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2,968,522

**PROCESS FOR PRODUCING SHAPED ARTICLES
OF TETRAFLUOROETHYLENE POLYMERS**

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The present invention relates to a method of extruding fluid polytetrafluoroethylene dispersions into continuous filaments.

It is well known that polymers from tetrafluoroethylene cannot be melt spun into textile denier fibers owing to their extremely high softening points and high melt viscosities. Normal dry or wet spinning is not possible because of the lack of solubility of polytetrafluoroethylene in known solvents. This means that polytetrafluoroethylene cannot be processed into continuous structures by any of the conventionally known spinning methods and only very few processes, all of them complicated, are known to produce continuous filaments from polytetrafluoroethylene.

One of these methods, described in U.S. Patent 2,685,707, to Llewellyn and Lontz, utilizes a water-free lubricated paste containing polytetrafluoroethylene. This process, however, does not provide white filaments of textile denier. Another method, described in U.S. Patent 2,559,750 to Berry, requires polytetrafluoroethylene particles having a certain shape, that is, some of the dispersed polytetrafluoroethylene particles are in the form of rods with a certain diameter to length ratio. Furthermore, these compositions must be extruded into a coagulating bath in order to yield filaments. Other processes, such as described in U.S. Patent 2,776,465 to J. Smith and U.S. Patent 2,772,444 to Burrows and Jordan, as well as British Patent 767,015, require the use of matrix materials. In these cases, the resulting filament either still contains matrix material, or, in case this matrix material has disintegrated at the high temperature of the sintering step for the polytetrafluoroethylene particles, charred particles remain to give it a dark color, unsatisfactory for certain applications.

It is an object of the present invention to produce a polytetrafluoroethylene filament. It is another object to produce a white polytetrafluoroethylene filament. Another object is the production of textile denier polytetrafluoroethylene filaments free of matrix material. A further object is the provision of a method for the production of filaments, films, ribbons, tapes, etc., from polytetrafluoroethylene particles.

These and other objects are accomplished by providing a liquid spinning mixture comprising from about 45% to about 85% by weight of dispersed particles of a tetrafluoroethylene polymer from about 2% to about 20% by weight of dispersing agent and from 0% to about 45% by weight of a water soluble organic thickener with a "dispersion number" greater than 5, for example, a polyalcohol, monoether or monoester of the polyalcohol each having at least two free hydroxy groups, a hydroxyalkyl

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amine, a polyhydroxyalkyl amine, carbohydrate or bis(omega-amino-alkylene) amine, said spinning mixture being characterized by a total organic material content of at least about 70%, the remaining proportion being water.

This mixture is formed into a shaped article under conditions of high shear, as, for example, by extruding through an orifice having a diameter between about 5 and about 15 mils and a length between about 0.5 and 5 inches, at a pressure of between about 1000 pounds per square inch and about 5500 pounds per square inch and a temperature of between about 50° C. and about 110° C. The resulting filament is collected preferably under tension.

Additional shear may be applied to the spinning mixture by passing it through a sand pack of from about 0.5 to about 1.5 inches in length prior to extruding through the spinning orifice. Under these conditions, a gel-filament emerges from the spinneret, which is wound up with a spin-stretch factor of up to about 1:5; i.e., the gel-filament is wound up at a rate up to 5 times as great as the spinning rate and consequently stretched. The wound up gel-filament is washed in acetone, dried, sintered at from about 375° C. to about 430° C. over a hot pin, and drawn up to about 10 times its original length.

The spinning mixtures of the present invention are dispersions of polytetrafluoroethylene. Such dispersions are prepared by transferring colloidal polytetrafluoroethylene particles from an aqueous phase to another continuous phase containing organic material alone or organic material in combination with water. The aqueous colloidal dispersion of the polymer contains from about 2% to about 20% by weight of a dispersing agent, such as Triton X-100, a non-ionic ethylene oxide-octyl phenol dispersing agent (reaction product of 12-13 moles of ethylene oxide with 1 mole of para-octyl phenol) and a non-ionic, water-miscible organic liquid which will form a continuous phase in the final mixture. Removal, as by evaporation, of part or all of the water from this mixture containing dispersing agent and organic liquid, produces a colloidal dispersion of polymeric particles in a continuous predominantly organic phase. The initial aqueous colloidal dispersion of polymeric tetrafluoroethylene utilized may be prepared by the processes described in U.S. Patents 2,478,229 and 2,559,752, both issued to Berry.

The organic liquid which in this embodiment forms the continuous phase of the spinning composition of this invention is non-ionic and water-miscible and has a "dispersion number" greater than 5, but preferably not more than 35. The term "dispersion number," as used herein, is the sum of the following oxygen and nitrogen values of the said water-soluble organic compounds: each alcoholic oxygen=4, each amino nitrogen=2, each ether oxygen=1. Other functional groups, e.g. —CO— of aldehydes or ketones count zero. For example, by this definition triethanolamine has the dispersion number=14, glycerin is 12, sucrose 33, aminopropanol 6, etc. Those non-ionic, water-miscible organic compounds having a dispersion number of 5 or less, such as methanol (dispersion number=4), monoethers (dispersion number=1), or ethylene diamine (dispersion number=4), do not provide suitable dispersions and, consequently, are not included within the operable range of useful compounds.

An aqueous polytetrafluoroethylene dispersion, such as marketed by du Pont under the trade name of TD-3, is readily used as the starting material. This aqueous dis-

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persion comprises about 60% by weight of polytetrafluoroethylene particles and about 6% by weight of Triton X-100, a dispersing agent described above. Examinations of such a dispersion in an electron microscope reveals mostly colloidal particles of 0.1 to 0.2 micron in diameter. Very few, if any, rod-like particles can be detected.

Having described the present invention in general terms, the following examples demonstrate specific embodiments. In these examples, parts and percentages are by weight unless stated otherwise.

Example I

A commercial aqueous polytetrafluoroethylene colloidal dispersion containing 60% polytetrafluoroethylene and 6% of Triton X-100, described above, is heated to 90° C., centrifuged, and water decanted. The resultant dispersion, which contains 69% polytetrafluoroethylene and 6% Triton X-100, is extruded at 90° C. and at 2,000 pounds per square inch through 0.8 inch of 150-200 mesh sand and thence through an orifice 8 mil in diameter with a length of 0.5 inch. The extruded filaments, having a gel tenacity of 0.0024 gram per denier, are dried, sintered and drawn 7× (seven times their original length) at 375° C. over a hot pin to yield a filament with a tenacity of 1.5 grams per denier.

Example II

To a commercial aqueous 60% polytetrafluoroethylene colloidal dispersion containing 450 parts of polytetrafluoroethylene and 27 parts of Triton X-100, are added 158 parts of an organic thickener mixture of ethylene glycol/glycerol, of percentage composition 60/40. This mixture is stirred slowly in a resin kettle for several hours at a reduced pressure of about 50 mm. and a temperature of 50° C. When the amount of polytetrafluoroethylene in this mix has increased to about 65% through evaporation of liquid, the mixture has the following composition: polytetrafluoroethylene 65%, dispersing agent (Triton X-100) 4%, organic solvent mixture 21% and water 10%.

Example III

The spinning mixture of Example II is heated to 90° C. and poured into a spinning cell. It is extruded at a pressure of 1600 pounds per square inch through a 0.3-inch thick sand pack which contains 150-200 mesh sand retained by a 325 mesh screen, and then through a 5 hole spinneret with hypodermic needle-type orifices of 500 mil length and 8 mil diameter. The yarn is wound up at a speed of 180 feet per minute. This wind-up speed is about twice the speed of extrusion. The additional pull reduces the denier of the yarn and increases its tenacity. A similar yarn which is piddled rather than pulled away from the spinneret does not give a sintered product of appreciable strength.

The bobbin containing the gel-filaments is immersed as a whole into an acetone bath until the glycols and dispersing agent are leached out. It is subsequently removed from the bath and dried. The yarn is then passed over a sintering roll at 375° C. with a contact time of 20 seconds. It is wound up with a slight draw of about 1.5× to about 2×. The yarn so obtained is completely colorless. It possesses a cold drawability of about 3× and is hot drawn to 8×, to yield a yarn having a tenacity of 1.5 to 2.0 grams per denier.

The viscosity of the above spinning mixture containing glycol/glycerol is such that when extruded without a sand pack, the mix drips out of the orifice or orifices without the formation of any fiber. This indicates that at least part of the effective shearing action stems from the sand pack.

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The viscosity of the commercial 60% polytetrafluoroethylene dispersion is about 24 centipoises at 0° C., dropping to about 12 centipoises at 32° C. and rising sharply with increasing temperature to a maximum of 137 centipoises at 80 to 90° C. Thus, for example at 80-90° C. and with a given spinneret and pressure conditions, better spinning is obtained than at temperatures between 40 and 75° C.

Example IV

To a commercial 60% polytetrafluoroethylene colloidal dispersion containing 450 parts polytetrafluoroethylene and 27 parts of Triton X-100, described above, is added 158 parts diethylene glycol. This mixture is stirred at 50° C. under partial vacuum until the mixture contains about 69% polytetrafluoroethylene. The mixture is poured at 50° C. into a spinning cell equipped with two 325 mesh screens but no sandpack, and a hypodermic needle type orifice of 250 mil length and 8 mil diameter. The shear-coalesced gel-filament is wound up at a rate of 520 feet per minute, by applying a pressure of about 1500 p.s.i. to the spinning mixture and a spin-stretch factor of about 2. The filament is washed thoroughly to remove organic solvent and Triton X-100 by repeatedly immersing the bobbin in acetone; dried, sintered over a hot pin at 375° C. with a contact time of 20 sec., and drawn 10× to a denier of 15.

Attempts to sinter this gel fiber without removing the glycol are unsuccessful because the fiber sticks to the sintering roll and is broken up into small sections. This fragility is also observed when the unwashed gel-filament is dried on the bobbin.

Example V

Following the procedure of Example II, spinning mixtures are prepared by replacing the glycerol/ethylene glycol mixture with other liquids. These liquids are listed below in sequence of thickening effects, the best thickeners listed in the beginning:

Triethanolamine	14
Glycerol	12
Diethanolamine	10
Diethylene glycol	9
Glycerol-alpha-monomethyl ether	9
Ethylene glycol	8
Monacetyl	8
Ethanolamine	6
Diethylene glycol monomethyl ether	6
Diethylene glycol monobutyl ether	6
Ethyl lactate	5
Ethylene glycol monomethyl ether	5

In the above table, ratings have been assigned to the various thickeners according to the previously given dispersion numbers. Each of these organic liquids is added to a separate aqueous polytetrafluoroethylene dispersion. Each mixture is spread on a glass plate and the resulting films are examined after allowing them to approach dryness. Films prepared from dispersions containing the thickeners whose ratings are less than 6, shows mud-cracking and have no fiber-forming tendencies, while those from dispersions containing thickeners with higher dispersion number values produce uncracked paste films. The paste forming these latter films can be rolled into a ball between fingers and then drawn out into a fiber several inches long.

Examples VI to XX

Several spinning dispersions, varying in polytetrafluoroethylene concentrations from 45-79% and in concentrations of glycerol/glycol of percentage composition 60/40 are extruded under conditions stated in the following table.

Example Number	"Teflon" (percent)	Triton (percent)	Thick- ener (percent)	H ₂ O (percent)	Orifice (inch)	Press. (p.s.i.)	Temp. (° C.)	As-Spun Tenacity (g.p.d.)	Elong. (percent)	Denier
6-----	69	6	15	10	0.01 x 1.0	2,000	80	.0029	27	468
7-----	63	6	18	13	0.01 x 1.0	3,100	110	.0073	35	484
8-----	59	6	21	14	0.01 x 1.0	4,000	94	.0053	100	605
9-----	57	6	24	13	0.01 x 1.0	4,000	95	.0045	114	894
10-----	47	3	41	9	0.013 x 1.0	4,800	82	.01	61	1,199
11-----	62	16	20	9	0.013 x 1.0	3,200	86	.0057	164	1,690
12-----	62	16	20	9	0.013 x 1.0	3,200	94	.0066	127	1,445
13-----	62	16	20	9	0.013 x 1.0	5,200	100	.0060	116	1,290
14-----	61	6	23	9	0.01 x 1.0	5,500	110	.011	48	289
15-----	61	6	23	9	0.01 x 1.0	2,200	108	.007	58	312
16-----	60	4	20	16	0.014 x 1.0	1,800	95	.0044	66	1,354
17-----	60	4	20	16	0.014 x 1.5	3,000	105	.01	54	942
18-----	60	4	20	16	0.005 x 0.5	4,800	100	.0038	107	423

¹Contains 3% white oil (purified mineral oil).

The lowest extrusion pressure for producing a strength in the gel filament of above 0.01 gram per denier is about 3,000 pounds per square inch with the above thickener. Higher pressures are found to give better tenacities. However, gel filaments with a dry tenacity of 0.001 gram per denier are usually strong enough to be subjected to further processes, e.g., washing, drying, sintering and drawing. The preferred minimum as-spun tenacity is about 0.0025 gram per denier.

Most of the gelled filaments listed in the table are obtained by piddling which means that no stretch is exerted on the gel-filament. In Examples 14 to 17 inclusive, the gel-filaments are wound up at a spin-stretch factor of about 1:1.5 to 1:2.

The gel-filaments of the present invention are normally washed with water and/or acetone or other well-known water-miscible volatile solvents to remove spinning solvent and dried. These operations can be carried out on a bobbin and no advantage is seen in carrying out these operations by winding them from the bobbin through a wash liquid, leading them through a drying chamber and rewinding them, unless the gel-filament is produced in a continuous process to which the present invention is easily adaptable.

Development of optimum mechanical properties in the filaments is dependent in part on sintering conditions, since incomplete sintering results in weak spots with attendant poor mechanical properties. The optimum sintering temperature for developing of optimum properties for a polytetrafluoroethylene filament is from about 375° C. to about 430° C. At this temperature, filaments are sintered about 7 seconds to develop optimum physical properties. Sintering temperatures higher than 430° C. are undesirable because of degradation of the polymer, while at temperatures below about 375° C. the contact time required to develop maximum properties is excessive.

Monofilament as well as multifilament yarns can be produced by this invention. Individual monofilaments may be processed separately or spun into yarns prior to processing to remove solvent, dispersion agent and thickener.

The present invention permits production of a perfectly white polytetrafluoroethylene filament of about one to more than two grams per denier tenacity after conventional processing, including sintering and drawing. The filaments from this process have high tenacity and are strong enough to be stretched, backwound, washed, and dried before the filament is effectively sintered into a continuous structure. The shear coalescing of the polytetrafluoroethylene dispersion into a gel filament is peculiar to the polytetrafluoroethylene polymer, since other polymers do not form a gel filament of sufficient strength to be processed when extruded as a fluid dispersion under the conditions of the present invention.

Under the conditions for carrying out the present process considerable shearing force is exerted on the polymer. Shear, as it is used in the present process cannot readily be measured. However, the manner in which

it varies with spinning conditions is qualitatively easily predicted.

The energy dissipated when shearing force is applied to a polymer increases with increasing pressure, increasing amount of solid particles in the dispersion, (as expressed by concentration), increasing size of number of obstacles in the flow of this dispersion (e.g., with increasing orifice length), increasing length of sand pack, decreasing orifice diameter, and increasing temperature. All these items are variables in the spinning process of the present invention and are discussed below.

Pressure.—A minimum pressure of 1000 pounds per square inch has been found to be a practical lower limit. However, by varying other shear inducing conditions, lower pressures might also be useful. Pressures in excess of 5500 pounds per square inch are operable, but no great advantage in using such pressures can be seen.

Concentrations.—The concentration referred to is the amount of solid polytetrafluoroethylene particles in the total amount of the fluid dispersion. It has been found that a concentration of 45% by weight of polytetrafluoroethylene polymer in the form of dispersed particles is a lower limit when organic thickeners are provided. In a dispersion of water alone, at least about 70% by weight of polytetrafluoroethylene is required. These particles have no shape requirement but should be in a size range of from 0.05 to 0.5 micron average diameter, as found in commercial polytetrafluoroethylene dispersions. The higher concentration limit is dictated by the rapid viscosity increase of the dispersion with increasing amount of solid particles. A practical limit of about 85% polytetrafluoroethylene particles is about the highest concentration at which the viscosity of said dispersion is still sufficiently low to make the composition fluid enough to be pourable and extrudable at sufficiently high pressure within the most economical temperature range.

Temperature.—A preferred range of extrusion temperature for the process of this invention is from about 50° C. to 110° C. The best temperature for extruding a polytetrafluoroethylene dispersion depends on the amount and the character of liquids in said dispersion. As noted above, better spinning is obtained at temperatures between about 80° C. and about 90° C. Water may be the sole liquid present or may be mixed with an organic thickener. In either case there is a minor amount of dispersing agent present also.

Dispersing agent.—The preferred dispersing agents in the composition of the instant invention are those present in commercially available polytetrafluoroethylene dispersions. Usually ammonium perfluorocaprylate, an ionic dispersing agent is used in preparing such dispersions and Triton X-100, a non-ionic ingredient, is added subsequently to the dispersion to keep the particles suspended. Triton X-100 is miscible with water up to about 30° C., but separates when the temperature is raised. It is this demixing property which is utilized in the thermal decantation method of concentrating the

commercial dispersion. Thus, ionic and non-ionic dispersing agents may be used in limited amounts, to total from about 2% to about 20% by weight of the dispersion. The total quantity of dispersing agents varies with the amount of dispersed polytetrafluoroethylene. Obviously, a dispersing agent, to be useful herein must be a non-coagulant for the suspended polymer particles.

Spinnerets.—Shear applied to the spinning mixture increases with decreasing orifice diameter. The preferred range for such an orifice diameter is from about 5 to about 15 mils. Shear also increases with increasing length of the spinneret shaft, for which the preferred range is from about 0.25 to 1 inch. When shorter needle shafts are used, additional shear may be obtained by inserting a sand pack or a set of fine screens prior to the spinning cell. For practical purposes, a 0.5–1.5 inch thick sand pack with 150 to 200 mesh sand produces adequate additional shear for ordinary spinneret, but thicker sand packs may be necessary with very short orifice shafts or very large diameter orifices.

The importance of the above conditions is indicated by the fact that a fluid polytetrafluoroethylene dispersion within the concentration limits useful for the process of this invention, when extruded through an ordinary spinneret, either drips out of the spinneret hole or holes, or else the solid polymer particles plug up the spinneret and no continuous filament can be obtained. By using a hypodermic needle-type spinneret within the above given dimensions, the same fluid polytetrafluoroethylene dispersion extrudes into a continuous gel-filament of adequate strength for further handling.

Another type spinneret which can be used to advantage in this invention is the split tapered plug spinneret. This spinneret is especially suitable for extrusion under high pressure and can be easily disassembled for cleaning purposes. It consists of a ring which is essentially of the same size as the standard spinneret ring it replaces. The hole in the ring is tapered. The plug is split through the center lengthwise and fits the tapered hole. Bosses are left on each side of each plug half and screws are used to fasten the two halves together. In making the plug, one or more piano wires are laid on one half of the plug, the other half is screwed to it, and the whole assembly pressed together. The screws and wires are then removed, the bosses machined off, and the two halves of the plug pressed into the ring, thus completing the spinneret. All joints of this split tapered plug spinneret are self-sealing. The cones can have various lengths and the orifices various diameters, depending on the amount of shear necessary for the desired extruded article. Theoretically, no limit to the length of orifice or orifices exists, but for practical purposes, tapered plugs from 0.5 inch to 5 inches length will produce enough shear for satisfactory extrusion of shaped articles from the fluid dispersions of the present invention. Orifice diameter, varying from about 5 to about 15 mils, also produces enough shear.

Dispersed particles.—As stated before, the composition useful for the process of the present invention contains preferably between about 45% and about 85% by weight of polytetrafluoroethylene particles which can vary in size from 0.05 to 0.5 micron average diameter. The shape of these particles is of little importance and a commercial polytetrafluoroethylene dispersion can easily be used as starting material for the production of a composition useful in the present invention. More specifically, rod-like particles as described in U.S. 2,559,750 referred to above are not required. The spinning mixture of the invention is fluid, of sufficiently high viscosity to be effectively spun, and of a viscosity low enough to permit spinning without plugging.

Polytetrafluoroethylene dispersions of high concentrations are made by using a commercial aqueous dispersion of the polymer, adding an organic thickener, and

removing a substantial portion of the water. This is achieved by thermal decantation or by evaporation of water, for example, at reduced pressure and increased temperature. By such methods there may be obtained a composition containing only a very small amount of water, say 1%, which can easily be shear coalesced into a gel filament.

Organic thickener.—The spinning mixture of this invention preferably contains an organic thickener in an amount up to about 45%. However, a substantial proportion of water may be present in the composition and in fact water may be the sole liquid in the spinning mixture, as long as the polytetrafluoroethylene particle content is high enough to produce a dispersion of sufficient viscosity to be effectively spun (i.e., above about 70%). Among the organic compounds which are useful are polyalcohols, monoethers and monoesters of polyalcohols, each having at least two free hydroxy groups, poly(hydroxyalkyl) amines, bis(omega-amino-alkylene) amine carbohydrates, etc. These liquids have to be selected such that they are water soluble and do not coagulate and separate polytetrafluoroethylene particles from an aqueous dispersion. The latter conditions can, of course, be achieved by the addition of a water-soluble dispersing agent which, obviously, has to meet the same conditions, namely, to be water-soluble, miscible with the organic liquid used as thickener, and a non-coagulant for the polytetrafluoroethylene particles.

Conversion of a polytetrafluoroethylene dispersion from a fluid, low-pressure filterable state to a firm gel-threadline, according to this invention, is accomplished by application of sufficient shear to the polytetrafluoroethylene particles. This shear generates long fibrils from the original spheroids, present in a commercial polytetrafluoroethylene dispersion with an average diameter of about 0.2 micron. The fibrils range in diameter from 0.1–0.01 micron and show in electron diffraction patterns an almost perfect orientation. The electron micrographs of the unsintered gel-filament show no free ends; i.e., the fibrils extend from one fibril particle to the next from which another fibril connects to the following etc., the fibrils being essentially parallel-aligned from the stretch applied during extrusion of the gel-filament. The sintered filament, however, cannot be distinguished from other continuous polytetrafluoroethylene filaments except by its aesthetic appearance, its physical properties, and its purity. Such filaments are particularly characterized by being absolutely white as compared with the darker-colored filaments of the prior art.

The product of the invention has, due to the nature of the polymer used, a large number of applications. The white, strong filaments can be spun into yarns which find their application in high temperature and electric insulation. The yarns can also be woven into fabrics of excellent high-temperature resistance useful as filter cloth for corrosive liquids at high temperatures, as press pad covers, etc. Of course, the present invention also permits the production of films, ribbons, tapes, etc., as well as filaments, if the shape of the orifice or orifices is changed appropriately. The filament obtained by the process of the present invention is carbon free, and is more economical to produce than prior art polytetrafluoroethylene products, since a purification step is not required.

Another advantage of the present process is the possibility of spinning low denier polytetrafluoroethylene filaments. Of course, it is possible to produce the present polytetrafluoroethylene filament in any desired color by adding the desired pigment to the fluid dispersion. Furthermore, the present process operates at high speed, it constitutes a continuous spinning procedure, it enables the spinning of a multifilament yarn, and operates at low pressure, again advantages over all the known prior art.

I claim:

1. The process of forming shaped articles of tetrafluoroethylene polymers comprising the steps of providing a mixture comprising from about 45% to about 85% by weight of dispersed particles of a tetrafluoroethylene polymer, from about 2% to about 20% by weight of a dispersing agent, less than about 45% by weight of a water soluble organic thickener comprising one of the group consisting of polyalcohols, monoethers of water soluble polyalcohols, and monoesters of water soluble polyalcohols, each having at least two free hydroxy groups, hydroxyalkyl amines, polyhydroxyalkyl amines, carbohydrates and bis(omega-amino-alkyl) amines, said mixture being characterized by a total organic material content of at least about 70%, the remaining proportion being water, and extruding this mixture under shear at least as high as the shear exerted on the mixture when it is extruded through an orifice having a diameter of 15 mils and a shaft length of 0.25 inch at a pressure of 1000 pounds per square inch and a polymer temperature of 50° C.

2. The process of forming shaped articles of tetrafluoroethylene polymers comprising the steps of providing a mixture comprising from about 45% to about 85% by weight of dispersed particles of a tetrafluoroethylene polymer, from about 2% to about 20% by weight of a dispersing agent, less than about 45% by weight of a water soluble organic thickener comprising one of the group consisting of polyalcohols, monoethers of water soluble polyalcohols, and monoesters of water soluble polyalcohols, each having at least two free hydroxy groups, hydroalkyl amines, polyhydroxyalkyl amines, carbohydrates and bis(omega-amino-alkyl) amines, said mixture being characterized by a total organic material content of at least about 70%, the remaining proportion being water, and extruding this mixture through an orifice having a diameter of from about 5 to about 15 mils and a shaft length of from about 0.25 inch to about 5 inches, at a pressure of from about 1000 pounds per square inch to about 5500 pounds per square inch and at a polymer temperature between about 50° C. and about 110° C., whereby a shaped article is formed.

3. The process of claim 2 wherein the polymer temperature is from about 80° C. to about 90° C.

4. The process of claim 2 including the additional step of sintering the resulting shaped article at a temperature between about 375° C. and about 430° C.

5. The process of claim 2 wherein the mixture is extruded at a spin-stretch factor of up to about 1:5.

6. The process of claim 4 wherein the mixture is extruded at a spin-stretch factor of up to about 1:5.

7. The process of claim 5 wherein the spin-stretch factor is between about 1:1.5 and about 1:2.

8. The process of claim 2 including the additional step of washing the resulting shaped article to remove organic material other than the polytetrafluoroethylene particles.

9. The process of claim 7 wherein the shaped article is washed with acetone.

10. The process of claim 2 wherein the mixture passes through a sand pack prior to extrusion through the orifices.

11. The process of claim 9 wherein the sand pack is from about 0.5 inch to about 1.5 inches in length.

12. The process of claim 2 wherein the mixture is extruded through a hypodermic-needle type spinneret assembly having orifices of from about 5 to about 15 mils diameter with a spinneret shaft length of from about 0.25 to about 1 inch.

13. The process of claim 2 wherein the mixture is extruded through a tapered-plug type spinneret assembly having an orifice of from about 5 to about 15 mils diameter with a spinneret shaft length of from about 0.5 to about 5 inches.

14. The process of claim 2 wherein the shaped article is a continuous filament.

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