumed silicas as the filler are stable and exhibit a high thixotropic ratio. U.S. Pat. No. 3,607,542 discloses the preparation of a water-resistant cyanoacrylate paste containing insoluble, inert fillers such as salts of calcium, titanium, zinc, tin, aluminum, iron and copper, among others. U.S. Pat. No. 4,105,715, discloses the use of finely divided organic powders such as polycarbonates, polyvinylidene fluorides, polyethylenes, and other polymeric powders are proposed as additives for cyanoacrylates. Blending insolvable materials with cyanoacrylate compositions can cause separation while the adhesive is stored, resulting in ineffective modification of the viscosity. Also, the presence of the fillers can sometimes affect the quality of the bonding.

The use of polymer additives to improve the viscosity of cyanoacrylate adhesives presents different disadvantages. Relatively small modification of the viscosity was achieved by using polymer additive as the viscosity modifier. The amount of the polymer thickener is limited due to the poor solubility of certain polymers in the cyanoacrylate monomer so that it was difficult to obtain highly viscous adhesives.

Increasing the amount of polymer thickener incorporated would result in spinnability, reduction of optical clarity and weakening of the adhesive bond. In addition, many polymer additives used as the thickener undergo decomposition under sterilization conditions, which lead to the decrease of the viscosity. Such instability becomes more obvious when the cyanoacrylate adhesive compositions are stabilized by acids, due to the fact that those acids destabilize the polymer thickener in the compositions. Curing or further polymerization of the cyanoacrylate adhesive occurs during the process of sterilization even in the presence of certain amounts of stabilizers. Sometimes polymerization induced by the sterilization is so serious that the cyanoacrylate compositions are no longer usable. In other cases, the shelf life of the sterilized cyanoacrylate compositions can be dramatically shorten even though these sterilized adhesive compositions are still usable. Presently, the only acceptable polymer thickener which can be successfully used for commercial cyanoacrylate adhesive compositions include poly (methylmethacrylate) or poly(vinylacetate). Therefore it would be desirable to provide a simple and effective method to prepare cyanoacrylate compositions with the controllable viscosity without sacrificing the shelf life stability of the cyanoacrylate compositions.

SUMMARY OF THE INVENTION

The present invention provides a stable and sterile cyanoacrylate adhesive composition with a controllable level of high viscosity, a method of preparing cyanoacrylate adhesive compositions with different range of viscosity, a method of packaging and sterilizing the cyanoacrylate adhesive, as well as a procedure of stabilizing the cyanoacrylate adhesive with the desired level of high viscosity using a combination of stabilizers.

The present invention provides a method of controlling the viscosity level of cyanoacrylate adhesive compositions. Cyanoacrylate adhesive compositions with different levels of viscosity are prepared by heating the cyanoacrylate monomer composition at mildly elevated temperature in the presence of a small amount of

pluronic polymer. The desired level of viscosity can be controlled by modifying the amount of polymer additive and the free radical or anionic stabilizers in the cyanoacrylate monomer. On the other hand, the highly viscous cyanoacrylate gel prepared according to the present invention can be further diluted with cyanoacrylate monomers to provide cyanoacrylate adhesive compositions with the desired level of viscosity, which represents another way to control the viscosity level of the cyanoacrylate adhesive composition.

The present invention provides a method of stabilizing cyanoacrylate adhesive compositions with different levels of viscosity by applying at least one free radical stabilizer and at least one acid stabilizer to the adhesive. In more preferred embodiments of the present invention, at least two free radical stabilizers and at least two acid stabilizers are used to stabilize the adhesive composition. The cyanoacrylate compositions with the combination of stabilizers disclosed in preferred embodiments of this invention provide at least two years shelf life after the sterilization.

The present invention provides a method of packaging the cyanoacrylate adhesive composition with the controlled level of high viscosity, which is stabilized with the combination of free radical and anion polymerization inhibitors. The cyanoacrylate adhesive compositions can be packaged in different applicators, which are then sterilized. Cyanoacrylate adhesive composition with the controlled level of viscosity can be uniformly dispensed onto the substrates from the applicator.

The present invention provides a method of preparing the sterile cyanoacrylate adhesive composition with the desired level of viscosity by sterilizing the composition after introducing the pluronic polymer additive. The sterile and stable cyanoacrylate adhesive composition with a biocompatible polymer additive is especially suitable to be used in the medical field.

The present invention provides a method of sealing tissue by spreading the sterilized cyanoacrylate adhesive composition with a desired level of high viscosity onto the tissue from the applicator, which is quickly cured to seal the tissue. Other advantages

of the current invention are apparent and/or will become obvious as disclosed in the detailed descriptions and in the appended claims.

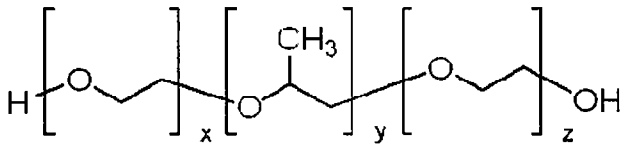
DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

According to the invention, a stabilized and sterilized cyanoacrylate adhesive composition with the desired level of high viscosity is provided. Cyanoacrylate compositions with different levels of viscosity are obtained by heating cyanoacrylate monomer in the presence of pluronic polymer to partially polymerize the cyanoacrylate monomer. The level of the viscosity of cyanoacrylate compositions is readily controlled by modifying the amount of pluronic polymer and polymerization inhibitor present in the cyanoacrylate monomer. The cyanoacrylate adhesive composition with the desired level of viscosity is then stabilized with the combination of one or more free radical and acid stabilizers. The further polymerization of the cyanoacrylate compositions with the desired level of high viscosity can be inhibited by using the combination of free radical and acid stabilizers in spite of the presence of pluronic polymer as the polymerization initiator. The cyanoacrylate compositions thus stabilized are stable for at least two years shelf life after packaging in the applicator and sterilization. The cyanoacrylate adhesive compositions with a desired level of high viscosity can be packaged with different applicators, which are then sterilized using different sterilization methods. Such stable and sterile cyanoacrylate adhesive compositions with the desired level of high viscosity can be used as medical tissue adhesive for sealing and aiding in the repair of tissue.

According to the present invention, cyanoacrylate adhesive compositions with the desired level of high viscosity can be prepared by heating the cyanoacrylate monomer in the presence of pluronic polymer. The cyanoacrylate monomer becomes partially polymerized by the pluronic polymer's addition and then the partial polymerization is quenched by adding stabilizers to the compositions to provide the desired level of viscosity. Cyanoacrylate adhesive compositions with the desired level of viscosity can also be prepared by diluting highly viscous cyanoacrylate compositions (e.g. thick

gel materials prepared according to the present invention) with cyanoacrylate monomers.

Pluronics, the trade name for poloxamers (the terms "poloxamer" and "pluronic" are interchangeably used herein), are nonionic tailback copolymers composed of a central hydrophobic chain of polyoxypropylene flanked by two hydrophilic chains of polyoxyethylene. Because the lengths of the polymer blocks can be customized, many different poloxamers exhibit slightly different properties. For the generic term poloxamer these copolymers are commonly named with the letter "P" followed by three digits, the first two digits times 100 gives the approximate molecular mass of the polyoxypropylene core and the last digit times 10 gives the percentage polyethylene content (e.g. P407 = poloxamer with a polyoxypropylene molecular mass of 4000 g/mole and a 70% polyoxyethylene content). For the Pluronic trade name, coding of these copolymers starts with a letter to define its physical form (L = liquid, P = paste, F = flake (solid)) followed by two or three digits. The first digit(s) refer to the molecular mass of the polyoxypropylene core (determined from BASF's Pluronic grid) and the last digit times 10 gives the percentage polyoxyethylene content (e.g. Pluronic F127 = pluronic with a polyoxypropylene molecular mass of 4000 g/mol and a 70 % polyoxyethylene content. Therefore P407 defines the same poloxamer as Pluronics F127. The general structure of pluronic polymer is shown in below.



Structure of pluronic polymer

[alpha-Hydroxy-omega-hydroxypoly(oxyethylene)$_x$ poly(oxypropylene)$_y$ poly(oxyethylene)$_z$ block polymer]

In the above formula, in one embodiment, x is from 5 to 200, in an alternative embodiment x is from 10 to 175, and in a still further alternative embodiment x is from 10 to 150.

In the above formula, in one embodiments, y is from 5 to 100, in an alternative embodiment y is from 15 to 80, and in a still further alternative embodiment y is from 20 to 60.

In the above formula, in one embodiments, z is from 5 to 200, in an alternative embodiment z is from 10 to 175, and in a still further alternative embodiment z is from 10 to 150.

In certain embodiments x may equal z. Typically, in a preferred embodiment, the poloxamers have a molecular weight of from about 2000 to about 20000 daltons, in other embodiments from about 3000 to about 18000 daltons.

The table below demonstrates some of the possible values of x, y and z for poloxamers.

Poloxamer	x	y	z
124	12	20	12
188	80	27	80
237	64	37	64
338	141	44	141
407	101	56	101

The pluronic polymers utilized in this invention include preferably pluronic F38 prill, pluronic F68 prill, pluronic F88, pluronic F108NF and pluronic F127 prill, in the preferable amount 0.02 to 0.5 %. Any other suitable pluronic polymer additive, such as, but not limited to, pluronic 10R5, pluronic 17R2, pluronic 17R4, pluronic 25R2, pluronic 25R4, pluronic 31R1, pluronic F68 LF, pluronic F68NF, pluronic F68 NF prill poloxamer 188, pluronic F77, pluronic F87, pluronic F98, pluronic F108, , pluronic F127, pluronic F127 NF, pluronic F127 NF prill poloxamer 407, pluronic L 10, pluronic L 101, pluronic, L121, pluronic L 31, pluronic L 35, pluronic, L 43, pluronic L44, pluronic, L44 NF poloxamer 124, pluronic, L 61, pluronic 62, pluronic

L62 LF, pluronic, L 62D, pluronic L64, pluronic L 81, pluronic L 92, pluronic N 3, pluronic P 103, pluronic P 104, pluronic P 105, pluronic P 123 surfactant, pluronic P 65, pluronic, P 84 and pluronic P 85, can also be used. (Pluronic polymers were obtained from BASF Corporation, 100 Campus Drive, Florham Park, New Jersey, USA). The use of biocompatible pluronic polymers as additives makes the cyanoacrylate adhesive compositions of the current invention especially suitable for medical use. Pluronic polymers such as pluronic F127 are preferred additives for medical applications as this pluronic polymer has been approved by FDA for medical use and they are biocompatible.

The amount of pluronic polymer added to the cyanoacrylate monomer depends upon the required level of viscosity and the presence of stabilizers in the cyanoacrylate monomer. The pluronic polymer additive is preferably present in an amount of about 0.01% to about 0.80 % by weight of the total weight of the cyanoacrylate compositions. In alternatively preferred embodiments, the pluronic polymer additive is present in an amount of about 0.02 % to about 0.5 % by weight, or about 0.04 % to about 0.30 %, and more preferably in an amount of about 0.07% to about 0.16 % by weight of the cyanoacrylate composition.

The present invention provides a method of preparing cyanoacrylate ester compositions with the desired level of viscosity using a combination of polymer additive and cyanoacrylate mixed at an elevated temperature. Pluronic polymer is not soluble in 2-cyanoacrylate adhesive compositions at room temperature. However, it may be dissolved at mildly elevated temperatures in the range of about 30 °C to about 70 °C, preferably from about 40 to about 65 °C, and more preferably from about 50 to about 60 °C. Dissolution of pluronic polymer in cyanoacrylate monomer induces the partial polymerization of the cyanoacrylate monomer to increase the viscosity of the composition to a desired level.

The mixing temperature also affects the performance of the cyanoacrylate compositions. In order to evaluate the effect of temperature, cyanoacrylate adhesive compositions were prepared at different temperatures in the presence of the pluronic

polymer. In most of the cases, the partial polymerization induced by the pluronic polymer occurs in the range of about 30 °C to about 70 °C, preferably at about 40 to °C about 60 °C to provide cyanoacrylate adhesives with a desired level of viscosity.

Pluronic polymers are mild polymerization initiators and partial polymerization can be controlled by modifying the amount of pluronic polymer and polymerization inhibitor in the cyanoacrylate monomer. Preferably, cyanoacrylate monomer pre-stabilized with a certain amount of free radical and acid stabilizer is partially polymerized to provide the adhesive composition with the desired level of viscosity.

The present invention provides a process for making cyanoacrylate adhesive compositions with the desired level of high viscosity while reducing undesired side reactions and inhibiting the further polymerization of the compositions by using a combination of free radical and acid stabilizers to provide an extended shelf life aftersterilization. It is well known that cyanoacrylate monomer is extremely sensitive to premature polymerization. Once polymerization is initiated, curing of the adhesive can be very rapid, which makes it very difficult to control the polymerization rate after the initiation of the polymerization. This creates the challenge of thickening cyanoacrylate adhesive compositions via partially polymerizing the cyanoacrylate monomer. The present invention provides a method to overcome such challenge by heating the cyanoacrylate monomer at the temperature range of 30 °C - 70 °C, preferably 40 °C - 65 °C, and more preferably 50 °C - 60 °C in the presence of pluronic polymer for a time period from about 0.5 to about 3.0 hours, in another embodiment from about 1.0 to about 2.5 hours. The pluronic polymers used in the present invention are difunctional block copolymer surfactant terminating in primary hydroxyl groups. The very small percentage of hydroxyl group in the molecule may make the pluronic polymer a mild polymerization initiator for cyanoacrylate monomer. The polymerization rate can be readily controlled by modifying the amount of pluronic polymer and polymerization inhibitor present in the cyanoacrylates monomer.

The present invention provides methods of controlling the viscosity level of the cyanoacrylate adhesive compositions. Cyanoacrylate adhesive compositions with the desired level of viscosity can be prepared by modifying the amount of polymer additive and the free radical or anion polymerization inhibitor. According to the present invention, cyanoacrylate compositions with various viscosities, including compositions which are gels and non-flowable forms can be obtained. Extremely viscous cyanoacrylate gel obtained according to the present invention can be further diluted with cyanoacrylate monomers to prepare cyanoacrylate adhesive compositions with the desired level of viscosity. Cyanoacrylate gel is the jelly-like and highly viscous liquid cyanoacrylate with reduced mobility compared to cyanoacrylate monomer. Cyanoacrylate gels prepared according to the present invention have a viscosity in the range of about 1000 cp to about 300,000 cp, preferably from about 1000 cp to about 100,000 cp, more preferably from about 1000 cp to about 50,000 cp and even more preferably from about 1000 cp to about 30,000 cp.

According to the present invention, the viscosity level of the cyanoacrylate adhesive compositions can be controlled. The viscosity level of the cyanoacrylate adhesive compositions is determined by many factors such as the amount of pluronic polymer, the amount of stabilizer present in the cyanoacrylate monomer, the mixing temperature and the mixing time before quenching the partial polymerization of the cyanoacrylate. The viscosity level of the cyanoacrylate adhesive compositions is dependent upon the rate of partial polymerization of cyanoacrylate. Therefore, to increase the viscosity of the cyanoacrylate adhesive one can increase the amount of pluronic polymer, decrease the amounts of the stabilizers, increase the mixing temperature and increase the mixing time.

Introducing a predetermined amount of pluronic polymer is into the cyanoacrylate monomer (without or with stabilizers) and mixing the pluronic polymer with the cyanoacrylate monomer to homogeneity at mildly elevated temperatures initiates the partial polymerization of cyanoacrylate. The viscosity of the cyanoacrylate adhesive composition increases as the polymerization of the cyanoacrylate monomer proceeds. Compared to the cyanoacrylate monomer in the absence of stabilizers, the partial

polymerization rate of the cyanoacrylate monomer pre-stabilized with stabilizer is easier to control, as is the viscosity level of cyanoacrylate adhesive composition. Once the partial polymerization of cyanoacrylate monomer is initiated, polymerization will continue until it is quenched by the addition of stabilizers. In the preferred embodiments of the present invention, the viscosity of the cyanoacrylate adhesive composition may be determined using a viscometer and once a desired level of viscosity is reached stabilizers may be immediately added to quench the polymerization so that the viscosity of said cyanoacrylate compositions can be stabilized at the desired level. The quenching of the partial polymerization may be accomplished by the addition of free radical stabilizer, anionic stabilizer and/or the combination of free radical and anionic stabilizer. In embodiments of the present invention, the free radical stabilizer is, but not limited to butylated hydroxyl anisole (BHA). BHA may be used in an amount of about 200 to about 15000 ppm of cyanoacrylate compositions preferably about 1000 to about 10000 ppm, more preferably about 2000 to about 8000 ppm. The preferred anionic stabilizer is, but not limited to sulfur dioxide in an amount of about 2 to about 500 ppm, preferably about10 to about 200 ppm.

Cyanoacrylate adhesive compositions prepared according to the preferred embodiments of the present invention for use in medical applications have a viscosity such that the adhesive stops running, flowing beyond the intended application site or is substantially prevented from dripping into the wound. The adhesive may adversely affect the healing of the wound if the adhesive runs into the wound. This is due to the fact that adhesive inside the wound may act as a barrier to two edges of the wound thereby preventing closure of the wound. On the other hand, cyanoacrylate adhesive compositions should not be so viscous as to block its application to the skin, such as when the adhesive is applied through an applicator. Adhesive compositions with viscosity of less than 3,000 centipoise (cp) are normally employed for medical applications such as wound closure. More preferably the adhesive compositions for medical applications such as wound closure having a viscosity of less than 2,000 cp are employed. In a more preferred embodiment, the viscosity of the adhesive compositions is in the range of from about 10 to about 1000 cp, preferably from about

20 to about 500 cp and more preferably from about 30 to about 300 cp, including from about 30 cp to about 200 cp, from about 40 cp to about 200 cp, from about 50 cp to about 200 cp, from about 60 cp to about 200 cp, from about 70 cp to about 200 cp, from about 80 cp to about 200 cp, from about 90 cp to about 200 cp, from about 100 cp to about 200 cp, from about 150 cp to about 200 cp, from about 200 cp to about 300 cp and from about 250 cp to about 300 cp.

The present invention also provides stable cyanoacrylate adhesive compositions with a desired level of viscosity. The stability of the cyanoacrylate adhesive compositions may be evaluated by the accelerated aging and viscosity test. The accelerated aging test of cyanoacrylate adhesive composition is performed in the oven at 80 °C for a period of 12 days. The cyanoacrylate compositions are tested for viscosity at intervals of 3, 6, 9 and 12 days. Based on prior stability studies for cyanoacrylate compositions and ASTM method, 12 days accelerated aging at 80 °C correlates to 2 years of shelf life at ambient temperatures (ASTM F1980-2). The accelerated aging test at 80 °C is initially conducted for bulk cyanoacrylate adhesive compositions with the desired level of high viscosity before packaging and sterilizing. Table 1 shows the viscosity result of the cyanoacrylate compositions at day 0 and day 12 of the accelerated aging test at 80 °C. The viscosity of the cyanoacrylate adhesive compositions increases after the accelerated aging but viscosities of the aged samples at day 12 are in the acceptable range of 10 to 3000 cp, preferably 20 to 3000 cp and more preferably 30 to 2000 cp. In the more preferred embodiments the viscosity of the adhesive composition after the accelerated aging test is only slightly changed from the initial viscosity testing at day 0. The viscosity of the adhesive composition even after aging will be acceptable as long as the adhesive is still dispensable via an applicator and the adhesives perform as intended. The use of the cyanoacrylate adhesive will dictate the absolute range of increased or decreased viscosity acceptable during aging, but in preferred embodiments the viscosity of the composition at day 12 of aging at 80 °C is within about 100 % (no change in viscosity) to 500 % (five times the viscosity) of the viscosity of the composition at day 0 (before accelerate aging testing). In preferred embodiments the viscosity of the composition at day 12 of aging at 80 °C is within about 100 % to 250 % of the viscosity of the composition at day 0 (before accelerate

aging testing) and in more preferred embodiments the viscosity of the composition at day 12 of aging at 80 °C is within about 100 % to 150 % of the viscosity of the composition at day 0 (before accelerate aging testing) In fact, the increase of the viscosity of the cyanoacrylate adhesive compositions after the accelerated aging test is not drastic, indicating that the bulk adhesive compositions before packaging and sterilizing are stable.

Table 1: Viscosity of cyanoacrylate adhesive compositions at day 0 and day 12 of the accelerated aging at 80 °C

Entry	Composition [a]	Average viscosity (cp) of the compositions before and after the accelerated aging at 80 °C	
		Day 0	Day 12
1a	OCA + 0.04 % F127	50.5	73.5
1b	OCA + 0.2 % F68	116.3	206.2
1c	OCA + 0.16 % F68	40.7	67.4
1d	OCA + 0.15 % F68	39.2	71.5
1e	OCA + 0.145 % F68	32.5	54.4
1f	33.8 % OCA gel in OCA monomer	84.5	90.7

[a] Octyl cyanoacrylate (OCA) monomer is pre-stabilized with different amount of stabilizers

The present invention provides sterile and stable cyanoacrylate adhesive compositions with the desired level of high viscosity. In addition to being stable, cyanoacrylate adhesive compositions should be sterile for medical use. According to the present invention, cyanoacrylate adhesive compositions with the desired level of viscosity may be sterilized. This is also an advantage of the present invention, as most of the prior cyanoacrylate compositions with polymer additives were not sterilized. The sterilization can be accomplished by common techniques, and is preferably

accomplished by methods including, but not limited to, chemical, physical, and irradiation methods. Examples of chemical methods include, but are not limited to, exposure to ethylene oxide. Examples of irradiation methods include, but are not limited to, gamma irradiation, electron beam irradiation, and microwave irradiation. Preferred methods of sterilizing the cyanoacrylate compositions of the present invention are chemical sterilization and electron beam sterilization.

As confirmed by the accelerated aging test at 80 °C for 12 days, the bulk cyanoacrylate adhesive compositions with the desired level of viscosity are relatively stable prior to sterilization. However, the performance of cyanoacrylate adhesive compositions can be drastically affected by the sterilization. Curing or further polymerization of the cyanoacrylate adhesive occurs during the process of sterilization even in the presence of stabilizers. Sometimes polymerization induced by the sterilization is so serious that the cyanoacrylate compositions are no longer usable. In other cases, the shelf life of the sterilized cyanoacrylate compositions can be dramatically shorten even though these sterilized adhesive compositions are still usable.

In order to solve the instability problem induced by the sterilization, the present invention provides a method of stabilizing cyanoacrylate adhesive compositions with the desired level of high viscosity by adding a combination of at least one free radical stabilizer and at least one acid stabilizer to the cyanoacrylate compositions. In more preferred embodiments of the present invention, at least two free radical stabilizers and at least two acid stabilizers are used to stabilize the adhesive composition. The combination of two or more free radical stabilizers and two or more acid stabilizers provides better stabilizing effects than the conventional combination of only one free radical and acid stabilizer. Compared to cyanoacrylate adhesive compositions with only one free radical stabilizer and/or one acid stabilizer, cyanoacrylate adhesive compositions with the desired level of high viscosity stabilized by the combination of at least two free radical stabilizers and/or at least two acid stabilizers inhibited effectively the sterilization-induced polymerization so that an extended shelf life can be obtained.

In embodiments of the present invention, the preferred primary free radical stabilizer is butylated hydroxyl anisole (BHA). BHA is used in an amount of about 200 ppm to about 15000 ppm of cyanoacrylate compositions preferably about 1000 ppm to about 10000 ppm, more preferably about 2000 ppm to about 8000 ppm. In preferred embodiments, BHA is used in combination with at least one more free radical stabilizer including without limitation, hydroquinone; catechol; hydroquinone monomethyl ether and hindered phenols such as butylated hydroxyanisol; 4-ethoxyphenol; butylated hydroxytoluene (BHT, 2,6-di-tert.-butyl butylphenol), 4-methoxyphenol (MP); 3-methoxyphenol; 2-tert.-butyl-4methoxyphenol; 2,2-methylene-bis-(4-methyl-6-tert.-butylphenol). In preferred embodiments, hydroquinone, 4-methoxyphenol and butylated hydroxytoluene are used as second or additional free radical stabilizers. MP is used in an amount of about 1 ppm to about 4000 ppm, preferably about 100 ppm to about 2000 ppm. Hydroquinone is used in an amount of about 1 ppm to about 2500 ppm, preferably from about 50 ppm to about 1500 ppm. BHT is used in an amount of about 1 ppm to about 10000 ppm, preferably from about 500 ppm to about 5000 ppm. The amount to be used can be determined by one of ordinary skills in the art using known techniques without undue experimentation.

In certain embodiments of the present invention, the preferred primary acid stabilizer is sulfur dioxide in an amount of about 2 ppm to about 500 ppm, preferably about 10 ppm to about 200 ppm. The second or additional acid stabilizers may be a very strong acid including without limitation perchloric acid, hydrochloric acid, hydrobromic acid, toluenesulfonic acid, fluorosulfonic acid, phosphoric acid, ortho-, meta-, or para-phosphoric acid, trichloroacetic acid, and sulfuric acid. The very strong acid is used in an amount of about 1 ppm to about 250 ppm, preferably from about 5 pm to about 50 ppm. Preferably, the very strong acid stabilizer is sulfuric acid, phosphoric acid or perchloric acid. More preferably, sulfuric acid is used as the additional strong acid stabilizer.

In other embodiments of the present invention, the second or additional acid stabilizers may be sultones or weak organic acids including, but not limited to, benzoic acid, cyanoacetic acid, chloroacetic acid and acetic acid. More preferably, 1,4-butane sultone or acetic acid is used as the additional acid stabilizer in an amount of from about 1 ppm to about 1000 ppm, preferably from about 100 ppm to about 500 ppm.

Preferred combinations are BHA as the primary free radical stabilizer with sulfur dioxide as the primary anionic stabilizer. In another embodiment there is combined BHA as the primary free radical stabilizer and sulfur dioxide as the primary anionic stabilizer with hydroquinone as the secondary free radical stabilizer and sulfuric acid as the secondary anionic (acidic) stabilizer. The secondary acidic stabilizer can also be a combination of sulfuric acid with acetic acid. Furthermore, instead or in addition to hydroquinone as the secondary free radical stabilizer BHT and/or 4-methoxyphenol can be used. The secondary acidic stabilizer can also be a sultone. Preferred plasticizers in combination with the above primary and optionally secondary free radical stabilizer(s) and primary and optionally anionic stabilizers are acetyt tributyl citrate, diisodecyl adipate, tributyl citrate.

In other embodiments the compositions of the invention comprise BHA in combination with sulfur dioxide, or BHA, sulfur dioxide, hydroquinone, sulfuric acid, acetic acid and tributyl citrate, or BHA, sulfur dioxide, 4-methoxyphenol, sulfuric acid, acetic acid and acetyl tributyl citrate, or BHA, sulfur dioxide, sulfuric acid, acetic acid, BHT and diisodecyl adipate, or BHA, sulfur dioxide, sulfuric acid, acetic acid, BHT and, optionally, 18-crown-6, or BHA, sulfur dioxide, sultone, acetic acid, BHT, MP and hydroquinone, or BHA, sulfur dioxide, sultone, acetic acid, BHT, MP, hydroquinone and acetyl tributyl citrate.

The amounts and preferred amounts as stated above for the individual constituents of the composition apply.

Cyanoacrylate adhesive compositions with the desired level of high viscosity may be subjected to sterilization after the stabilization with the combination of different free radical and acid stabilizers. The performance of the adhesive compositions after the

sterilization is dependent on how these compositions are prepared. According to the present invention, cyanoacrylate adhesive compositions with the desired level of high viscosity may be prepared such that even after sterilization the composition retains the desired viscosity. In the methods of the present invention where the cyanoacrylate compositions are prepared by heating the cyanoacrylate monomer in the presence of pluronic polymer, the viscosity of said compositions increases or remains the same, after the sterilization. The increase in viscosity can be controlled within a very small percentage by applying the suitable combination of free radical and acid stabilizers in the preferred embodiments. Therefore, the viscosity of the cyanoacrylate adhesive compositions can be readily targeted to a desired level even after sterilization.

In the methods of the present invention where the cyanoacrylate adhesive compositions with a desired level of high viscosity are prepared by diluting extremely viscous cyanoacrylate gel with cyanoacrylate monomer, the viscosity of the adhesive composition decreases, or remains the same, after the sterilization. The decrease in viscosity of the cyanoacrylate adhesive compositions is due to the degradation of the partial polymer of cyanoacrylate caused by the sterilization. The decrease in viscosity of the cyanoacrylate adhesive compositions, after the sterilization, varies depending on the original viscosity and the percentage of the cyanoacrylate gel in the compositions. The decrease in viscosity after sterilization can be drastic in certain circumstances. However, with the compositions of the present invention the change in viscosity can be controlled to an acceptable range. The use of the cyanoacrylate adhesive will dictate the absolute range of increased or decreased viscosity acceptable after sterilization but in preferred embodiments the viscosity of the composition after sterilization is within about 25 % (one-quarter the viscosity) to 100 % of the viscosity of the composition before sterilization. In preferred embodiments the viscosity of the composition after sterilization is within about 30 % to 100 % of the viscosity of the composition before sterilization and in more preferred embodiments the viscosity of the composition after sterilization is within about 50 % to 100 % of the viscosity of the composition before sterilization. As shown in Table 2, modifying the percentage of the cyanoacrylate gel and applying the suitable combination of free radical and acid stabilizers can control the change in viscosity that occurs upon sterilization.

Table 2: Viscosity of the cyanoacrylate adhesive compositions with the desired level of high viscosity before and after the sterilization

Entry [a]	Composition	Average viscosity (cp)	
		Before sterilization	After sterilization
2a	OCA + 0.14 % F68	75.6	76.4
2b	OCA + 0.118 % F68	56.4	60.7
2c	OCA + 0.112 % F68	50	54.9
2d	33.8 % of OCA Gel in OCA	77	44.1
2e	49.5 % of OCA Gel in OCA	121.6	88.7
2f	33.8 % of OCA Gel in OCA	69.5	40.7
2g	28.5 % of OCA Gel in OCA	52.7	40.5
2h	28.5 % of OCA Gel in OCA	54.4	39.2
2i	49.5 % of OCA Gel in OCA	117.1	85.4

a. High viscosity cyanoacrylate compositions from 2a to 2c were prepared directly by heating cyanoacrylate monomer in the presence of pluronic polymer. High viscosity cyanoacrylate compositions from 2d to 2i were prepared by diluting extremely viscous cyanoacrylate gel with cyanoacrylate monomer.

The present invention provides sterile and stable cyanoacrylate adhesive compositions with the desired level of high viscosity, which are compatible with suitable packaging. The said cyanoacrylate adhesive compositions may be packaged in high density polyethylene (HDPE) bottles and different applicators, and then sterilized. The stability of the sterilized cyanoacrylate adhesive compositions with the desired level of high viscosity in different packages is evaluated by the accelerated aging test. The accelerated aging test of the sterilized cyanoacrylate adhesive composition is performed in the oven at 80 °C for a period of 12 days. Table 3 summarizes the selected viscosity results of the sterilized cyanoacrylate adhesive compositions in different packages at day 0 and day 12 of the accelerated aging test performed at 80

°C. By comparing the performance and viscosity of said compositions at day 0 with that at day 12 of the accelerated aging at 80 °C, the sterilized cyanoacrylate adhesive compositions with the desired level of viscosity in various packages exhibit dramatically different stability. In certain embodiments of the present invention, some sterilized cyanoacrylate adhesive compositions are cured at as early as day 3 of the accelerated aging at 80 °C. The shortened shelf life of such sterilized cyanoacrylate adhesive compositions might be due to the decomposition of free radical and/or acid stabilizer induced by sterilization. In more preferred embodiments, however, the sterilized cyanoacrylate adhesive compositions with the desired level of viscosity exhibit excellent stability with only a slight increase in viscosity at day 12 of the accelerated aging at 80 °C compared to that at day 0. Therefore, cyanoacrylate adhesive compositions with the desired level of high viscosity developed in the preferred embodiments of the present invention can be packaged and sterilized to provide at least two years shelf life by selecting suitable package and desired combinations of free radical and acid stabilizers.

Table 3: Performance of the sterilized cyanoacrylate compositions with the desired level of viscosity

Entry	Composition [a]	Plasticizer	Ave. viscosity (cp) before and after aging at 80 °C		Comment
			Day 0	Day 12	
3a	OCA + 0.11 % F68	5% ATBC	42.7	N/A	Cured at day 12
3b	OCA + 0.105 % F68	1% ATBC	33.7	74.8	
3c	33.8 % of OCA gel in OCA monomer	N/A	41.9	219.2	
3d	34.7 % of OCA gel in OCA monomer	5 % ATBC	38.2	52.3	
3e	OCA + 0.11 % F68	5 % TBC	41.1	N/A	Too viscous to dispense
3f	28.5 % of OCA gel in OCA monomer	N/A	43.3	84	
3g	OCA + 0.1446 % F68,	N/A	95.2	N/A	Cured at day 3
3h	OCA + 0.15% F127	N/A	140.2	N/A	Cured at day 9
3i	49.5 % of OCA gel in OCA monomer	5% ATBC	85.2	N/A	Too viscous to dispense

[a]. Final compositions with the desired viscosity are stabilized with at least two free radical stabilizers and at least two acid stabilizers in the varying amount.

According to certain embodiments of the present invention, a plasticizer may be included in the sterilized and stabilized cyanoacrylate adhesive compositions with the desired level of high viscosity. The plasticizing agent preferably does not contain any moisture and should not affect adversely the stability of the cyanoacrylate compositions. Examples of suitable plasticizers include, but are not limited to, tributyl citrate (TBC), acetyl tributyl citrate (ATBC), dimethyl sebacate, diethylsebacate, triethyl phosphate, tri(2-ethyl-hexyl)phosphate, tri(p-cresyl) phosphate, diisodecyl adipate (DIDA), glyceryl triacetate, glyceryl tributyrate, dioctyl adipate (DICA), isopropyl myristate, butyl stearate, lauric acid, trioctyl trimellitate,

dioctyl glutarate (DICG) and mixtures thereof. Tributyl citrate, diisodecyl adipate and acetyl tributyl citrate are preferred plasticizer in an amount of about 0 % to about 30 %, preferably about 1 % to about 20 %, and more preferably about 2 % to about 10 %, based on the total weight of the composition.

The effect of the amount of plasticizer on the performance of the cyanoacrylate adhesive compositions with the desired level of high viscosity has been evaluated. Table 4 shows the effect of plasticizer ATBC on the performance of the cyanoacrylate adhesive compositions. Cyanoacrylate adhesive compositions in Table 4 were stabilized with the same amount of free radical and acid stabilizers. However, the amount of plasticizer (ATBC) was varied. The decrease in viscosity of the adhesive compositions with different amount of ATBC is almost the same. However, the long term stability of the adhesive compositions is different for the adhesive compositions with different amount of plasticizer as confirmed by the accelerated aging at 80 °C for 12 days. The viscosity of the composition with 10 % of plasticizer increases from about 40 cp at day 0 to about 208 cp at day 12 of the accelerated aging at 80 °C. However, the viscosity of the adhesive compositions with less plasticizer increases from about 40 cp at day 0 to a maximum of 92 cp at day 12 of the accelerated aging at 80 °C. These observations confirm that the presence of greater concentration of plasticizer adversely affect the stability of the adhesive compositions, probably because the plasticizer decomposes due to sterilization.

Table 4: Effect of plasticizer on the stability of the cyanoacrylate compositions

Composition	Plasticizer (ATBC)	Average viscosity (cp)		
		Before sterilization	After sterilization	
			Day 0	Day 12 at 80 °C
4a	0	52.7	43.3	84
4b	1%	54.4	39.2	91.8
4c	5%	53.1	40.0	88.3
4d	10%	52.1	39.4	208.2

Crown ether, an accelerator may be included in the sterile and stable cyanoacrylate adhesive compositions with the desired level of high viscosity. Examples of crown ether include, but are not limited to, 15-crown-5, 18-crown-6, dibenzo-18-crown-6, tribenzo-18-crown-6, dicyclohexyl-18-crown-6, benzo-15-crown-5, dibenzo-24-crown-8, dibenzo-30-crown-10, asym-dibenzo-22-crown-6, dimethylsila-11-crown-4, dimethylsila-14-crown-5, dimethylsila-17-crown-6, dibenzo-14-crown-4, dicyclohexyl-24-crown-8, asym-dibenzo-22-crown-6, cyclohexyl-12-crown-4, 1,2-decalyl-15-crown-5, 1,2-naphtho-15-crown-5, 3,4,5-naphthyl-16-crown-5, 1,2-methyl-benzo-18-crown-6, 1,2-methylbenzo-5,6-methylbenzo-18-crown-6, 1,2-t-butyl-18-crown-6, 1,2-vinylbenzo-15-crown-5, 1,2-vinylbenzo-18-crown-6, 1,2-t-butyl-cyclohexyl-18-crown-6, and 1,2-benzo-1,4-benzo-5-oxygen-20-crown-7. The crown ether is used in an amount of 0 to 2000 ppm, preferably 50 to 1000 ppm, and more preferably 100 to 500 ppm. The amount to be used can be determined by one of ordinary skills in the art using known techniques without undue experimentation.

According to the present invention, the cyanoacrylate compositions may contain small amounts of dyes such as derivatives of anthracene and other complex structures. These dyes include without limitation, 1-hydroxy-4-[4-methylphenylamino]-9,10 anthracenedione (D&C violet No. 2); 9-(o-carboxyphenyl)-6-hydroxy-2,4,5,7-tetraiodo-3H-xanthen-3-one disodium salt, monohydrate (FD&C Red No. 3); disodium salt of 6-hydroxy-5-[(4-sulfophenyl)azo]-2-naphthalene-sulfonic acid (FD&C Yellow No. 6,); and 2-(1,3-dihydro-3-oxo-5-sulfo-2H-indole-2-ylidine)-2,3-dihydro-3-oxo-1H-indole-5 sul-fonic acid disodium salt (FD&C Blue No. 2).

According to the present invention any cyanoacrylate (ie, an ester of cyanoacrylic acid), preferably a 2-cyanoacrylate ester monomer may be used. The 2-cyanoacrylate is preferably an aliphatic cyanoacrylate ester and preferably an alkyl, cycloalkyl, alkenyl and (C_{2-8})alkoxy(C_{2-8})alkyl, 2-cyanoacrylate ester. The alkyl group may contain from 2 to 12 carbon atoms, and is preferably a C_2 to C_8 alkyl ester, and is most preferably a C_4 to C_8 alkyl ester. Suitable 2-cyanoacrylate esters include without limitation, the methyl, ethyl, n-propyl, iso-propyl, n-butyl, n-pentyl, iso-pentyl, n-

hexyl, cyclohexyl, n-heptyl, iso-heptyl, n-octyl, 2-octyl, 2-ethylhexyl, 2-methoxyethyl and 2-ethoxyethyl esters. The 2-cyanoacrylate monomers may be used alone, or they may be used in mixtures. The alkenyl group may contain from 2 to 12 carbon atoms, and is preferably a C_2 to C_8 alkenyl ester, and is most preferably a C_4 to C_8 alkenyl ester. The cycloalkyl group may contain 3 to 7 carbon atoms, preferably 5 or 6 carbon atoms. 2-Cyanoacrylates (also called alpha-cyano acrylates) useful according to the present invention are also disclosed in U.S. Pat. No. 6,143,805, column 3, line 54 to column 4, line 55, the disclosure thereof is incorporated herein as if fully set forth herein.

In the embodiments of the present invention, cyanoacrylate gel can be prepared by using one cyanoacrylate monomer, which can be diluted with the mixture of other cyanoacrylate monomers for adhesive compositions with the desired level of high viscosity. The properties of the cyanoacrylate adhesive compositions can be modified by mixing different cyanoacrylate monomers. By introducing a cyanoacrylate monomer with a shorter alkyl chain to a cyanoacrylate monomer with a longer alkyl chain, the cure time and degradation rate of adhesive can be shortened and the tensile strength can be improved. Inversely, cyanoacrylate adhesive with a shorter alkyl chain will offer better flexibility by incorporating longer alkyl chain cyanoacrylate monomers. One preferred cyanoacrylate adhesive composition is prepared by diluting 2-octyl cyanoacrylate gel that is made according to the present invention with n-butyl cyanoacrylate monomer.

The 2-cyanoacrylate monomer used in the invention is synthesized based on the procedures known in the prior art by reacting cyanoacetate with formaldehyde in the presence of a basic condensation catalyst at elevated temperature to give a low molecular weight polymer. A depolymerization step followed under high temperature and high vacuum in the presence of acidic and anionic inhibitors, yielding a crude monomer that can be distilled under high temperature and high vacuum in the presence of radical and acidic inhibitors. The distilled 2-cyanoacrylate monomers are then formulated with free radical and acidic inhibitors depending upon their application to provide the necessary stability.

According to the present invention, cyanoacrylate adhesive compositions with the desired level of high viscosity may be packaged in, but not limited to, plastic applicator. The plastic applicator is composed of a reservoir container and a sponge application tip. The container part is preferably air and water tight with sealing that prevents contamination of the adhesive inside the applicator. The sponge tip is saturated with liquid adhesive once it is folded over so that adhesive can be dispensed uniformly onto the wound site. The container size and sponge tip can be varied dependent on the volume of the adhesive. Cyanoacrylate adhesive will polymerize very rapidly when it is stored in a very small amount. To prevent premature polymerization a minimum of about 0.1 mL to 4 mL, preferably 0.2 mL to 2 mL, and more preferably 0.3 mL to 1 mL of adhesive should be packaged in the applicator. In order to extend the shelf life, the volume of the container is preferably about 50 to 80 percent and more preferably 60 to 80 percent filled.

According to the present invention, the cyanoacrylate adhesive compositions with the desired level of high viscosity are sterilized. The sterilization can be accomplished by common techniques, and is preferably accomplished by methods including, but not limited to, chemical, physical, and irradiation methods. Examples of chemical methods include, but are not limited to, exposure to ethylene oxide. Examples of irradiation methods include, but are not limited to, gamma irradiation, electron beam irradiation (E-beam), and microwave irradiation.

In preferred embodiments of the present invention, E-beam is used to sterilize the cyanoacrylate adhesive compositions with the desired level of viscosity. An initial fluence of the E-beam radiation is maintained at a minimum of about a 2 μCurie/cm^2. Preferably, the E-beam radiation has an initial fluence of from about 2 to about 25 μCurie/cm^2. The dose of E-beam irradiation applied should be sufficient enough to sterilize both the package and the adhesive inside. The E-beam irradiation can be in a suitable dosage of from about 5 to about 50 kGy, and more preferably from about 12 to 25 kGy. E-beam irradiation is preferably conducted at ambient atmosphere conditions and the exposure time to the irradiation is preferably within 60 seconds.

In order to reduce the bioburden, the cyanoacrylate adhesive compositions with the desired level of high viscosity can be filtered through a 0.2 μm filter prior to sterilization. The applicators with the overpack may also be sterilized with heat, ethylene oxide and heat prior to the final E-beam irradiation.

The entire package elements and adhesive inside are preferably sterile. The sterility of the cyanoacrylate adhesive compositions with the desired level of high viscosity may be analyzed by Bacteriostasis and Fungistasis tests. In embodiments of the present invention, a Sterility Assurance Level (SAL) should be obtained at a minimum of 10^{-3}. In more preferred embodiments, the Sterility Assurance Level may be at least 10^{-6}.

The present invention discloses stable, sterile cyanoacrylate compositions with the desired level of high viscosity, which are especially suitable for use in medical applications. In use, the cyanoacrylate adhesive composition is applied to the desired tissue area as a liquid which then polymerizes upon contact with tissue. The desired high viscosity of said cyanoacrylate adhesive compositions prevents the runniness of the adhesives encountered by the low viscous adhesive compositions.

The following non-limiting examples are intended to further illustrate the present invention.

Unless otherwise specified all amounts mentioned herein are by weight, the percentages are in weight percent.

EXAMPLES

Viscosity Measurement (Brookfield Viscosity):

Viscosity was measured at 25 °C using Brookfield programmable DV-II + Viscometer. Typically, the following viscosity measurement procedure was followed: after turning on the viscometer it is observed that all conditions have been set for

testing such as speed setting, zero gap adjustment and temperature setting. Then the spindle (CPE40) and the cup is cleaned with acetone and let dry. 21 Drops of the test sample are dropped into the cup being mindful to position the drops to the middle of the cup. Next the cup is brought into position and the cup is slowly secured with the retaining arm. Then the MOTOR ON/OFF/ESCAPE key is turned and the sample is allowed to come to equilibrium prior to sample readings. The sample readings are taken in triplicate and then the average is calculated. Any residue is removed with cleaning solution prior to next sample measurement. First cleaning is made with plain Kim-wipe and excess sample is removed, then cleaning solution is used. This is repeated 2 - 3 times. Excessive cleaning of spindle should be done by removal from the viscometer followed by resetting the zero gap.

EXAMPLE 1

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 118 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 189 mg of pluronic F127 and stirred at 60 °C for 2 hours. After it cools down, the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 17 s and the average viscosity for the sample is 58.9 cp.

EXAMPLE 2

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 128 g of 2-octyl cyanoacrylate monomer was mixed with small amounts of BHA and SO_2 and stirred at room temperature (20 °C) for 2 hours. Then 90 mg of pluronic F68 was added and stirred at 60 °C for 3 hours. After cooling down to room temperature, 474 mg of BHA, 12.2 ppm of SO_2 and 7.8 ppm of D&C Violet were added and the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 25 s and the average viscosity for the sample is 24.5 cp.

EXAMPLE 3

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 119.6 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 227 mg of pluronic F127 and stirred at 60 °C for 2 hours. After it cools down, the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 21 s and the average viscosity for the sample is 123.4 cp.

EXAMPLE 4

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 109 g of the 2-octyl cyanoacrylate monomer was mixed with small amounts of BHA and SO_2 and stirred at room temperature for half an hour. Then 142 mg of pluronic F68 was added and stirred at 60 °C for 1 hour. After cooling down to 40 °C, 294 mg of BHA, SO_2 and D&C Violet were added and the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 31 s and the average viscosity for the sample is 39.2 cp.

EXAMPLE 5

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 109.7 g of the 2-octyl cyanoacrylate monomer was mixed with a small amount of SO_2 and stirred at room temperature for 1.5 hours. Then 132 mg of pluronic F38 was added and stirred at 60 °C for 2 hours. After cooling down to room temperature, BHA, SO_2 and D&C Violet were added and the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 22 s and the average viscosity for the sample is 52.7 cp.

EXAMPLE 6

To a two neck round bottom flask equipped with a thermometer and a magnetic stir bar, 103.3 g of 2-octyl cyanoacrylate monomer in the presence of BHA and SO_2 was mixed with 124 mg of pluronic F127 and stirred at 60 °C for 2 hours. After it cools down, the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 16 s and the average viscosity for the sample is 343.4 cp.

EXAMPLE 7

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 176.2 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 705 mg of pluronic F68 and stirred at 60 °C for 1.5 hours. After it cools down, the resulting cyanoacrylate adhesive composition was subjected to viscosity and set time test. The average set time for the sample is 12 s and the average viscosity for the sample is 182.5 cp.

EXAMPLE 8

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 144.7 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 289 mg of pluronic F38 and stirred at 60 °C for 1.5 hours. After it cools down, highly viscous 2-octyl cyanoacrylate gel was obtained.

EXAMPLE 9

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 111.5 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 245 mg of pluronic F127 and stirred at 60 °C for 2 hours. After it cools down, highly viscous 2-octyl cyanoacrylate gel was obtained.

EXAMPLE 10

In a polyethylene bottle equipped with a magnetic stir bar, 33.9 g of 2-octyl cyanoacrylate gel was mixed with 90.4 of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 and stirred at room temperature for 5 hours. The average viscosity of the cyanoacrylate compositions thus prepared is 66.8 cp.

EXAMPLE 11

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 114.8 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 628 mg of pluronic F108 NF and stirred at 60 °C for 2 hours. After cooling down to room temperature, 2-octyl cyanoacrylate gel was obtained.

EXAMPLE 12

To a polyethylene bottle equipped with a magnetic stir bar, 50 g of 2-octyl cyanoacrylate gel was mixed with 53.6 g of 2-octyl cyanoacrylate monomer and stirred at room temperature for 6 hours. The average set time and viscosity for the sample are 15 s and 57.1 cp, respectively.

EXAMPLE 13

In a 9.46 liter (2.5 gallon) high density polyethylene (HDPE) container, 2.822 kg (6.23 lbs) of 2-octyl cyanoacrylate gel was mixed with 3.438 kg (7.59 lbs) of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 and blended with a mechanic stirrer at room temperature for 7 hours. The average set time and viscosity for the sample are 42 s and 62.5 cp, respectively.

EXAMPLE 14

To a polyethylene bottle equipped with a magnetic stir bar, 78 g of 2-octyl cyanoacrylate with a viscosity of about 110 cps was mixed with 33 g of n-butyl cyanoacrylate monomer and 0.56 g of diisodecyl adipate, which were stirred at room temperature for 6 hours. The average viscosity for the sample is 40.6 cp.

EXAMPLE 15

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 278 g of 2-octyl cyanoacrylate monomer stabilized with small amounts of BHA and SO_2 was mixed with 306 mg of pluronic F68 and stirred at 50 °C for 2 hours. The resulting solution was stabilized with BHA and SO_2 and filtered by filtration flask to provide a cyanoacrylate adhesive composition with the viscosity about 45 cp. More stabilizers were added to the composition, which include 200 ppm of hydroquinone, 10 ppm of sulfuric acid, 200 ppm of acetic acid, and 80 more ppm of SO_2. 5% of tributyl citrate was added as the plasticizer.

EXAMPLE 16

2-Octyl cyanoacrylate gel was diluted with 2-octyl cyanoacrylate monomer to provide an adhesive composition with a viscosity about 80 cp which was primarily stabilized with BHA and SO_2. The composition was further stabilized with additional stabilizers including 300 ppm more of BHA, 5 ppm of sulfuric acid, 200 ppm of 4-methoxyphenol, and 300 ppm of acetic acid. The composition was packaged, sterilized and tested for stability.

EXAMPLE 17

A diluted 2-octyl cyanoacrylate composition with the viscosity of about 47 cp was stabilized with BHA as the free radical inhibitor and SO_2 as the anion inhibitor. In order to extend the stability of the composition, 500 ppm of 4-methoxyphenol, 5 ppm

of sulfuric acid, 10 more ppm of SO_2 and 200 ppm of acetic acid were further added to the adhesive composition. In addition, 1% of diisodecyl adipate was added as a plasticizer.

EXAMPLE 18

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 301 g of 2-octyl cyanoacrylate monomer stabilized with BHA and SO_2 was mixed with 436 mg of pluronic F68 and stirred at 55 °C for 2 hours. The resulting solution was stabilized with BHA and SO_2 and filtered by filtration flask to provide a cyanoacrylate adhesive composition with the viscosity about 44 cps. 5% of acetyl tributyl citrate was added as the biocompatible plasticizer. More stabilizers were added to the composition, which include 10 ppm of sulfuric acid, 200 ppm of acetic acid, 500 ppm of 4-methoxyphenol, and 80 more ppm of SO_2.

EXAMPLE 19

To a polyethylene bottle equipped with a magnetic stir bar, 2500 ppm of BHT and 1000 ppm of acetic acid as the additional stabilizers were added to 28 g of 2-octyl cyanoacrylate composition with a viscosity at about 35 cp which was primarily stabilized with BHA and SO_2.

EXAMPLE 20

2-Octyl cyanoacrylate gel was diluted with 2-octyl cyanoacrylate monomer in the presence of BHA and SO_2 to provide an adhesive composition with a viscosity of 130 cp. The adhesive composition was mixed with additional stabilizers including 5 ppm of sulfuric acid, 200 ppm of acetic acid, 2500 ppm of BHT, and 40 more ppm of SO_2. The composition was mixed with 15% of diisodecyl adipate as the plasticizer and 270 ppm of 18-crown-6 as the accelerator.

EXAMPLE 21

To a three neck round bottom flask equipped with a thermometer and a magnetic stir bar, 273 g of 2-octyl cyanoacrylate monomer stabilized with a small amount of SO_2 was mixed with 317 mg of pluronic F68 and stirred at 48 °C for 2 hours. The resulting solution was stabilized with BHA and SO_2 and filtered by filtration flask to provide a cyanoacrylate adhesive composition with the viscosity about 79 cps. Stabilizers were added to the adhesive composition, which include 5 ppm of sulfuric acid, 200 ppm of acetic acid, 2500 ppm of BHT, and 80 more ppm of SO_2. 18-crown-6 as was used as the accelerator and 10% of acetyl tributyl citrate was included as the plasticizer.

EXAMPLE 22

Highly viscous 2-octyl cyanoacrylate gel was diluted with 2-octyl cyanoacrylate monomer in the presence of BHA and SO_2 to provide an adhesive composition with a viscosity of about 90 cp. The resulting adhesive composition was stirred at 60 °C for 2 hours, then mixed with additional stabilizers including 200 ppm of sultone, 500 ppm of acetic acid, 3000 ppm of BHT, 2000 ppm of MP, 1500 ppm of hydroquinone, and 80 more ppm of SO_2.

EXAMPLE 23

In a polyethylene bottle equipped with a magnetic stir bar, a diluted 2-octyl cyanoacrylate composition with the viscosity of about 72 cp was stabilized with BHA as the free radical inhibitor and SO_2 as the anion inhibitor. Other stabilizers were further added to the adhesive composition including 200 ppm of sultone, 5 ppm of sulfuric acid, 500 ppm of acetic acid, 3000 ppm of BHT, 2000 ppm of MP, 1500 ppm of hydroquinone, and 80 more ppm of SO_2. Acetyl tributyl citrate was added as the plasticizer in the amount of 5%.

CLAIMS

What is claimed is:

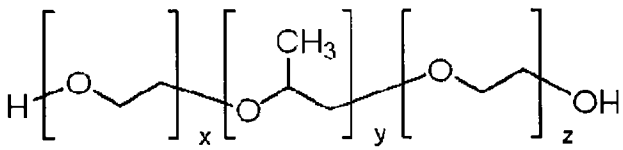
1. An adhesive composition comprising one or more cyanoacrylate(s) and one or more pluronic polymer additive(s).

2. The adhesive composition of claim 1, wherein the cyanoacrylate(s) is a cyanoacrylate ester monomer.

3. The adhesive composition of claim 2 wherein the cyanoacrylate ester monomer is selected from the group consisting of alkyl, cycloalkyl or alkylalkoxyl cyanoacrylate monomer.

4. The adhesive composition of claim 3, wherein the cyanoacrylate ester monomer is 2-cyanoacrylate ester.

5. The adhesive composition of claim 1, 2, 3 or 4, wherein the pluronic polymer has the following general formula:



wherein x is from 5 to 200, y is from 5 to 100, and z is from 5 to 200.

6. The adhesive composition of claim 5, wherein the pluronic polymer additive(s) is selected from the group consisting of pluronic F38 prill, pluronic F68 prill, pluronic F88, pluronic F108NF and pluronic F127 prill, pluronic 10R5, pluronic 17R2, pluronic 17R4, pluronic 25R2, pluronic 25R4, pluronic 31R1, pluronic F68 LF, pluronic F68NF, pluronic F68 NF prill poloxamer 188, pluronic F77, pluronic F87, pluronic F98, pluronic F108, pluronic F127,

pluronic F127 NF, pluronic F127 NF prill poloxamer 407, pluronic L 10, pluronic L 101, pluronic, L121, pluronic L 31, pluronic L 35, pluronic, L 43, pluronic L44, pluronic, L44 NF poloxamer 124, pluronic, L 61, pluronic 62, pluronic L62 LF, pluronic, L 62D, pluronic L64, pluronic L 81, pluronic L 92, pluronic N 3, pluronic P 103, pluronic P 104, pluronic P 105, pluronic P 123 surfactant, pluronic P 65, pluronic, P 84, pluronic P 85, and mixtures thereof.

7. The adhesive composition of claim 6, wherein the pluronic polymer additive(s) is selected from the group consisting of pluronic polymer F127, F88, F38, F68, F108 NF, and mixtures thereof.

8. The adhesive composition of claim 5, 6 or 7, wherein the pluronic polymer additive(s) is present in an amount of about 0.01% to about 0.50 % by weight of cyanoacrylate.

9. The composition of claims 1, 2, 3, 4, 5, 6, 7 or 8 further comprising one or more free radical stabilizers and/or one or more anionic stabilizers or mixtures thereof.

10. The composition of claim 9, wherein the anionic stabilizer is selected from the group consisting of sulfur dioxide, boron oxide, phosphoric acid, acetic acid, benzoic acid, cyanoacetic acid, 1,4-butane sultone, boron trifluoride, perchloric acid, hydrochloric acid, sulfuric acid, sulfonic acid and mixtures thereof.

11. The composition of claim 9, wherein the anionic stabilizer is 1,4-butane sultone in an amount of about 100 to about 3000 ppm.

12. The composition of claim 9, wherein the anionic stabilizer is sulfur dioxide in an amount of about 10 to about 500 ppm.

13. The composition of claim 9, wherein the anionic stabilizer is sulfuric acid in an amount of about 2 to about 30 ppm.

14. The composition of claim 9, wherein the anionic stabilizer is acetic acid in an amount of about 200 to about 4000 ppm.

15. The composition of claim 9, wherein the free radical stabilizers are selected from the group consisting of butylated hydroxyanisole, hydroquinone (HQ), catechol, hydroquinone monomethyl ester, butylated hydroxytoluene (BHT), 4-ethoxyphenol, 4-methoxyphenol, and mixtures thereof.

16. The composition of claim 15, wherein the free radical stabilizer is butylated hydroxyanisole in an amount of about 3000 to about 15000 ppm.

17. The composition of claim 15, wherein the free radical stabilizer is hydroquinone in an amount of about 50 to about 3000 ppm.

18. The composition of claim 15, wherein the free radical stabilizer is 4-methoxyphenol in an amount of about 200 to about 5000 ppm.

19. The composition of claim 14, wherein the free radical stabilizer is butylated hydroxytoluene in an amount of about 2000 to about 10000 ppm.

20. The adhesive composition of claims any one of claims 1 to 19, wherein a plasticizer may be included in an amount of about 0.50 % to about 20 %.

21. The adhesive composition of any one of claims 1 to 20 which is stable and which has a viscosity of the composition measured after 12 days in an accelerated aging test at 80 °C is from about 100 % to about 150 % of the viscosity of the composition measured at time zero.

22. The adhesive composition of any one of claims 1 to 21 which is sterile and which was sterilized by a method selected from the group consisting of gamma irradiation, electron beam irradiation, and microwave irradiation.

23. A method of making a stable adhesive composition with a desired viscosity comprising adding pluronic polymer to cyanoacrylate to form a mixture and heating the mixture to about 30°C to about 70°C for about 0.5 to about 3.0 hours.

24. The method of claim 23, wherein the mixture is heated in the absence of free radical stabilizers.

25. The method of claim 23, wherein the mixture is heated in the absence of anionic stabilizers.

26. The method of claim 23, wherein the mixture is heated in the presence of free radical and anionic stabilizers.

27. The method of claim 23 further comprising adding one or more stabilizers to the mixture after heating the mixture.

28. The method of claim 27, wherein the stabilizers are chosen from the group consisting of anionic stabilizers, free radical stabilizers and mixtures thereof.

29. A method of making a stable adhesive composition with a desired level of high viscosity comprising adding cyanoacrylate gel to a cyanoacrylate monomer composition to from a mixture and mixing the mixture together at about room temperature (20 °C) for about 2 to about 10 hours.

30. The method of claim 29 further comprising adding one or more stabilizers to the mixture after the desired viscosity is obtained.

31. The method of claim 30, wherein the stabilizers are chosen from the group consisting of anionic stabilizers, free radical stabilizers and mixtures thereof.

32. The adhesive cyanoacrylate composition as defined in any one of claims 1 to 22 for use in the medical field for sealing tissue, closing wounds and the protection of surface injuries.

33. The adhesive composition of claim 32, wherein the surface injuries are selected from abrasions, burns, lacerations, sores and open wounds.