

1

3,350,871

YARN BLEND

Norwin Caley Pierce, Greenville, and Cecil Everett Reese, Kinston, N.C., assignors to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

No Drawing. Filed Aug. 3, 1964, Ser. No. 387,209

11 Claims. (Cl. 57—140)

ABSTRACT OF THE DISCLOSURE

Composite yarns of at least two species of filaments, continuous or staple, at least one of which is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation, at least one other species having a lower shrinkability than that of the first species. The products of this invention are utilized in a wide variety of fabric structures.

This invention relates to composite synthetic yarns and more particularly to yarns comprising two or more species of filaments, continuous or staple, at least one of which comprises a polyester which crystallizes in a non-extended conformation.

It is known to blend two or more species of filaments which differ in some selected characteristic such as, for example, in their ability to shrink on exposure to shrinking conditions, into a composite yarn. In U.S. Patent 1,976,201, for instance, it is shown that doubling of two threads, one of which has been stretched and can shrink, results in a yarn which when fabricated into a woven or knitted structure and thereafter subjected to shrinking conditions provides a bulky structure. If such fibers are cut to a short length staple and spun to yarns on a staple system such as the cotton processing system, a lofty, wool-like structure will be obtained. If the filament blend is processed as a continuous filament yarn, an increase in bulk will also be achieved, but much of the tactility of fabrics made of synthetic, continuous filament will be retained. Mixed shrinkage in continuous filament yarns can also be employed to produce novel fabric structures such as crepes, seersuckers, waffle-surface fabrics, etc.

This invention provides an improved yarn comprising filaments which shrink to unequal extents. This invention also provides mixed-shrinkage filament synthetic yarns which are capable of a variety of fabric structures depending on the choice of finishing treatments in the production of the fabric. This invention further provides synthetic, continuous-filament, mixed-shrinkage yarn in which the differential in shrinkage among components is retained, and even enhanced, through taut yarn or fabric heat-setting processes.

These and other advantages are achieved in this invention in a physical blend of two or more species of continuous filament yarns or staples at least one of which species is a polyester partly crystalline in a stable conformation 90% or less the length of the fully extended molecular conformation which species has the higher shrinkability in the drawn, composite yarn, and by a critical process of manufacture of the yarns and fabrics therefrom. The term "stable" means that the polymer does not irreversibly change its crystalline conformation under conditions which do not melt the polymer.

It is preferred that a second species, that is, a species which shrinks less than the indicated polyester when the blend of fibers in the yarn is subjected to shrinking conditions, comprises a polymer which is more extended in its crystalline conformation than is the polyester polymer of the first species. Even more desirable results are attained if a second species of fiber in the blend comprises a polymer which crystallizes in a conformation in which

2

the crystalline repeat-distance is 95% or more that of the fully extended chemical repeat-distance.

The fact that one of the species is a polyester polymer which is non-extended to the extent that the average crystalline repeat-distance is 90% or less that of the fully extended chemical repeat-distance makes such a species highly desirable in mixed-shrinkage yarns. It is known that this structure confers unique response to high temperature or other structure-softening treatments. Although the reasons for this unique response to thermal treatments are not fully understood and the invention should not be limited by theoretical considerations, the discussion which follows may assist in understanding the scope of this invention.

Bulking a blend of fibers in a yarn of this invention is the result of a difference in length change among filament species arising from a difference between species in retraction from draw, shrinkage, or both; these, in turn, are due to molecular disorientation involving bond rotation leading to molecular conformation changes. The forces leading to such changes arise from directionally unbalanced kinetic energy of bond rotation as a result of molecular orientation during drawing. There is essentially no phenomenological distinction between retraction-from-draw and shrinkage. The distinction is found only in the environment required for the effect to occur. Retraction-from-draw is fully analogous to retraction from stretch in an elastomer in that it occurs at room temperature. The bulk resulting from differential in retraction-from-draw, therefore, will develop upon unwinding from its package a yarn comprising two species of filaments which differ in retraction-from-draw and allowing the yarn to relax. Shrinkage refers to that contraction in length which occurs when an oriented fiber is for the first time heated under conditions of low restraint (or none) to a given temperature above ambient temperatures. In general, both shrinkage and retraction from draw are enhanced by higher orientation in the amorphous zones of the fiber. Stable crystallites in the fiber cannot contribute to shrinkage, since there is no opportunity for bond rotation in a zone where, by definition, it is prevented by intermolecular order. The potential of a fiber species to shrink is effected, however, by changes in the degree of crystallinity. The direction of this effect, that is, to increase or to decrease shrinkage, is determined by the characteristic crystalline conformation of the polymeric species.

If the polymer crystallizes in an extended conformation (as do most polyesters), that is, one in which the length of the crystalline repeat-unit closely approaches that of the fully extended chemical repeat-unit, a unit added will increase the length of the crystallite more than its removal reduces the length of the amorphous region; thus the partially crystalline "extended-type" component loses amorphous orientation (and potential shrinkability) as it continues to crystallize. If, on the other hand, the added chemical repeat-unit, being of the non-extended type, increases the length of the crystallite less than its removal reduces the length of the amorphous region, an increase in amorphous orientation results. Thus, further crystallization of such non-extended polymer components results in higher tendency to shrink.

From the above discussion, it follows that the unusual properties of the blend of fiber species in a yarn of this invention are fully realized only if the overall orientation of the high shrinkage species of fiber in the blend is greater than its orientation in its crystalline conformation. Thus it is desirable that this, the more shrinkable component, be the more highly oriented member.

Orientation of synthetic fiber may be accomplished in either or both of two ways: (1) by withdrawing the solidifying filament from the spinneret at a rate higher than its

extrusion velocity and (2) by mechanical stretching of the solidified filament. Where the two species of filament are processed individually, it is a simple matter to orient the species comprising the non-extended crystallinity polymer to a greater extent than the component which will be the less-shrinkable species. Alternatively, it may be desirable to process the several species simultaneously, in which case achieving higher orientation in one species requires that this, the high-shrinkage species, receive more orientation during spinning. This may conveniently be done, for example, by suitable use of melt-viscosity adjuvants in one component, such that the more-shrinkable species is given more shear in extrusion from the spinnerets.

Maintenance of the required differential in shrinkage and retraction-from-draw between species during high temperature processing requires a good degree of geometrical stability intermolecularly in the high-shrinkage species of polymer, except for those rearrangements necessary to fiber shrinkage. Otherwise, the potential energy required for shrinkability may be dissipated by molecular rearrangements to a more stable condition (of lower shrinkage). It has been found that some polymers which crystallize in a non-extended conformation fail to meet the requirements for the high-shrinkage species of this invention apparently due to unstable intermolecular geometry. It will be obvious that any intermolecular order instability ("slippage") will result in reduced total orientation whether it occurs in the crystalline or the amorphous regions of the fiber.

A major problem in the production of mixed-shrinkage, continuous-filament yarns arises from premature retraction of one species of filament, leading to loopiness in the species which retracts less. Such loopiness tends to back up at guides, tangle, and break down the running end. Further, continuous filament yarn with large, random loops has little or no utility in the manufacture of bulky fabrics of the type provided by this invention. The tendency of the high-shrinkage filament of this invention to increase in shrinkability (and in shrinkage force) when annealed under tension makes mixed-shrinkage yarns comprising such filaments even more subject to loopiness. It is essential, therefore, that the mixed-shrinkability yarn of this invention be handled at relatively low temperatures at all stages through conversion to greige fabrics so that the advantages of this discovery can be attained. While the actual difference in shrinkability of the various species in a yarn of the invention is not a limiting consideration, as a practical matter differential shrinkage characteristic of known mixed shrinkage yarns may be used in this invention. For example, the high shrinkage component may have a residual shrinkage of 6 to 10% or more, while the low shrinkage component will have a shrinkability on the order of 2 to 4%.

Subject to the limitation that at least one species be a polyester partly crystalline in stable conformation not greater than 90% of the length of the fully extended molecular conformation, it is apparent that fibers of yarns of the present invention can be any of the polymers heretofore employed in yarns composed of either natural or man made fibers. Condensation polymers and copolymers, e.g. polyesters, polyamides and polysulfonamides, and especially those that can be melt spun readily are preferred. Suitable polymers are available, for instance, among the fiber-forming polyesters and polyamides which are described in U.S. Patents Nos. 2,071,250, 2,071,253, 2,465,319, 2,190,770, 2,130,523 and 2,130,948. The polyesters that are preferred for the species exhibiting the critical stable conformation are poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene 2,6-dinaphthalate) and poly(trimethylene bibenzoate). Trimethylene 2,6-dinaphthalate is referred to herein after sometimes simply as trimethylene dinaphthalate. Poly(ethylene terephthalate) is the preferred polyester for the other species, but other polyesters such as the corresponding copolymers of ethylene terephthalate con-

taining sebacic acid, adipic acid or isophthalic acid as well as those containing recurring units derived from glycols with more than four carbon atoms can be used as well, for example poly(transcyclohexanedimethylene terephthalate). Preferred polyamides comprise, for example, such polymers as poly(hexamethylene adipamide), poly(hexamethylene sebacamide), poly(epsilon caproamide) and copolymers thereof.

From the foregoing and the data in the following table, it is apparent that typical species-pairs that are within the invention include any one or more of (1) poly(trimethylene terephthalate), (2) poly(tetramethylene terephthalate), (3) poly(trimethylene dinaphthalate) and (4) poly(trimethylene bibenzoate) with any one or more of (a) poly(ethylene terephthalate), (b) poly(trans-cyclohexanedimethylene terephthalate), (c) poly(ethylene 2,6-dinaphthalate), (d) poly(1,3-cyclobutane dimethylene terephthalate), (e) poly(1,3-cyclobutane dimethylene bibenzoate) and (f) poly(hexamethylene adipamide). In addition natural fiber materials may be included in the blends.

The conformations of a number of polymers in their crystallites have been determined from X-ray and model data. Table 1 gives the chemical and crystalline repeat-distance for a number of polymers:

TABLE 1.—REPEAT-DISTANCES (A.)

Polymer repeat-unit	Chemical	Crystalline	Percent Extended
Ethylene terephthalate	10.9	10.7	98
Trimethylene terephthalate	12.2	9.1	75
Tetramethylene terephthalate	13.4	11.7	87
Trans-cyclohexanedimethylene terephthalate	14.7	14.2	97
Ethylene 2,6-dinaphthalate	13.4	13.1	98
Trimethylene dinaphthalate	14.5	11.5	79
Trimethylene bibenzoate	16.6	13.3	80
1,3-cyclobutane dimethylene terephthalate	14.3	13.4	94
1,3-cyclobutane dimethylene bibenzoate	18.6	18	97
Hexamethylene adipamide	17.4	17.2	99

Determinations of this nature are accomplished as follows: Measurement of the "% Extended" parameter is done as follows (the order of steps A and B is immaterial):

Step A—Measurement of crystalline repeat distance.—A parallel bundle of oriented and partly crystalline fibers is mounted in an X-ray beam with the fiber axis perpendicular to the beam. A flat photographic film is placed in and perpendicular to the X-ray beam at a distance of a mm. from the fiber array on the opposite side from the X-ray source. The film is suitably exposed and developed to show a "fiber pattern" consisting of a family of more-or-less complete hyperbolae with its axis parallel to the fiber axis, i.e., on the so-called meridian. The distance on the film along this line from the primary-beam image to each hyperbola is measured and designated e_n , n being the ordinal number of the layer line counting away from the equator as zero. The diffraction angle u_n is defined as $u_n = \tan^{-1} e_n/a$. The identity period (Crystalline Repeat) is then simply calculated from

$$\text{I.P.} = \frac{n\lambda}{\sin u_n}$$

where λ is the wavelength of the X-rays used. The above notation follows G. L. Clark, "Applied X-Rays," McGraw-Hill, New York (1955), p. 401. The patterns from various polymers and particular values of e_n , of course, differ.

Step B—Measurement of chemical repeat-distance.—A molecular model of the polymer in question is made from a commercially available scale-model kit such as the "Dreiding" kit manufactured by W. Buchi, Flawil, Switzerland. The interatomic bonds along the chain are rotated so as to give the longest straight length along the molecular chain. The distance from any nucleus in the chain to the corresponding nucleus in the next repeat-unit

is measured, converted to Angstrom units, and designated the Chemical Repeat of the polymer.

Step C—Calculation of percent extended.—The Crystal-line Repeat-Distance from Step A (which is in Angstrom units) is divided by the length calculated from measurements in Step B. The result is multiplied by 100 to give the percent extended.

If the result of Step C is greater than 100%, obviously the crystal repeat-unit consists of more than one chemical repeat-unit. The actual number can sometimes be estimated from geometrical considerations or from a more detailed analysis of the X-ray pattern. Since the crystal repeat must be an integral number of chemical repeats, assigning one chemical repeat therefore gives the maximum possible extension: if there were two chemical repeats, the percent extension would be halved, etc.

The art of composite yarns to which the present invention generally relates is well developed, and reference may be made to techniques already known for application to the present discovery. In addition, the various spinnerets described in various patents as well as the manner of using them may be employed in this invention. The quantity of the various species in any yarn can be varied widely. In general, however, the nonextended component usually comprises 20 to 80% of the blend. The denier of the filaments will be that usually produced in this art in general, and is not of particular significance to the invention.

Filaments suitably are produced for the present invention by conventional co-spinning procedures, though individually obtained filaments can also be employed. Generally in co-spinning, two melts are metered to different rings of holes in a spinneret. A sealing means prevents mingling of the two melts at the back face of the spinneret. The two melts flow through individual channels of the spinneret where they emerge as individual species of filaments as they leave the spinneret assembly.

The filaments generally are withdrawn from the spinneret at a speed that attenuates the filaments, and they are thereafter drawn. The conditions applied for drawing the spun multi-species yarn of this invention may vary within wide limits. In addition to the processes of drawing indicated in some of the examples given hereinafter, other known procedures that do not result in an annealing of the yarn species may be used. Temperatures up to about 95° C. have been employed. In general, the precise amount of draw is established by use of feed and drawing rolls which are driven at the appropriate differential in speed, care being taken to assure that the yarn doesn't slip on either. Two methods for assuring positive control of speed which are appropriate for feeding to or withdrawing from a drawing zone are described in U.S. 3,101,990.

Thereafter, the yarn is processed to greige goods by conventional techniques. For example, fabrics can be made from the continuous filament yarn, or the yarn can first be cut to staple length and then spun to desired form for conversion to a fabric. However accomplished, it is necessary to avoid any annealing of the yarn that permits differential retraction of the various species until the greige fabric has been produced. Otherwise the yarn may become loopy and be relatively useless. Finishing is accomplished by heat setting in the greige at a controlled width followed by boil-off scouring or analogous treatment to develop bulk. A second heat-setting step is sometime employed following boil-off.

In preparing fabrics, these fiber blends can be used exclusively (100% fabrics) or for only part of the fabric. Where 100% fabrics are made, boil-off scour applied after heat setting or following lagging treatment results in a pleasant surface pucker which can be modified by a second heat setting. Where the yarns are used only for filling, pucker is likewise developed in boil-off scour. In this instance, the amount, frequency and amplitude of the pucker can be controlled by controlling the amount of shrinkage in the warp during heat setting.

The invention will be described further in conjunction

with a series of examples. In the examples, except as otherwise indicated, the terms employed in evaluating polymers and fibers have the following meanings:

Relative viscosity refers to the ratio of the viscosity of a 10% solution of the polymer in a mixture of 10 parts of phenol and 7 parts of 2,4,6-trichlorophenol (by weight) to the viscosity of the solvent itself, both measured at 25° C. and expressed in the same units.

Intrinsic viscosity is defined as the limit of the fraction

$$\ln(r)/c$$

as concentration c approaches zero, where r is the relative viscosity as defined above, except that relative viscosity is measured at several concentrations to facilitate extrapolation to zero concentration, and the solvent employed in this measurement is a mixture of three parts of methylene chloride and one part of trifluoroacetic acid (by weight). A more detailed discussion of methods of measuring relative and intrinsic viscosities is given in Preparative Methods of Polymer Chemistry, Sorenson & Campbell, Interscience, 1961.

EXAMPLE I

This example illustrates batch preparation of poly(trimethylene terephthalate), coded herein PPT polymer.

Catalyst for this preparation is prepared as follows: Sodium (2.5 gms.) is dissolved in 300 ml. of n-butanol. Tetrabutyl titanate (37 gms.) is then added and the mixture diluted to 500 ml. with n-butanol.

Dimethyl terephthalate (5.45 kg.) and trimethylene glycol (4.54 kg.) are heated for 100 minutes at 225° C. in the presence of 99 cc. of the stock catalyst solution described above. During this time, 1.8 kg. of methanol are removed. The resulting low molecular weight material, to which a small amount of titanium dioxide has been added as a delusterant, is heated further, with stirring, for 6 hours at 250° C. under an absolute pressure of 0.4 mm. of mercury during which time the glycol evolved during further condensation is removed. The resulting polymer has an intrinsic viscosity of 0.71.

Poly(trimethylene terephthalate) can be made in a variety of ways, many of which are well-known in the art. Since the process detail employed in its manufacture is not critical to the utility of PPT polymer in practice of this invention, polymer made by several processes has been employed herein indiscriminately.

EXAMPLE II

This example illustrates a means of enhancing the molecular weight, as evidenced by an increase in intrinsic viscosity, of a polymer such as that prepared in Example I.

PPT polymer of less than 1.0 intrinsic viscosity is cut twice to pass through a 1/8 inch mesh screen, dried 6 hours at 150° C. and placed in a vessel through which inert gas is passed. The inert gas and vessel are heated to 180° for two hours, then to 200° C. for an additional 12 hours. The polymer and apparatus are then cooled and the polymer removed. The intrinsic viscosity of the finished polymer is 1.29. A second batch of this polymer is prepared and found to have an intrinsic viscosity of 1.36.

Polyethylene terephthalate (PET polymer) may be prepared by any of a variety of procedures known in the art, such as one of the methods taught by Whinfield and Dickson in U.S. Patent 2,465,319, or one of the methods of Griffing and Remington described in U.S. Patent 3,018,272. While each of these methods may have merit over another in some respect such as in the production of a whiter polymer or in improved space-time yield, these differences are not critical to the purpose of this invention. PET polymer employed in these examples has accordingly been derived from several procedures as dictated only by convenience and availability.

EXAMPLE III

A PPT polymer of 1.9 intrinsic viscosity and a PET

polymer of 30 relative viscosity are cospun to 25 filaments each by delivering equal volumes of the two polymer melts to two concentric rings of 25 holes each in the same spinneret, the PTT polymer being extruded from the inner ring of holes. The two melts are prevented from mixing by an inter-ring seal on the back face of the spinneret. The resulting 50-filament yarn is withdrawn from the spinneret at 1035 y.p.m. It is subsequently drawn to $2.67\times$ (that is, to 267% of its as-spun length) in a bath of water maintained at 90–92° C.

The intervening draw rolls operating at a surface speed of 666 y.p.m., are held at room temperature to prevent loopiness in the yarn as delivered, which is encountered at higher (annealing) temperatures. The yarn is passed through an interlacing jet such as that depicted in FIGURES 1 and 3 of the Bunting et al. U.S. Patent 2,985,995 using sufficient air pressure to the jet to produce the desired interlace between the draw rolls and windup. The windup speed is adjusted for good package formation. The final yarn has a denier of 66, a tenacity of 2.5 grams per denier (g.p.d.), an elongation of 20.4%, an initial modulus of 22 g.p.d., and a boil-off shrinkage of 40%.

Two yarns (i.e. two packages) are twisted to two levels of Z-twist, one of 7 turns per inch (t.p.i.) for warp, and the other 3 t.p.i. for filling. The warp yarns are twist-set on the package at 57° C., 74% R.H. (by injection of moisture) for one and three-quarter hours, and heated for 15 minutes at the same temperature, without injection of moisture, to dry the package. This low temperature does not produce a loopy yarn. The yarns are used to make two fabrics by conventional procedures, a 100% fabric and a filling-only fabric in which the warp comprises a 70-denier, 34-filament yarn comprising only PET-polymer filaments.

In slashing of the warp yarns for the 100% fabric, the size bath is maintained at room temperature, and the drying cans are held below 80° C. Higher temperature leads to unacceptable loopiness due to premature annealing.

Both the 100% and the filling-only fabrics are woven as plain taffetas, the 100% fabric having thread counts of 88 warp and 64 fill and the filling only fabric 104 and 72, respectively, in the greige. Several samples of each fabric are heat-set taut in a tenter frame, using various widths, for 5 minutes at 160° C. The filling-only fabrics are given a boil-off scour, whereupon a pucker develops, the amplitude of which is dependent on the amount of shrinkage allowed during heat-setting. Fabrics ranging from a fine crepe to a high "waffle-like" surface are obtained by varying relaxation during heat-setting over the range of 0 to 60%. The 100% fabrics develop a pucker, the character of which is very different from that of the filling-only fabric due to the retraction along the warp as well as the fill. The fabric can be reheat-set to a range of pucker from fine crepe to waffle-weave limited on the high pucker side only by the amplitude of the boiled-off pucker.

EXAMPLE IV

A PPT polymer of 1.4 intrinsic viscosity and a PET polymer of 30 relative viscosity are cospun to 25 filaments each by the process described in Example III except for the following detailed differences: The filaments are withdrawn at 864 yards per minute, drawn $3.01\times$ in a bath maintained at 94–95° C. to draw rolls having a surface speed of 2600 y.p.m. The drawn yarn denier is 66, tenacity is 3.3 g.p.d., elongation at break is 23.4% and modulus 51 g.p.d. Tenacity is determined from a stress-strain curve. Further inspection of the stress-strain curve showed that the yarn begins to yield at approximately 1.84 g.p.d. and at a corresponding elongation of 4.8%. Its boil-off shrinkage is 22%.

The yarn is interlaced in a jet such as referred to in Example III such that a needle inserted through the bundle of filaments and moved back and forth along the length of the yarn will encounter obstructions to further

passage averaging approximately three inches apart. In general, breakage of filaments is required to move the needle beyond such an obstruction. The interlaced yarn is then twisted to 3 t.p.i. Z and woven (filling only) as 78 picks per inch in a 70-denier, 34-filament warp of PET yarns.

The greige fabric (104×78 picks per inch, warp×fill) is heat-set on a tender frame at greige width at 160° C. for 5 minutes. It is then scoured up to the boil in a relaxed condition, whereupon a crepe surface is obtained.

In this as in all fabrics produced from the yarn of this invention, the amount of bulk obtained is high for the amount of shrinkage allowed due to setting of the low-shrinkage ("extended"-type) filaments at minimum shrinkage before boil-off.

EXAMPLE V

A PPT polymer of intrinsic viscosity of 0.95 is spun at 1200 y.p.m. to give a 307-denier, 34-filament spun yarn. The spun yarn is drawn by the water-wick process (yarn wet with water before passing over a 86° C. hot shoe with 3 wraps) at a draw ratio of 2.74 and a speed of 454 y.p.m. The drawn yarn is coned into several packages which are combined, crimped and cut into 3" staple without heat relaxation. Cut staple is combined with a PET polymer yarn in a ratio of 80/20. The blend staple is further combined with wool to give a polyester/wool blend of 55/45. The final blend is spun into a 16/1 cc. yarn, twisted 14 turns per inch Z and woven into a 2 x 2 right hand twill which on mill finishing gives a 7 oz./yd.² fabric. This fabric, when compared to one of analogous construction but without the PET polymer filaments, has a small, desirable stretch whereas the control has essentially none. Such stretch has been shown useful in tailoring garments, and leads to improved wear comfort. This illustrates broad additional utility in blends comprising natural fibers such as cotton and/or wool.

From the foregoing discussion and examples the outstanding results attained in accordance with the present invention in physical blends of continuous filament yarn and staple yarn in which at least one component is a polyester partly crystalline in non-extended conformation not greater than 90% of the chemical repeat-distance are apparent. Fabrics prepared from the yarns can be readily dyed by ordinary techniques resulting in attractive and very useful products.

It should be understood that the extent of crystallinity in composite filaments of this invention is generally that which is characteristic of composite filaments known heretofore. The term "partly" as used in the definition of the invention is present merely to eliminate from the scope of the invention the limiting situation of complete crystallinity wherein shrinkage would disappear. The critical limitation in this invention is the character of the polyester that must be present in all of the claimed composite filaments, namely its crystallites being in stable conformation that is 90% or less of the length of the fully extended molecular conformation. When crystallinity is present in these composite filaments, that limitation is met because it is a physical or structural characteristic of the special polyesters that must be present. When that limitation is met, the unusual responses demonstrated in the case result. Hence, the scope of the crystallinity has a minimum level of only the presence of some crystallinity, and a maximum level of any amount short of complete crystallinity so that shrinkage is possible. Similarly, the molecular weight of the polymers used may vary widely, and generally will be in the range conveniently employed in the synthetic polymer art.

In the practice of this invention, the additives normally employed in the manufacture of synthetic fibers may be used and are substantially without adverse effect on properties of the yarn obtained. It is possible, as examples, to add antistatic agents, delusterants, fluorescent brighteners, dyes, pigments, surface rougheners and the like to

one or all species within reasonably wide limits without adversely influencing differential shrinkage, stretch or other property appreciably. Addition of topical finishes may also be practiced.

This invention is applicable in the production of blends of fiber of any cross-sectional shape. Those which may be employed include, for example, round, oval, ribbon, double round and trilobal.

While the exemplified development of bulk by shrinking has exclusively involved treatment in hot or boiling water in this specification, it is recognized that operative alternatives exist which also would be within the scope of this invention. Treatment with a transitory plasticizer, for example, can lower the glass transition temperature of a polymer sufficiently to accomplish the necessary shrinkage at a temperature substantially below the boiling point of water; it is conceivable that such treatment could shrink the fiber at room temperature. Further, polymers vary widely in glass transition temperature, and treatment at temperatures substantially above 100° C. may be necessary to shrink fiber made from the high glass-transition-temperature components.

The product of this invention is advantageously utilized in a wide variety of fabrics such as, for example, crepes, and waffle weaves, as well as new fabric types not now available.

It will be apparent to one skilled in synthetic fiber art that other combinations of polymers in the fiber species may meet the requirements of this invention which is that the polymer of at least one species of fiber must be a polyester capable of partial, stable crystallization in a non-extended conformation, that is, in which the crystalline repeat-distance is 90% or less that of the chemical repeat-distance of the species, said species being higher in shrink-ability at moderately elevated temperature than the other component such that said fiber species is the high shrinkage member of the fiber mixture. It is understood, therefore, that this invention is not to be limited to the particular polymeric species exemplified but only in accordance with the appended claims.

What is claimed is:

1. An improved composite yarn comprising a physical blend of at least two species of filaments having different shrinkabilities, at least one species being a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation, and at least one other species being one which is more extended in its crystalline conformation than the first species in the resulting composite yarn.

2. A yarn in accordance with claim 1 in which the yarn is composed of continuous filaments.

3. A yarn in accordance with claim 1 in which the species that is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation is selected from the group consisting of poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene dinaphthalate) and poly(trimethylene bibenzoate).

4. A yarn in accordance with claim 1 in which the species that is a polyester partly crystalline in stable con-

formation not greater than 90% of the length of its fully extended molecular conformation is poly(trimethylene terephthalate) and a second species of said yarn is poly(ethylene terephthalate).

5. A stretchable fabric composed of yarn including an improved composite yarn comprising a physical blend of at least two species of filaments having different shrinkabilities, at least one species being a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation, and at least one other species being one which is more extended in its crystalline conformation than the first species in the resulting drawn composite yarn.

6. A fabric in accordance with claim 5 in which the yarn is composed of continuous filaments.

7. A fabric in accordance with claim 5 in which the species that is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation is selected from the group consisting of poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene dinaphthalate) and poly(trimethylene bibenzoate).

8. A fabric in accordance with claim 5 in which the species that is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation is poly(trimethylene terephthalate) and a second species is poly(ethylene terephthalate).

9. A stretchable woven fabric having its filling composed of an improved composite yarn comprising a physical blend of at least two species of continuous filaments having different shrinkabilities, at least one species being a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation, and at least one other species being one which is more extended in its crystalline conformation than the first species in the resulting drawn composite yarn.

10. A woven fabric in accordance with claim 9 in which the species of the filling that is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation is selected from the group consisting of poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene dinaphthalate) and poly(trimethylene bibenzoate).

11. A woven fabric in accordance with claim 9 in which the species of the filling that is a polyester partly crystalline in stable conformation not greater than 90% of the length of its fully extended molecular conformation is poly(trimethylene terephthalate) and a second species is poly(ethylene terephthalate).

References Cited

UNITED STATES PATENTS

3,199,281 8/1965 Maerov et al. ----- 57—140

FRANK J. COHEN, *Primary Examiner*.

60 J. PETRAKES, *Examiner*.