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HIGH BULK YARN FORMABLE MIXTURES OF LINEAR POLYMERIC THERMOPLASTIC MATERIALS

George E. R. Lamb, Mendham, Dusan C. Prevorsek, Morristown, Abraham M. Kotliar, Westfield, and Hendrikus J. Oswald, Morristown, N.J., assignors to Allied Chemical Corporation, New York, N.Y.

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ABSTRACT OF THE DISCLOSURE

The invention contemplates the preparation of fibrillated yarns or strands having high bulk and good tactile properties from a unitary structure, e.g. monofilaments. The monofils, tapes, films and the like hereafter referred to as a monofil are extruded from polymer mixtures consisting of (A) a low molecular weight polyester and (B) one or more of the following polymers; (i) a fiber forming polyamide, (ii) a fiber forming polyester and (iii) a fiber forming polyolefin in blends or mixtures whose composition is capable of producing suitable fibers. The splitting of the monofil into a relatively high bulk structure containing many fibrils is effected by suitable mechanical working which breaks or fissures the monofil into separate fibrils.

This application is a continuation of application Ser. No. 779,310, filed Nov. 20, 1968, now abandoned.

This invention relates to mixtures of linear polymeric materials capable of being extruded into fibers, films, or tapes, mixtures which after orientation are readily splittable in a direction parallel to the orientation. In particular this invention relates to mixtures of mutually incompatible fiber or film-forming polymers, wherein the system consists essentially of a polymer blend including a low molecular weight polyester which of itself does not possess good fiber forming characteristics but which upon suitable fibrillation of filaments prepared from the mixture provides a product of excellent characteristics.

Yarns made from continuous filaments, as such, are not suitable for textile applications where good tactile properties, covering power, i.e. high bulk per unit weight of fabric, comfort, or aesthetic qualities are important factors. The main reason for the inadequacy is that since continuous filaments have a smooth surface, a uniform diameter and a circular or near-circular cross section, they have a tendency to pack closely in the yarn. Consequently, the fabrics made from such yarns have too high a density which affects their thermal insulating capacity and covering power. Also, wearing apparel made from such dense yarns have a relatively high contact area with the skin of the wearer which affects the tactile properties and comfort; this is often reflected by a clammy feeling on the wearer. For these reasons a large percentage of the total production of continuous filaments of synthetic fiber forming polymers intended for textile applications is bulked subsequently in a number of costly operations generally referred to as texturing, crimping, etc. or has to be cut and spun into staple yarns.

The production of yarns from staple fibers is a time consuming and costly process which involves a series of complex operations. Cut fibers have to be combined into assemblies suitable for drawing operation where the fibers are aligned into bundles and the bundle is reduced to a smaller diameter which is twisted. Twisting is necesesary

to prevent excessive slipage of adjacent fibers past one another. It is obvious that such structures have a very low translational efficiency, that is, the strength of the fiber assembly is much lower than that of the individaul component.

The cost of staple yarn production increases rapidly as the denier of the spun yarn decreases. The higher cost is primarily due to the necessity for obtaining great uniformity of fibers in the smaller yarn bundle, the need of greater amounts of twist to secure adequate yarn strength, and the fact that machine output is lower on a per pound basis. Beside the high cost, conventional staple yarn technology has additional shortcomings. For example, while it is very difficult to achieve a high degree of unifority in the yarn texture and denier and to secure good translational efficiency, it is probably even more difficult to achieve intentionally random or regular nonuniformity in texture and/or denier. Those skilled in the art will recognize that such functional nonuniformity is required when fabrics with special aesthetic requirements such as material appearance are the consideration.

The development of a relatively high bulk soft and comfortable yarn from a monofil, rather than from staple fiber, it will thus be apparent, offers considerable economical advantages since its production by-passes several complicated and costly operations requiring enormous specialty equipment. Additionally, a suitable composition method for producing a bulk yarn of commercially attractive characteristics from a monofil provides for the manufacturer of synthetic fibers a market heretofore reserved substantially for textile mills which prepare yarns from staple fiber.

It is known that some oriented polymers can be split into more or less coarse fibers if subjected to a suitable mechanical action. Usually the splitting is achieved in a continuous manner by passing the material which is intended for fibrillation through a device where successive portions of the film or fiber are subjected to a mechanical action which can introduce and propagate simultaneously a multiplicity of cracks. Thereafter fibrillation may be enhanced for example by subjecting the fissured monofilanent to an air jet. A suitable procedure is disclosed for example in the U.S. patent application of Prevorsek et al., Ser. No. 680,678 filed on Nov. 6, 1967. Types of deformation capable of producing effective splitting, are those which lead to complex stress fields with large values of stress gradient such as bending, rubbing, rolling, twisting, longitudinal compression, longitudinal drawing over a sharp edge, etc.

Some polymers such as melt extruded polyolefins, e.g. polyethylene, polypropylene, or any combination of two or more blended polyolefins, preferably those which have some measure of incompatibility, in the form of oriented films or fibers are particularly suitable for processing by these techniques. Another group of polymers which can be split relatively easily are wet or dry spun polyacrylics such as polyacrilonitrile and related materials. Here the splittability is attributed to the sponge-like structure obtained by the particular process.

Melt spun polyamides such as poly(caprolactam) or polyhexamethylene adipamide (nylon 6 or nylon 66) etc., on the other hand, under normal conditions resist fibrillation to a degree where a technologically attractive fibrillated product cannot be obtained in an economically attractive way. Since the fibers of the group of polyamides are particularly useful in a broad range of textile applications it would be desirable to find an efficient and economic method which would increase the splittability of polyamides or other synthetic fibers to a significantly greater degree, i.e. to that presently encountered for example with polyolefins.

The desirability of producing a more readily splittable fiber, e.g. polyamide, has been recognized before and attempts to accomplish this are known. The disclosed methods, however, involve either a complicated process where one of the components of the mixture is removed from the composition during the process and splitting is limited to the simple separation of unlike polymers extruded side-by-side, or the processing consists of splitting films of the material, where the thickness of the film is limited to very low values.

We have now found a method which allows us to prepare fibers from polymeric compositions which are relatively resistant to splitting, e.g. polyamides, and which are readily splittable, i.e. fibrilated, to a degree much greater than found with normally easily splittable fibers, e.g. polyolefins or blends of olefins. In addition, by controlling the processing conditions it is possible to prepare bulky structures which have a large percentage of free fibril ends and substantial fibril interlacing. Thus, these materials are also suitable for knitting or weaving apparel yarns. In this case it is necessary to combine sufficiently high tenacity with good covering power, hairy surface, low bulk density etc., in order to achieve good shape stability, comfort and good tactile properties in the finished fabrics. Although split fiber or split film technology has made successful entries in the textile field, the applications are usually limited to relatively simple and coarse structures. The manufacturing of fine textile fabrics is still almost exclusively based on the use of staple yarns.

It is an object of this invention to provide a longitudinally oriented film or monofil consisting essentially of at least 50% and up to 95%, preferably 60% to 90% of a fiber forming polymer or mixture of fiber forming polymers selected from the group (i) polyamides, (ii) polyesters and (iii) polyolefins and at least 5% and up to 50%, preferably 20% to 40% of a polyester characterized of itself, as having inadequate fiber forming property, i.e. having a molecular weight too low for fiber strength, which can be converted into a fibrillated product using any known method of fibrillating molecularly oriented crystalline organic polymers.

Another object of this invention is to provide fiber forming compositions suitable for production of fine apparel yarns without the necessity to extrude continuous filaments or formation of staple fiber as an intermediate step.

A further object of this invention is to provied fiber forming compositions comprising polyamides as an essential substantial component which can be converted into fibrillated products of great fineness without the necessity to use intermediate steps such as swelling, removal of a component, etc. to increase the splittability.

Other objects, features and advantages and means of obtaining them will be apparent from the description provided hereinafter in greater detail.

According to the present invention there is provided a method for producing relatively high bulk fibrillated monofils a term employed to encompass films, filaments or tapes, of any suitable cross-section, which comprises extruding a monofil of an intimate mixture of (a) a low molecular weight polyester having a reduced viscosity in metacresol between 0.1 and 0.35 deciliter/gr., preferably between 0.15 and 0.25 deciliter/gr. and (b) one or more of the following polymers, (i) a fiber forming polyamide, (ii) a fiber forming polyester and (iii) a fiber forming polyolefin. The polyester (a) is characterized as having per se an inadequate fiber forming character, i.e. mainly excessively low molecular weight.

This invention also includes processes where the orientation is achieved in several steps executed at the same or various temperatures, and processes involving in addition to extrusion and orientation, also quenching and heating operations.

In the process of the present invention the mixture may be suitably formed into a monofil, e.g. as by being

extruded using a conventional single screw extruder. The mixture may be fed as a dry blend or it may be preblended using a kneader or a Banbury mixer, or any other suitable means for obtaining an intricate mixture of the polymers including those using solvents which are evaporated before feeding the pre-blend into the extruder.

The polyamides preferably used in the practice of these inventions are those having a number-average molecular weight above 8000 and includes mixtures incorporating polyamides.

The term "polyamide" as used in this invention contemplates polyamides as well as copolyamides which contain less than 30% of a modifying constituent, whether it be a second acid, a second amine, a lactam such as caprolactam, etc. These copolyamides may contain other linkages, such as ester groups, but at least 70% of the linking groups in the polymer must be amide groups. The polyamides and copolyamides may be aliphatic, aliphatic-aromatic, heterocyclic, etc. Specific polyamides include, for example, poly(hexamethyleneadipamide), poly(hexamethylenesebacamide), poly(iminocarbonylpentamethylene), poly(iminocarboxylhexamethylene), poly(iminocarbonyldecamethylene), poly(iminocarbonylundecamethylene), poly(iminocarbonyltetradecamethylene) and the copolymers thereof. Those prepared from aliphatic diamines have been found to operate most satisfactorily and they are preferred. As specific examples of diamines which may be used may be mentioned: ethylene diamine, propylene diamine, butylene diamine, tetramethylene diamine, pentamethylene diamine, hexamethylene diamine, paraxylylene diamine, p-phenylenediamine, etc.

Any of the dibasic acids or their derivatives which are capable of forming polyamides by reaction with diamine may be utilized as constituents of the polyamide. The most common class are the dicarboxylic acids and their derivatives. Suitable dibasic acids which may be used are: oxalic, malonic, succinic, glutaric, adipic, pimelic, suberic, azelaic, sebacic, terephthalic, isophthalic, hexahydroterephthalic, cyclohexylene dicarboxylic, etc.

The term polyester in this invention when used either as the fiber forming or as the nonfiber forming constituent is intended to include polyesters and copolyesters which contain less than 30% of a modifying constituent, whether it be a second acid, a second diol or both. The preferred polyesters for purposes of this invention are those obtained from ethylene glycol and terephthalic acid. Polyethylene terephthalate for example is a particularly suitable polyester. The copolyester may contain more than three combined copolymerizable constituent if desired and may involve other linkages such as amide and ether linkages.

Any of the dibasic acids or their derivatives which are capable of forming polyesters with glycols may be utilized as constituents of the polyester. Suitable dibasic acids include: terephthalic, isophthalic, naphthalene dicarboxylic (1.5; 2.6; and 2.7), hexahydrotetraphthalic, dibenzoic, substituted terephthalic, oxalic, malonic, succinic, adipic, suberic, sebacic, etc.

Suitable glycols include in addition to those having a general formula $HO(CH_2)_nOH$ where $n=2$ to 10, e.g., diethylene glycol, butylene glycol, neopenthyl glycol, decamethylene glycol, butylene glycol, neopentyl glycol, decamethylene glycol, cyclohexane dimethanol, etc. also diphenols such as bisphenols, naphthalene diphenols (1.4; 1.5; 2.6; 2.7 and the like).

Additional suitable fiber forming polyamides and polyesters which may be utilized due regard being given to selection of appropriately low molecular weight for the polyesters are disclosed for example in such U.S. patents as 2,071,250; 2,071,253; 2,130,523; 2,130,948; 2,190,770 and 2,465,319. The term polyolefin in this invention is intended to include crystalline polyolefinic homopolymers such as polypropylene, polyethylene polybutene-1, poly-(4-α-methylpentene-1), poly(3-methylbutene-1) as well as crystalline polyolefin copolymers.

The precise explanation of the interrelated functional effect of each of the components, the fiber forming ones and the low molecular weight polyester, i.e. the component which is relatively non-fiber forming, cannot be put forward for each specific case because of the complexity of the structure and multitude of processing variables which affect the morphology of the final product. It is believed, however, that the low strength of the polyester component and the significant incompatibility between the components which constitute the microfibrils and those which form the matrix plays an important role in the case of fibrillation observed with these systems. By varying the relative amount of the low molecular weight polyester in the blend, and by controlling selectively the processing conditions in all phases of the process we have discovered that it is possible to prepare split yarns having the unique qualities which permit the use of such split yarns (which heretofore have been known to be suitable only for weaving of coarse mats, net bags, sacking, or for twisting into twine and ropes or cordage), in relatively more expensive wearing apparel and other fabrics.

The following examples will illustrate specific embodiments of the invention. It will be understood that the details provided therein are not to be construed as limitations on the invention. Parts given are parts by weight unless otherwise stated.

EXAMPLES I(A)

A dry blend was prepared of 70 parts of nylon 6 having a reduced viscosity in metacresol of 2.3 deciliter/gr. and 30 parts of a low molecular weight polyethylene terephthalate (reduced viscosity in metacresol equals 0.18 deciliter/gr.) This blend was then extended at a rate of 8.5 gr./min. through a 0.020 inch diameter spinnerette at a melt temperature of 550° F. The emerging monofilament was quenched in water at 20° C. and taken up at a speed of 500 f.p.m. to an 8 mil filament.

The monofilament was drawn three times over a heated block kept at 190° C. at a rate of 300 f.p.m. and was then reduced to 150 denier. The filament was flattened to about 0.002 inch by passing through a set of rollers running at a linear speed of 200 f.p.m. and fibrillated by an air jet operating at a pressure of 80 p.s.i. at the same linear speed. The resulting fibrillated yarn contained about 177 fibrils per cross-section which corresponds approximately to 0.86 denier/fibril. The yarn has a zero twist tenacity of 1.26 grams per denier, *ve* equals 10.5 and *tm* equals 12.8 grams per denier.

EXAMPLE I(B)

The above experiment was repeated using a fiber forming grade of polyester (having a reduced viscosity of 0.65 decilit/gr. in metacresol) instead of the low molecular weight polyester. The resulting flattened monofil and did not show any signs of fibrillation after being passed through the air jet.

EXAMPLE II(A)

A dry blend was prepared of nylon 6 having a reduced viscosity of 2.3 decilit/gr. in metacresol, polyethylene terephthalate (reduced viscosity of 0.5 in metacresol) and low molecular weight polyethylene terephthalate (reduced viscosity of 0.18 in metacresol) in the ratio of 30 parts of nylon 6, 35 parts of polyethylene terephthalate, and 3 parts of low molecular polyethylene terephthalate. The blend was extruded at a rate of 8.0 grams per minute using a 0.030 inch diameter spinnerette. The melt temperature was 550° F. The monofilament was quenched in water and taken up at a rate of 380 feet/minute.

The resulting monofil which has a diameter of 0.010 inch was drawn three times over a heated block kept at 190° C. at a take up speed of 300 ft./min. The fibrillation was carried out as described in Example I. The fibrillated yarn which has a denier of 250 had approximately 261 fibrils per crosssectional area. Average denier per fibril was therefore slightly less than 1.0.

EXAMPLE II(B)

Example II(A) was repeated using a dry blend consisting of 30 parts of nylon 6 and 70 parts of polyethylene terephthalate (reduced viscosity of 0.5 in metacresol). The resulting monofil showed only a slight tendency to split into coarse fibrils of an average denier of 30.

EXAMPLE III(A)

A dry blend was prepared consisting of 50 parts of nylon 6 (reduced viscosity in metacresol of 2.3 decilit/g.), 20 parts of polypropylene having a melt index of 7.5 grams per 10 minutes and 30 parts of low molecular weight polyester (reduced viscosity in metacresol of 0.18 decilit/gr.). This blend was then extruded at a rate of 8.0 gr./min. using a 0.030 inch diameter spinnerette. The resulting temperature was 550° F. The extruded monofilament was quenched in water at 20° C. and taken up at a rate of 380 ft./min. The resulting 0.010 inch diameter monofil was drawn three times its length over a heated block kept at 190° C. at a take up speed of 300 ft./min. The fibrillating process was carried out as described in Example I. After splitting the yarn had a denier of 250 with approximately 283 fibrils per cross-sectional area (average denier per fiber equals approximately 0.88). The fibrillated yarn had a zero twist tenacity of 1.15 g./den.

EXAMPLE III(B)

A similar blend as described in Example III(A) was prepared using a fiber forming grade of polyethylene terephthalate (reduced viscosity in metacresol equals 0.56 decilit/gr.) instead of the low molecular weight polyesters. After processing the blend using the same extrusion, drawing and fibrillating conditions as in Example III(A) the resulting monofil split only in sections of 3 to 6 fibrils per cross-sectional area. The product had no usefulness in textile applications.

EXAMPLE IV(A)

A dry pellet blend of 70 parts of polypropylene with a molecular weight of 296,000 and 30 parts of poly(ethylene terephthalate) with a molecular weight of 5000 was extruded in the form of a monofilament 0.015 inch in diameter. The filament was stretched to a draw ratio of 4 over a heated block kept at 150° C. The stretched filament was then fibrillated by being crushed between rollers spaced 0.002 inch apart and subsequently being blown through an air jet as described in Example I. The resulting fibrillated yarn consisted of about 150 fibrils per cross-section which was equivalent to approximately 1.7 denier per fibril.

EXAMPLE IV(B)

A monofilament was made in a manner identical with that described in Example IV(A), but that the molecular weight of the poly(ethylene terephthalate) was 15,000. When stretched, rolled and blown through an air jet as indicated in Example IV(A), the filament showed little tendency to fibrillate and split into only a few coarse fibers.

EXAMPLE V(A)

A dry pellet blend of 30 parts of poly(tetramethylene terephthalate) of molecular weight 4000 and two parts of nylon 6 of molecular weight 22,000 was extruded in the form of a monofilament 0.015 inch in diameter. The monofilament was drawn to a draw ratio of 4 over a heated block kept at 170° C. then crushed between rollers and blown in an air jet as described in Example IV(A). The resulting fibrillated yarn consisted of about 100 fibrils each of about 2.5 denier, on the average.

EXAMPLE V(B)

A monofilament was prepared in a manner identical to that described in Example V(A), except that the poly(tetramethylene terephthalate) was a molecular weight 16,000. When drawn, crushed and blown in an air jet as

indicated in Example V(A), this monofilament showed no tendency to fibrillate and essentially retained its integral form.

EXAMPLE VI (A)

A dry pellet blend of 30 parts of poly(tetramethylene-2,7-naphthalate) having a molecular weight of 7000 and 70 parts of nylon 6 with a molecular weight of 22,000 was extruded into a monofilament 0.014 inch in diameter. The monofilament was stretched to a draw ratio of 4 over a heated block kept at 190° C., then crushed between rollers and blown in an air jet in the manner described in Example V. This treatment yielded a yarn containing about 150 fibrils in each cross-section, each fibril being about 1.7 denier.

EXAMPLE VI(B)

A monofilament was prepared in a manner identical to that described in Example VI(A), except that the molecular weight of the poly(tetramethylene-2,7-naphthalate) was 20,000. When drawn, crushed and blown in an air jet in the manner indicated in Example VI(A), this monofilament showed a minimal capacity for fabrillation and only split into a few coarse fibers.

EXAMPLE VII(A)

A dry pellet blend of 70 parts of poly(iminocarbonyl undecamethylene), also known as nylon 12 with a molecular weight of 25,000 and 30 parts of poly(ethylene terephthalate) having a molecular weight of 5000 was extruded into a monofilament 0.015 inch in diameter. The filament was stretched to a draw ratio of 4.5 over a heated block kept at 160° C. The drawn filament was then crushed between rollers and blown in an air jet as described in Example VI. This procedure yielded a fibrillated yarn consisting of about 80 fibrils, each of about 2.8 denier.

EXAMPLE VII(B)

A monofilament was prepared in a manner identical to that described in Example VII(A) except that the molecular weight of the poly(ethylene terephthalate) was 16,000. When drawn, crushed and blown in an air jet as

indicated in Example VII(A), this monofilament showed no tendency to fibrillate and retained its integral form.

It will be apparent to those skilled in the art in view of the nature of the inventive disclosure that various modifications may be effected without departure from the scope of the invention. The several details disclosed as illustrative should not be construed as placing limitations on the invention except as required by the appended claims.

We claim:

1. A fibrillated monofilament comprising an oriented extrudate consisting essentially of an intimate mixture of (I) at least 60% and not more than 90% by weight of a fiber-forming polymer selected from the group consisting of polyamides, polyesters and polyolefins, and mixtures thereof; and (II) from at least 10% to 40% of a polyester which of itself is characterized as having low strength and inadequate fiber-forming characteristics and having a reduced viscosity in metacresol between about 0.1 and about 0.35 deciliter/gram.

2. The monofilament of claim 1 wherein the polyamide (I) is nylon 6 and the polyester (II) is polyethylene terephthalate.

3. The monofilament of claim 1 wherein the polyamide (I) is nylon 66 and the polyester (II) is polyethylene terephthalate.

4. The monofilament of claim 1 wherein the polyolefin (I) is polypropylene and the polyester (II) is polyethylene terephthalate.

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ROBERT F. BURNETT, Primary Examiner

J. C. GIL, Assistant Examiner

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