Jan. 14, 1964 A. L. BREEN 3,117,362

COMPOSITE FILAMENT

Filed June 20, 1961 3 Sheets-Sheet 1

FIG. 1

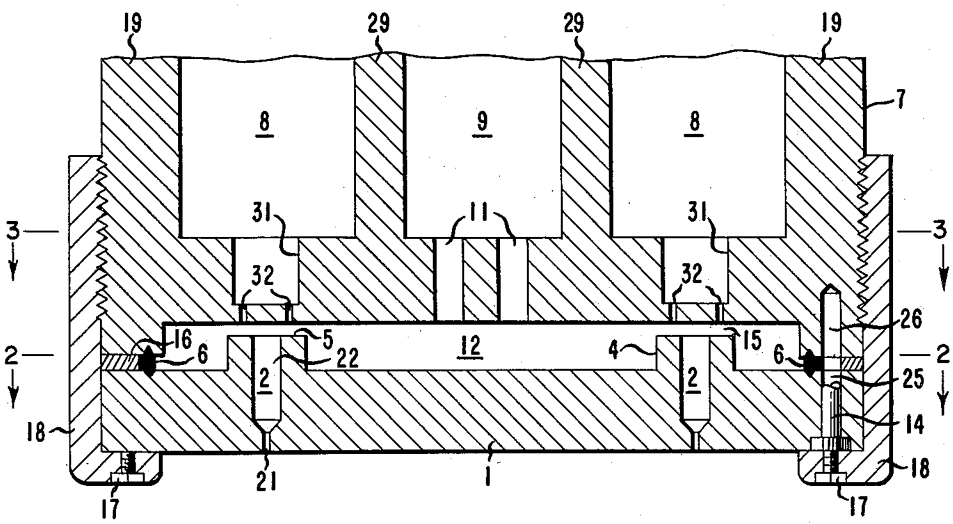


FIG. 2

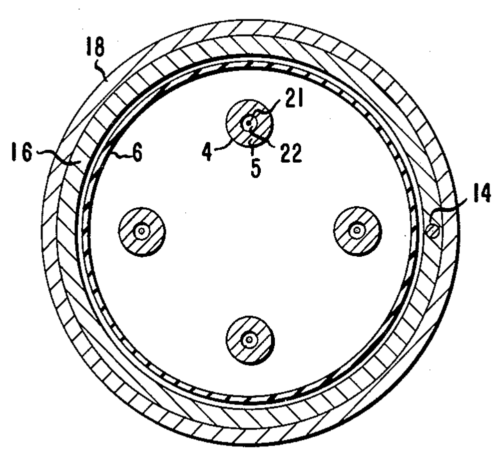
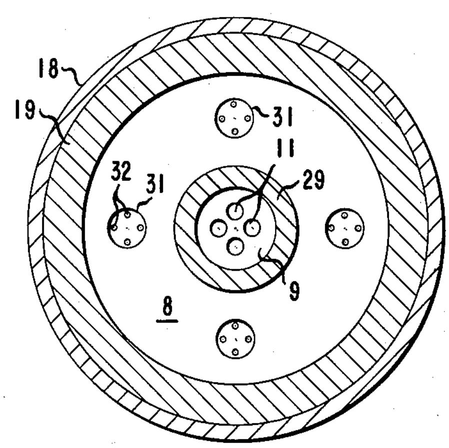


FIG. 3



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Filed June 20, 1961 3 Sheets-Sheet 2

FIG. 4

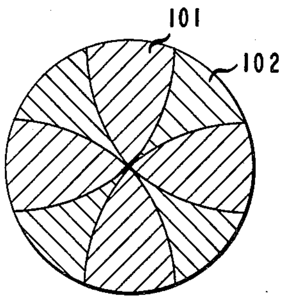


FIG. 5

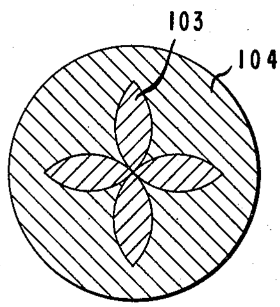


FIG. 6

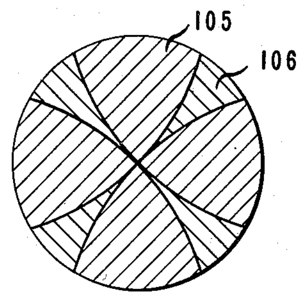


FIG. 7

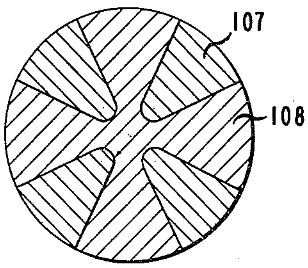


FIG. 8

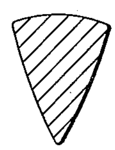


FIG. 9

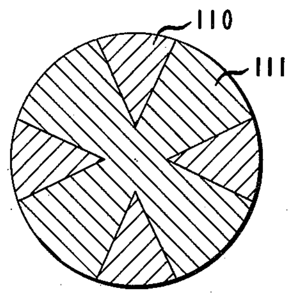


FIG. 10

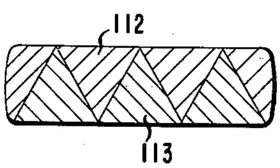
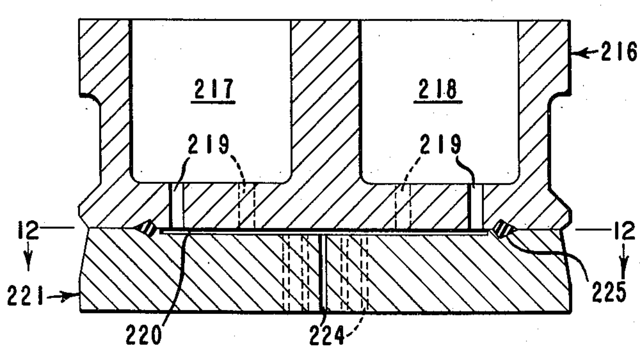


FIG. 11



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Jan. 14, 1964 A. L. BREEN 3,117,362

COMPOSITE FILAMENT

Filed June 20, 1961 3 Sheets-Sheet 3

FIG. 12

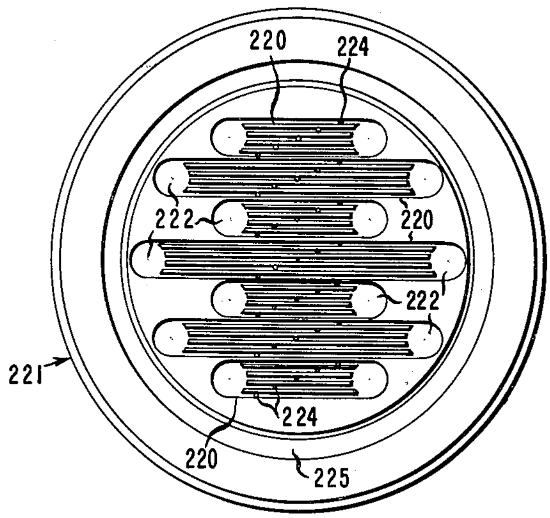


FIG. 13

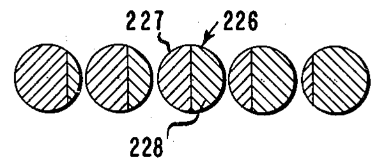
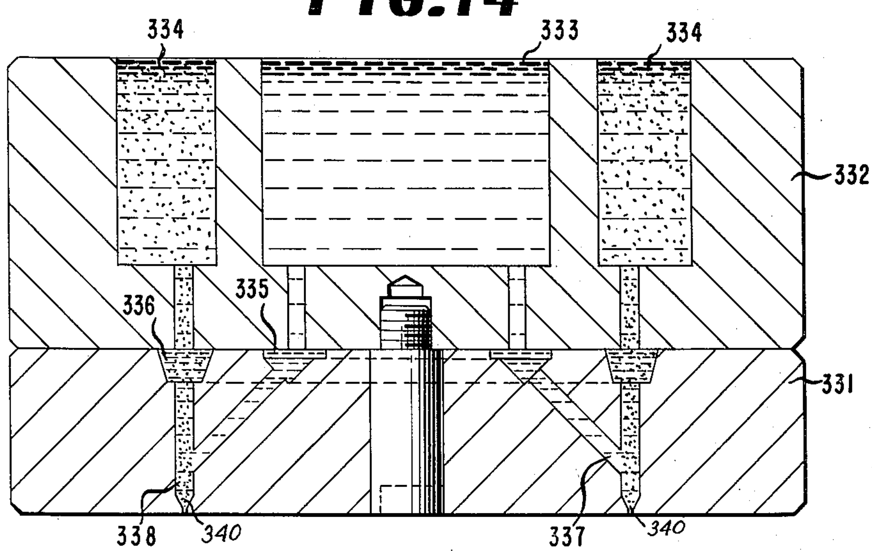


FIG. 14



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Patented Jan. 14, 1964

3,117,362
COMPOSITE FILAMENT

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Filed June 20, 1961, Ser. No. 118,470
19 Claims. (Cl. 57—140)

This invention relates to improved synthetic textile filaments and yarns and a process for their production.

This application is a continuation-in-part of my copending applications Serial No. 412,871, filed February 26, 1954, now abandoned, Serial No. 738,166, filed May 27, 1958, now abandoned, and Serial No. 754,064, filed August 8, 1958, now abandoned.

Filaments consisting of two or more components are known in the art. Such filaments are produced by extruding the different components from the spinneret in side-by-side relationship or in an eccentrically disposed sheath-core arrangement. The components usually are so selected that they have different shrinkage characteristics when the filament is heated in a relaxed state with the result that a crimped fiber can be produced. Yarns composed of these crimped or crimpable filaments have been found useful in producing yarns and fabrics having certain desired properties and aesthetic qualities. However, in the field of synthetic fibers produced from polymers such as the polyamides and polyesters it has not been possible to achieve the desired level of such properties and aesthetic appeal except in limited areas. Further improvements in the properties and aesthetics are very desirable. Particularly, a yarn of synthetic fibers having the aesthetic appeal and properties of silk fibers would be highly desirable in view of the other excellent functional characteristics of these synthetic fibers.

Much effort has been expended towards the preparation of yarns and fabrics that are silk-like from filaments of modern synthetic polymers. Although various proposed methods have duplicated one or more of the important characteristics of a silk fabric, a completely satisfactory substitute has not yet been found.

The desirability of producing textile filaments having one or more sharp longitudinal edges in order to produce silk-like yarns has long been recognized. Despite numerous proposals mainly drawn to extrusion orifice designs, it has not been feasible to produce textile filaments having sufficiently well defined sharp edges in cross-section by the extrusion of melts or solutions of fiber-forming polymers. This is due to the fact that the surface of a filament formed by extrusion through an orifice rapidly tends to assume the transverse cross-sectional contour of a circle, the smallest boundary for the given cross-sectional area.

It is accordingly one object of this invention to provide a synthetic textile filament which may be used to produce yarns and fabrics of greatly enhanced aesthetic appeal and improved properties.

Another object is to provide a synthetic textile filament which may be used to produce yarns and fabrics similar to silk in aesthetic quality.

A further object is to provide a process for the production of these filaments.

Other objects and advantages will become apparent from the examples and discussion to follow.

The above objects are accomplished by the provision of a composite filament comprising a first longitudinally extending component of one synthetic polymeric composition, and an adhering second distinct longitudinally extending component of another synthetic polymeric composition, said components closely fitted together along at least one contacting surface to form the composite filament, said contacting surface forming at least one longitudinally extending, sharp-edge configuration, said components having different shrinkage potentials when subject to heat and under certain conditions being readily separable along said contacting surface into separate filaments, at least one of which is provided with a longitudinally extending sharp-edge configuration. Preferably, in order to cause component separation to occur as desired, the average adhesion force between the contacting surfaces of the dry components is controlled and is in the range of about 13.0 g./cm. up to the force to draw the material of the weaker component. The component, which has the higher shrinkage has the higher denier.

In the accompanying drawings,

FIGURE 1 is an axial cross-section of a spinneret assembly used to prepare filaments of the present invention,

FIGURE 2 is a reduced transverse cross-sectional view of the assembly of FIGURE 1 taken at line 2—2 of FIGURE 1,

FIGURE 3 is a reduced transverse cross-sectional view of the FIGURE 1 assembly taken at line 3—3 of that figure,

FIGURE 4 through 7, 9, 10 and 13 are transverse cross-sectional views of examples of various filaments embodying the present invention,

FIGURE 8 is a transverse cross-sectional view of a single component element formed by the separation of a composite filament,

FIGURE 11 is an axial section of a modified version of a spinneret assembly used to prepare filaments of the invention,

FIGURE 12 is a transverse cross-sectional view of the assembly of FIGURE 11 taken at line 12—12, and

FIGURE 14 is an axial cross-sectional view of another version of a spinneret assembly used to prepare filaments of this invention.

The composite filaments of my invention, may be stretched and the resultant drawn filaments subjected to a shrinking treatment to produce filaments having a large number of crimps per unit length. The crimp in the filaments of this invention is brought about by a difference in shrinkage of the two components in the after treatment. The polyester component in a polyester-polyamide composite filament, when the drawn composite filament is subjected to shrinkage treatment, contracts to a greater extent than the polyamide component if the filaments have been cold drawn. This results in a distinct permanent helical crimp whereby the inner portions of the cross sections in the single coils are formed by the polyester. If the filaments are length stabilized as disclosed in my U.S. Patent 2,931,091, shrinkage treatment at moderate temperatures, i.e., about 100° C., would result in the polyamide shrinking to a greater extent than the polyester component and becoming the load-bearing component. However, at higher temperatures the shrinkage of the polyester component becomes greater so that the polyester component becomes the load-bearing element.

Although the crimped filaments described above may be used to produce yarns and fabrics of somewhat improved aesthetics, it is desirable that the filaments also are treated to separate the filament components. This results in the creation of filaments of significantly reduced denier and the separation is accomplished so that the low denier filaments produced have sharp edges, which in combination with the bulking effect due to differential shrinkage of the components results in novel improved silk-like yarns having a high level of aesthetic appeal and excellent functional qualities. In general and preferably, the polymers adhere well throughout processing of the side-by-side structures prior to the component separating step. The strength of the bonding between the components of the composite filaments depends to some extent on the particular polymers of the components. In the production of these structures, for instance from polyamide, polyester combinations, it has been found possible to separate or pull apart the components to produce filaments, either substantially polyamide or substantially polyester, which have very sharp boundary lines or surfaces. The shape of such structures depends on the location of the boundary between the two polymers and the composite and the shapes may be, for example, crescent or oval. Thus, while the components adhere well during the initial steps of drawing and winding of the yarn, they may be readily split apart by suitable treatment of the yarn, such as drawing under tension over a sharp edge with a significant change in direction of movement.

In accordance with one embodiment of the invention a composite filament having a substantially uniformly shaped transverse cross section along its length is composed of segments of at least two dissimilar synthetic polymeric compositions. This cross section is provided with at least two segments of at least one of said polymers, any contact between such segments of the same polymer being substantially point contact as extruded. This may be accomplished through the use of a spinneret assembly as more completely described below. After drawing as desired, the filament may be separated into its component sections by the desired action. Alternatively, all sections composed of one polymer composition are separated or removed as for example, by dissolution or chemical decomposition.

By the term "segment" is meant a portion of a filamentary transverse cross-section having at least one sharp point formed by the intersection, at a small acute angle, of two straight or curved lines, which are the boundaries of different polymer components. The segment may have: one sharp point such as in a tear-drop-shape as shown in **110** of FIGURE 9; two sharp points such as in a lens-shape as shown in **103** of FIGURE 5, or such as in the shape shown in **107** of FIGURE 7; three sharp points as in a plane triangle illustrated by segments **112** and **113** of FIGURE 10 or curvilinear triangle as shown in FIG. 8; or a multiplicity of sharp points such as in a figure formed by the joining of 2 or more simple segments as in a formée cross.

FIGURE 1 shows in axial section a spinneret assembly useful for this purpose. Front or bottom plate **1** with orifices **2** is recessed at the back about plateau-like protrusions **4**. Back or top plate **7** is sealed against and spaced from the front plate by gasket **6** and shim **16**. Relatively unconstricted region **12** between the two plates is interrupted at intervals by constricted regions **15** between the opposing face of the back plate and plateaus **5** of the protrusions from the front plate. The back plate is partitioned on top by outer wall **19** and inner wall **29** into annular chamber **8** and central chamber **9**. The annular chamber communicates with the constricted regions between the two plates through lead holes **31** and orifices **32**, and the central chamber communicates with the intervening relatively unconstricted region through holes **11**. The two plates are retained in place by cap **18** which is threaded onto the end of the back plate and is fixed to the front plate with set screws **17**. The upper part of the housing (not shown) receives suitable piping or other supply means for separate connection to the two chambers, which may constitute distribution or filtering spaces as desired. Pin **14** through cylindrical openings (opening **25** in the front plate and opening **26** in the back plate) near one edge of the plates ensures rotational positioning of the two plates.

FIGURE 2 shows a reduced view of the plan of the front plate. Appearing in this view are four plateaus, each concentric with an extrusion orifice and uniformly spaced about a circle inside the outer gasket. As shown in this view and in FIGURE 1, each orifice consists of capillary **21** at the exit end and larger counterbore **22** extending to the capillary from the plateau. Also visible, supported in a shallow annular groove, is gasket **6**, the opposing face of the back plate being similarly grooved to ensure a good seal between the two plates. FIGURE 3 shows a reduced view of the back plate sectioned as indicated on FIGURE 1. Visible are the concentric outer and inner walls, the capillaries and counterbores of four apertures spaced uniformly on a circle between the two walls, and four openings located within the central chamber defined by the inner wall. As shown in this view, the apertures in the top or back plate opposite the orifices of the bottom plate are each composed of four terminal capillaries **32** and introductory counterbore or lead hole **31**.

Operation of the described apparatus in the practice of this invention is readily understood. Different polymer compositions are supplied to the inner and the outer chambers, respectively, of the back plate; the former flows through the openings into the relatively unconstricted space between back and front plates, through the relatively constricted regions between the plateaus and the opposing plate face, and through the extrusion orifices while the latter passes first through the apertures in the back plate and directly onto the top of the plateau and then through the aligned orifices in the front plate.

In the preparation of side-by-side structures a spinneret such as that shown by FIGURES 11 and 12 also may be used. The spinneret shown is composed of two parts. In the upper portion **216** are two chambers **217** and **218** cooperating with holes **219** in the bottom plate of the top portion. These holes permit the feeding of polymer to grooves or recesses **220** in the bottom portion **221** of the spinneret. The polymer coming from hole **219** goes into the recess **222** immediately below it and is fed to a plurality of recesses **220**. Each recess contains and cooperates with a spinneret hole **224**. In each spinneret, provision is made for a gasket **225** and conventional means, as by bolting or pressure, can be used to hold the various spinneret elements in place during operation. In this arrangement polymer coming from chamber **217** and the other polymer coming from chamber **218** meet at the orifices **224** and are extruded simultaneously to form side-by-side structures. Cross sections of such structures are indicated in FIGURE 13 by reference numeral **226**.

A spinneret of the type shown in FIGURE 14, in which two polymeric compositions are fed through converging channels to spinneret orifices **340** located in bottom plate **331** may be used to form the filaments of this invention. The two polymeric compositions are fed separately from annular channels **333** and **334**, respectively, which are positioned in top plate **332**, into channel mouths **335** and **336**, respectively. The polymer streams are advanced through the channels to positions **337** and **338** and are then simultaneously extruded through the orifices to form side-by-side structures.

The following examples are given to illustrate applicant's invention and are not to be considered as limiting in any sense.

EXAMPLE I

Side-by-side composite crimped filaments were produced from the poly(hexamethylene adipamide) and poly(ethylene terephthalate). The polymers were melted separately and the melts were led separately to the holes of the spinneret similar to that described by FIGURES 11 and 12, with the exception that instead of a grouping of five channels-five orifices as shown in FIGURE 12 a grouping of four channels-four orifices was used with the orifices being all close to the center line rather than being staggered as shown in FIGURE 12. The filaments were attenuated by winding them up at about 100 times the speed with which they leave the spinneret. They were then cooled by a transverse stream of air. The composite filaments thus obtained were drawn over two sets of cold rolls whereby the second pair was driven at a circumferential speed being 3.0 times as high as of the first pair. When the drawn filaments were placed in boiling water, the filaments crimped spontaneously. The crimped filaments had, on an average, 80 crimps per inch and a crimp permanence of 95%.

Sometimes it might be desirable to spin through one spinneret a bundle of filaments which comprises composite filaments containing the components in various ratios. Such a bundle of two-component composite filaments may comprise, for example, filaments consisting of 20% by weight of the polyamide and 80% by weight of the polyester, 30% of the polyamide and 70% of the polyester, 40% of the polyamide and 60% of the polyester, and 50% of the polyamide and 50% of the polyester. Such filament bundles containing composite filaments with various ratios of components have, after crimping, unique properties and have special applications, especially in the field of producing worsted fabrics from continuous crimped filaments. They can very conveniently be produced by utilizing the spinneret which is shown by FIGURES 11 and 12. In FIGURE 12 it will be noted that the orifices **224** are staggered. The pressure on the melts in the first instance is the same, but where the paths from chamber **217** and from chamber **218** to a given spinneret differ in length a difference in pressure on the respective polymers at the orifices will occur because the difference in pressure drops. Thus, at those orifices nearest the feed side supplied by chamber **217** a filament will be extruded which contains more of the polymer coming from chamber **217** than of the polymer coming from chamber **218**. Conversely, more polymer coming from chamber **218** will appear in filaments coming from orifices located near chamber **218**, these filaments having less of the polymer coming from chamber **217**. These filament bundles obtained contain the polyamide and the polyester in the various ratios. After drawing these filaments as described, and placing them in the boiling water, a yarn of crimped continuous filaments is obtained which has desirable properties due to the fact that the single composite filaments in the bundle show varying degrees of crimp tightness and extensibility.

These filaments varied in polyamide/polyester amounts some being in 20/80, 40/60, 50/50, 30/70 ratios, respectively, for example. Typical cross-sections of such filaments are shown in FIGURE 13 wherein **227** designates polyamide and **228** designates polyester.

EXAMPLE II

Side-by-side composite filaments were prepared from poly(hexamethylene adipamide) having a relative viscosity of 40 in cresol and poly(ethylene terephthalate) having a relative viscosity of 29 in a solution of trichlorophenol (7 parts) and phenol (10 parts) following the general procedure of Example I. A spinneret of the type shown in FIGURE 14 was employed. The two polymers were fed to the spinneret holes **340** in ratio by weight of 37% polyamide and 63% polyester. The composite filaments had trilobal cross-section of the type disclosed in U.S. Patent 2,939,201. The filaments are attenuated by winding them up at about 500 times the speed at which they leave the spinneret. The filaments were air quenched and drawn to a ratio 3.7 over a 90° C. pin and wound into a package in the conventional manner. The final drawn yarn consisted of 26 filaments of 2.7 denier each, the polyamide component being 1.0 denier and the polyester component 1.7 denier. When the yarn is placed in hot water in a relaxed state without agitation, the filaments crimp. The filaments, in fabric form, were split apart by suitable mechanical action and heat set at 400° F. A fabric made of such separated-component filaments was characterized by a warm, soft hand, good resilience, a non-synthetic subdued luster, high bulk, high cover and excellent uniformity of dyeing despite being made of polymers of different dyeing characteristics. In addition, the fabric highly resembled silk in aesthetics. The cohesion between the polyester and polyamide components in the filaments can conveniently be determined by cutting about 8 cm. lengths of the filaments, splitting the components apart at one end by flexing the end, or if necessary by immersing the end in a swelling agent for one of the components, e.g., a 5% aqueous formic acid solution, attaching one of the split apart components to a sensitive strain gage and the other component end to a rod which is drawn away from the strain gage at a constant rate of 2.4 cm./min. The force required to pull the components apart is recorded by an electronic recorder attached to the strain gage. The strain gage employed was a Statham Instrument Company gage having a range of ±0.15 oz. The signal from the gage was fed to a preamplifier, then to an amplifier and finally to a conventional Sanborn recorder. The rod to which one of the component ends was attached was floated in a horizontal position in a container of water by means of two corks. A filament or strand of yarn was attached to one end of the rod and the other end of the yarn passed around a small motor driven roller to drawn the rod away from the strain gage at a slow, constant rate of 2.4 cm./min. To compensate for differences in denier and cross-sectional shape, the length L of the interface between the adhered components of the composite filament is determined and the measured force, F, divided by this value. This length L is measured on a photomicrograph taken at high magnification of a transverse cross section of the composite filament by rolling a map reader along the clearly visible line at the interface of the different components.

Since the measured force varies as the composite filament is split apart, the percentages of the filament length which split within given ranges of force are multiplied by the mean force for each range and the sum of these values divided by 100 to obtain the average force required to split the filament. In carrying out this operation the ranges shown in the following table were employed. The values shown in the first column in the following table for percent splitting are averages of values obtained on 17 filaments. Likewise, the interface length L used in the calculation was the average for the same 17 filaments. The values of Tables I and II correspond to filaments of a highly satisfactory nature and performance according to this invention, whereas the values of Table III correspond to filaments approaching unsatisfactory nature and performance.

Table I

Percent Split	Range, g./cm.	Mean, g./cm.	Percent Split× Means	Avg., g./cm.
21.7	0–3	1.5	33	
16.1	3–6	4.5	73	
24.2	6–12	9.0	218	
10.2	12–18	15.0	152	
10.6	18–24	21.0	222	
6.4	24–36	30.0	192	
3.3	36–48	42.0	138	
2.2	48–72	60.0	132	
2.7	72–144	108.0	292	
2.6	144–170	141.0	353	
100.0			1,805	18

Table II

Percent Split	Range, g./cm.	Mean, g./cm.	Percent Split× Means	Avg., g./cm.
16.2	0–3	1.5	24	
15.3	3–6	4.5	69	
20.5	6–12	9.0	185	
11.6	12–18	15.0	174	
5.0	18–24	21.0	105	
6.5	24–36	30.0	195	
3.5	36–48	42.0	147	
2.4	48–72	60.0	144	
7.6	72–144	108.0	820	
5.6	144–200	172.0	962	
5.8	200–250	225.0	1,310	
100.0			4,137	41.4

Table III

Percent Split	Range g/cm.	Mean, g/cm.	Percent Split × Means	Avg., g/cm.
46.0	0–3	1.5	69	
15.9	3–6	4.5	72	
15.1	6–12	9.0	136	
7.5	12–18	15.0	112	
3.3	18–24	21.0	69	
4.4	24–36	30–0	132	
1.9	36–48	42.0	80	
2.7	48–72	60.0	162	
3.2	72–95	84.0	268	
100.0			1,000	10.0

An average cohesion value of at least about 13 g./cm. was determined to characterize satisfactory samples of preferred yarns tested. These values were determined in the manner described above.

The fabric made from the yarn was judged to be more silk-like in aesthetics than any synthetic fabric available, including fabrics with trilobal filament cross-sections and mixed shrinkage, filaments. The fabric had a combination of a warm, soft hand; good resilience and a non-synthetic, subdued luster. In addition the fabric had high bulk and cover and excellent uniformity of dyeing in spite of the fact that it was made up of polymers which dyed differently.

The fabric was subjected to 15 wash cycles along with nylon and Du Pont "Dacron" polyester fiber controls and evaluated after each fifth wash. The fabric made from the filaments of this invention was found to be superior to nylon in launderability and about equivalent to 100% "Dacron" fabrics which are well known for their excellent performance.

EXAMPLE III

Example II was repeated except that the composite filaments were of 4 denier each, the poly(ethylene terephthalate) and poly(hexamethylene adipamide) components each being 2 denier. The fabric made from this yarn had good bulk and cover but lacked the warmth, softness, and luxurious handle exhibited by the fabric of Example II.

EXAMPLE IV

A spinneret similar to that shown in FIGURES 1 to 3 with 17 orifices was constructed. The plateau 4 was ⅛ inch in diameter and 1/16 inch high. The counterbore **22** was 40 mils in diameter and extended to within 48 mils of the face of the spinneret. The capillary **21** had a diameter of 12 mils. The lead hole **31** in the upper plate 7 was 3/32 inch in diameter and was drilled to within 94 mils of the bottom of plate 7. The upper orifices 32 were 9 mils in diameter and were drilled on a circle having a 39.5 mil radius the center of which was concentric with the upper lead hole and with the plateau in the orifice in the lower plate. The spinneret was assembled with a 3 mil thick shim **16**.

Poly(hexamethylene adipamide) of η_r (relative viscosity) 36 in 90% formic acid at 25° C. was fed to chamber 9 of the spinneret and extruded to form the triangular segments of the filament and poly(ethylene terephthalate) of η_r 33 in a 7/10 mixture of tetrachlorophenol/phenol at 30° C. and containing 0.3% of TiO_2 was fed to annulus 8 and then through orifices 32 to form the formée cross segment of the filament's cross-section. The two molten polymers were extruded in the ratio of 9.5/10.0 by volume respectively at 290° C. and the yarn wound up at 1,000 y.p.m. The yarn was drawn 4× over an 88° C. pin and then passed over a 140° plate to reduce shrinkage. A cross-section of a typical filament is shown in FIGURE 7. The yarn had a tenacity of 3.9 g.p.d., an *Mi* (initial modulus) of 53, an ultimate elongation of 32% and a total denier of 50.

The yarn was knitted into a tubing which was quite lean in appearance and had poor visual covering power. The tubing was extracted for 3 hours with 98% formic acid in a Soxhlet extractor, removed, rinsed with water and dried. Despite the loss of about 50% of the fiber weight by dissolution of the polyamide sectors the visual covering power of the tubing was greatly increased. The extracted tubing had a soft silk-like handle and was scroopy. The cross-section of filaments remaining in the extracted fabric resembled a formée cross as shown in **103** of FIGURE 7.

EXAMPLE V

Using the same spinneret as in Example IV, poly(ethylene terephthalate) of η_r 26.9 in a 7/10 mixture of tetrachlorophenol/phenol at 30° C. and containing 0.3% of TiO_2 was fed to chamber **8** of the spinneret and extruded as the segments of a composite filament designated **101** in FIGURE 4 while poly(hexamethylene adipamide) of η_r 36 in 90% formic acid at 25° C. was fed to chamber **9** and extruded as the segments of a composite filament designated **102** in FIGURE 4. The polymers were extruded at 290° C. and the yarn wound up at 400 y.p.m. The yarn was drawn 4.3× over a 98° C. pin. The resulting yarn had a tenacity of 4.1 grams per denier, an initial modulus of 56 and had a denier per filament of 8.3. A portion of the drawn yarn was wound on a perforated metal bobbin and immersed in cold 98% formic acid for 3 hours. After rinsing and drying the residual polyester yarn had a tenacity of 3.8 g.p.d., a *Mi* of 73, an ultimate elongation of 28% and a total denier of 80 for the 68 filaments then present. A typical cross-section of a filament is shown in FIGURE 8.

A portion of the original yarn was woven into a 2 x 2 twill fabric having 120 yarns per inch in the warp and 84 yarns per inch in the filling. The resulting fabric was immersed in 98% formic acid for 60 minutes until the poly(hexamethylene adipamide) sectors were dissolved from the composite filaments. The fabric possessed all of the properties of a silk fabric as liveliness and drape, the subtle scroop of silk, the handle, the low denier per filament, the high modulus and good recovery properties.

A repetition of the above spin with positions of the two polymers changed gives filaments which after treatment with formic acid leaves fillet-shaped sectors of the polyester similar to segment **102** of FIGURE 4.

EXAMPLE VI

The following example illustrates the different cross-sections obtained by varying the volume of polymers delivered to various sectors of the composite filaments. Using the spinneret of Example IV with a three mil shim, poly(ethylene terephthalate) of η_r 28.1 in a 7/10 mixture of tetrachlorophenol/phenol at 30° C. and containing 2.0% of TiO_2 was fed to chamber **8** of the spinneret and poly(ethylene terephthalate) of η_r 31 in 90% formic acid at 25° C. fed to chamber **9**. The polymers were extruded at 290° C. and the yarn wound up at 1,000 y.p.m. The volume of the two polymers entering the composite filaments were varied by adjustment of their respective constant displacement pumps. In the first spin the volumes of the pigmented polymer to the non-pigment polymer was 1:1 and filaments were obtained having cross-sections similar to that shown in FIGURE 4. When the ratio of pigmented to bright polymer was set at 4/16, filaments with cross-sections similar to FIGURE 5 were obtained. When the pumps were adjusted to give a ratio of 16/4 as above cross-sections similar to FIGURE 6 were obtained.

The above spins are repeated replacing the unpigmented polyester with the copolyester poly[ethylene/poly(ethylene oxide glycol terephthalate] with a composition of 80/20 by weight, the poly(ethylene oxide) glycol units having a molecular weight of 6,000. Upon immersing the yarns in a hot 5% solution of NaOH the segments corresponding to **102**, **104**, **106** in FIGURES 4, 5, and 6 are dissolved and residual cross-sections of poly(ethylene terephthalate) corresponding to **101**, **103**, **105** in FIGURES 4, 5, and 6 remain in the respective yarns.

EXAMPLE VII

Using the apparatus and polymers of Example IV, the positions of the two polymers were reversed. The polyester and polyamide were extruded at 290° C. at a ratio of 12/16 by volume respectively and the composite filaments wound up at 500 y.p.m. The yarn was drawn 4.2× over a 100° C. pin. A typical cross-section of the drawn filament is shown in FIGURE 9. A portion of a yarn was wrapped on a perforated metal tube and immersed in acetone for 5 minutes. The dried yarn was pulled over the edge of a glass microscope slide under a tension of about 0.5 g.p.d. so that the yarn suffered a 90° change of direction in the process. The above process caused the filament to partially fragment longitudinally along the interfaces of the sectors. A total of three passages of the yarn over the sharp edge caused complete separation of the polyester and polyamide segments so that the yarn was composed of filaments which in cross-section resembled **110** and **111** of FIGURE 9.

The composite filaments in the above drawn yarn were also completely separated into the polymeric components by one passage through an air jet as described in U.S. Patent No. 2,783,609 at a feed rate of 50 y.p.m. and a windup rate of 48 y.p.m. using two cu. ft. of air per minute at 90 p.s.i. to operate the jet.

A portion of the above-drawn yarn not exposed to acetone or fragmented was wound on a perforated metal tube and placed in 98% formic acid at the boiling point for 30 minutes. The tube and yarn was then placed in cold formic acid for an additional 15 minutes, rinsed with water and dried. The residual polyester filaments, which in cross-section resembled segment **110** of FIGURE 9, had a tenacity of 3.6 g.p.d., an ultimate elongation of 31%, a M*i* of 63, and a denier per filament of 1.0. The yarn was used as a filling face in the weaving of a satin with yarn of round cross-section, poly(ethylene terephthalate), as a warp. The fabric had a dry, crisp, silk-like handle across the filling band but was less silk-like than the fabric of Example I.

EXAMPLE VIII

Using the apparatus and polymers as in Example VII composite filaments are extruded and the continuous filaments wound up at 500 y.p.m. The yarn is dipped in acetone and then drawn 2× over a pin at 88° C. The segments of polyester break and split during drawing so that a yarn somewhat resembling a yarn spun from staple fibers is obtained in which the bundle of cruciform-like filaments of polyamide in cross-section have the broken short lengths of polyester microfibers substantially evenly randomly interposed and engaged therewith which project laterally beyond the original periphery of the filaments.

EXAMPLE IX

Solutions of polyacrylonitrile and cellulose acetate, both in dimethylformamide are dry spun from the spinneret of Example IV. The resulting filaments in cross section have alternate segments of the two polymers with a crenulated periphery. An acetone bath dissolves the cellulose acetate portions of the filaments and leaves small denier filaments of polyacrylonitrile of shape similar to FIGURE 8.

EXAMPLE X

Linear polypropylene having a melt index of 9 and poly(hexamethylene adipamide) having a relative viscosity of 39 were extruded in equal proportions by weight following the general procedure of Example II. The filaments were drawn to a ratio of 2.7, the drawn yarn consisting of 34 filaments having a denier of 2.53 each. The filaments were treated as in Example II except that the

heat setting step was omitted. The filaments which were round in cross-section were split by suitable mechanical action into elliptical polyamide filaments and crescent shaped linear polypropylene filaments. The fabric made of such separated component filaments had excellent bulk and cover and was similar to a fine cotton fabric in hand.

The composite filaments have been produced in the examples by the melt spinning technique. Obviously, other spinning methods like "plasticized melt" spinning, dry spinning, wet spinning, can be employed successfully. In some instances, particularly when the melting behavior or the solubility of the components in a combination would not permit spinning the components by similar methods, a combination of dissimilar methods can be used. Thus, for instance, one component, can be spun as a solution in a high boiling solvent or as a plasticized melt, while the other component is extruded as a molten polymer. In these instances, the solvents or plasticizers may be wholly or partially removed subsequently, preferably by washing them out by the help of low boiling solvents.

The composite filaments illustrated in many of the examples of this invention have substantially, smoothly rounded cross-sections before separating of the components. Others have trilobal shapes. However, it will be apparent to those in the art that by altering the shape of the orifice, the final cross-section can be controlled to a certain extent. Although square filaments cannot be extruded, filaments in cross-section which resemble a square with rounded corners can be obtained by the use of square or slotted orifices and these in turn would offer segments that are plane triangles or a combination of plane and curvilinear triangles for example. Similarly, cross-sections in the shape of ellipses, cruciforms, etc., can be extruded and segments placed in such filaments as desired. Generally, by smoothly rounded cross sections, a cross section being free from sharp points and edges is intended.

It will also be obvious to those skilled in the art that other modifications of the composite filaments and hence of the shape of the residual filaments after dissolution can be altered by changing the number and placement of the upper orifices **32** (FIGURE 1). Other means of altering the configuration of the composite filaments will be by varying the diameters of the upper orifices used in relation to the size of the plateaus, and/or the rate at which polymers are extruded through the upper orifices **32** and over the plateau. Alteration of the viscosities of the component polymers affects the configuration obtained. A low viscosity polymer tends to be pushed inward more readily by the flow of a more viscous polymer and hence alters the shape of the segment that it will make. The configuration in the component filaments is also affected by the interfacial tension and the individual tendencies of the polymers to set the spinneret surfaces.

Although the spinneret used in the examples is a convenient apparatus for the preparation of the filaments of this invention it will be obvious to those skilled in the art that other spinnerets can be used. Other spinnerets permit the production of filaments or ribbons having alternating segments as shown in FIGURE 10 which can be split or dissolved apart to give sharp edged filaments.

The process of this invention affords a convenient means of obtaining filaments having one or more sharp points in transverse cross-section and of a lower denier than can be otherwise attained. Thus, the invention permits the production of sharp-edged filaments having a denier of 0.1 to 10 or larger. Its greatest utility, however, is in the range of 0.1 to 5 denier per filament. The novel filaments and yarns can be used to obtain new and improved effects in fabric handle, scroop, appearance and covering power by proper selection of the polymer composition and filamentary cross-section.

Suitable pairs of components for use in this invention can be found in all groups of synthetic fiber-forming materials. Where it is desired to separate the filament into its component sections by mechanical action, the components should have low adhesion to each other. Obviously, this is not necessary where one component of the pair is to be removed by dissolution or chemical decomposition. Because of their commercial availability, ease of processing and excellent properties, the condensation polymers and copolymers, e.g., polyamides, polysulfonamides and polyesters and particularly those that can be readily melt spun are preferred for application in this method. Suitable polymers can be found for instance among the fiber-forming polyamides and the polyesters which are described in such patents as U.S. Patents 2,071,250; 2,071,253; 2,130,523; 2,130,948; 2,190,770; and 2,465,319. The preferred group of polyamides comprises poly(hexamethylene-adipamide), poly(hexamethylene sebacamide), poly(epsilon-caproamide) and the copolymers thereof. Suitable polyesters, besides poly (ethylene terephthalate), are the corresponding copolymers containing sebacic acid, adipic acid, isophthalic acid as well as the polyesters containing recurring units derived from glycols with more than two carbons in the chain, e.g., diethylene glycol, butylene glycol, decamethylene glycol and trans-bis-1,4-(hydroxy methyl)-cyclohexane.

Other groups of polymers useful as components in filaments of the present invention can be found among the polyurethanes, the polyureas, cellulose esters and cellulose ethers as well as among the polyvinyl compounds including such polymers as polyethylene, polyacrylonitrile, polyvinyl chloride, polyvinylidene chloride, polyvinyl alcohol, and copolymers containing the monomers of these polymers and similar polymers as disclosed in U.S. Patents 2,601,256; 2,527,300; 2,456,360; and 2,436,926.

When it is desired to remove all sections composed of one polymer composition by dissolution, a solvent for such polymer is selected that will not dissolve or have an adverse effect on sections composed of other polymer compositions. Thus, as illustrated in Example IX, formic acid may be used to remove the polyamide sections from the filament having both polyester and polyamide sections in its cross-section. The extent of dissolution of the soluble portion can be controlled as desired.

Similarly, all sections composed of one polymer composition can be removed by chemical decomposition. Thus, polyester sections of a polysegmented filament having alternate polyester and polyamide sections, would be degraded by treatment with hot caustic as would the copolyamide or polyurea portions of polysegmented filaments having copolyamide-polyacrylonitrile or polyurea-polyacrylonitrile alternating sections by treatment with mineral acids.

The preferred filaments for the production of improved silk-like yarns of improved aesthetics and properties are the two component filaments in which the two components adhere sufficiently during the spinning and drawing of the yarn but may be later split into individual components when the adhesive bond holding the filament components together is broken or one of the components is dissolved away. For this purpose the polyamide-polyester combinations are most suitable. These filaments have the advantage that the as-spun yarn is of sufficiently high denier so that it is easily handled, while the benefits of much lower denier, finer filaments are realized in the final yarn due to the splitting or separation of the filament component. In addition, differential shrinkage provides bulk and cover in the yarn.

In producing silk-like yarns the denier of the lower shrinkage component should be lower than that of the higher shrinkage component and the denier of the lower shrinkage components should preferably be no higher than 1.8. The denier of the higher shrinkage component preferably should be higher than that of the lower shrinkage component in order to provide the desired resilience in the yarn. However, if both components basically have high resilience this is not necessary. The shrinkage referred to here is the shrinkage encountered in heat setting of fabric.

The yarn of Example VIII is believed to have valuable uses in the production of improved fabrics having high bulk, cover, the scroop and hand of high quality fabrics.

The preferred filaments for making silk-like yarns have the characteristic that they crimp when subjected to boiling water and can be split when subjected to sufficient mechanical working. For producing yarns for this type, the polyester-polyamide combination is most suitable.

In order that the preferred composite filaments perform satisfactorily during spinning and drawing, and yet are substantially separated easily by suitable mechanical action into individual components, the average adhesion force between the dry filament components should preferably be at least 13 g./cm. and obviously can be no higher than the force to draw the weaker material of the two components.

The difference in shrinkage between the different components of the filament should be at least 1% in order to provide the necessary bulk and cover in fabrics. For the production of silk-like yarns, the differential shrinkage should be in the range of about 1 to 8% preferably 2 to 5%. As indicated above the difference in shrinkage refers to the difference realized in the complete heat treatment of the filaments, which may include a boiling water treatment and a heat setting treatment.

In accordance with the requirements of the Patent Laws, I have described various embodiments of my invention. Modifications and other embodiments may occur to those skilled in the art and such of these as fall within the spirit of my invention are intended to be covered by the following claims.

I claim:

1. A unitary spun composite filament having a substantially uniformly shaped transverse cross-section along its length with a smoothly rounded contour, said filament comprising a first longitudinally extending component of substantially uniformly shaped cross section along its length of one synthetic polymeric composition, and an adhering second distinct longitudinally extending component of substantially constant cross section of another synthetic polymeric composition, said components closely fitted together along at least one contacting surface to form the composite filament, said contacting surface forming at least one longitudinally extending sharp-edge configuration, said adherent components readily separable along said surface into separate independent filaments at least one of which is provided with a longitudinally extending sharp-edge configuration.

2. The composite filament of claim 1 in which the component provided with the sharp-edge configuration has a denier in the range of about 0.1 and 5.0.

3. The composite filament of claim 2 in which one of said components is of a poly(ethylene terephthalate) composition and said other component is of a poly(hexamethylene adipamide) composition.

4. The composite filament of claim 2 in which said component provided with the sharp-edge configuration is of a polyacrylonitrile composition.

5. A unitary spun composite filament having a substantially uniformly shaped cross section along its length with a smoothly rounded contour, said filament comprising a first longitudinally extending component of substantially uniformly shaped cross section along its length of one synthetic polymeric composition, said one composition being insoluble in a given solvent, and an adhering second distinct longitudinally extending component of substantially uniformly shaped cross section along its length of another synthetic polymeric composition said another composition being soluble in said given solvent, said components spun together and closely fitted along at least one longitudinally extending contacting surface to form the composite filament, said first component comprising a plurality of substantially parallel axially extending

portions in contact with each other along longitudinally extending lines, said components spun together in fitting relationship along at least one longitudinally extending contacting surface, said contacting surface forming at least one longitudinally extending sharp-edge configuration, said components readily separable along said surface and said portions of said first component readily separable along said longitudinally extending lines to form a plurality of filaments each having at least one longitudinally extending sharp-edge.

6. The filament of claim 5 in which said second component is readily separable from said first component by subjecting the composite filament to the action of said given solvent.

7. The composite filament of claim 1 in which said one component is a poly(ethylene terephthalate) composition and said other component is a poly(epsilon caproamide) composition.

8. The composite filament of claim 1 in which one of said components is of a linear polyester composition and said other component is of a linear polyamide.

9. The composite filament of claim 1 in which one of said components is of a linear polyhydrocarbon composition and the said other component is of a linear polyamide composition.

10. The composite filament of claim 1 in which one of said components is of a linear polyester composition and said other component is of a linear polyhydrocarbon composition.

11. The composite filament of claim 1 in which the average level of adhesion forces between said components is at least 13 g./cm. but less than the force required to draw either of said components.

12. The composite filament of claim 5 in which said component having the sharp-edge configuration has a denier of from about 0.1 to about 5.0.

13. A unitary spun composite filament having a substantially uniformly shaped cross-section along its length with a smoothly rounded contour, said filament comprising a first longitudinally extending component of one synthetic polymeric composition, and an adhering second distinct longitudinally extending component of another synthetic polymeric composition, said components closely fitted together along at least one contacting surface to form the composite filament, said contacting surface forming at least one longitudinally extending sharp-edge configuration, said adherent components readily separable along said surface into separate independent filaments at least one of which is provided with a longitudinally extending sharp-edge configuration, one of said components itself being additionally readily fracturable and separable into a plurality of disconnected short lengths along its length.

14. The composite filament of claim 13 in which said components thereof have substantially uniformly shaped transverse cross sections along their lengths.

15. A yarn comprising a uniformly randomly intermixed plurality of filaments, said plurality of intermixed filaments comprising a first group of one synthetic polymeric composition and a second group of a second synthetic polymeric composition, said filaments of said first group of a continuous unbroken length throughout said yarn and having a substantially constant irregular transverse cross section of a given size, substantially all of said filaments of said second group broken into short lengths having a substantially constant sharp-pointed transverse cross sections of a size significantly reduced relative to the size of said cross section of said first group of filaments, the transverse cross-sectional configurations of said filaments such that a given predetermined number of each group can be fitted together in a complementary geometric pattern to form a composite bundle pattern of substantially rounded transverse cross-sectional form.

16. The yarn of claim 15 in which said filaments of said first group are of a linear polyamide composition and said filaments of said second group are of a linear polyester composition.

17. The yarn of claim 15 in which said filaments of said second group have a denier of from about 0.1 to about 5.0.

18. The yarn of claim 15 in which said filaments of said second group are adhered to said filaments of said first group over a first portion of their lengths and the second portion of said second group filaments are separated from the other filaments and extend irregularly in a direction transversely of the other filament and yarn axes.

19. The filament of claim 1 wherein one of the said components is broken at frequent intervals along the length thereof, the broken component being separated from the unbroken component for a short distance adjacent each break, the ends of the said separated, broken component extending transversely of the unbroken component to form fibrous protrusions along the length of the filament.

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