United States Patent [19] | [11] 3,775,960
Ogawa et al. | [45] Dec. 4, 1973

[54] SEWING THREAD AND A METHOD OF PREPARING SAME

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[22] Filed: **Oct. 6, 1970**

[21] Appl. No.: **78,457**

[30] **Foreign Application Priority Data**

Oct. 8, 1969	Japan	44/80993
Nov. 13, 1969	Japan	44/91225
Dec. 8, 1969	Japan	44/98772
Dec. 8, 1969	Japan	44/98773
Apr. 4, 1970	Japan	45/28854
June 25, 1970	Japan	45/55839

[52] **U.S. Cl.** .... **57/140 R,** 57/140 C, 57/157 R, 57/157, 112/413, 112/415

[51] **Int. Cl.** **D02g 3/44,** D02g 3/02

[58] **Field of Search** .... 57/139, 140 R, 140 BY, 57/156, 157 R, 157 S, 157 TS; 2/237; 260/78 L, 78.3; 112/413, 415

[56] **References Cited**

UNITED STATES PATENTS

3,559,213	2/1971	Goodman	2/237
3,379,001	4/1968	Campbell	57/140 BY
3,582,445	6/1971	Okuhashi	57/140 BY X
3,592,873	7/1971	Ishida et al.	260/78 L X
3,343,363	9/1967	Stow et al.	57/140 R
3,299,171	1/1967	Kobloch et al.	57/140 R UX
3,575,907	4/1971	Kitazawa et al.	260/78.3 X

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[57] **ABSTRACT**

Improved sewing threads having an initial modulus of elasticity in tension of no less than 0.5 g/d, preferably no less than 5 g/d, a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 70 percent are described as to their preparation and use. The threads are suitable for machine sewing of stretch fabrics.

8 Claims, 7 Drawing Figures

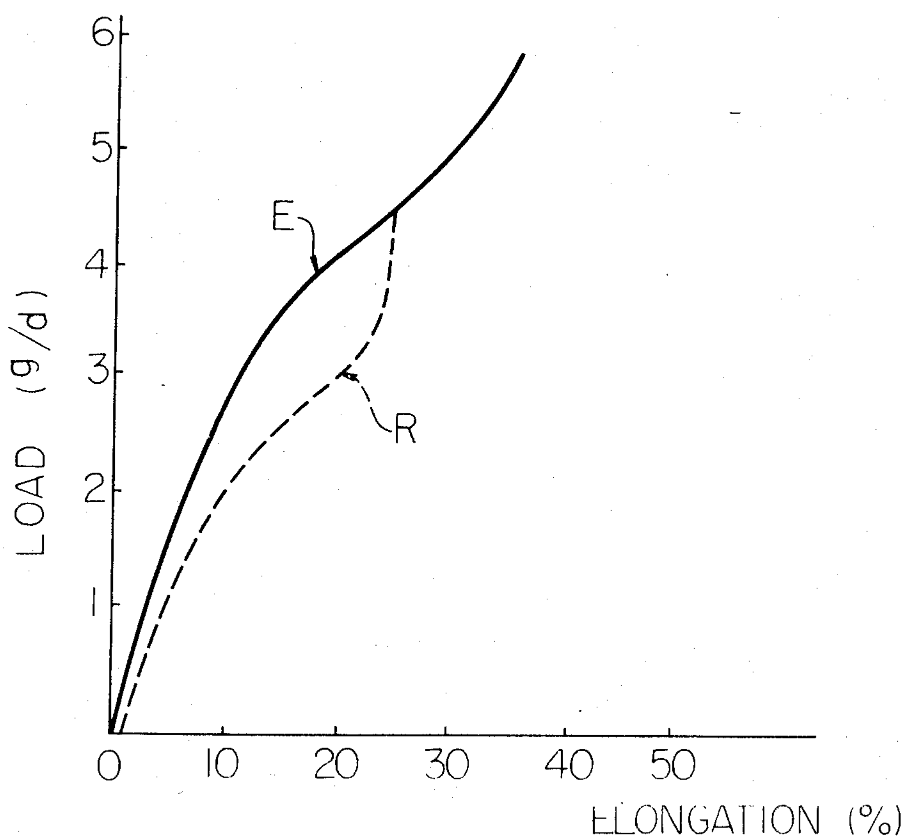

Fig. 1

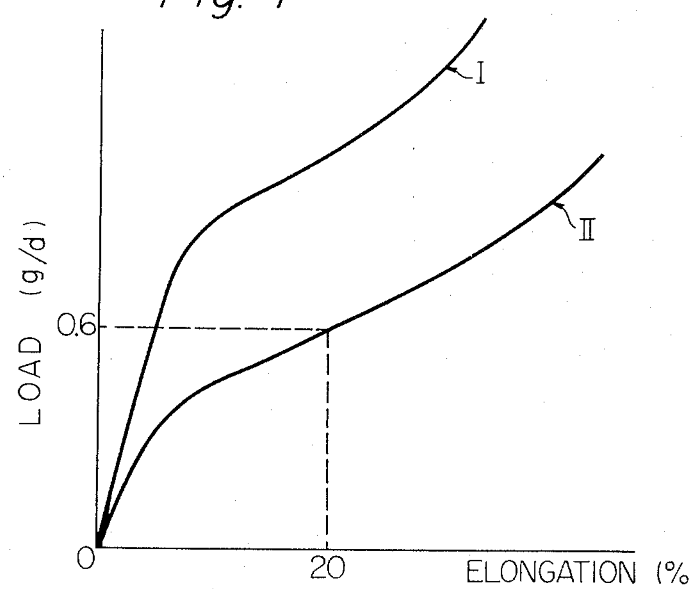

Fig. 2

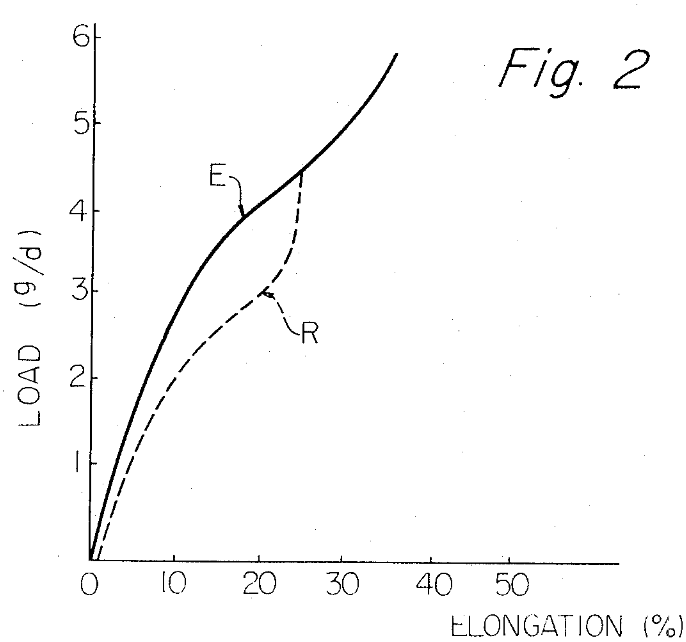

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Fig. 3

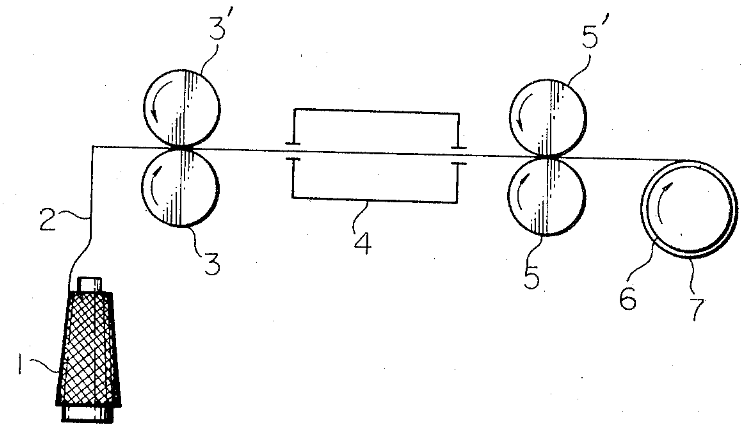
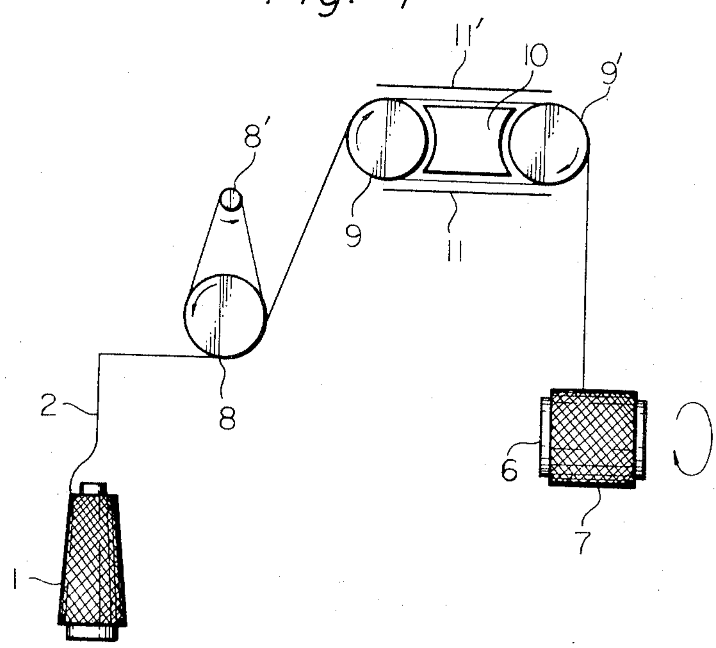


Fig. 4



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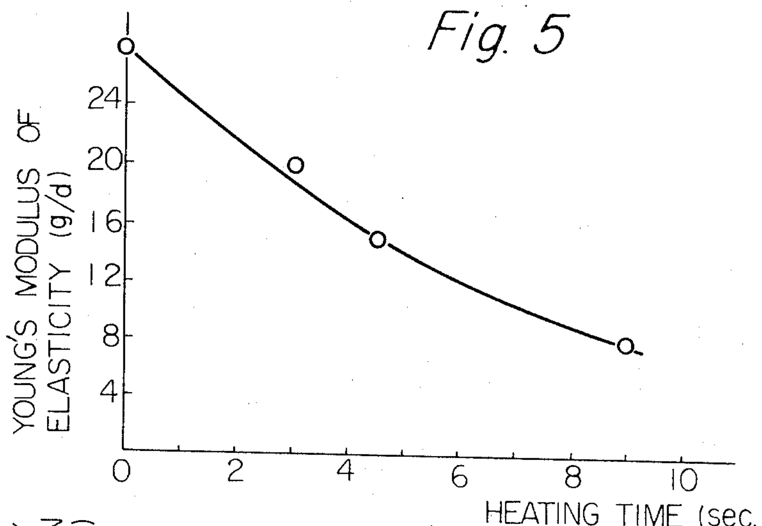

Fig. 5

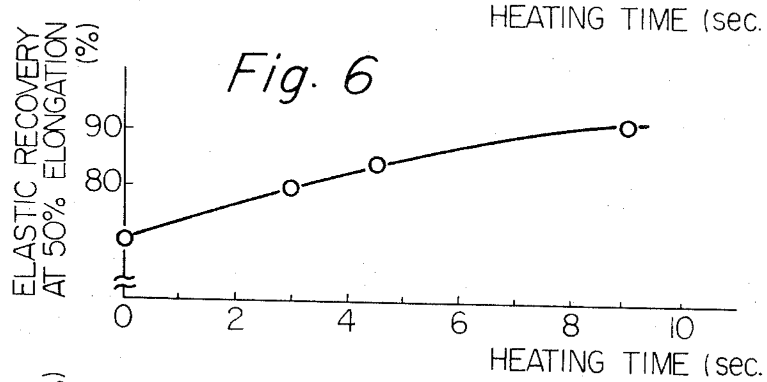

Fig. 6

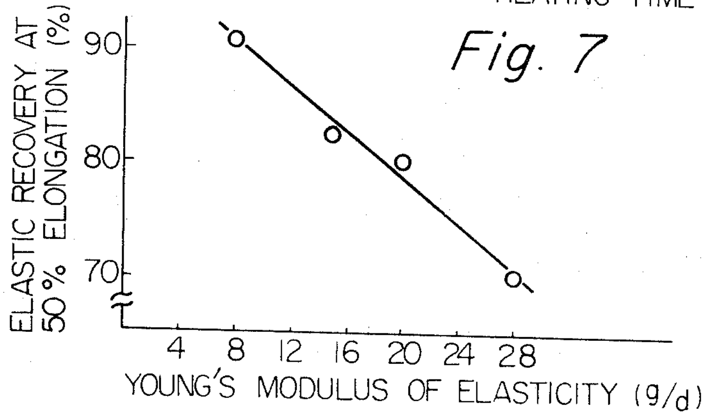

Fig. 7

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SEWING THREAD AND A METHOD OF PREPARING SAME

This invention relates to a sewing thread used for machine-sewn textile fabrics, particularly knitted or woven fabrics having both elastic stretching and contracting properties and to a method of preparing the sewing yarn. It also relates to a knitted or woven fabric sewn with the above sewing thread and to a method of preparing the knitted or woven fabric.

Stretch fabrics, that is, knitted or woven fabrics having both elastic stretching and contracting properties have been widely used as clothing such as athletic clothing, work clothes, underwear and outerwear since they are lively and comfortable to wear.

However, conventional stretch clothing has many defects; the clothing does not have sufficient stretchability in spite of the fabric's own stretchability and accordingly, in case they are compelled to pull excessively during use, the sewing threads are broken and the clothing becomes open at the seams. The reason for the above is that a non-stretch yarn is usually employed as a machine sewing thread and consequently, the seamed part of the clothing has less stretchability.

In order to obviate the above defect, many methods have been utilized; for example, a method using thermoplastic bulky yarn having stretchability as machine sewing thread and a particular sewing method such as an over lock sewing method and a chain stitch sewing method, etc. However, these methods also have the following weak points, respectively.

Concerning the method using bulky yarns or filaments, bulky filaments usually have great difficulty in tying up in a densified bundle and their crimps are easily straightened even with a slight tension and consequently, they are not suitable as machine sewing threads and, even if the bulky yarn is used as a bobbin thread, the stretchability of the seamed part of the resultant fabric is not improved whenever non-stretch yarn is used as a needle thread.

According to an over lock sewing method, the stretchability of the seamed part may be considerably improved, but only edge parts of fabrics can be sewn with the machine and the consumption of sewing threads is remarkably high. According to a chain stitch sewing method, only in the case that the tension applied at the sewing part is relieved at sewing, can stretchability of the seamed part be obtained, but undesirable openings are formed at the resultant seams and in case the sewn thread is worn out, the seams easily come loose.

In any of the methods described above, it cannot be avoided that the tensile stress in the seamed parts of the fabric is higher than that in the remaining parts.

On the other hand, an attempt has been made to employ a highly stretchable elastomer yarn, such as polyurethane segment elastomer yarn (spandex) and polyester block elastomer yarn, as a sewing thread so that the sewn thread may be similarly elongated and contracted conforming to extension and contraction of the stretch fabric. However, in view of the facts that such a class of elastomeric yarn has too low an initial modulus of elasticity in tension and therefore, it is easily and excessively elongated by tensile force exerted at the time of sewing and it does not produce satisfactory seams and that the yarn has a high surface frictional coefficient it is consequently, not suitable as a sewing thread.

Furthermore, since stretch fabrics are usually used for such uses as athletic clothing, the fabrics often carry static electricity due to the friction between fibers and therefore, frequent troubles arise upon use thereof.

Conventional conductive fibers do not have stretchability. Therefore, even in the case when a sewing thread containing the conductive fibers as one fiber component is used, the resultant clothing also does not exhibit sufficient stretchability, and accordingly, when they are compelled to pull excessively during use, they also become open at the seams as described above. Moreover, the sewing thread containing the conventional conductive fibers has a tendency to lose its conductivity even in the case when the thread is pulled only to the length less than that corresponding to the elongation at break. Consequently, the conductivity gradually decreases and finally vanishes due to tensile force exerted by a sewing machine or to other strains exerted during use.

Furthermore, in the seams of conventional clothing, unless sewing conditions are delicately changed from place to place during sewing, the resultant seams do not become uniform as a whole. This is undesirable in most clothing. On the other hand, in order to control the stretchability of particular parts of the seams, very complicated sewing processes are needed and working efficiency is reduced.

Now, the inventors have succeeded in obviating the defects mentioned above from a thorough search for sewing threads, particularly machine sewing threads, for stretch fabrics.

An object of the present invention is to provide a novel sewing thread useful for sewing, particularly lock stitch sewing knitted or woven fabrics having high stretchability.

A more specific object of the present invention is to provide a sewing thread which does not shrink to a higher degree than the stretch fabric due to ironing and washing and, accordingly, seam puckering of the resultant clothing does not occur.

Another object of the present invention is to provide a sewn stretch fabric which does not come open in the seams even in case it is expanded to the maximum elongation and, swiftly contracts to its original length in case the tension is relieved.

A further object of the present invention is to provide a sewn stretch fabric which has both high stretchability and antistatic property, more specifically a stretch fabric sewn with machine sewing threads which have antistatic property resisting repeated elongations.

A further object of the present invention is to provide a sewn stretch fabric having seams, at least one of which has different elastic recovery and/or initial modulus of elasticity in tension from others, in order to comply with the demands of users thereof.

Other objects and advantages of the present invention will become apparent from the following description.

According to the present invention, a sewing thread comprising at least one thermoplastic elastic fiber, particularly pivalolactone polymer fiber and having an initial modulus of elasticity in tension of no less than 0.5 g/d, a breaking elongation of no less than 30 percent, preferably no less than 50 percent, an elastic recovery at 25 percent elongation of no less than 70 percent and a breaking tenacity of preferably no less than 1.5 g/d is provided.

More preferably, the sewing thread has the following characteristics in addition to the above; an initial modulus of elasticity in tension of no less than 5 g/d, a yield strength of no less than 0.6 g/d and a shrinkage in boiling water of no more than 1 percent.

Further, the sewing thread of the present invention may also comprise from 3 to 97 percent by weight of at least one thermoplastic elastic fiber and from 97 to 3 percent by weight of at least one non-elastic fiber.

Referring to the attached drawings,

FIG. **1** and FIG. **2** show load-elongation curves of the control sewing thread and of the sewing thread of the present invention, respectively,

FIG. **3** and FIG. **4** show preferred embodiments of the heating apparatus, and

FIGS. **5, 6** and **7** show relationships between heating time and Young's modulus, between heating time and elastic recovery, and between Young's modulus and elastic recovery of polypivalolactone fiber, respectively.

High stretchability is usually needed in such uses as, for example, clothes such as sportswear, casual wear, underwear and hosiery; upholsteries such as bed clothes and sofa covers. In such uses, it is presumed that an elongation of at least about 30 percent is preferable. A sewing thread suitable for sewing the above clothes and upholsteries should exhibit such characteristics as listed below.

1. The sewing thread has a sufficient tenacity so as not to break at the time of machine-sewing when stress in tension of more than approximately 200 g is usually exerted and at the time of using the resultant stretch clothes.

2. The sewing thread extends conforming to the elongation of stretch fabrics during use and it withstands tension until the extension of the fabric reaches a maximum.

3. It does not easily and excessively extend by tension exerted upon the thread at the time of machine sewing or by stress in tension exerted during hand sewing.

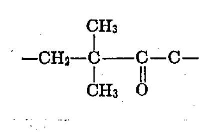
4. Instantaneous recovery force and elastic recovery from a high elongation are so large that the sewn threads assist the stretch fabric in recovering from elongation.

5. Shrinkage due to both washing and ironing is slight; in other words, the thread shows little shrinkage in boiling water and high heat resistance.

6. The sewing thread does not break at sewing by a high speed machine.

A sewing thread of the present invention has the above-listed characteristics. The thread is composed of at least one thermoplastic elastic fiber made from, for example, pivalolactone polymer and modified polyamide. Particularly, those made from pivalolactone polymers are preferred.

Pivalolactone polymer is a kind of linear ester polymer and has the repeating unit shown by the following formula;



It is prepared through the polymerization of hydroxypivalic acid or its ester as disclosed in U.S. Pat. No. 2,658,055 or through the polymerization of pivalolactone as disclosed in British Pat. No. 766,347. By the term "pivalolactone polymer" in the present invention there is meant polymers containing more than 70 mole percent of the above repeating unit in the molecule, that is, pivalolactone polymer includes not only polypivalolactone but also pivalolactone copolymer containing pivalolactone and no more than 30 mole percent of other lactones such as β-propiolactone, α,α-diethyl-propiolactone or α-chloromethyl-pivalolactone. No more than 30 mole percent of the comonomer is allowed to exist in the polymer because it damages the highly orienting property with crystallinity which is required in the structure of fibers. Further, pivalolactone polymer of the resent invention may include a blended polymer of the above polypivalolactone or pivalolactone copolymer with other polymer, the latter polymer being contained in such a small amount that it does not affect the polymer characteristics. Pivalolactone polymer fibers may be in the form of monofilament, multifilament or short-cut staple.

Pivalolactone polymer has quite different properties from other polymers, which are widely employed in melt spinning, for example, polyamides and polyesters such as polyethylene terephthalate. Since pivalolactone polymer rapidly reaches high crystallinity, specific conditions for the preparation of the fibers by melt spinning should be laid down.

Several preferred examples of the preparation of the fibers are given below.

Pivalolactone polymer fiber may be prepared by a method which comprises three steps; first, melt-extruding pivalolactone polymer having an intrinsic viscosity $[\nu]$ of at least 0.7 through orifices having diameters of more than 0.5 mm at a temperature from 240 to 280°C and secondly, drawing the extruded filament to a great extent while it is in a molten or plasticized state with such a spinning draft ratio (A) that satisfies the following equation;

$$A \geqq 1,367[\nu]^{-5.612}$$

and finally, drawing the resultant filament at a temperature (T°C) defined by the following two equations;

$$T \geqq -282 + 1,744R - 1,605R^2$$

(wherein R designates degree of orientation of the filament immediately after the above second step.)

$$220 \geqq T \geqq 10$$

A second method for the preparation of pivalolactone polymer fiber which comprises melt-extruding pivalolactone polymer having an intrinsic viscosity $[\nu]$ of at least 1.1 through orifices having a relatively large diameter at a temperature from 240 to 310°C and then, drawing the extruded filament at a high drawing ratio while it is in a molten or plasticized state with such a spinning draft ratio (A') that satisfies the following two equations;

$$A \geqq 2,460[\nu]^{-5.970}$$

$$A \geqq 76[\nu]^{-1.599}$$

The drawn filaments described above exhibit a load-elongation curve similar to the curve (I) shown in FIG. **1**, in other words, the filaments have such characteristics that a portion of the load-elongation curve, at which a decrease of the differential coefficient of the curve occurs with an increase of load, that is, a yield point exists within a range below 20 percent elongation. In the case where the drawn filaments are subjected to heating under a tension by a conventional method, a load-elongation characteristic, which is similar to the curve (I), but different in the point at which the resultant filaments have a remarkably increased elongation, is obtained. It is, however, noted that the above drawn filaments and the heat-treated filaments have a shrinkage in boiling water from 1.5 to 5.0 percent and therefore, they cannot be used for sewing threads. On the other hand, when the above drawn filaments are subjected to heating under relaxed conditions, the resultant filaments exhibit a load-elongation curve similar to the curve (II) shown in FIG. 1. However, the resultant filaments also are not suitable for sewing threads because they have such a low initial modulus of elasticity in tension that a large variation in strain is caused by a slight variation in stress.

It is found that, in the case drawn filaments are subjected to he following heat-treatment, the resultant filaments have a load-elongation characteristic and an elastic recovery, both being specifically suitable for sewing threads, and have a considerably reduced shrinkage in boiling water. A method of the heat-treatment comprises subjecting drawn filaments substantially composed of pivalolactone polymer or yarns composed of the drawn filaments to a first heating at a temperature of no less than 150°C, preferably no less than 160°C under a tension of no less than 0.2 g/d, preferably 0.3 g/d for at least 0.1 sec and then, subjecting the resultant filaments or yarns to a second heating at a temperature of no less than 110°C, preferably 120°C, but no more than that in the above first heating under relaxed conditions for at least 1 sec.

Referring to FIGS. **1**, **2**, **3** and **4**, the method of preparing a pivalolactone polymer fiber suitable for the preparation of sewing threads is more fully described.

The first heating in the above method may be carried out by a conventional apparatus, one embodiment of which is shown in FIG. **3**. Reference numbers **1**; **2**; **3**, **3'**; **4**; **5**, **5'**; **6** and **7** designate a bobbin of drawn filaments or yarns; a travelling filament or yarn; a pair of feed rolls, both being nipped to each other; a heating apparatus; a pair of delivery rolls, both being nipped to each other; a winding tube and a heat-treated filament or yarn, respectively. A filament or yarn **2** from the bobbin **1** is fed through the feed rolls **3**, **3'** to the heating apparatus **4** and delivered through rolls **5**, **5'** and then, wound on the tube **6**. Since both peripheral speeds of the rolls **5**, **5'** and the rolls **3**, **3'** are so regulated that the former speed is larger than the latter, the filament may be under a tension of at least 0.2 g/d, preferably at least 0.3 g/d between both pairs of rolls. An upper limit of the tension is not specifically fixed and the tension may be voluntarily applied so long as the filament is not drawn to the breaking elongation. The heating in the apparatus **4** may be dry heating, wet heating or other conventional heatings. In the case of a heating temperature of less than 150°C, the elastic recovery of the resultant filament is insufficient. The upper limit of heating temperature is the melting point of pivalolactone polymer, that is, approximately 240°C. The travelling speed of the filament or yarn in the apparatus **5** should be properly determined depending on the length of the apparatus so that the heating time may be at least 0.1 sec.

The above is the most simplified embodiment of the first heating, but it should be understood that the heating can be effected otherwise, for example, the filament is heated in a pressure-resistant vessel as it is wound on a bobbin.

The second heating of the above method can be effected either continuously or interruptedly from the first heating. In the preferred embodiment, the second heating is also carried out using a similar apparatus to that shown in FIG. **3**, wherein the filaments are heated under substantially relaxed conditions by regulating both peripheral speeds of the feed rolls and delivery rolls. The filament may be also heated in the form of a skein. The heating temperature in the second step should be no higher than that of the first heating. In case the heating temperature exceeds that of the first heating, the resultant filaments exhibit load-elongation curves similar to the curve (II) shown in FIG. **1**, which should be avoided. It is desirable to adopt a high temperature within a ange from 110°C to the temperature of the first heating.

Referring to FIG. **4**, which shows another preferred embodiment of the above method; reference numbers **1**, **2**, **6** and **7** are applied to the same parts as stated above for FIG. **3**, respectively, and **8**, **8'**; **9**, **9'**; **10** and **11**, **11'** designate a pair of Nelson rolls consisting of a first roll **8** and an idler roll **8'** attached thereto; a pair of second rolls; a plate heater, and plates for retaining warmth, respectively. A filament **2** wound off from a bobbin **1** is wound on a pair of Nelson rolls **8**, **8'** several times and then, subjected to heating both at a plate heater **10**, which is surrounded with plates **11**, **11'** located between a pair of second rolls **9**, **9'**, and at the pair of heated second rolls **9**, **9'**, on which the filament is wound several times or in scores, and finally wound on a tube **6**. In this case, the filament may be under a voluntary tension between both pairs of first rolls and second rolls by regulating both peripheral speeds of the two pairs of rolls. The first roll **8** is usually heated by means of a suitable heater such as an electric heater. Working conditions such as heating temperature, tension and heating time are similar to those stated above.

The pivalolactone polymer filaments, thus obtained, exhibit such a type of load-elongation curve as shown in FIG. **2**. Referring to FIG. **2**, reference marks (E) and (R) designate a load-elongation curve and a recovery curve upon unloading, respectively. As clearly shown in FIG. **2**, the resultant filament usually has a breaking tenacity of at least 2 g/d and a breaking elongation of at least 30 percent, and more specifically, the curve in FIG. **2** exhibits a breaking tenacity of more than 6 g/d and a breaking elongation of by far more than 35 percent. Further, though the filament exhibits an initial modulus of elasticity in tension of no less than 0.5 g/d, usually no less than 8 g/d and in some cases, approximately 80 g/d, the filament has a yield point in the area above a load of 0.6 g/d and below an elongation of 20 percent, and more specifically, the curve shown in FIG. **2** exhibits a yield point in the vicinity of a load of above 3 g/d and an elongation of about 10 percent. At the above point, a rapid decrease in a differential coefficient occurs with an increase in stress and thereafter, a rapid increase in elongation occurs with a slight increase in load.

The filament also exhibits high elastic recovery percentage of elongation, i.e. at least 95 percent, 92 percent, 88 percent, 85 percent and 70 percent at 5 percent, 10 percent, 15 percent, 20 percent and 25 percent elongation, respectively. Further, the filament has an excellent elastic recovery force, which is apparent from the fact that a differential coefficient of the above recovery curve on unloading (R) increases with a decrease in load within an area 20 percent elongation. It is also superior in other recovering properties and accordingly, a reduction of recovery due to repeated elongation is not seen.

The filament is superior in thermal stability, which is one of the predominant characteristics of polypivalolactone fiber. It withstands a temperature of approximately 210°C at dry heating and approximately 180°C at wet heating both under tension. Such a high thermal resistance takes high rank among synthetic fibers and cannot be seen in conventional thermoplastic elastomers.

It is also surprising that shrinkage in boiling water at 100°C is at most 1 percent. Shrinkage in boiling water of the sewing thread of the present invention is given in Table 1 in comparison with that of the conventional polyamide sewing thread.

TABLE 1

	Shrinkage in boiling water (%)
Invention	> 1.0
Control	1.5-5.0

The sewing thread of the present invention is prepared from thermoelastic elastic fibers particularly pivalolactone polymer fibers having the characteristics described above. It is, however, noted that the filament or yarn may be twisted by conventional steps either prior to the heat treatment described above or after the heat treatment.

The twisted yarn should have a fineness of no less than 70 denier. Thus, the yarn or thread has sufficient initial modulus of elasticity, which consequently produces the properties that the thread withstands the tension exerted at sewing and is not excessively and easily elongated and accordingly, smooth sewing is effected.

The sewing thread of the present invention may be subjected to conventional finishings such as dyeing, oiling and, if desired, waxing.

Besides pivalolactone polymer, an example of thermoplastic elastomer component of the sewing thread is modified polyamides, particularly n-substituted polyamides such as that obtained from n-substituted hexamethylene diamine and sebacic acid.

Stretch fabrics, which are sewn with the above thread are for example, flat knitted hosieries, warp knitted goods such as tricot, cotton stretch fabrics made by mercerization wool stretch fabrics made by thermal or chemical treatment, woven fabrics made of elastomer yarn and fabrics made of textured yarn.

The sewing thread of the present invention has predominant physical properties other than those described above, which will be hereinafter described.

The sewing thread should have an initial modulus of elasticity in tension of no less than 0.5 g/d, preferably no less than 5 g/d. In case an initial modulus of elasticity is less than 0.5 g/d, the thread is excessively elongated by tension exerted at sewing and accordingly, satisfactory seams cannot be formed. In this case, sewing may only be effected by hand sewing or by machine sewing with reduced speed, but sufficient efficiency is not obtainable.

The sewing thread also should have a breaking elongation of no less than 30 percent, preferably no less than 50 percent and more preferably no less than 80 percent. In case breaking elongation is less than 30 percent, the resultant seams of stretch fabric is inferior in stretchability.

The elastic recovery at 25 percent elongation should be no less than 70 percent. In case it is less than 70 percent, sewn threads unavoidably lengthen by repeated elongation.

The sewing thread of the present invention may include not only thermoplastic elastic fiber yarn, but also, a composite yarn comprising from 3 to 97 percent by weight of at least one thermoplastic elastic fiber and from 97 to 3 percent by weight of at least one non-elastic fiber.

The thermoplastic elastic fiber, which is suitable for the sewing thread of the present invention is described hereinbefore. On the other hand, non-elastic fiber, which is also used for the above sewing thread, includes various natural and synthetic fibers, for example, vegetable fibers such as cotton, hemp, etc.; animal fibers such as wool, silk, etc.; thermoplastic polymer fiber such as polyamide, polyester, polyacrylonitrile, polypivalolactone and the like, each polymer being used in the form of homopolymer, copolymer, terpolymer or modified polymer.

As to the proportion of both elastic and non-elastic fibers, the sewing thread of the present invention contains from 3 to 97 percent by weight, preferably from 5 to 95 percent by weight of elastic fiber component. In case the amount of elastic fiber component is less than 3 percent, the sewing thread has no stretchability. On the contrary, in case it is more than 97 percent, the elastic fiber component reveals itself on the thread surface, which is accordingly, not preferable.

One of the important characteristics of the composite sewing thread, in which the elastic fiber component is covered with non-elastic fiber, as compared with the sewing thread composed of only elastic fiber, resides in that no breaking of the former thread due to hot needles occurs.

Methods of the preparation of the sewing thread comprising both components of elastic fiber and non-elastic fiber are hereinafter described.

In case the thermoplastic elastic polymer is used in the form of filaments, the elastic filaments may be doubled with non-elastic fibers, being in the form of filament or staple, while the elastic filaments are drafted by a conventional covering machine, twisting machine or spinning frame. On the other hand, in case the elastic fiber is used in the form of short-cut staple, elastic fiber and non-elastic fiber may be mixed together in the form of raw fiber or silver.

In the preparation of the composite sewing thread, doubling and twisting processes are usually necessary. The tension and number of twists at doubling vary depending upon the end use. For example, as a sewing thread available for cotton knitted underwear, it is desirable that an elastic yarn is covered with a cotton yarn or a blended yarn of cotton and polyester fiber. For acrylic jersey outerwear, an elastic yarn is desirably covered with acrylic yarns. In case a stretch fabric is composed of staple fibers, for example, in the case of the above acrylic jersey, it is preferred that an elastic yarn is covered with an acrylic spun yarn. For nylon filament fabrics such as a nylon tricot lingerie, an elastic yarn is preferably covered with nylon filaments. As listed above, when a surface yarn of sewing thread is the same material as that of stretch fabric, the thread adapts itself to the stretch fabric well and therefore, the seams are inconspicuous.

In case infusible fibers such as cotton, wool, silk, viscose rayon and the like are used as a surface yarn of the sewing thread, breaking of the sewing thread due to a red-hot needle, which could otherwise occur at the moment high speed sewing is stopped, does not occur.

In connection with the doubling process, it is noted that a sewing thread, which has an elongation corresponding to that of the stretch fabric, should be prepared. For stretch fabrics having a high stretchability, sewing threads having a high elongation should be prepared. For the reverse fabric, the reverse sewing thread is desirable. In case the sewing thread having a very high elongation is desired, it is advantageous to employ elastic filaments. On the contrary, for the preparation of the sewing thread having a lower elongation, elastic fibers may be employed either in the form of filament or staple fiber. If elastic filaments are employed, the elongation of the resultant thread is easily regulated in the doubling process; elastic filaments are doubled with non-elastic filaments or yarns, while the former are stretched under a predetermined tension and fed to a twisting process. Similarly, when staple-spun yarns are employed as elastic fibers, an elongation of the thread can be regulated by the following method; staple fibers are subjected to a treatment, by which the fibers are given shrinkability and spun to a yarn and the resultant yarn is subjected to shrinking to obtain a stretchable yarn, which is stretched in the same manner as described above.

Twisting may be effected by conventional methods using a ring twisting machine, a covering machine, etc. It is also possible that yarns are tied up together by applying a sizing agent, heat, etc. without twisting.

Further, according to the present invention, there is provided a method suitable for the preparation of a sewing thread, which has not only a high stretchability and elastic recovery, but also, an eminent resistance to tensile force whereby the thread is not affected by the tension change occuring at sewing.

The method comprises treating multifilament or yarn substantially composed of pivalolactone polymer with an oiling agent containing phenolic antioxidant and a swelling agent as at least one component comprising nonionic surface active agent and/or neutral oil and successively subjecting the resultant filament or yarn to continuous heating at a temperature not less than 35°C below the melting of the pivalolactone polymer and not higher than said melting point to obtain agglutinated multifilament or yarn.

An oiling agent, which is used in the above method, contains a swelling agent as at least one component comprising nonionic surface active agent and/or neutral oil, both of which exhibit sufficient affinity for pivalolactone polymer multi-filament or yarn. The oiling agent performs a function in accelerating the elastomerization of multifilaments at a heating process and promoting the agglutination of the multifilaments.

As a nonionic surface active agent, polyoxyethylene alkyl ethers such as polyoxyethylene lauryl ether and polyoxyethylene octyl ether; polyoxyethylene saturated fatty acid diesters such as polyoxyethylene dioctanoate, polyoxyethylene dilaurate and polyoxyethylene dioleate; polyoxyethylene saturated fatty acid monoesters such as polyoxyethylene monolaurate and polyoxyethylene mono-oleate; and polyoxyethylene alkyl phenyl ethers such as polyoxyethylene nonyl phenyl ether, are enumerated.

As neutral oil, dibasic acid diesters such as dioctyl azelate and dilauryl sebacate; fatty acid polyester oligomers such as polyethylene glycol adipate having a molecular weight of less than 5,000; hydrocarbons such as liquid paraffin and paraffin wax; fatty acid esters such as methyl stearate, methyl oleate and oleyl oleate; higher alcohols such as lauryl alcohol and stearyl alcohol; and higher fatty acids such as lauric acid and stearic acid.

A swelling agent, which is used in the above method, may be applied to filaments either alone or as one component of the oiling agent. In case a swelling agent is mixed with other oiling agents, an amount of no less than 10 percent by weight, preferably no less than 20 percent by weight of the swelling agent based on the weight of non-volatile component (i.e. component other than solvent) of the oiling agent should be employed. In the case of the amount of less than 10 percent by weight, agglutination cannot be accelerated and in this case, if temperature is compulsorily raised, deterioration or breaking of yarn occurs. Both emulsion type- and solution type-oiling agents can be used.

In order to effect both the elastomerization and the agglutination of pivalolactone polymer multifilament or yarn in a heating process, the above oiling agent applied to the multifilament or yarn should contain antioxidant. Antioxidant effectively prevents the thermal deterioration of multifilament in a heating process. Phenolic antioxidants, for example, di-tert-butyl hydroxy toluene, 4,4'-thio-bis(6-tert.butyl-3-methylphenol) and 1,3,5-trimethyl-2,4,6-tris(3,5-di-tert.butyl-4-hydroxybenzyl) benzene are very effective. As to the amount of phenolic antioxidants, 0.05 – 5 percent by weight, particularly 0.1 – 2 percent by weight based on the weight of the above swelling agent is preferred. In the case of less than 0.05 percent by weight, a significant effect cannot be obtained and the amount of more than 5 percent by weight does not increase the effect to any great extent. It is more preferable that the phenolic antioxidant be used together with other stabilizers, for example, phosphoric esters such as trioctyl phosphite.

The oiling agent can be applied to multifilament or yarn at any steps prior to the heating process. For example, it can be applied as spinning oil or as drawing oil. It is most preferable that the oiling agent be applied immediately before the elastomerization and the agglutination of filament occur due to heating.

As to the heating temperature in the heating process, a range from 35°C below the melting point of pivalolactone polymer to the melting point, particularly from 30°C below the melting point to 5°C below the melting point is preferable. If the heating temperature exceeds the melting point, the resultant filament is degraded and its quality is deteriorated. On the contrary, a temperature less than 35°C below the melting point results in insufficient agglutination.

A preferred embodiment of the heating process in the above method will be described referering to FIG. 4.

Multifilament is preheated by a pair of Nelson rolls **8, 8'** and then wound on heated rolls **9, 9'**. The filament is heated by the rolls **9, 9'** and a plate heater **10** and finally, wound on a tube **6**. Preheating by the Nelson rolls is rather preferable because it enables the shortening of the heating time. Heating time means the time, during which the filament travels from a contacting point to the roll **9** to a leaving point of the roll **9'**. The heating time varies depending upon, for example, heating temperature, number of windings on the rolls **9, 9'** and the travelling speed of filaments. A heating time is usually no more than 30 sec, preferably no more than 20 sec. A heating for more than 30 sec sometimes produces deterioration of filaments. Filament or yarn is preferably drawn to more than 1.05 times their original length in the heating process, because, if not, they are insufficiently wound on the rolls and accordingly, the agglutinated filament or yarn is inferior in resistance to tensile force. It is noted that the heating may also be effected by a conventional apparatus other than that shown in FIG. **4.**

Untwisted multifilament is sometimes used in the above method, but in some cases, those previously twisted may also be used. In the former cases, agglutinated filament having a flat cross section are obtainable, but in the latter cases, a circular cross section is obtainable, the latter being preferable as a sewing thread.

A multifilament or yarn is agglutinated; that is, individual filaments are tied tightly together in a bundled form through the heating process. The resultant thread is not loosened even after scores of repeated elongation and shrinkage. It has a high resistance to tensile force and consequently, such kinds of obstacles as puckering due to the change of tension exerted at sewing do not occur.

Further, according to the present invention, a sewing thread which has an excellent antistatic property besides the above-mentioned characteristics is provied. The sewing thread contains at least on thermoplastic elastic yarn or filament component having a conductive metal surface layer.

A method of preparing the sewing thread containing the yarn component having a conductive metal surface layer comprises coating a thermoplastic elastic yarn or filament having a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 80 percent with metal while the thermoplastic elastic yarn or filament is under a drawn state to the extent from 10 to 90 percent of the breaking elongation and then, uniting the resultant yarn or filament with a thermoplastic elastic yarn or filament and/or non-elastic yarn or filament to form a thread. The method will be hereinafter described.

Conventional methods for depositing metal can be utilized for depositing conductive metal on the thermoplastic elastic yarn of the present invention. For example, chemical plating employing nickel, copper, cobalt, chrome, zinc and tin can be utilized. Among the above metals, nickel and copper are preferred from economical view points and the facility of chemical plating. In addition to chemical plating, electric plating can be applied to the chemically plated elastic yarn. By this method, the resultant yarn has a more improved antistatic property. Vacuum evaporation of metals is also utilized. In this case, copper, chrom, nickel, gold, silver, zinc, uranium, palladium, platinum, etc. are employed.

At the time of metal coating, elastic yarn is drawn in a range from 10 to 90 percent, preferably from 25 to 75 percent of the breaking extension. If an elongation is less than 10 percent of the breaking elongation, conductivity of the resultant yarn significantly reduces at the time when tensile force is exerted. In the case of more than 90 percent, difficulties in economy and working efficiency are caused. Coating can be effected either continuously or interruptedly.

The thickness of the metal surface layer is 0.01 – 30 micron, preferably 0.05 – 25 micron and more preferably 0.1 – 20 micron. In the case of a thickness less than 0.01 micron, conductivity and durability of the resultant yarn are inferior. On the other hand, metal surface layer having a thickness of more than 30 micron affects elastic recovery of the resultant yarn.

A sewing thread containing the conductive yarn as at least one component can be prepared by conventional methods. In order to achieve the object of the present invention, that is, to provide a sewing thread particularly suitable for a high stretch fabric, the conductive elastic yarn is preferably doubled and twisted with non-conductive elastic yarn. It is also preferred to use non-conductive and non-elastic yarn in addition to the above. In the latter case, it is desirable that the non-conductive and non-elastic yarn is doubled and twisted with the conductive elastic yarn while the latter yarn is under a drawn state or that the former yarn is used as a sheath component of a covered yarn or a core spun yarn.

As to the proportion of a conductive elastic yarn, an amount of no more than 50 percent, particularly no more than 25 percent and more particularly no more than 10 percent by weight based on the weight of a thread is preferable. Use of more than 50 percent does not increase the conductivity to any great extent.

On the other hand, as to the proportion of elastic yarns containing both conductive and non-conductive yarns, an amount of no less than 30 percent, particularly no less than 5 percent by weight based on the weight of a thread is preferable. In case the amount is less than 3 percent, elongation and elastic recovery of the resultant thread is significantly reduced.

A stretch fabric which is sewn with the above sewing thread has the following predominant characteristics: (1) it exhibits excellent antistatic property due to the conductive yarn or filament component, (2) the seams have a high elongation.

Further, according to the present invention, a sewn stretch fabric, which has the seams exhibiting excellent stretchability, is provided. The sewn stretch fabric has the seamed parts formed with a sewing thread as hereinbefore described, and particularly at least one of the seamed parts has a sewn thread having a different elastic recovery and/or initial modulus of elasticity in tension from others.

The above sewn stretch fabric is prepared by the following method; sewing a stretch fabric with a sewing thread composed of pivalolactone polymer fiber having an initial modulus of elasticity in tension of no less than 15 g/d and then, subjecting the resultant sewn stretch fabric to heating. The heating is preferably carried out in the following manner; at least one seamed part of the sewn stretch fabric is subjected to heating under a different condition from that applied to other seamed parts. The method will be hereinafter described.

The sewing thread, which is used for sewing the above stretch fabric, comprises pivalolactone polymer fibers having a high initial modulus of elasticity in tension of preferably no less than 15 g/d. In case the initial modulus of elasticity in tension is less, the resultant sewing thread is easily and excessively extended by tensile force exerted at sewing and therefore, satisfactory seams cannot be formed.

In practice of sewing, any type of conventional machines can be used, but a lock stitch machine is preferred. Because, the seams, which are beautiful and both sides of which resemble each other, are obtainable and the thread consumption in lock stitch machine-sewing is the least. Further, the machine has a simple and inexpensive structure and accordingly, it has widely spread to home use. It is one of the effects of the present invention, and it has never been achieved heretofore that stretchable clothes, wherein there is no difference between the seamed part and the cloth part in elongation and resistance to tensile force are obtainable. In the case when a chain stitch sewing machine or an over lock machine is used, the resultant seamed parts have high elongation. It is, however, not preferable from economical view points because sewing efficiency is reduced and thread consumption increases.

One of the predominant advantages of the above method resides in that elastomerization degree, i.e. elastic property, may be varied from place to place in an individual suit of clothes.

The heating treatment after sewing is carried out at a temperature of 140 – 210°C, preferably 150 – 200°C. When the temperature is less than the lower limit, sewn threads cannot be sufficiently elastomerized. On the other hand, in the case of a temperature of more than 210°C, some obstacles such as melting and adherence of threads to each other, discoloration and thermal deterioration arise. Heating time is from 1 to 10 sec, preferably from 1.5 to 9 sec. In the case of a time out of the above range, the same obstacles as those described above, i.e. insufficient elastomerization or thermal deterioration, airse. Either dry heating or wet heating may be employed. Heating may be effected under a predetermined pressure or without aplying any pressure. But, the pressure during heating is effective, because it makes the outside appearance or shape of the clothes fine.

Referring to FIG. 5, FIG. 6 and FIG. 7, which show the relationship of Young's modulus vs. heating time, of elastic recovery vs. heating time and of elastic recovery vs. Young's modulus, respectively, a mutual relationship exists between the elastic property of the seams and the heating condition.

As shown in FIG. 5, though pivalolactone polymer fiber is given sufficient stretchability by heating, an initial modulus of elasticity in tension (Young's modulus) of the fiber is slightly reduced. The reduced Young's modulus does not produce difficulties in practical sewing. It is, however, advantageous that a thread having a high Young's modulus is used in the sewing machine for industrial use, the working speed of which is yearly increasing. Thus, according to the above method, sewing is effected using a thread having a high Young's modulus and thereafter, the resultant seams are subjected to heating to elastomerize them, as shown in FIG. 7. Therefore, it is possible that only the seams, which need elastomerization, are elastomerized by varying heating conditions from place to place within an individual suit of clothes, and that the elastomerization degree of each seam is regulated with perfect freedom.

For example, as to knitted underwear, the seams of shoulder parts do not need stretchability in the least, but the seams of skirt hem and side hems need high stretchability and the seams of neck hem need moderate stretchability. The above method advantageously suits such clothes. According to conventional methods it is very troublesome in both processes of preparing sewing threads and of sewing to use properly many sewing threads having a different stretchability from each other for the preparation of one suit of clothes. On the other hand, the method of the present invention has advantages that the above defects are prefectly obviated and that elastic property of each seam is controlled with perfect freedom.

In order that the invention may be more fully understood, the following examples are given by way of illustration only.

In the examples, tensile tests are carried out using Tensilon under the following conditions; a length of specimen, 2 cm; extending speed, 2 cm/min; recovering speed, 2 cm/min; initial load, 0.1 g/d. Elongation, initial modulus of elasticity and yield strength are measured from the above results by the conventional determining procedure. Elastic recovery is measured by determining the ratio (in percent) of recoverable extension of the total extension impressed upon the specimen under the same program of strain rate as the above, wherein one minute is used for relaxing the specimen after returning to its original length. Shrinkage in boiling water is measured by determining the ratio (in percent) of shrinkable length to the original length after dipping the specimen in boiling water under a relaxed condition for 30 min. Intrinsic viscosity [ν] of pivalolactone polymer is measured in mixed solvent of phenol/O-clorophenol (6/4) at 30°C.

Example 1

Polypivalolactone having an intrinsic viscosity of 2.4 was extruded using a 20 mmϕ extruder. Spinning conditions were as follows: temperatures at inlet and outlet of cylinder, 220°C and 270°C, respectively; temperature of spinneret, 270°C, orifice diameter and No. of holes, 0.3 mm ϕ and 36; temperature of air, 15°C; extrusion rate, 3.5 g/min; take-up speed, 780 m/min. The formed filaments were drawn to 2.1 times their original length on a plate heater at 160°C to obtain drawn polypivalolactone filaments having a fineness of 75 d/36 fils.

The drawn filaments were twisted 920 turns per meter in the S direction. Three of the twisted filaments were then doubled and twisted 630 turns per meter in the Z direction. The resultant yarn (A) had such a tensile property as curve I shown in FIG. 1 and had a shrinkage in boiling water of 5 percent and an elastic recovery at 25 percent elongation of 40 percent. Then, the yarn (A) was subjected to heating through a heating apparatus as shown in FIG. 3 under various conditions. Results of tensile test of the heated yarn are given in Table2.

TABLE 2

Heating time (sec.)	Heating temp. (°C)	Tension (g/d) 0.1*	0.2	0.3	0.5	1.0
5	140	**56%	58	60	60	break
		***T	I		II	
	150	73%	77	80	80	81
		I	I	I	I	I
	160	81%	86	88	88	88
		I	I	I	I	I
	180	86%	90	92	93	break
		I	I	I	I	I
1	140	50%	51	52	52	break

	I	I	I	I	
150	70%	70	79	80	break
	I	I	I	I	
160	80%	83	84	85	86
	I	I	I	I	I
180	86%	90	91	93	break
	I	I	I	I	I

*Tension (in g/d) applied at heating
**Numerical values listed in the upper row are an elastic recovery at 25% elongation (in %).
***Curve I shown in FIG. 1

All the heated-yarns exhibit a shrinkage in boiling water of more than 2 percent. Among the heated yarns listed in Table 2, those having been heated at a temperature of 140, 150, 160 and 180°C under a tension of 0.3 g/d for 5 sec, were then subjected to a second heating in saturated steam at a temperature of 100, 110, 130, 150 and 170°C under a relaxed condition for 5 sec using a similar apparatus to that shown in FIG. 3. Testing results are given in Table 3.

TABLE 3

Heating Temp. (0.3 g/d, 5 sec)		100°C	110°C	130°C	150°C	170°C
	ER*	60%	61	61	69	82
140		I	I	I	II	II
	S **	1.7%	1.5	0	0	0
	ER	80%	81	82	86	89
150		I	I	I	II	II
	S	1.5%	1.1	0	0	0
	ER	88%	88	88	90	90
160		I	I	I	I	II
S		1.4%	0.8	0	0	0
	ER	92%	92	92	93	93
180		I	I	I	I	I
	S	1.1%	0.4	0	0	0

*Elastic recovery at 25% elongation
**Shrinkage in boiling water

As apparently shown in Tables 2 and 3, heating under tension (a first heating) should be effected at a temperature of no less than 150°C, preferably no less than 160°C and under a tension of no less than 0.2 g/d, preferably no less than 0.3 g/d. Heating under a relaxed condition (a second heating) should be effected at a temperature of no less than 110°C, preferably no less than 130°C, but no more than the temperature of the first heating. Moreover, both heatings under tension and under a relaxed condition are necessary,

All the heated yarn has an initial modulus of elasticity of more than 20 g/d, a breaking elongation of more than 30 percent, an elastic recovery at 25 percent elongation of more than 80 percent and a shrinkage in boiling water of less than 1 percent.

Example 2

The heated yarn by the method described in Example 1 under the following conditions; first heating, temperatures 160°C, tension 0.3 g/d, time 5 sec; second heating, temperature 130°C, time 5 sec, was subjected to cheese dyeing with disperse dyes at a temperature of 100°C. The resultant yarn was then subjected to oiling and waxing by conventional methods to obtain a sewing thread.

Shrink proofed 40 lb broads composed of polyethylene terephthalate fiber/cotton (65/35) were separatedly sewn with the above sewing thread and with a commercially available 40 lb polyethylene terephthalate sewing thread. Puckering tests were made. There was no difference between the two in workability at sewing and in puckering property.

Cotton hosieries were also separately sewn with the two threads using a lock stitch machine. The polyethylene terephthalate thread prevented the hosiery from extending and it was broken by excessive pulling. On the other hand, the sewing thread of the present invention not only easily extended conforming to extension of the hosiery, but also, remarkably promoted the recovery of the hosiery, which had a weak recovering force in itself. Sewing conditions were as follows: sewing machine, Singer lock stitch machine 241- 11 type; number of revolutions, 5,000 rpm; needle, Organ DA No. 11; stitch number, 8 - 10 inch; bobbin thread was the same as needle thread.

For comparing with the sewing thread of the present invention, two polypivalolactone sewing threads (B) an (C) were prepared by the following method: sample yarns (A) and (C) were subjected to a first heating at 150°C and 170°C, respectively under tension and then, subjected to a second heating at 170°C and 100°C, respectively, under relaxed condition. Both yarns were subjected to dyeing, oiling and then waxing in the same manner as described above. The thread (B) had a large proportion of stress to strain and therefore, puckering was observed even before washing. The thread (C) had a small proportion of stress to strain, but puckering violently occurred after washing.

A sewing thread, which was prepared from pivalolactone copolymer containing 10 percent of α, α -diethylpropiolactone by the method of the present invention, also exhibited excellent elastic properties.

Example 3

Drawn and twisted yarns (A) in Example 1 were subjected to a first heating by a heating apparatus shown in FIG. 4 under the following conditions: temperatures of the first roll, the second roll and a plate heater were 180°C, 216°C and 220°C, respectively; heating time was approximately 0.1 sec; traveling speed on a plate heater was 700 m/min; tension between the first and the second rolls was 0.5 g/d. Then, the yarn was subjected to a second dry-heating through a heating apparatus shown in FIG. 3 at a temperature of 180°C under relaxed condition for 1.3 sec.

The resultant thread also had excellent elastic properties.

Example 4

Polypivalolactone ([ν] = 2.4) was extruded through a 20 mm extruder. Spinning conditions were as follows: temperatures at inlet and outlet of cylinder, 220 and 270°C, respectively; temperature of spinneret, 270°C; orifice diameter and no. of holes, 0.3ϕmm and 24; temperature of air, 15°C; extrusion rate, 8.5 g/min; take-up speed, 900 m/min. The extruded filaments were drawn and twisted to 1.7 times their original length on a plate heating at 160°C to obtain drawn polypivalolactone filaments having a fineness of 50 d/24 fils.

The filaments were then subjected to a first heating through a heating apparatus shown in FIG. 4 under the following conditions; temperatures of the first roll, the second roll and a plate heater were 170°C, 215°C and 219°C, respectively; heating time was approximately 0.1 sec; traveling speed on a plate heater was 700 m/min; a tension between the first and the second rolls was 0.5 g/d. The filaments were successively subjected to a second dry-heating at a temperature of 170°C under a relaxed condition for approximately 1.1 sec through an apparatus shown in FIG. 3.

The resultant filaments had such a tensile property of curve I shown in FIG. 1 and exhibited a breaking tenacity of 2.7 g/d, a breaking elongation of 80 percent, an initial modulus of elasticity in tension of 16 g/d, an elastic recovery at 25 percent elongation of 88 percent, a yield strength of 0.8 g/d and a shrinkage in boiling water of 3 percent.

The filaments were twisted 950 turns per meter in the S direction. Three of the twisted filaments were then doubled and twisted 640 turns per meter in the Z direction. The resultant yarn was subjected to dyeing, oiling and then waxing in the same manner as described in Example 2. The thread, thus obtained, had a breaking elongation of 100 percent, an initial modulus of elasticity in tension of 15 g/d and a yield strength of 0.6 g/d. Other properties were similar to those before twisting.

The sewing threads obtained in this example were slightly different from those described in Examples 1, 2 and 3; they were not suitable for the fabric having a relatively low stretchability because both initial modulus of elasticity in tension and yield strength were somewhat low. On the other hand, they were particularly suitable for the fabric having a high stretchability, for example, a knitted underwear and a jersey. The thread sewn only by a lock stitch machine not only easily extended conforming to the extension of knitted underwear, which was usually brought about at the time of putting on and taking off, but also, it remarkably improved recovery of the underwear due to its strong recovery force. A sewn thread composed of polyethylene terephthalate fiber prevented extension of the underwear even in the case when a lock stitching was applied, and it was broken by excessive pulling.

Example 5

Polypivalolactone chips having an intrinsic viscosity $[\nu]$ of 2.10 was melt-spun through an extruder having a diameter of 40 mm ϕ under the following conditions; temperatures at inlet, middle part and outlet of cylinder was 230°C, 260°C and 260°C, respectively; temperature of a nozzle holder was 260°C; diameter of orifice and no. of holes were 0.3 mm ϕ and 48; temperature of air was 45°C; extrusion rate was 20 g/min; take-up speed was 800 m/min; and temperature of the take-up chamber was 20°C; to obtain two bundles of filaments. The drawn filaments were continuously contacted with a hot roll heater at a temperature of 205°C for elastomerization. Resultant filaments had a total fineness of 100 d/36 fils, a breaking elongation of 210 percent, a breaking elongation of 95.0 percent and an initial modulus of elasticity in tension of 14.2 g/d.

The above filaments were then drawn at a draft ratio of 2.0 by a drawing and twisting machine, but a practically effective ratio was 1.3. The filaments were then twisted 900 turns per meter in the S direction. Three of the twisted filaments were doubled and twisted 600 turns per meter in the Z direction and taken up on a bobbin and then subjected to heating in steam at a temperature of 100°C for 5 min after subjected to softening and waxing, the resultant sewing thread exhibited a total fineness of 225 denier, a breaking tenacity of 1.6 g/d, a breaking elongation of 15 percent, an elastic recovery of 95 percent at 25 percent elongation and an initial modulus of elasticity of 6.7 g/d.

A cotton knitted underwear (an athletic shirt for men) was sewn with the above thread by a lock stitch machine. The knitted goods were prepared by a flat knitting machine from a pure cotton spun yarn (No. 52 two folded yarn) under conditions that wale and course were 32/inch and 46/inch, respectively. Rub knitted goods made of No. 25 cotton spun yarn were fitted to hem parts such as neck line and arm hole lines. But, a skirt of the shirt was turned up to form a skirt hem. The resultant underwear is designated as "D". The lock stitch sewing was carried out using a lock stitch Singer 281-1 type under the following conditions; no. of revolutions, 3,000 rpm; needle Organ No. DA 14; stitch number, 10/inch; bobbin thread was the same as needle thread. The sewing could be smoothly effected. For comparison, cotton knitted under wear, the same as that described above, was sewn with No. 80 cotton sewing thread wherein a double two-thread chain stitch (using two needles and three threads) and plain stitch were properly adapted to hem parts and shoulder parts, respectively. The resultant underwear is designated as sample E. Tensile properties of both underwear D and E are shown in Table 4.

TABLE 4

	D	E
Machine	Lock stitch	Two thread chain stitch and interlock
Consumption of sewing thread (ratio)	1	12
Breaking elongation (%)*		
Skirt hem part	150	140
Neck hem part	110	65
Arm hole hem part		65
Elastic recovery at 130% elongation (%)		
Skirt hem part	59	31
Neck hem part	—	—
Arm hole hem part	13	—
Elastic recovery at 100% elongation (%)		
Skirt hem part	82	50
Neck hem part	79	—
Arm hole hem part	79	—
Elastic recovery at 50% elongation (%)		
Skirt hem part	94	75
Neck hem part	90	60
Arm hole hem part	90	60
Elastic recovery (work recovery at 50% elongation (%)		
Skirt hem part	75	12
Neck hem part	78	17
Arm hole hem part	78	17
Machine for hem parts	Lock stitch	Two thread chain stitch

*Breaking elongation is meant by an elongation at the time when the sewn thread is broken.

When the skirt hem part, neck hem part and arm hole hem part were extended by 150 percent, 110 percent and 110 percent, respectively, the knitted goods were broken. Tests of tensile properties were carried out by a similar method to that described above except that specimen length was 10 cm and both extending and recovering speed were 20 cm/min and specimen width was 12 mm.

As apparently shown in Table 4, the underwear of the present invention has several advantages. First, it exhibits a high elastic recovery. It is noted that an elastic recovery of approximately 60 percent remains even in a case of 130 percent elongation which is close to the breaking elongation. A usefulness of the present invention is also proven from a fact that it has a high elastic recovery exceeding 90 percent at 50 percent elongation which is presumed as the limit stress worked during daily use. Work recovery is also excellent and accordingly, it shows the highest dimensional stability which has never been seen in conventional knitted goods. Secondly, it has a high breaking elongation. Therefore, the sewn thread is not broken by abrupt and excessive pulling during use. Considering that it has a low density, it may safely be said that it has a remarkably high tenacity. Thirdly, a comsumption of the sewing thread is far reduced in comparison with conventional threads. Fourthly, a lock stitch can be used and therefore, labor conditions and equipment are remarkably improved.

Next, washing tests of samples D an E were carried out to observe dimensional stabilities of every hem part. A cycle of washing with warm water at 60°C for 10 min and drying was repeated ten times. Lengths after the fifth and the tenth cycles are shown in Table 5, wherein the length is designated by a ratio to the length (expressed as 100) before testing.

TABLE 5

Sample	Hem parts	Fifth	Tenth
	Neck	101	102
D	Arm hole	101	102
	Skirt	101	101
	Neck	107	108
E	Arm hole	109	109
	Skirt	109	107

The underwear of the present invention did not slacken after washing. It has excellent dimensional stabiliities for washing as apparently shown in Table 5.

Wearing tests were made in the following manner: a man wore both underwear D and E in turns every other day for 60 days, wherein washing was performed after every wearing. Results are shown in Table 6.

TABLE 6

Sample	Hem part	Before wearing	After wearing
	Neck	100	105
D	Arm hole	100	104
	Skirt	100	106
	Neck	100	123
E	Arm hole	100	121
	Skirt	100	125

The underwear of the present invention has also excellent dimensional stabilities for wearing. One of the defects in conventional knitted underwear is the fact that they gradually lengthen to a great extent during long use. So, the present invention obviates this defect.

Example 6

Undrawn polypivalolactone filaments described in Example 5 were drawn to 2.5 times their length at room temperature using a drawing and twisting machine and then, heated at a temperature of 180°C for 30 min for shrinking and elastomerizing. Shrinkage was 40 percent. Three of the resultant filaments were doubled and twisted, numbers of first twist and second twist being 900 T/M (S) and 600 T/M (Z), respectively. After being taken up on a bobbin, the resultant yarn was heated in steam at a temperature of 110°C and then subjected to softening and waxing to obtain a sewing thread having a total fineness of 200 d, a breaking tenacity of 1.73 g/d, a breaking elongation of 80 percent, an elastic recovery at 25 percent elongation of 97 percent and an initial modulus of elasticity in tension of 7.2 g/d.

Using the above sewing thread, a pair of ski pants (referred to as F) was sewn from twilled fabric having a warp density of 152/inch and a weft density of 90/inch and being woven from a doubling and twisting yarn of two 70 d woolie nylons (warp) and a two folded No. 30 worsted yarn. All the seams were formed by lock stitching except for eyelet stitching and a hem fray-preventing stitch. Sewing conditions were as follows; lock stitch machine, Lock Stitch Singer 281-1-type; number of revolutions, 5,000 rpm; needle, Organ DA No. 8; stitch number, 12/inch; bobbin thread was the same as needle thread. Sewing was smooth. For comparision, the same pair of ski pants as that described above was sewn with No. 60 polyester sewing thread. Resultant pair of pants is referred to as G. A two-thread chain stitch machine (Union Special 51300 type) was used under the following conditions; number of revolutions, 3,000 rpm; needle, Union Special 032; stitch number, 12/inch; bobbin thread was the same as needle thread. A sewing thread consumption in the latter chain stitch was three times as large as that in the former lock stitch.

After wearing for a month, knee distortion and change of seat seam were observed. As to knee distortion, F was superior to G. Because, sewn threads in both side seams of the knee area in F mitigated bagginess due to their high recovering force, but the sewn threads in G did not. The seat seam of F did not change in the least although a sewn thread density was low because of the lock stitch. On the other hand, in the seat seam of G, openings were caused and sewn threads were in sight.

Example 7

Drawn polypivalolactone filaments having a crystal orientation of 0.90 were subjected to relaxing in an aqueous solution containing 90 percent phenol at a temperture of 70°C for 10 min to shrink by 80 percent. The shrunken filaments were well washed with acetone, dried and then subjected to dry heating at a temperature of 190°C under a tension sufficient to maintain the length constant for 30 min to obtain elastic filaments having a breaking tenacity 1.6 g/d, a breaking elongation of 290 percent, an initial modulus of elasticity in tension of 4.9 g/d and an elastic recovery at 25 percent elongation of 96 percent. Three bundles of the filaments were doubled and twisted by the same method as that in Example 5 to produce a sewing thread having a total denier of 225 d. Using the sewing thread, a swimsuit (referred to as H) was sewn from interlock jersey knitted from two folded yarns of 150 d woolie nylon. All seams were formed by lock stitching except hem fray-preventing stitch. Sewing conditions were similar to those in Example 6. For comparison, two swimsuits were sewn with a No. 50 nylon sewing thread and the same sewing thread as that described above, respectively, by two-thread chain stitching, which were referred to I and J, respectively. In a comparison between H and I, the seams of H did not change in the least after long wearing, but, those of I fissured. Further, in a comparison between H and J, an interesting fact was observed; in a chain stitch, a high tension usually cannot be applied to a needle thread at the time of sewing because, in case a high tension is applied, the resultant seams do not have a sufficient elongation for conforming to elongation of fabric. Consequently, in the case of I having a nylon sewn thread, the seams loosened and looked poor. On the other hand, in the case of J, since a polypivalolactone needle thread was moderately elongated due to tensile force at the time of sewing and the elongation fully recovered after sewing, the resultant seams tightened, looked nice and were firm. Puckering could not be seen. The seams not also extended conforming to extension of the swimsuit, but also improved its recovery.

Breaking elongation of sewn threads in a skirt hem part of the swimsuits and elastic recovery of seamed parts are given in Table 7.

TABLE 7

Specimen	H	I	J	Unsewn jersey
Breaking elongation (%)	95.3	60.5	120	—
ER at 40% elongation (%)	85.1	69.1	80.2	68.1
ER at 80% elongation (%)	80.1	break	79.2	62.0

Example 8

A commerically available bandage was longitudinally sewn with the same sewing thread as that described in Example 5 by a tuck stitch machine. The resultant ribbed bandage exhibited a breaking elongation of 130 percent and a good elastic recovery.

Example 9

Cotton knitted goods similar to that used in Example 5 were sewn in a straight line in the transverse direction with various sewing threads as listed in Table 8 by a lock stitch machine. Tensile properties of the resultant knitted goods are given in Table 9. Testing conditions were as follows: specimen width was 4.0 cm, on a center line of which the seams existed; specimen length, 6.0 cm; extending speed, 2 cm/min; recovering speed, 2 cm/min.

TABLE 8

No.	Sewing thread	Fineness (d)	Initial modulus of elasticity in tension (g/d)	Breaking elongation (%)	Elastic recovery at 25% elongation (%)
1	Polypivalolactone	225/3	20.1	86.2	94
2	do.	225/3	14.6	87.8	95
3	do.	225/3	10.3	88.0	94
4	do.	225/3	7.6	86.5	95
5	do.	225/3	5.1	90.5	95
6	do.	225/3	1.2	102.0	97
7	N-substituted polyamide	240	1.5	152.3	91
8	Polyester	225/3	75.2	28.4	—
9	Nylon	225/3	26.4	21.8	—
10	Cotton	No. 60/3	27.3	24.4	—

TABLE 9

No.	Load 0.5 kg Breaking elongation (%)	Load 0.5 kg Elastic recovery at 25% elongation (&)	Load 1.0 kg Breaking elongation (%)	Load 1.0 kg Elastic recovery at 25% elongation (%)
Unsewn fabric	85.6	81.8	138.7	72.2
1	28.6	91.2	82.3	81.2
2	48.5	90.5	86.7	80.4
3	60.2	94.3	90.8	82.5
4	78.4	90.1	128.2	84.6
5	82.3	93.6	132.4	85.2
6	83.4	92.8	135.6	86.4
7	84.3	87.9	134.4	84.4
8	18.4	80.2	25.2	74.3
9	22.3	81.4	28.3	76.4
10	10.1	84.5	16.8	80.2

Example 10

Polypivalolactone having an intrinsic viscosity [ν] of 2.4 was melt-spun, drawn and then, subjected to dry heating at a temperature of 200°C under a tension of 0.5 g/d for 0.2 sec to obtain elastic filaments having a fineness of 25 d/12 fils, a breaking elongation of 70 percent and an elastic recovery at 25 percent elongation of 82 percent. The elastic filaments were united with cotton yarn by a conventional apparatus to obtain a No. 50 core spun yarn, while the elastic filaments were drafted to 1.50 times their length. Three of the resultant yarns were then doubled and twisted to obtain a No. 50 elastic thread. The resultant thread was subjected to scouring, bleaching and then waxing to obtain a sewing thread having a breaking strength of 730 g, an initial modulus of elasticity in tension of 7.0 g/d, a breaking elongation of 90 percent and an elastic recovery at 25 percent elongation of 80 percent.

Using the sewing thread, cotton knitted underwear was sewn by a Lock Stitch Singer 241-11-type machine under the following conditions; number of revolutions, 5,000 rpm; needle, Organ DA No. 11; stitch number, 8 – 10/inch; bobbin thread was the same as needle thread. The resultant seams were not broken even by excessive pulling and an elastic recovery of the underwear was remarkably improved. For comparison, the same cotton knitted underwear as that described above, was sewn with a No. 40 cotton sewing thread under the same conditions as those described above. The seams of the control underwear could not be extended and the sewn thread was broken by excessive pulling.

Example 11

A polyester multifilament having a fineness of 75 g/36 fils and two bundles of polypivalolactone filaments were separately twisted 900 turns per meter in the S direction and then doubled and twisted 600 turns per meter in the Z direction. The resultant yarn was subjected to dyeing and waxing to obtain a sewing thread having an initial modulus of elasticity in tension of 48.2 g/d, a breaking strength of 790 g, a breaking elongation of 80 percent and an elastic recovery at 25 percent elongation of 85 percent. The sewing thread exhibited peculiar characteristics; in the case when it is elongated to a great extent, the polyester component easily passes the yield point and therefore, the component bulges out of the thread at the time of relieving tension. When the thread is elongated to an extent exceeding about 30 percent, the polyester component is broken. Therefore, in the case when a lock stitch sewing machine is used, the thread should be preferably applied to textile goods having a relatively low elongation and it should be preferably applied to such a use where a high initial modulus of elasticity of polyester component may be utilized to the greatest extent.

Polyethylene terephthalate taffeta for umbrellas was sewn with the above sewing thread by a lock stitch machine under the same conditions as those in Example 10 except that the number of revolutions was 3,000 rpm. Workability at sewing of polypivalolactone sewing thread was improved due to polyester fiber component. The seams of the taffeta extended with a perfect freeness conforming to extension of the taffeta and were not broken after long use.

Example 12

A drawn polypivalolactone filament having a fineness of 2.5 denier was cut to a length of 70 mm. The staple fiber was blended with cotton at a blended ratio of 1/3 (the former/the latter) to form No. 50 single yarn. Three of the single yarns were then doubled and twisted and then subjected to finishing by a conventional method to obtain a sewing thread having a breaking elongation of 52 percent, an elastic recovery at 25 percent elongation of 71 percent and an initial modulus of elasticity in tension of 60.5 g/d. The sewing thread is also available for stretch fabrics particularly having a relatively low elongation.

Example 13

N,N'-diisobutyl-hexamethylene-diamine[I] and hexamethylene-diamine[II] were mixed at various ratios listed in Table 10. Various n-substituted copolyamides were prepared from the mixture and sebacic acid.

TABLE 10

Sample No. of N-substituted copolyamide	I (mole %)	II (mole %)
1	45	55
2	50	50
3	55	45
4	60	40

The copolyamides were melt spun at a temperature of 180°C to obtain monofilaments each having a fineness of 50 denier. The monofilament was united with cotton, while the monofilament was drawn to 1.4 times its original length, to obtain a No. 50 core spun yarn. Three of the yarns were doubled and twisted and then subjected to scoring, bleaching and waxing to obtain a sewing thread having the tensile properties listed in Table 11.

TABLE 11

Sample No.	Initial modulus of elasticity in tension (g/d)	Breaking elongation (%)	Elastic recovery at 25% elongation (%)
1	1.0	70	73
2	0.8	70	82
3	0.5	75	86
4	0.4	77	87

With the above four sewing threads, cotton knitted fabrics were separately sewn. Sewing with sample 1 was smooth. Sewing with sample 2 could be smoothly effected in case of tension applied to the needle thread was slightly relieved. Sewing with sample 3 could be achieved but with considerable difficulty, but sewing with sample 3 could not be achieved at all.

Example 14

Drawn elastic filaments, which were the same as those used in Example 10, were united with acrylic spun yarn, while the drawn elastic filaments were drafted to 1.50 times their length, to obtain a No. 48 core spun yarn. Three of the resultant yarns were doubled and twisted and then subjected to finishing to obtain a sewing thread having an initial modulus of elasticity in tension of 6.9 g/d, a breaking strength of 710 g, a breaking elongation of 85 percent and an elastic recovery at 25 percent elongation of 81 percent.

Cut acrylic jersey was sewn with the above thread to obtain a sweater for ladies. Sewing was smooth. The sweater had the following advantages in comparison with a sweater sewn with cotton sewing thread.

1. Since the surface material of the sewn thread was the same as that of the fabric, the sewn thread was inconspicuous.

2. Since the sewn thread had stretchability, the seamed part could be freely extended conforming to extension of the fabric. An elastic recovery of the seams was also improved.

3. The resultant sweater looked nice because sewing could be effected without the gathering of the seam part contrary to conventional non-stretch sewing threads.

Example 15

A bundle of drawn elastic filaments, which was the same as that used in Example 10, was united with two silk yarns each having an average count of 21, while the elastic filaments were drafted to 1.5 times their length. Three of the resultant yarns were doubled and twisted and then subjected to finishing to obtain a sewing thread having an initial modulus of elasticity of 8.3 g/d, a breaking elongation of 81 percent and an elastic recovery at 25 percent elongation of 84 percent.

Jersey, which was knitted from spun yarn, was sewn with the above sewing thread to form a sweater. The sweater also had similar advantages to those listed in Example 14 in comparison with a sweater sewn with silk sewing thread.

Example 16

Polypivalolactone chips having an intrinsic viscosity of 2.01 were melt spun at a temperature of 279°C. Undrawn filaments were drawn to 1.8 times their original length on a plate heater at a temperature of 180°C to obtain multifilaments having a fineness of 80 d/36 fils. In the spinning process, a solution of 10 g of polyoxyethylene dilaurate having a molecular weight of 300 and 50 mg of 4,4'-thiobis-(6-tertiary-butyl-3-methylphenol) in 200 ml of Newsol Deluxe (mineral oil made by Japan Petroleum) was applied as spinning oil. Pick up was 40 percent owf. The drawn multifilament had a breaking tenacity of 3.2 g/d, a breaking elongation of 62 percent and an elastic recovery at 25 percent elongation of 46 percent. Three of the multifilament were doubled and twisted 89 turns per meter in the Z direction.

Resultant yarn was subjected to continuous heating by the apparatus shown in FIG. 4 under the following conditions: a first heated roll **8**, 180°C, 760 m/min, 5 winds; second heated rolls **9, 9'**, 180°C, 820 m/min, 30 winds; plate heater **10**, 180°C; heating time, 4.1 secs. From the tests wherein temperatures of second heated rolls and of a plate heater **10** were varied, it was found that the yarn was broken at a temperature of 237°C and that the yarn was internally agglutinated at a temperature of no less than 206°C. In the case where the yarn was wound around the heated rolls **9, 9'** three times, the yarn was agglutinated at a temperature of no less than 207°C and was broken at a temperature of 241°C. From these results, it is apparent that polypivalolactone agglutinates at a temperature of more than about 205°C. Effects of the heating temperature on the tensile properties are shown in Table 12. Sample multifilaments were wound around the heated rolls **9, 9'** three times.

TABLE 12

No. of sample	Heating temp. (°C)	Breaking tenacity (g/d)	Elongation (%)	ER at 25% elongation (%)
1	190	3.12	83.2	81.5
2	200	3.02	86.1	82.9
3	205	3.02	94.3	86.9
4	215	2.94	98.6	92.6
5	225	2.80	98.4	92.4
6	235	2.60	82.4	86.0
7	Unheated	3.20	62.1	46.8

As apparently shown in Table 12, in order to obtain a good agglutination and high tensile properties, a temperature range from 205°C to 235°C is preferable.

For comparison, agglutinated filaments were prepared by the same method as that described above except that the spinning oil did not contain antioxidant. Results are given in Table 13.

TABLE 13

No. of sample	Heating temp. (°C)	Breaking tenacity (g/d)	Elongation (%)	ER at 25% elongation (%)	Agglutination
8	190	2.73	81.3	82.2	non
9	200	2.53	84.9	84.3	non
10	205	2.42	88.3	87.6	slight
11	215	2.39	92.5	91.2	good
12	225	2.03	90.6	94.4	good
13	235	1.72	82.1	86.5	good
14	Unheated	3.21	62.8	46.8	—

As apparent from the above table, in the case of the oiling agent not containing antioxidant, yarn quality is deteriorated through heating. Particularly, breaking tenacity is remarkably reduced through heating at a high temperature.

In the cases where di-tert.butyl hydroxytoluene and 1,3,5-trimethyl-2,4,6-tris (3,5-di-tert.butyl-4-hydroxybenzyl) benzene were separately used as antioxidant in place of 4,4'-thiobis-(6-tert.butyl-3-methylphenol), similar results as the above were obtained.

Example 17

Sample filaments No. 1, No. 3, No. 4, No. 5 and No. 6 listed in Table 13 were separately subjected to softening, antistatic treating and waxing to produce sewing threads. Using these threads, broad clothes woven from a two folded No. 60 blend yarn of polyethylene terephthalate fiber and cotton were sewn one over another by a lock stitch Singer 241-11-type machine under the following conditions; number of revolutions, 5,000 rpm; needle, Organ DA No. 11; stitch number, 12/inch; bobbin thread was the same as needle thread. Sewing was continued until the sewing thread was broken and the seam length at the time of breaking was measured. For comparison, using a commercially available polyethylene terephthalate sewing thread (60 d/3), similar tests were repeated. Results are given in Table 14.

TABLE 14

Sewing thread	3 cloths in piles	4 cloths in piles
No. 1	0–1 m	0–1 m
No. 3	5–10 m	2–5 m
No. 4	≧10 m	≧10 m
No. 5	≧10 m	7–10 m
No. 6	5–7 m	4–6 m
Polyethylene terephthalate thread	≧10 m	≧10 m

As apparently shown in Table 14, the thread No. 4 was the most excellent. As the thread No. 3 was insufficient in agglutination, the resultant seam length was short. In the sewing thread No. 6, as it did not have a smooth surface, extraordinary tension abruptly arose in a needle eye and consequently, the thread was broken.

Example 18

The sewing thread No. 4 used in Example 16, a commercially available polyethylene terephthalate sewing thread (60 d/3), a nylon textured bobbin thread (110 d/2) and a commercially available cotton sewing thread (60^s) were tested. An elongation at breaking of the seam part and an elastic recovery at 50 percent elongation of the seam part were measured. Sewing conditions were as follows; lock stitch machine, Singer 241-11-type; chain stitch machine, Union Special 51300BU; needle, Organ 11. The specimen for testing was jersey having a width of 5 cm and knitted from polyethylene terephthalate textured yarn. Testing conditions were as follows: specimen length, 10 cm; extending rate, 20%/min; recovering rate, 20%/min.

TABLE 15

Needle thread	Bobbin thread	Sewing method	Breaking elongation (%)	Elastic recovery (%)
PET*	PET	Lock stitch	32	78 (85)**
PET	Nylon	Lock stitch	35	77 (84)
No. 4	No. 4	Lock stitch	98	85 (76)
Cotton	Cotton	Lock stitch	16	79 (88)
PET	Nylon	Chain stitch	38	77 (84)
Cotton	Cotton	Chain stitch	37	76 (84)
No. 4	No. 4	Chain stitch	120	82 (71)

* A commerically available polyethylene terephthalate sewing thread.
** Numerical value in parenthesis indicates an elastic recovery of the very jersey specimen.

As apparent from Table 15, the sewn thread No. 4 had excellent tensile properties in both cases of lock stitch and chain stitch, which could never been obtained in the conventional sewn threads.

Example 19

Pivalolactone copolymer chips prepared from 97 mole percent of pivalolactone and 3 mole percent of β-propiolactone and having an intrinsic viscosity of 1.98 (dl/g) were melt spun at a temperature of 272°C and then, drawn to 2.3 times their original length on a plate heater at a temperature of 168°C to form a multifilament having a total fineness of 75 d/36 fils. As spinning oil, an emulsion containing 0.5 percent by weight of Ionox 330 (Phenolic antioxidant made by Shell), 30 percent by weight of dioctyl azelate and the remaining percent of ESK-502 (an emulsion containing 10 percent by weight of a mixed oil containing 60 percent by weight of oleyl laurate, 11 percent by weight of mineral oil, 15 percent by weight of polyethylene oxide oleyl ether and 14 percent by weight of polyethylene oxide sorbitol monooleate (made by Takemoto Yushi, Japan) was applied to the filament before drawing.

Three of the drawn multifilaments were doubled and twisted 89 turns per meter in the Z direction and then the resultant yarn was subjected to heating by the apparatus shown in FIG. 4 under the following conditions: a first heated roll **8**, 160°C, 650 m/min, 5 winds; second heated rolls **9**, **9'**, 204°C, 820 m/min, 20 winds; plate heater **10**, 215°C; take up speed, 810 m/min.

The resultant yarn had a round cross section and each filament of the yarn was sufficiently agglutinated with each other. The yarn had a breaking tenacity of 2.53 g/d, a breaking elongation of 102 percent, an initial modulus of elasticity in tension of 19.8 g/d and an elastic recovery at 25 percent elongation of 92.7 percent. The yarn was subjected to softening, antistatic treating and waxing to obtain a sewing thread. Sewing tests were carried out in the same manner as those in Example 17. Four broad cloths were sewn one over another. Resultant seam length was more than 10 m.

In the case where the spinning oil did not contain dioctyl azelate, resultant yarn was not agglutinated and consequently, it could not be used in sewing.

Example 20

Polypivalolactone chips having an intrinsic viscosity [ν] of 2.10 were melt spun and drawn to form filaments having a fineness of 75 d/36 fils. The filaments were twisted 870 turns per meter in the S direction. Then, three of the filaments were doubled and twisted 590 turns per meter in the Z direction and subjected to dyeing with disperse dyes at a temperature of 130°C and then subjected to oiling and waxing by conventional methods to obtain a sewing thread having a total fineness of 220 d, a breaking elongation of 58.9 percent, an elastic recovery at 25 percent elongation of 42 percent and an initial modulus of elasticity in tension of 28 g/d.

A cotton knitted underwear (an athletic shirt for men) was sewn with the above sewing thread under the same conditions as those described in Example 6 except that the number of revolutions was 5,000 rpm. Sewing was smooth. The athletic shirt was pressed on a heated plate at a temperature of 160°C under a pressure of 1 ton for 4 sec. The finished shirt (designated as sample K) looked nice and puckering did not occur. Tensile properties of sample K are given in Table 16 in comparison with sample E described in Example 5.

TABLE 16

	K	E
Machine	Lock stitch	Two thread chain stitch and interlock
Consumption of sewing thread (ratio) >	1	12
Breaking elongation (%)*		
Skirt hem part	≧ 150	140
Neck hem part	≧ 110	65
Arm hole hem part	≧ 110	65
Elastic recovery at 130% elongation (%)		
Skirt hem part	59	31
Neck hem part	—	—
Arm hole hem part	—	—
Elastic recovery at 100% elongation (%)		
Skirt hem part	82	50
Neck hem part	79	—
Arm hole hem part	79	0
Elastic recovery at 50% elongation (%)		
Skirt hem part	94	75
Neck hem part	90	60
Arm hole hem part	90	60
Elastic recovery (work recovery) at 50% elongation (%)		
Skirt hem part	75	12
Neck hem part	78	17
Arm hole hem part	78	17
Machine for hem parts	Lock stich	Two thread chain stich

Breaking elongations of the skirt hem part, neck hem part and arm hole hem part were the same as those of sample D in Example 5. The athletic shirt also had the same advantages as those described in detail in Example 5.

Then, in order to observe dimensional stabilities of every hem part, washing tests were carried out in the same manner as those in Example 5. Results are given in Table 17.

TABLE 17

Sample	Hem parts	Fifth	Tenth
	Neck	101	102
K	Arm hole	101	102
	Skirt	101	101
	Neck	107	108
E	Arm hole	109	109
	Skirt	109	107

Wearing tests were also made in the same manner as those in Example 5. Results are shown in Table 18.

TABLE 18

Sample	Hem part	Before wearing	After wearing
	Neck	100	105
K	Arm hole	100	105
	Skirt	100	108
	Neck	100	123
E	Arm hole	100	121
	Skirt	100	125

Example 21

Sewing tests of the thread used in Example 21 were made in the same manner as those described in Example 17 in comparison with cotton No. 60 sewing thread. Results are given in Table 19.

TABLE 19

Sewing thread	Number of cloths in piles		
	3	4	5
Pivalolactone	more than 10 m	more than 10m	more than 10m
cotton	do.	do.	do.

As apparent from Table 19, polypivalolactone sewing thread exhibited the same workability in sewing as that of cotton sewing thread.

Example 22

Using the sewing thread used in Example 20, a pair of ski pants as sewn from the same twilled fabric as that used in Example 6 in the same manner as that in Example 6. Both sides seams and a seat seam were subjected to ironing at a temperature of 160°C for approximately 8 sec. Resultant pair of ski pants (designated as sample L) looked nice.

After wearing for a month, knee distortion and change of seat seam were observed. As to knee distortion, sample L was superior to the pair of pants before ironing. The seat seam of sample L did not change in the least, but, in the seat seam of the pair of pants before ironing, openings were caused and sewn threads were in sight.

Example 23

Block copolymer having an intrinsic viscosity [ν] of 2.20 and containing 5 mole percent of polyethylene oxide having a molecular weight of 4,000 and 95 mole percent of polypivalolactone was melt at a temperature of 280°C and then formed filaments were drawn on a plate heater at a temperature of 160°C to obtain drawn filaments having a fineness of 50 d/24 fils and an initial modulus of elasticity in tension of 28 g/d. The filaments were twisted dyed and then finished by conventional methods to obtain a sewing thread. A long-sleeved sweater for men was sewn with the above sewing thread from knitted fabric of polyethylene terephthalate crimped yarn by a lock stitch sewing machine. Sewing machine and conditions were the same as those in Example 20. Only both elbow seams, a skirt hem seam and a neck hem seam of the sweater were subjected to heat-setting by a steam iron at a temperature of 180°C for approximately 6 sec. Such kinds of conventional sweater usually are sewn by a two-thread chain stitch method using polyester sewing thread as needle thread and polyester crimped thread as bobbin thread. The sweater of the present invention is superior to the conventional sweater sewn by a two-thread chain stitch method. Because, the former exhibits excellent dimensional stabilities after long wearing and it is easily put on and taken off without the least bit of hard feeling in seam parts.

Example 24

Elastic polypivalolactone filaments having a fineness of 50 d/24 fils were subjected to degreasing in an aqueous bath containing neutral detergent and then, activated in a bath containing palladium chloride and hydrochloric acid. The filaments were then subjected to chemical plating with copper in an alkaline bath (Chemical copper plating bath No. 100; made by Hoshino Seiyaku, Japan) at room temperature for 10 min. Relationship between the extension (in percent) at the time of plating and tensile properties of the resultant conductive filaments are shown in Table 20.

TABLE 20

Extension at the time of plating	Breaking elongation, percent	Breaking tenacity (g./d.)	ER at 25% elongation, percent	Volume resistivity (Ω cm.)[2]	Volume resistivity at 50% elongation[2]
Before plating	80.2	2.5	96.8	10^{12}–10^{13}	$\geq 10^{12}$
0	80.1	2.4	96.3	1.3×10^{-3}	$\geq 10^{12}$
10 (12.5)[1]	74.4	2.3	94.8	1.5×10^{-3}	0.8×10^{-3}
20 (25.0)	70.6	2.4	90.5	1.8×10^{-3}	1.3×10^{-3}
30 (37.5)	68.8	2.2	88.8	2.3×10^{-3}	1.4×10^{-3}
50 (62.5)	62.6	2.1	87.1	2.5×10^{-3}	1.8×10^{-3}
60 (75.0)	61.2	1.9	86.2	2.9×10^{-3}	1.9×10^{-3}

[1] Numerical value in parenthesis designates a percentage of the extension at the time of plating to breaking elongation.
[2] Determined at room temperature and R. H. of 40%.

As is apparent from Table 20, an extension in a range from 10 to 90 percent of the breaking elongation during metal coating produces such an effect that the resultant filament has high electroconductivity even in the case where it is extended.

Further, the resultant filaments maintained their electroconductivity after repeated elongation (50 percent) and contraction. However, as to the filaments, which had been chemically plated without applying tension, their conductivity was reduced every time they were elongated. The volume resistivity of the latter filaments increased to more than $10^{12}\Omega$cm after the fifth elongation.

Example 25

An elastic polypivalolactone filament yarn having a fineness of 50 d/24 fils, which had been chemically plated with copper under a drawn state by 30 percent (corresponding to 37.5 percent of the breaking elongation) by the same method described in Example 24, and two elastic polypivalolactone filament yarns each having the same fineness as the above were doubled and twisted under the following conditions; first twist, 900 T/M (S direction); final twist, 600 T/M (Z direction). After setting in steam at a temperature of 110°C, the yarn was subjected to softening and waxing to produce a sewing thread. It had a breaking elongation of 70 percent and an elastic recovery at 25 percent elongation of 90 percent. In the case when three 40^s cotton broad cloths were sewn one over another with the sewing thread at 5,000 rpm by a lock stitch machine, a seam length at the time of breaking was more than 10 m.

Electrostatic properties of the sewing thread were observed. A bundle of 10 threads having a length of 25 cm was rubbed with a glass rod having a diameter of 3 cm under a load of 500 g. After rubbing 20 times back and forth, static electricity was determined by a leaf electroscope. In the case of the above sewing thread, the leaf did not open. But, as to the thread which did not contain electroconductive fiber, the leaf made an angle of 12.5°.

Using the above sewing thread, a long-sleeved V neck sweater was sewn from acrylic jersey by a lock stitch machine. As to the sweater, no electrostatic trouble was arisen both at the time of putting on or taking off and after repeating the same action. The seams maintained an elongation of more than 50 percent. For comparison, a sewing thread was prepared from non-elastic polyethylene terephthalate filaments. It also did not exhibit electrostatic property. But, a sweater sewn with the thread by a lock stitch machine was not satisfactory for putting on and taking off because the seams did not extend. In the case when putting on and taking off were repeated, it displayed static electricity by a crackling sound at the fifth time.

Example 26

A polyurethane segment elastomer monofilament having a fineness of 40 d was continually passed through a plating bath at room temperature under a drawn state by 10 percent (corresponding to 25 percent of the breaking elongation) for 80 sec to form a nickel surface layer. The plating bath contained 20 g/l of nickel surface, 24 g/l of sodium hypochlorite and 27 g/l of lactic acid and had a pH of 5.6. Volume resistivity of the filament was $2.4\times10^{-3}\Omega$cm at its original length and $1.7\times10^{-3}\Omega$cm at 50 percent elongation. On the other hand, the monofilament, which had been chemically plated without applying tension, had a volume resistivity of $1.5\times10^{-3}\Omega$cm at its original length, but, $10^{12}\Omega$cm at 50 percent elongation.

Next, an elastic polypivalolactone filament yarn having a fineness of 40 d also was chemically nickel plated under a drawn state by 100 percent. The resultant yarn and an elastic polypivalolactone filament yarn having a fineness of 50 d/24 fils were doubled. Then, the doubled yarn and an elastic polypivalolactone filament yarn having a fineness of 75 d/36 fils were doubled and twisted under the following conditions; first twist, 900 T/M, S direction; final twist, 600 T/M, Z direction; to obtain a sewing thread.

Using the sewing thread, a V neck athletic shirt and athletic pants were sewn from polyester jersey by a lock stitch machine. The resultant seams had a high stretchability. Electrostatic troubles were not arisen in the least.

What we claim is:

1. A method of preparing a pivalolactone polymer fiber or yarn used for the preparation of a sewing thread, which comprises subjecting a drawn fiber substantially composed of pivalolactone polymer or a yarn composed of said drawn fiber to a first heating at a temperature of from 150°C to 240°C, under a tension of no less than 0.2 g/d for no less than 0.1 sec. and then subjecting said fiber or yarn to a second heating at a temperature of no less than 110°C, but no more than said temperature in said first heating, under relaxed conditions for no less than 1 sec., to obtain a fiber or yarn having an initial modulus of elasticity in tension of no less than 0.5 g/d, a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 70 percent.

2. A polypivalolactone fiber or yarn prepared by the process of claim 1.

3. A method of preparing a sewing thread which comprises treating a multifilament or yarn, substantially composed of pivalolactone polymer, with an oiling agent containing phenolic antioxidant and a swelling agent comprising nonionic surface active agent and/or neutral oil and then subjecting the resultant multifilament or yarn to continuous heating at a temperature of not less than 35°C below the melting point of said pivalolactone polymer and not higher than said melting point to obtain agglutinated multifilament or yarn having an initial modulus of elasticity in tension of no less than 0.5 g/d, a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 70 percent.

4. An agglutinated multifilament or yarn prepared by the process of claim 2.

5. A method of preparing a sewing thread, which comprises coating a thermoplastic elastic yarn or filament having a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 80 percent, with a conductive metal surface layer of a thickness of from 0.01 to 30 microns, while said thermoplastic elastic yarn or filament is under a drawn state in the range of from 10 to 90 percent of the breaking elongation and then uniting the resultant yarn or filament with a thermoplastic elastic yarn or filament and/or non-elastic yarn or filament to form a thread.

6. A sewing thread prepared by the process of claim 5.

7. A sewn stretch fabric having seamed parts formed with a sewing thread comprising polypivalolactone polymer fiber and having an initial modulus of elasticity in tension of no less than 0.5 g/d, a breaking elongation of no less than 30 percent and an elastic recovery at 25 percent elongation of no less than 70 percent, wherein at least one of said seamed parts has a sewn thread having a different elastic recovery and/or initial modulus of elasticity in tension from sewn threads in other seamed parts.

8. A method of preparing a sewn stretch fabric, which comprises sewing a stretch fabric with sewing thread comprising polypivalolactone polymer fiber having an initial modulus of elasticity in tension of no less than 15 g/d, and then heating the stretch fabric at a temperature of from 140 to 210°C for from 1 to 10 seconds, with at least one seamed part of the stretch fabric being heated under different conditions from the conditions applied to other seamed parts so that said one seamed part has a sewn thread having a different elastic recovery and/or initial modulus of elasticity in tension in comparison with sewn threads in other seamed parts.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3 775 960 Dated December 4, 1973

Inventor(s) Yasuhiro Ogawa, Kazuo Nooya, Norio Awata and Yukio Yamakawa

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 4, line 2; change "claim 2" to ---claim 3---.

Signed and sealed this 7th day of May 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents