

FIBER GLASS PRODUCT INCORPORATING STRING BINDERS

Cross Reference to Related Application

5 This application claims priority to, and incorporates by reference in full, the following co-pending application of Applicant: U.S. Provisional Patent Application No. 60/364,247, filed March 13, 2002, entitled "String Binders and Fiber Glass Products Incorporating String Binders."

Field of the Invention

10 The present invention relates generally to fiber glass products comprising string binders and to methods for producing fiber glass products comprising string binder.

Background of the Invention

15 Preforms made from glass fibers have been used for many years to provide a method of reinforcing polymer composites. Composite fabricators learned early on that it was very difficult to take prefabricated mats and fabrics made with either chopped or continuous glass fibers and place them in a mold containing complex geometric contours. This normally resulted in wrinkles and folds in the reinforcing material, which caused
20 poor and inconsistent structural integrity. A mat of chopped fibers that could be produced with the same net shape as the final part and placed in the mold prior to the introduction of the matrix polymer would provide a vastly superior reinforcement.

 The process of molding composites using a directed fiber preform can vary dramatically. Most preform molding is done using a closed mold process, which means
25 that a matched mold assembly, using a top and bottom die, is brought together to shape the final part. Another option is to use a rigid mold as a base and a flexible top made from a polymer sheet or bag, which can then be used to compress the material through external forces or as an indirect result of having vacuum applied between the mold halves. Matrix thermosetting resins such as polyester, vinyl ester, urethane, and epoxy
30 are typically used for preform molding. The resin can be placed into the mold with the preform prior to it being closed or it can be transferred, injected, or infused directly into the mold after being brought together. When a fabricator chooses to produce his own

reinforcing preforms, he can purchase the glass strands in a continuous form, such as a roving or spool, which reduces his material costs significantly compared with that of a fabricated mat or fabric. The costs to the fabricator are reduced because the fiber glass supplier has reduced processing and labor costs in making a roving (as compared with making a mat or fabric) and because freight is lower due to the higher density and packaging efficiency of the roving as compared to rolls of mat. Also, the fabricator also has the freedom to produce the fiber preforms at any thickness, chop length, or configuration, which the fabricator determines is desirable for the requirements of the final product.

The preparation of directed fiber preforms generally requires that once the reinforcing strands have been chopped and placed in the proper shape, a binder component be applied to hold the strands together. This binder is advantageous in allowing the preform to be handled and eventually transferred to the mold. The binder is preferably sufficiently strong to maintain the integrity of the preform shape and yet still allow flexibility for placement in the mold. Preferably, the type and amount of binder does not interfere with the function of the matrix resin. The binder preferably will not significantly limit the wetting of fibers or significantly reduce the flow or cure of the resin during molding.

Binders typically can be either thermosetting or thermoplastic in composition. They may be in the form of a solid or a liquid. Both of these types of binders require energy to cause the binder to cure or, in the case of thermoplastic, to melt. Liquid binders generally use water as a solvent/carrier and therefore may require a drying process to remove the moisture prior to use. Various powders and fibers can also be used for mixing with the chopped glass strands and thereby holding the preform together. These are then heated to cause melting or cure and thereby hold the preform together.

Another form of solid binder is a string binder. Previously, string binders have been made from single polymer compositions to form the synthetic fibers. In order for these fibers to be mixed with the glass fibers, it is desirable that they be composed of a high-strength thermoplastic polymer sufficiently strong to maintain the fiber's integrity through the chopping process. The higher strength polymers may require higher temperatures to reach their melting point. Thus, it would be desirable to have a string

binder that will melt at significantly lower temperatures and still maintain sufficient strength to process with the glass fibers.

Summary

5 The present invention provides string binders advantageous for use in fiber glass applications. Embodiments of the present invention may be particularly advantageous for use in preform fabrication processes.

 A non-limiting embodiment of a fiber glass roving of the present invention comprises a plurality of fiber glass ends and at least one bicomponent string binder
10 comprising a core and an outer sheath. The core, in one non-limiting embodiment, may comprise polyethylene terephthalate. The sheath, in non-limiting embodiments, may comprise copolyester or glycol modified polyethylene terephthalate. The bicomponent string binder may comprise a plurality of bicomponent string binder filaments, each filament having a core and an outer sheath, and/or a bundle comprising a plurality of such
15 bicomponent string binder filaments. Each filament of the bicomponent string binder, in non-limiting embodiments, may have a denier greater than thirty denier.

 In non-limiting embodiments of fiber glass rovings of the present invention, the outer sheath of a bicomponent string binder filament may comprise at least fifty weight percent of the string binder based on the total weight of the string binder. In a further
20 non-limiting embodiment, the outer sheath of a bicomponent string binder filament may comprises at least seventy weight percent of the string binder based on the total weight of the string binder.

 The string binder, in a non-limiting embodiment of a fiber glass roving, may comprise more than three weight percent of the fiber glass roving based on total weight of
25 the fiber glass roving. In a further non-limiting embodiment, the string binder may comprise from three percent to eighteen weight percent of the fiber glass roving based on total weight of the fiber glass roving. In another non-limiting embodiment, the string binder may comprise from three percent to twelve weight percent of the fiber glass roving based on total weight of the fiber glass roving.

30 The present invention also relates to fiber glass preforms made from fiber glass rovings of the present invention that include bicomponent string binder.

The present invention also relates to methods of forming multi-end fiber glass rovings. In one non-limiting embodiment, a method of the present invention comprises providing a plurality of fiber glass ends to a roving winder at a first tension and providing at least one fiber glass end and a plurality of bicomponent string binder filaments to the roving winder at a second tension. Each bicomponent string binder filament may have a core and an outer sheath. The fiber glass ends and the plurality of bicomponent string binder filaments are wound to form a multi-end fiber glass roving. In one non-limiting embodiment, the second tension may be less than the first tension.

The core, in one non-limiting embodiment, may comprise polyethylene terephthalate and the outer sheath may comprise copolyester. In another non-limiting embodiment, the core may comprise polyethylene terephthalate and the outer sheath may comprise glycol modified polyethylene terephthalate.

In another non-limiting embodiment of a method of the present invention, the at least one fiber glass end and the plurality of bicomponent string binder filaments may comprise up to fifty weight percent string binder based on the total weight of the at least one fiber glass end and the plurality of bicomponent string binder filaments. The at least one fiber glass end and the plurality of bicomponent string binder filaments, in a further non-limiting embodiment, may comprise from fifteen to fifty weight percent string binder based on the total weight of the at least one fiber glass end and the plurality of bicomponent string binder filaments.

In fiber glass rovings formed by non-limiting embodiments of methods of the present invention, the string binder filaments may comprise more than three weight percent of the multi-end fiber glass roving based on total weight of the multi-end fiber glass roving. In another non-limiting embodiment, the string binder filaments may comprise from three to eighteen weight percent of the multi-end fiber glass roving based on total weight of the multi-end fiber glass roving. The string binder filament may also comprise from three to twelve weight percent of the multi-end fiber glass roving based on total weight of the multi-end fiber glass roving.

Detailed Description of the Invention

For the purposes of this specification, unless otherwise indicated, all numbers expressing quantities of ingredients, reaction conditions, and so forth used in the

specification are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, 5 each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific 10 examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific 15 examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. Moreover, all ranges disclosed herein are to be understood to encompass any and all subranges subsumed therein. For example, a stated range of "1 to 10" should be considered to include any and all subranges between (and 20 inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges beginning with a minimum value of 1 or more, e.g. 1 to 6.1, and ending with a maximum value of 10 or less, e.g., 5.5 to 10. Additionally, any reference referred to as being "incorporated herein" is to be understood as being incorporated in its entirety.

It is further noted that, as used in this specification, the singular forms "a," "an," 25 and "the" include plural referents unless expressly and unequivocally limited to one referent.

The present invention relates to string binders that may be advantageously used in fiber glass applications. The present invention also relates to fiber glass rovings and, in particular, to multi-end fiber glass rovings. The present invention also relates to methods 30 for producing multi-end fiber glass rovings. Embodiments of the present invention include string binders advantageous for use in preform fabrication processes. The present invention further relates to preforms.

As used herein, the term "end" means a plurality of individual filaments that are at least partially coated with a binder and gathered together for subsequent use or processing.

5 An embodiment of a fiber glass roving of the present invention comprises a plurality of fiber glass ends and at least one bicomponent string binder. The fiber glass roving can be a continuous strand multi-end fiber glass roving assembled with at least one bicomponent string binder. The bicomponent string binder can be a continuous bicomponent synthetic fiber made from thermoplastic polymers having a core and an outer sheath. In one non-limiting embodiment, the string binder is processed along with
10 the glass fibers, and when properly chopped and applied to a preform screen, the string binder becomes dispersed with the glass fibers in the preform.

String binders of the present invention are preferably made from thermoplastic polymers. The thermoplastic composition of a string binder, in a further non-limiting embodiment, is such that when heat is applied to preform, a portion of the string binder
15 will melt and come in contact with the glass fibers. When the preform is cooled the thermoplastic will once again harden and become an adhesive between the glass fibers. Further, string binders useful in the present invention also should have sufficient strength to withstand the mechanical stress of being assembled into a roving while still capable of being chopped before assembly into a preform.

20 In one non-limiting embodiment, the string binders of the present invention are produced as bi-component fibers (i.e., filaments). Bicomponent fibers may be formed by extruding two polymers from the same spinneret with both polymers contained within the same filament. In one non-limiting embodiment, a string binder fiber or filament comprises a core and an outer sheath. The core, in one non-limiting embodiment,
25 comprises a high strength thermoplastic polymer. The high strength thermoplastic polymer provides structural integrity to the string binder. The thermoplastic polymer used in the core may be strong enough to withstand being wound into a roving with fiber glass using a roving winder and strong enough to be fed into a chopper gun, yet not so elastic that it can not be chopped. The thermoplastic polymer in the core, in other words,
30 provides support in the bicomponent string binder during assembly of the multi-end fiber glass roving, but should also perform well in subsequent processes involving chopping (e.g., the preparation of preforms). The thermoplastic polymer in the core should also

have a higher melting temperature than the polymer in the sheath. The thermoplastic polymer in the core preferably does not melt during processing, such as a chopping operation.

5 Examples of polymers useful as a core for a bicomponent string binder include, without limitation, polyethylene terephthalate, polypropylene, nylon, and other polymers having similar performance characteristics. These polymers may be characterized as having a melting temperature greater than 200° C and a tensile strength between two and six pounds. Suitable polymers may have a melting temperature between 200° C and 325° C.

10 In one non-limiting embodiment, the core of the string binder comprises polyethylene terephthalate. One example of a suitable polyethylene terephthalate for use in the present invention is CRYSTAR 3915 commercially available from E.I. du Pont de Nemours and Company.

15 As noted above, the core is surrounded by an outer sheath to form the bicomponent string binder. In one non-limiting embodiment, the outer sheath comprises a thermoplastic polymer. The thermoplastic polymer forming the outer sheath, upon melting, acts as a binder. For example, in a preform application, once the fiber glass and the string binder have been chopped and placed in the proper shape, the preform may be heated to melt the thermoplastic polymer in the outer sheath, which holds the fiber glass preform together. Thermoplastic polymers useful as outer sheaths in embodiments of the
20 present invention may be selected based on the operating/processing temperature of the downstream operation. For example, for string binders to be used in fiber glass rovings for preform application, the thermoplastic polymer used in the outer sheath melts at quickly at temperatures of 130°C or higher.

25 Thermoplastic polymers useful as the outer sheaths of string binders for use in preform applications can be sufficiently strong to maintain the integrity of the preform shape and yet still allow flexibility for placement in the mold. In addition, the outer sheath thermoplastic polymer preferably does not interfere with the function of the matrix resin. In particular, the outer sheath thermoplastic polymer preferably does not
30 significantly limit the wetting of fibers or significantly reduce the flow or cure of the resin during molding.

Examples of polymers useful as an outer sheath for a bicomponent string binder include, without limitation, copolyester, glycol modified polyethylene terephthalate (PETG), polystyrene, and others having similar performance characteristics. These polymers may be characterized as having glass transition temperatures between 50° C and 100° C and viscosities between 1000 and 9000 poise at 190° C as measured by a capillary rheometer at shear rates between 340 and 3400 inverse seconds (s^{-1}).

In one non-limiting embodiment, the outer sheath of the bicomponent string binder comprises copolyester (e.g., coPET). In another non-limiting embodiment, the outer sheath of the bicomponent string binder comprises glycol modified polyethylene terephthalate (PETG). In another non-limiting embodiment, the outer sheath may comprise an isophthalate modified polyethylene terephthalate.

A suitable polymer for use in the present invention include CRYSTAR 3991 commercially available from E.I. du Pont de Nemours and Company. A suitable copolyester is copolyester 20110, which is a 0.47 I.V. (inherent viscosity) PETG commercially available from Eastman Chemical Company.

In one non-limiting embodiment, the majority of the bicomponent string binder is the outer sheath. In one non-limiting embodiment, the outer sheath of the bicomponent string binder comprises at least fifty weight percent of the string binder based on the total weight of the string binder. In another non-limiting embodiment, the outer sheath of the bicomponent string binder comprises at least seventy weight percent of the string binder based on the total weight of the string binder. In an embodiment where the core of the bicomponent string binder is polyethylene terephthalate homopolymer and the outer sheath is polyethylene terephthalate copolymer, the outer sheath may comprise between seventy and eighty weight percent of the string binder based on the total weight of the string binder.

String binders useful in the present invention may be provided as a bundle of bicomponent string binder filaments, each filament having a core and an outer sheath. A bundle of string binders may comprise, in some embodiments, more than fifty filaments. In a further embodiment, the bundle may comprise between fifty and two-hundred fifty filaments. The denier of a string binder filament, in one non-limiting embodiment, may be more than thirty denier. In another embodiment, the denier of a string binder filament is between thirty and fifty denier.

String binders useful in the present invention can be produced in accordance with techniques known to those of ordinary skill in the art. String binders of the present invention can be purchased, for example, from Fiber Innovation Technology Incorporated (FIT), of 398 Innovation Drive, Johnson City, Tennessee 37604. One example of suitable
5 bicomponent string binder is DPL 1092, which is commercially available from FIT.

A non-limiting embodiment of a fiber glass roving of the present invention comprises a continuous strand fiber glass product and a string binder of the present invention. In one non-limiting embodiment, a fiber glass roving comprises a plurality of fiber glass ends and at least one bicomponent string binder comprising a core and an outer
10 sheath. The fiber glass ends include a chemical sizing that already has the proper type of performance characteristics for the desired application.

Persons of ordinary skill in the art will recognize that a number of glass fibers can be utilized in embodiments of the present invention. Non-limiting examples of glass fibers suitable for use in the present invention can include those prepared from fiberizable
15 glass compositions such as "E-glass", "A-glass", "C-glass", "S-glass", "ECR-glass" (corrosion resistant glass), and fluorine and/or boron-free derivatives thereof.

In general, any fiber glass product that is currently used in chopped or continuous glass reinforcement applications may be used in roving products of the present invention. For preform applications, most fiber glass products conventionally used in preform
20 applications may be used to form fiber glass rovings of the present invention. For example and without limitation, fiber glass products useful in preform applications generally have high strand integrity, can be chopped with minimal static or fuzz generation, allow rapid and thorough wetting of strand bundles, and allow adequate coupling to the matrix resin in the composite.

25 In one non-limiting embodiment, a glass fiber for use as a reinforcement in preform applications comprises a collection of strands comprising 16-micron diameter E-Glass fibers treated with a sizing that is chemically compatible with multiple thermoset matrix resin systems. An example of such a glass fiber is PPG's 5524 product, which is commercially available from PPG Industries, Inc. String binders and fiber glass rovings
30 of the present invention can be used in other binder applications, in addition to preform applications, such as chopped strand mats, continuous strand mats, woven fabrics, and knit fabrics.

The amount of string binder to use in fiber glass rovings of the present invention can depend on a number of factors, including the type of application, the shape and density of the preform, the matrix resin to be used, and the total glass content.

5 In one non-limiting embodiment of fiber glass rovings of the present invention, the string binder can comprise three weight percent or more of the fiber glass roving based on total weight of the fiber glass roving. The string binder can comprise up to twenty weight percent of the fiber glass roving based on total weight of the fiber glass roving. In other embodiments, the string binder can comprise from three percent to eighteen weight percent of the fiber glass roving based on total weight of the fiber glass roving. The
10 binder, in other embodiments, can comprise from three percent to twelve weight percent of the fiber glass roving based on total weight of the fiber glass roving.

The present invention also relates to preforms made from fiber glass rovings of the present invention. Preforms of the present invention may be manufactured using techniques known to those of ordinary skill in the art.

15 The present invention also relates to methods of forming multi-end fiber glass rovings that include a string binder. In one non-limiting embodiment, a method of forming a multi-end fiber glass roving comprises providing a plurality of fiber glass ends to a roving winder at a first tension; providing at least one fiber glass end and at least one bundle of bicomponent string binder filaments, each filament having a core and an outer
20 sheath, to the roving winder at a second tension; and winding the fiber glass ends and the at least one bundle of bicomponent string binder filaments to form a multi-end fiber glass roving, wherein the second tension is less than the first tension. In another embodiment, a method of the present invention may further comprise passing the plurality of fiber glass ends through a friction-bar assembly prior to providing the plurality of fiber glass ends to
25 the roving winder. A method of the present invention, in another embodiment, may further comprise passing the at least one fiber glass end and at least one bundle of bicomponent string binder filaments through an electronically controlled magnetic tension wheel assembly prior to providing the at least one fiber glass end and at least one bundle of bicomponent string binder filaments to the roving winder.

30 In one non-limiting embodiment, a method of the present invention can be implemented by modifying a commercial roving winder to include two different sources of tensioning. The fiber glass can be fed to the roving winder at higher tension and under

higher friction. This higher tension can be necessary in order to hold the fiber glass ends together as they are fed to the roving winder. String binder, in non-limiting embodiments, may not be able to handle the friction and/or tension normally experienced by fiber glass ends due, in part, to the potential for damage and/or breakage of the string binder. A majority of the glass fibers, in one non-limiting embodiment of the present invention, proceed through a conventional friction-bar type of tensioning, while a smaller portion of the glass fibers along with the string binder proceeds through an electronically controlled magnetic tension wheel assembly.

With conventional friction-bar type tensioning, the strands are dragged across a series of offset ceramic bars to provide tension. In a non-limiting embodiment of an electronically controlled magnetic tension wheel assembly, the assembly comprises two rotating wheels around which the strands travel. These wheels may be, in a non-limiting embodiment, three to four inches wide with a diameter of four to five inches. The strands can proceed around each wheel for about 270 degrees. The strands go clockwise around the first wheel and counterclockwise around the second. Magnetic brakes provide drag to each wheel and thereby provide tension to the strands.

In one non-limiting embodiment, a small portion of the glass fibers along with the string binder are provided with tension using the magnetic tension wheel assembly. The magnetic tension wheel assembly can be less abrasive and destructive to the string binder than conventional friction-bar type tensioning. In one non-limiting embodiment, the ratio of the smaller portion of the glass fibers to the string binders in the second supply fed to the winder is between 1:1 and 5:1 by weight. In another non-limiting embodiment, the ratio of the smaller portion of the glass fibers to the string binders in the second supply fed to the winder through the magnetic tension wheel assembly is 2:1 by weight. The total proportion of glass fibers to string binder by weight in a non-limiting embodiment of a finished package can be between 5:1 and 18:1. In another non-limiting embodiment, the ratio of fiber glass to string binder in a finished package can be between 8:1 and 10:1.

Fiber glass rovings of the present invention, in one non-limiting embodiment, may be formed using a roving winder, such as Model No. 868 or Model No. 858, both of which are commercially available from FTS/Leesona of Burlington, NC. A magnetic tension wheel assembly, as described above, may be added to such roving winders for providing string binder to the roving winder in accordance with techniques known to

those of ordinary skill in the art. When a roving winder, such as the Leesona 868, is used, the fiber glass ends and string binder may be wound at speeds of between 500 and 1500 feet per minute. The selection of winding speeds is often a compromise of productivity and space limitations. Often, economic considerations govern the selection of winding conditions. Therefore, any specifications related to winding conditions of the roving winder, unless otherwise stated, should not be viewed as technically limiting on the present invention.

The performance of an embodiment of a fiber glass roving of the present invention is such that the string binder filaments will feed and transfer to the chopper mechanism, chop cleanly, and deposit uniformly with the glass fibers to a preform screen assembly. The sheaths of the string binder filaments melt quickly at a predetermined temperature, such as for example, at a temperature of 130°C or higher. Upon cooling, the melted sheaths maintain adhesion between the glass bundles and allows the fabricator to remove the assembled preform from the porous forming die and subsequently place the preform in storage or directly into a mold for use as a composite reinforcement. In the molding process, the assembled preform allows the resin to flow through it and provides even penetration so that all air is removed and all individual strands have come in contact with the resin.

A finished composite part, made from a preform comprising a string binder of the present invention can exhibit a uniform appearance with minimal to no resin-rich areas and minimal to no obvious defects as a result of uneven wetting or high void content. The string binder filaments do not cause visible interruptions or variation in the surface texture due to lack of proper dispersion or compatibility with the matrix resin.

Desirable characteristics, which can be exhibited by the present invention, include, but are not limited to, the provision of string binder for use with fiber glass as a reinforcement that melts at a significantly lower temperature than conventional string binders, the provision of a multi-end roving that can be used to produce a preform with lower energy costs for the process, the provision of a multi-end roving that can be used to produce preforms with overall shorter cycle times, the provision of a string binder for use in fabricating preforms that results in a lower level of binder waste as compared to powder binders, the provision of a multi-end roving that produces a preform with a more uniform concentration of binder, the provision of a multi-end roving that has favorable

wetting properties and produces a composite with a uniform surface appearance, the provision of a binder that does not require water or a thermosetting reaction, the provision of a binder that does not require the removal of moisture during production and also reduces corrosion and other maintenance issues associated with water borne systems, the
5 production of a binder that eliminates emissions that are associated with liquid binders during polymerization cure (including, for example, improved environmental and safety conditions).

Various embodiments of the invention have been described in fulfillment of the various objects of the invention. It should be recognized that these embodiments are
10 merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. A fiber glass roving, comprising:
a plurality of fiber glass ends; and
a plurality of bicomponent string binder filaments, each filament comprising a core
and an outer sheath,
- 5 wherein the core comprises polyethylene terephthalate, wherein the outer sheath comprises
a copolyester or a glycol modified polyethylene terephthalate and wherein the plurality of
string binder filaments comprises up to twenty weight percent of the fiber glass roving
based on total weight of the fiber glass roving.
- 10 2. The fiber glass roving of claim 1, wherein the outer sheath comprises glycol
modified polyethylene terephthalate.
3. The fiber glass roving of claim 1, wherein the outer sheath comprises copolyester.
- 15 4. The fiber glass roving of any of claims 1 to 3, wherein the plurality of string binder
filaments comprises more than three weight percent of the fiber glass roving based on the
total weight of the fiber glass roving.
5. The fiber glass roving of any of claims 1 to 3, wherein the plurality of string binder
20 filaments comprises from three to eighteen weight percent of the fiber glass roving based
on the total weight of the fiber glass roving.

6. The fiber glass roving of any of claims 1 to 3, wherein the plurality of string binder filaments comprises from three percent to twelve weight percent of the fiber glass roving, based on the total weight of the fiber glass roving.
- 5 7. The fiber glass roving of any of claims 1 to 6, wherein the plurality of bicomponent string binder filaments comprises at least one bundle of bicomponent string binder filaments.
8. The fiber glass roving of claim 7, wherein each filament of bicomponent string
10 binder is greater than thirty denier.
9. The fiber glass roving of any of claims 1 to 8, wherein the other sheaths of the plurality of bicomponent string binder filaments comprises at least fifty weight percent of the string binder, based on the total weight of the string binder filaments.
- 15
10. The fiber glass roving of any of claims 1 to 9, wherein the other sheaths of the plurality of bicomponent string binder filaments comprises at least seventy weight percent of the string binder, based on the total weight of the string binder filaments.
- 20 11. A method of forming a multi-end fiber glass roving, comprising:
providing a plurality of fiber glass ends to a roving winder at a first tension;
providing at least one additional fiber glass end and a plurality of bicomponent string binder filaments, each filament having a core and an outer sheath, to the roving winder at a second tension; and

winding the fiber glass ends and the plurality of bicomponent string binder filaments to form a multi-end fiber glass roving,
wherein the second tension is less than the first tension.

5 12. The method of claim 11, wherein the core comprises polyethylene terephthalate and wherein the outer sheath comprises copolyester.

13. The method of claim 11, wherein the core comprises polyethylene terephthalate and wherein the outer sheath comprises glycol modified polyethylene terephthalate.
10

14. The method of any of claims 11 to 13, wherein the at least one additional fiber glass end and the plurality of bicomponent string binder filaments comprise up to fifty weight percent string binder based on the total weight of the at least one additional fiber glass end and the plurality of bicomponent string binder filaments.

15. The method of any of claims 11 to 13, wherein the at least one additional fiber glass end and the plurality of bicomponent string binder filaments comprise from fifteen to fifty weight percent string binder, based on the total weight of the at least one additional fiber glass end and the plurality of bicomponent string binder filaments.
15

16. The method of any of claims 11 to 15, wherein the string binder filaments comprise more than three weight percent of the multi-end fiber glass roving based on total weight of the multi-end fiber glass roving.
20

17. The method of any of claims 11 to 15, wherein the string binder filaments comprise from three to eighteen weight percent of the multi-end fiber glass roving based on total weight of the multi-end fiber glass roving.
- 5 18. The method of any of claims 11 to 15, wherein the string binder filaments comprise from three to twelve weight percent of the multi-end fiber glass roving, based on total weight of the multi-end fiber glass roving.
19. A preform comprising the fiber glass roving of any of claims 1 to 10.