US 20050241745A1

(19) **United States**

(12) **Patent Application Publication**
Bansal

(10) **Pub. No.: US 2005/0241745 A1**

(43) **Pub. Date: Nov. 3, 2005**

(54) **PROCESS FOR MAKING FINE SPUNBOND FILAMENTS**

(76) Inventor: **Vishal Bansal**, Richmond, VA (US)

Correspondence Address:
E I DU PONT DE NEMOURS AND COMPANY
LEGAL PATENT RECORDS CENTER
BARLEY MILL PLAZA 25/1128
4417 LANCASTER PIKE
WILMINGTON, DE 19805 (US)

(21) Appl. No.: **10/837,956**

(22) Filed: **May 3, 2004**

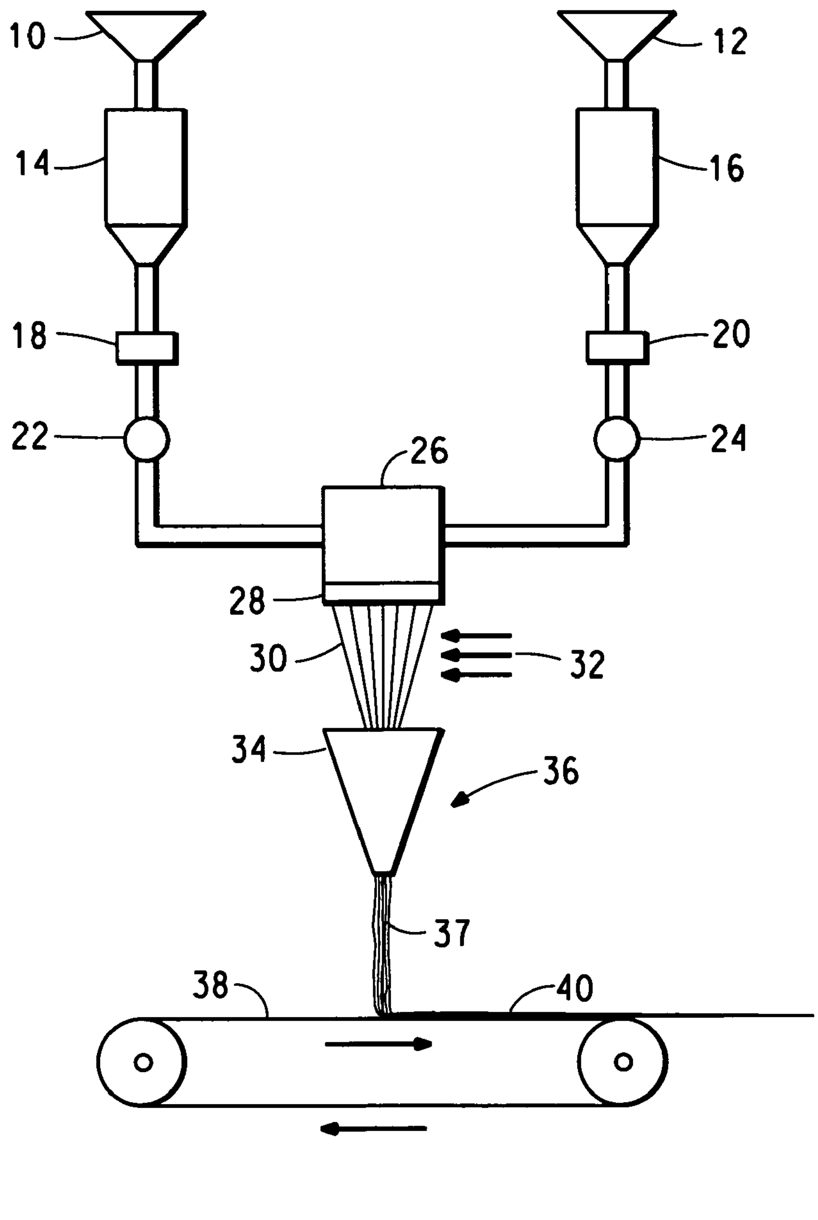
Publication Classification

(51) Int. Cl.[7] **D04H 3/16**

(52) U.S. Cl. **156/167**; 156/433

(57) **ABSTRACT**

A method is provided for preparing webs of spunbond fibers having reduced diameter. The spunbond fibers can be single component fibers or multiple component fibers having a symmetric cross-section, or combinations thereof. The fibers are re-heated and drawn in a secondary drawing step after quenching to provide fibers having at least a 5% reduction in average fiber diameter compared to fibers that have not been re-heated and drawn in a secondary drawing step.



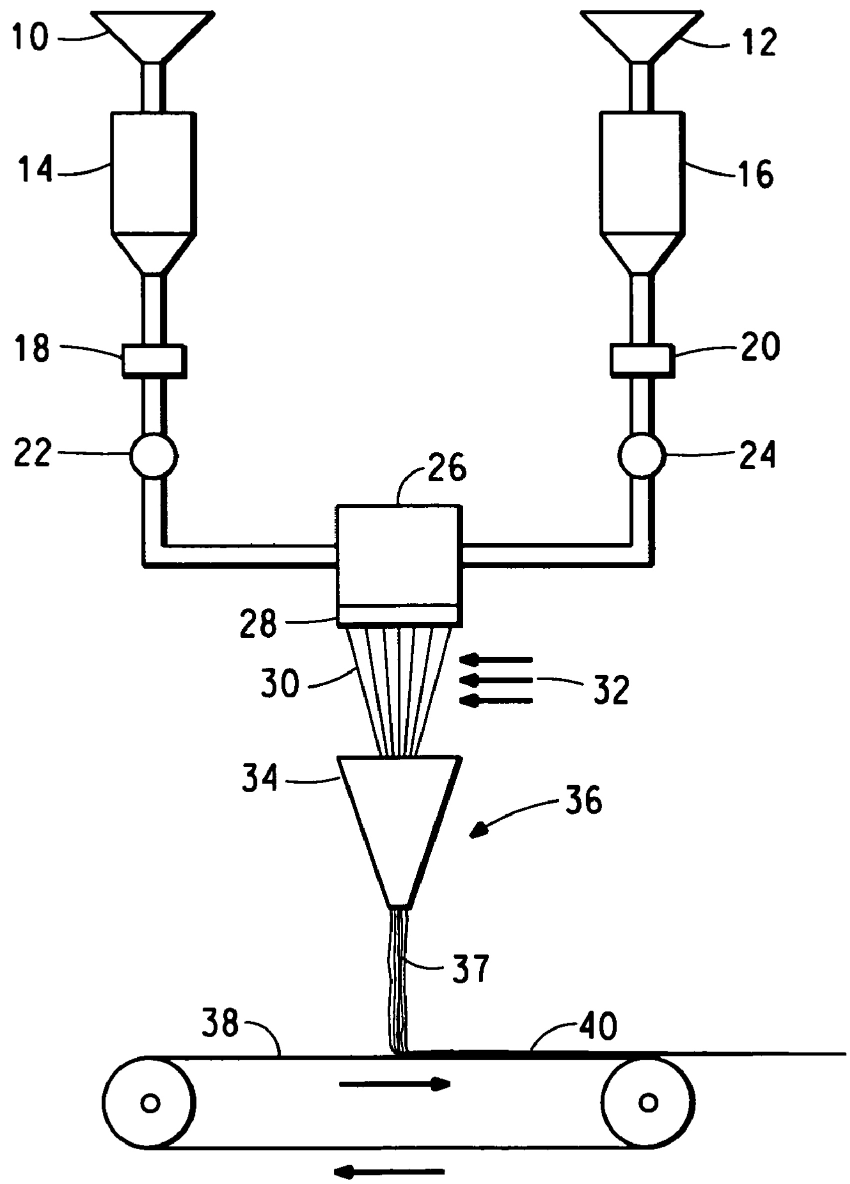


FIG. 1

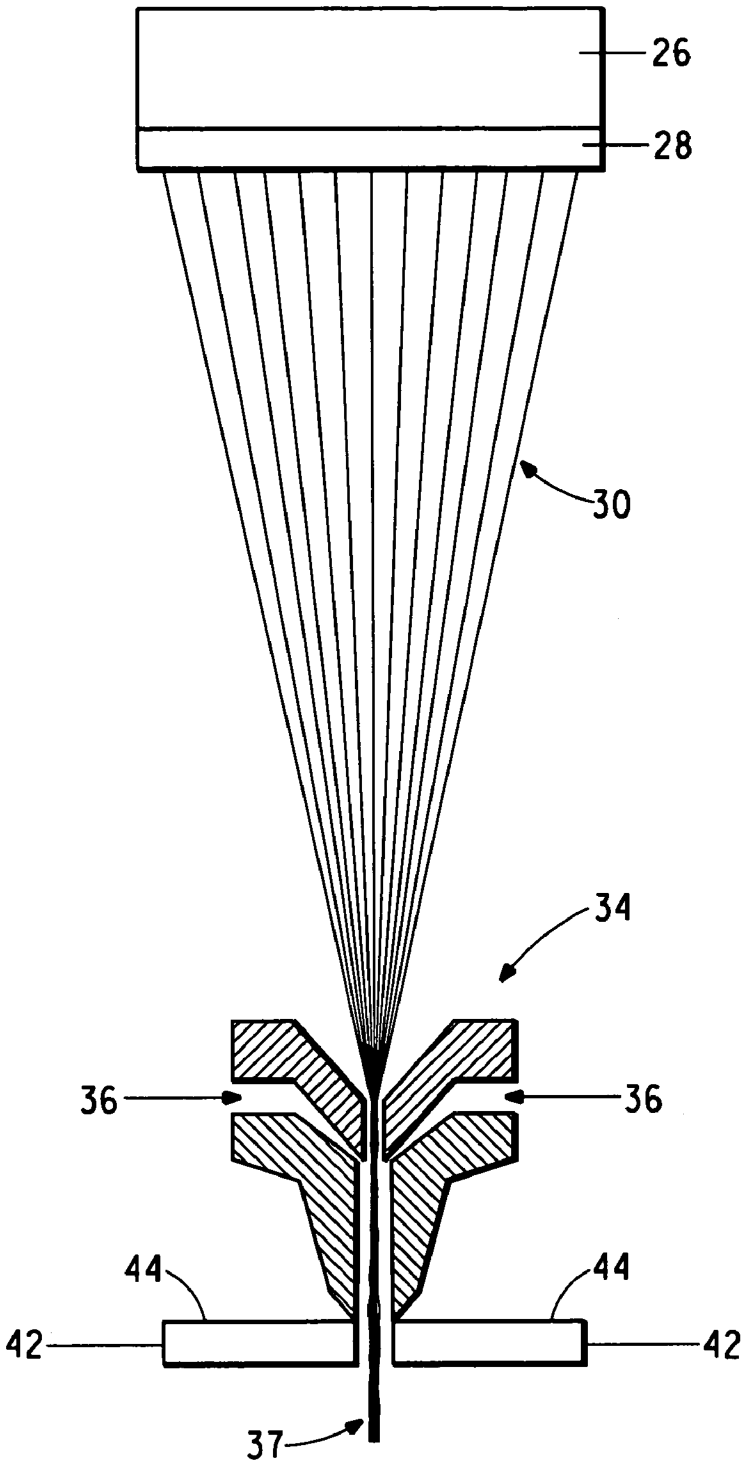


FIG. 2

PROCESS FOR MAKING FINE SPUNBOND FILAMENTS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a method for forming spunbond filaments having reduced diameters.

[0003] 2. Description of the Related Art

[0004] In conventional spunbond methods, one or more extruders supply molten polymer to a spin pack in which the polymer is spun through openings to form a curtain of filaments. The filaments are partially cooled in an air quenching zone and generally pass through a pneumatic jet prior to being laid down on a moving belt, scrim, or other fibrous layer. The tension applied to the fibers by the pneumatic jet causes them to be drawn near the spinneret face to reduce the fiber size and to increase fiber strength. Spunbond fibers generally have a diameter greater than about 5 micrometers. The fiber diameter can be reduced by lowering the polymer throughput per hole, increasing the pneumatic draw jet pressure, reducing the spin-line distance (distance between the exit of the polymer capillaries in the spinneret and the entrance of the pneumatic jet), lowering the polymer viscosity, and general optimization of the spinning process. However, such methods are limited by the degree of reduction in fiber diameter that can be achieved due to process instabilities that can occur as a result of these approaches. For example, the frequency of spinning defects such as polymer drips and broken filaments can increase, which is unacceptable in a commercial spunbond process. In addition, reducing the throughput per hole has a negative impact on process economics. Reducing the polymer viscosity can have a negative effect on other fiber properties such as fiber strength.

[0005] U.S. Pat. No. 6,379,136 to Najour et al. describes an apparatus for preparing sub-denier spunbond nonwovens comprising a two-sided multilevel quench system and a vertically moveable draw jet assembly with adjustable primary and secondary jet-nozzles and a variable width draw jet slot. U.S. Patent Application Publication No. 2003/0178741 describes a method for reducing spunbond filament diameters in a spunbond process in which quench air fed to a quenching chamber is divided into at least 2 streams in the vertical direction, wherein the air velocity of the quench air in the lowermost stream is set higher than that of the quench air in the uppermost stream. Both of these methods are not easily adaptable to pre-existing spunbond lines. In addition, some of the process instabilities described above, such as increased drips and fiber breaks, may occur using these processes.

[0006] U.S. Pat. No. 5,418,045 to Pike et al. describes a method for making a nonwoven fabric comprising crimped bicomponent continuous filaments having an asymmetric cross-section that includes a heating step to activate the latent crimp of the filaments prior to laydown. In one embodiment, heated air is used in the aspirating jet to activate the latent crimp.

[0007] There remains a need for a low cost method for reducing the diameter of spunbond fibers using currently existing spunbond equipment.

BRIEF SUMMARY OF THE INVENTION

[0008] A method for preparing a spunbond nonwoven fabric comprising the steps of:

[0009] melt spinning a plurality of continuous polymeric filaments from a spinneret, wherein the continuous filaments are selected from the group consisting of single component filaments and multiple component filaments having a symmetric cross-section and comprising at least a first polymeric component and at least a second polymeric component;

[0010] drawing the filaments in a first drawing step;

[0011] quenching the drawn filaments;

[0012] passing the quenched filaments through a pneumatic draw jet,

[0013] supplying the draw jet with a gaseous stream, the gaseous stream applying a tension to the filaments as the filaments and the gaseous stream pass through and exit the draw jet;

[0014] heating the filaments while under the tension applied by the gaseous stream to a temperature sufficient to draw the filaments in a second drawing step thereby reducing the average filament diameter by at least 5 percent compared to the average filament diameter that is achieved when the filaments are not heated and drawn in a second drawing step in an otherwise identical process; and

[0015] collecting the filaments on a collecting surface to form a nonwoven web.

[0016] This invention is also an apparatus for practicing the method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 shows a side-elevation view of a conventional spunbond apparatus for preparing a bicomponent spunbond web.

[0018] FIG. 2 shows a cross-sectional view of one embodiment of an apparatus for practicing the method of the present invention that includes a heating means below the exit of the pneumatic draw jet.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention is directed toward a method for preparing a spunbond nonwoven fabric comprising filaments having a reduced diameter. The method of the present invention can be performed using conventional spunbond equipment with only minor modification being required.

[0020] The term "copolymer" as used herein includes random, block, alternating, and graft copolymers prepared by polymerizing two or more comonomers and thus includes dipolymers, terpolymers, etc.

[0021] The term "polyolefin" as used herein, is intended to mean any of a series of largely saturated open chain polymeric hydrocarbons composed only of carbon and hydrogen. Typical polyolefins include, but are not limited to, polyethylene, polypropylene, polymethylpentene and various combinations of the ethylene, propylene, and methylpentene monomers.

[0022] The term "polyethylene" (PE) as used herein is intended to encompass not only homopolymers of ethylene, but also copolymers wherein at least 85% of the recurring units are ethylene units and includes "linear low density polyethylenes" (LLDPE), which are linear ethylene/α-olefin copolymers having a density of less than about 0.955 g/cm^3 and "high density polyethylenes" (HDPE), which are polyethylene homopolymers having a density of at least about 0.94 g/cm^3.

[0023] The term "polypropylene" as used herein is intended to encompass not only homopolymers of propylene, but also copolymers wherein at least 85% of the recurring units are propylene units.

[0024] The term "polyester" as used herein is intended to embrace polymers wherein at least 85% of the recurring units are condensation products of dicarboxylic acids and dihydroxy alcohols with linkages created by formation of ester units.

[0025] The term "polyamide" as used herein is intended to embrace polymers containing recurring amide (—CONH—) groups. One class of polyamides is prepared by copolymerizing one or more dicarboxylic acids with one or more diamines.

[0026] The term "nonwoven fabric, sheet, layer or web" as used herein means a structure of individual fibers, filaments, or threads that are positioned in a random manner to form a planar material without an identifiable pattern, as opposed to a knitted or woven fabric. The terms "fiber" and "filament" will be used interchangeably throughout this application. Examples of nonwoven fabrics include meltblown webs, spunbond webs, carded webs, air-laid webs, wet-laid webs, and spunlaced webs and composite webs comprising more than one nonwoven layer.

[0027] The term "spunbond fibers" as used herein means fibers that are melt-spun by extruding molten thermoplastic polymer material as fibers from a plurality of fine, usually circular, capillaries of a spinneret with the diameter of the extruded fibers then being rapidly reduced by drawing and then quenching the fibers. Spunbond fibers are generally continuous fibers.

[0028] The term "meltblown fibers" as used herein, means fibers that are melt-spun by meltblowing, which comprises extruding a melt-processable polymer through a plurality of capillaries as molten streams into a high velocity gas (e.g. air) stream. Meltblown fibers generally have a diameter between about 0.5 and 10 micrometers and are generally discontinuous fibers but can also be continuous.

[0029] The term "spunbond-meltblown-spunbond nonwoven fabric" (SMS) as used herein refers to a multi-layer composite sheet comprising a web of meltblown fibers sandwiched between and bonded to two spunbond layers. Additional spunbond and/or meltblown layers can be incorporated in the SMS fabric, for example spunbond-meltblown-meltblown-spunbond (SMMS), etc.

[0030] The term "multiple component fiber" as used herein refers to a fiber that is composed of at least two distinct polymeric components that have been spun together to form a single fiber. The at least two polymeric components are arranged in distinct substantially constantly positioned zones across the cross-section of the multiple component fibers, the zones extending substantially continuously along the length of the fibers. An example of a multiple component fiber is a bicomponent fiber that is made from two distinct polymer components, such as sheath-core fibers that comprise a first polymeric component forming the sheath and a second polymeric component forming the core that is completely surrounded by the sheath. Multiple component fibers are distinguished from fibers that are extruded from a single homogeneous or heterogeneous blend of polymeric materials. The term "multiple component spunbond web" as used herein refers to a spunbond web comprising multiple component spunbond fibers. The term "bicomponent spunbond web" as used herein refers to a spunbond web comprising bicomponent spunbond fibers. A multiple component web can comprise both multiple component and single component fibers.

[0031] The method of the present invention is suitable for preparing spunbond nonwoven fibers having reduced diameter wherein the spunbond fibers are selected from the group consisting of single component fibers and multiple component fibers having a substantially symmetric cross-section. The fibers may have a round cross-section. The fibers can also have a multi-lobal or other cross-section, however if the fibers are multiple component fibers they are preferably substantially radially symmetric. By "radially symmetric" cross-section is meant a cross-section for which rotation of the fiber about its longitudinal axis by 360°/n, in which "n" is an integer greater than 1 representing the "n-fold" symmetry of the fibers, results in a fiber that is indistinguishable from the fiber before rotation, including the position of the distinct polymeric components. In determining the symmetry of a fiber, a cross-section is taken perpendicular to the fiber axis. For fibers having a non-round cross-section, the "effective diameter" is equal to the diameter of a hypothetical round fiber having the same cross sectional area. It is understood that when the term average fiber diameter is used for fibers having a non-round cross-section, that the average fiber diameter is the average effective diameter.

[0032] In one embodiment, the fibers are bicomponent fibers with the two polymers arranged in a concentric sheath-core configuration.

[0033] Polymers suitable for forming the spunbond fibers include polyolefins, polyesters, and polyamides, and copolymers thereof. Examples of suitable polyolefins include polyethylenes (such as LLDPE and HDPE) and polypropylene. Examples of polyesters include poly(ethylene terephthalate) (PET), which is a condensation product of ethylene glycol and terephthalic acid and poly(1,3-propylene terephthalate), which is a condensation product of 1,3-propanediol and terephthalic acid. Examples of polyamides suitable for use in the present invention include poly(hexamethylene adipamide) (nylon 6,6) and polycaprolactam (nylon 6). Examples of polymer combinations suitable for use in bicomponent fibers having a symmetric cross-section include polyester/polyethylene, polyester/polyester copolymer and polypropylene/polyethylene. Preferred polymer combinations include poly(ethylene terephthalate)/polyethylene, poly(ethylene terephthalate)/linear low density polyethylene, poly(ethylene terephthalate)/poly(ethylene terephthalate) copolymer and polypropylene/linear low density polyethylene. When the fibers have a symmetric sheath-core cross-section (e.g. concentric sheath-core), the lower melting polymer (generally the second polymer named in each polymer combination above) preferably forms the sheath component. Poly(ethylene terephthalate) copolymers suitable for use in making fibers in the process of the present invention include amorphous and semi-crystalline poly(ethylene terephthalate) copolymers. For example, poly(ethylene terephthalate) copolymers in which between about 5 and 30 mole percent based on the diacid component is formed from di-methyl isophthalic acid, as well as poly(ethylene terephthalate) copolymers in which between about 5 and 60 mole percent based on the glycol component is formed from 1,4-cyclohexanedimethanol can be used. Poly(ethylene terephthalate) copolymers that have been modified with 1,4-cyclohexanedimethanol are available from Eastman Chemicals (Kingsport, Tenn.) as PETG copolymers. Poly(ethylene terephthalate) copolymers that have been modified with di-methyl isophthalic acid are available from E. I. du Pont de Nemours and Company (Wilmington, Del.) as Crystar® polyester copolymers.

[**0034**] In another embodiment, the fibers have a segmented pie cross-section having an even number of alternating segments of distinct polymers arranged in a configuration that is substantially radially symmetric. The segmented filaments are chosen so that they do not readily split in the second drawing step. However, to provide an even finer filament size, the filaments may be subjected to further processing, such as hydroentangling, or the like, to cause the filaments to split. It is preferable the adjacent polymer segments have a solubility difference of two or more $(cal/cm^3)^{1/2}$. The polymer combination suitable for use is polypropylene or polyethylene alternating with polystyrene, poly(ethylene terephthalate) or polyamide. Alternatively, polystyrene can alternate with polyamide and poly(ethyleneterephthalate) can alternate with polyamide.

[**0035**] **FIG. 1** shows a side-elevation view of a conventional spunbond apparatus for preparing a bicomponent spunbond web. It is understood that the method of the present invention can also be used for preparing spunbond nonwovens comprising single component fibers by using a spin block designed to spin single component fibers or by feeding the same polymer into hoppers **10** and **12** shown in **FIG. 1**. Alternately, multiple component spunbond webs comprising more than two polymeric components can be prepared by introducing one or more additional extruders and spinning multiple component fibers from three or more polymers using an appropriately designed spin block. To form bicomponent fibers in this apparatus, two different thermoplastic polymers are fed into the hoppers **10** and **12**, respectively. The polymer in hoppers **10** and **12** are fed to extruders **14** and **16**, respectively, which each melt and pressurize the polymer contained therein and force it through filters **18** and **20** and metering pumps **22** and **24**, respectively. The two polymer streams are combined in spin block **26** by known methods to produce the desired bicomponent filament cross-section. In one embodiment, the multiple component fibers comprise bicomponent sheath-core fibers wherein the fibers comprise between about 5 and 60 weight percent of the sheath component and between about 40 and 95 weight percent the core component. More preferably, the bicomponent fibers comprise between about 15 and 40 weight percent of the sheath component and between about 60 and 85 weight percent of the core component. In one embodiment, the polymeric sheath component has a lower melting point than the polymeric core component to facilitate thermal bonding of the spunbond fabric. For example, the sheath component can have a melting point that is at least 10° C. lower than the melting point of the highest-melting component and more preferably has a melting point that is at least 20° C. lower than the melting point of the highest-melting component. For example, the sheath component can be a polyethylene such as linear low density polyethylene, high density polyethylene, or a blend thereof and the core component can be a polyester such as poly(ethylene terephthalate).

[**0036**] The melted polymers exit spin block **26** through a plurality of capillary openings on the face of the spinneret **28** to form a curtain of filaments **30**. The capillary openings may be arranged on the spinneret face in a conventional pattern, for example rectangular, staggered, or other configuration. The filaments are cooled with quenching air **32** and then passed through a pneumatic draw jet **34** before being laid down to form a bicomponent spunbond web. The quenching air is provided by one or more conventional quench boxes that direct air against the filaments, generally at a rate of about 0.3 to 2.5 m/sec and at a temperature in the range of 5° C. to 25° C. In one embodiment of the process of the present invention, a two-sided quench system is used, wherein quench air is directed onto the curtain of filaments from both sides, to achieve a more uniform quench and reduce or eliminate development of latent crimp which can occur when an asymmetric (e.g. one-sided) quench is used. During the quenching step, the temperature of the filaments is sufficiently reduced so that the filaments do not stick to each other or to the inner walls of the jet while passing through the jet. For example, when spinning poly(ethylene terephthalate), the filaments can be quenched to a filament temperature less than or equal to about 150° C.

[**0037**] Air **36** is fed into draw jet **34** and provides the draw tension on the filaments that causes them to be drawn (i.e., the primary draw) near the spinneret face **28**. The filaments **37** exiting the draw jet are deposited onto a laydown belt or forming screen **38** to form a web **40** of continuous filaments. In the present invention, the filaments are re-heated while under the tension applied to them by air **36** that is fed into pneumatic draw jet **34**. The filaments are re-heated to a temperature that causes the filaments to be drawn (i.e., the secondary draw) and the average filament diameter to be reduced by at least five percent, more preferably at least 10 percent compared to the average filament diameter that is achieved when the fibers are not re-heated. In the re-heating step, however, the filaments should not be heated to a temperature that is so high as to cause the filaments to stick together when they contact each other or to stick to the inner walls of the draw jet. For example, when spinning poly(ethylene terephthalate) spunbond filaments, heating the filaments to temperatures greater than about 70° C. and less than 225° C. has been found to provide the desired reduction in fiber diameter. The air velocity and air pressure in the draw jet should also be sufficient to provide an attenuation force sufficient to achieve the desired secondary fiber draw. This secondary drawing of the fibers is believed to occur in the pneumatic draw jet or essentially just after exiting the draw jet (depending on whether the filaments are re-heated in the pneumatic draw jet or after exiting the pneumatic draw jet).

[**0038**] For the re-heating step, air **36** that is introduced into the pneumatic draw jet can be heated to a temperature that is sufficient to achieve the desired reduction in fiber diameter. However, because it can be costly to heat large quantities of air, the filaments are preferably heated after they exit the pneumatic draw jet. In a preferred embodiment, the filaments are heated by a heating means after they exit the pneumatic draw jet while still under tension imposed by the air **36**. In the embodiment shown in **FIG. 2**, the re-heating step is conducted by blowing heated air **42** through nozzles **44** onto both sides of the curtain of filaments as they exit draw jet **34**. Instead of using hot air, a radiant heating means could be placed near the exit of the pneumatic jet. Conventional infrared panel heaters would be a suitable heating means. The heating means is preferably located no more than 20 cm from the exit of the draw jet and more preferably no more than 0.5 cm from the exit of the draw jet. The undissipated velocity of the air exiting the pneumatic draw jet contributes to the secondary draw on the filaments at this stage and further reduces the diameter.

[**0039**] The filaments are preferably single component filaments or multiple component filaments having a substantially symmetric cross-section. If the filaments are multiple component filaments having an asymmetric cross-section, they will develop crimp during the re-heating step due to differential shrinkage of the different polymer components, which is believed to reduce or even eliminate any secondary draw that is achieved in the re-heating step. The method of the present invention is especially suitable for making spunbond filaments having small diameters. In contrast, adjusting other process parameters in an effort to reduce fiber diameter generally results in the problems described above. The filaments **37** preferably have an average filament diameter of less than 14.5 micrometers after the re-heating step, more preferably less than about 10 micrometers. After drawing the filaments in the secondary drawing step, they are laid down to form a spunbond web, and optionally bonded, as is known in the art. The method of the present invention can be conducted on conventional spunbonding equipment, with minimal modification to insert a heating means at the exit of the pneumatic draw jet or to provide a source to heat the air introduced into the pneumatic draw jet.

[**0040**] It has been found that spunbond webs prepared using the method of the present invention have a softer, more pliable hand than spunbond webs prepared in the absence of a secondary draw step. The change in hand was surprisingly higher than expected based on the reduction in fiber size alone. Without wishing to be bound by theory, it is possible that the reheating and secondary drawing step modifies the crystal morphology of the polymers forming the spunbond fibers to provide a much more pliable hand than spunbond fibers that are spun in a conventional spunbond process.

[**0041**] In another embodiment of the present invention, a multi-layer nonwoven sheet can be prepared by using multiple spinblocks in series or alternating with meltblowing dies to form spunbond-meltblown-spunbond nonwovens. Any number of spunbond and meltblown layers can be laid down to form multi-layer nonwoven sheets.

TEST METHODS

[**0042**] In the description above and in the examples that follow, the following test methods were employed to determine various reported characteristics and properties.

[**0043**] Average Fiber Diameter was measured by optical microscopy and is reported as an average value in micrometers. The fibers were mounted on an optical slide for measuring fiber size. For each spunbond fabric, the diameters of about 100 fibers were measured and averaged. The fibers used for fiber diameter measurements were collected manually by removing fibers at four different locations across the width of the curtain of filaments, prior to the filaments contacting the collection belt. About twenty-five fibers were collected from each of the four collection locations.

EXAMPLES

Examples 1A and 1B

[**0044**] A spunbond bicomponent sheet was made with a PET component and a polyester copolymer component. The PET component had an intrinsic viscosity of 0.53 dl/g (as measured in U.S. Pat. No. 4,743,504), and is available from DuPont as Crystar® polyester (Merge 3949). The PET resin was dried in a through-air drier at an air temperature of 120° C., to a polymer moisture content of less than 50 parts per million. The polyester copolymer was a poly(ethylene terephthalate) copolymer modified with 1,4-cyclohexanedimethanol, available from Eastman Chemicals as Merge PETG 20372. The PET polymer was heated to 290° C. and the polyester copolymer was heated to 275° C. in separate extruders. The two polymers were separately extruded and metered to a spin-pack assembly, where the two melt streams were separately filtered and then combined through a stack of distribution plates to provide multiple rows of filaments having a concentric core-sheath cross-section. The PET component formed the core and the polyester copolymer component formed the sheath. The spin-pack assembly consisted a total of 3360 round capillary openings and was heated to 290° C. Each capillary had a diameter of 0.23 mm and length of 0.92 mm. The polymer throughput was of 0.5 g/hole/min. The fibers were 30 weight percent polyester copolymer.

[**0045**] The filaments were cooled in a cross-flow quench (2-sided) and an attenuating force was provided to the fibers by passing them through a rectangular slot jet. The air pressure in the jet was 70 psig.

[**0046**] A secondary hot air drawing unit was attached about 0.5 cm below the exit of the pneumatic jet as depicted in **FIG. 2**. The hot air slots were 0.5 inch (1.27 cm) long in the vertical direction and extended the entire width of the pneumatic draw jet. The exits of the air jets were located about 2 inches (5.08 cm) from each side of the curtain of filaments.

[**0047**] The fibers exiting the jet were collected on a forming belt. Vacuum was applied underneath the belt to help pin the fibers to the belt after laydown. The belt speed was adjusted to yield a nonwoven sheet with basis weight of 70 g/m^2. The fibers were then thermally bonded between a set of embosser roll and anvil roll. The bonding conditions were 150° C. roll temperature and 250 pounds per lineal inch (4475 kg per meter) nip pressure. The sheet was then collected into rolls on the winder.

[**0048**] Two different combinations of hot air speed and temperature in the secondary hot air drawing unit were evaluated as represented by 1A and 1B. The results are shown in Table 1.

Comparative Example A

[0049] Comparative Example A was run under identical conditions as Examples 1A and 1B, except that no air was passed through the secondary drawing unit. The results are shown in Table 1.

Example 2A and 2B

[0050] A spunbond web was made using the process described in Example 1 except that a PET polymer (Crystar® Merge 1988), intrinsic viscosity of 0.58 dl/g) was fed through both the extruders to form 100% PET filaments. Two different combinations of hot air speed and temperature in the secondary hot air draw unit were evaluated as represented by 2A and 2B. The results are shown in Table 1.

Comparative Example B

[0051] Comparative Example B was run under identical conditions as Examples 2A and 2B, except that no air was passed through the secondary drawing unit. The results are shown in Table 1.

Example 3

[0052] A spunbond web was made using the process described in Example 1, except that a PET polymer (Crystar® Merge 1988, intrinsic viscosity of 0.58 dl/g) was fed through both the extruders, and infrared panels were used instead of hot air jets to heat the filaments in the secondary drawing step. Two infrared heater panels (10.16 cm long in the vertical direction and extending the entire width of the pneumatic draw jet) were attached below the exit of the pneumatic draw jet, one panel on either side of the exit of the jet. The infrared panels were ceramic infrared heater panels made by Chromalux and had a surface temperature of about 1400° F. (760° C.). The panels were located about 3 inches (7.62 cm) from each side of the curtain of filaments. The results are shown in Table 1.

Comparative Example C

[0053] Comparative Example C was run under identical conditions as Example 3, except that no infrared heating step was used. The results are shown in Table 1.

TABLE 1

Average Fiber Size				
Example Number	Hot Air Temp (° C.)	Hot Air Velocity (ft/sec)*	Average Fiber Diameter (μ)	Standard Deviation of Fiber Diameter
Example 1A	200	21	6.4	0.9
Example 1B	132	30	8.2	1.1
Comparative Ex. A	—	—	9.2	2.1
Example 2A	200	21	6.6	1.3
Example 2B	132	30	7.8	0.8
Comparative Ex. B	—	—	9.5	2.2
Example 3	N/A	N/A	7.6	1.4
Comparative Ex. C	N/A	N/A	9.5	2.2

*1 foot/second = 30.5 centimeter/second

What is claimed is:

1. A method for preparing a spunbond nonwoven fabric, comprising the steps of:

a. melt spinning a plurality of continuous polymeric filaments from a spinneret, wherein the continuous filaments are selected from the group consisting of single component filaments and multiple component filaments having a symmetric cross-section and comprising at least a first polymeric component and at least a second polymeric component;

b. drawing the filaments in a first drawing step;

c. quenching the drawn filaments;

d. passing the quenched filaments through a pneumatic draw jet,

e. supplying the draw jet with a gaseous stream, the gaseous stream applying a tension to the filaments as the filaments and the gaseous stream pass through and exit the draw jet;

f. heating the filaments while under the tension applied by the gaseous stream to a temperature sufficient to draw the filaments in a second drawing step, thereby reducing the average filament diameter by at least 5 percent compared to the average filament diameter that is achieved when the filaments are not heated and drawn in a second drawing step in an otherwise identical process; and

g. collecting the filaments on a collecting surface to form a nonwoven web.

2. The method of claim 1, wherein the heating step comprises blowing hot air on the filaments as they exit the draw jet.

3. The method of claim 1, wherein the heating step comprises exposing the filaments to radiant heat as they exit the draw jet.

4. The method of claim 1, wherein the multiple component filaments comprise bicomponent filaments that have a concentric sheath-core cross-section.

5. The method of claim 4, wherein the sheath comprises a polymer selected from the group consisting of polyethylenes and polyester copolymers and the core comprises a polymer selected from the group consisting of polypropylenes, polyesters, and polyamides.

6. The method of claim 5, wherein the sheath comprises a polymer selected from the group consisting of polyethylenes and polyester copolymers and the core comprises a polyester.

7. The method of claim 6, wherein the core comprises poly(ethylene terephthalate).

8. The method of claim 7, wherein the sheath comprises linear low density polyethylene.

9. The method of claim 5, wherein the sheath comprises a polyester copolymer selected from the group consisting of poly(ethylene terephthalate) modified with di-methyl isophthalic acid, and poly(ethylene terephthalate) modified with 1,4-cyclohexanedimethanol.

10. The method of either of claims **1** or **6**, wherein the filament diameter is reduced by at least 10 percent compared to the average filament diameter that is achieved when the filaments are not heated and drawn in a second drawing step.

11. The method of either of claims **1** or **6**, wherein an average filament diameter of less than 14.5 micrometers is achieved after the second drawing step compared to the average filament diameter that is achieved when the filaments are not heated and not drawn in a second drawing step in an otherwise identical process.

12. The method of claim 11, wherein an average filament diameter of less than 10 micrometers is achieved after the second drawing step.

13. The method of claim 1, wherein the continuous filaments comprise single component filaments.

14. The method of claim 13, wherein the single component filaments comprise polyester filaments.

15. The method of claim 14, wherein the polyester comprises poly(ethylene terephthalate)

16. The method of claim 1, wherein the multiple component filaments comprise bicomponent filaments that have a segmented pie cross-section having an even number of alternating segments, wherein adjacent segments comprise different polymers.

17. The method of claim 16, wherein adjacent polymer segment combinations are selected from the group consisting of polypropylene/polystyrene, polypropylene/poly(ethylene terephthalate), polypropylene/polyamide, polyethylene/polystyrene, polyethylene/poly(ethylene terephthalate), polyethylene/polyamide polystyrene/polyamide and poly-(ethylene terephthalate)/polyamide.

18. The method of claim 17, wherein the adjacent polymer segment combination is polypropylene/poly(ethylene terephthalate)

19. The method of claim 17, wherein the adjacent polymer segment combination is polyethylene/poly(ethylene terephthalate).

20. An apparatus for forming a nonwoven web of polymeric continuous filaments, comprising:

a. a spinneret for spinning continuous polymeric filaments;

b. a quenching means positioned below the spinneret;

c. a pneumatic draw jet having a filament inlet and a filament exit positioned below the quenching means, through which the polymeric filaments are passed together with a gaseous stream that is fed to the pneumatic draw jet;

d. a means for heating the polymeric filaments to a temperature sufficient to draw the filaments after the filaments exit the draw jet, the heating means located no more than 20 cm below the exit of the draw jet; and

e. a collecting surface for collecting the filaments to form a nonwoven web.

21. The apparatus of claim 20, wherein the heating means comprises a hot air jet.

22. The apparatus of claim 20, wherein the heating means comprises a radiant heat source.

23. The apparatus of claim 22, wherein the radiant heat source comprises an infrared heat source.

24. The apparatus of either of claims **21** or **22**, wherein the heating means is located no more than 0.5 cm from the exit of the draw jet.

* * * * *