REINFORCED POLYMERIC ARTICLES

Applicants: VORBECK MATERIALS CORPORATION, Jessup, MD (US); KORDSA GLOBAL ENDOSTRYEL IPLIK VE KORD BEZI SANAYI VE TICARET A.S., Istanbul (TR)

Inventors: İlhan A. Aksay, Princeton, NJ (US); Bora Buyskuldu, Kocaeli (TR); Nurcin Javaheerian, Kocaeli (TR); John S. Lettow, Washington, DC (US); Gustavo Pino, Istanbul (TR); Kate Redmond, Baltimore, MD (US); İbrahim O. Yıldırım, Istanbul (TR)

Assignees: VORBECK MATERIALS CORPORATION, Jessup, MD (US); KORDSA GLOBAL ENDOSTRYEL IPLIK VE KORD BEZI SANAYI VE TICARET A.S., Istanbul (TR)

(* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 90 days.

This patent is subject to a terminal disclaimer.

Appl. No.: 14/736,838

Filed: Jun. 11, 2015

Prior Publication Data

Related U.S. Application Data
Continuation of application No. 13/870,603, filed on Apr. 25, 2013, now Pat. No. 9,085,667, which is a continuation of application No. 13/234,654, filed on Sep. 16, 2011, now Pat. No. 8,449,959, which is a (Continued)

Int. Cl.
C08K 3/04 (2006.01)
C08J 5/04 (2006.01)

U.S. Cl.
C08K 3/04 (2013.01); C08J 5/04 (2013.01);
D01F 1/10 (2013.01); C08J 2321/00 (2013.01).

Field of Classification Search
CPC .......... C08L 23/00; C08L 67/00; C08L 1/02;
C08L 77/02; C08L 77/06; C08L 67/02;
C08L 21/00; C08L 7/00; C08L 9/00; C08L 11/00; C08L 15/02; C08L 27/06; C08L 75/04;
C08L 77/00; B32B 1/08; B32B 5/00; C08K 7/00, C08K 3/04

References Cited
U.S. PATENT DOCUMENTS
2,947,340 A 8/1960 French
2,979,101 A 4/1961 Willis

FOREIGN PATENT DOCUMENTS
EP 1574551 9/2005

OTHER PUBLICATIONS

Primary Examiner — Michael C Miggins
(74) Attorney, Agent, or Firm — Oblon, McClelland, Maier & Neustadt, L.L.P.

ABSTRACT
Polymeric article reinforced with a reinforcing component.
The reinforcing component includes a composition made from at least one polymer and graphene sheets.

8 Claims, 1 Drawing Sheet
Related U.S. Application Data
Provisional application No. 61/160,590, filed on Mar. 16, 2009.

Int. Cl.
DOIF 1/10
C08L 21/00

U.S. Cl.
CPC .......................... CO8J 227/06 (2013.01); CO8L 21/00 (2013.01); Y10T 428/1352 (2015.01); Y10T 428/1352 (2015.01); Y10T 428/1352 (2015.01); Y10T 428/1352 (2015.01); Y10T 428/1352 (2015.01); Y10T 428/24921 (2015.04); Y10T 428/30 (2015.01)

References Cited
U.S. PATENT DOCUMENTS
4,204,984 A 5/1980 Neubert
7,659,539 B2 2/2010 Pnld’homme et al.
8,066,964 B2 11/2011 Pnld’homme et al.
8,105,976 B2 1/2012 Pnld’homme et al.
8,110,026 B2 2/2012 Pnld’homme et al.
8,110,026 B2 2/2012 Pnld’homme et al.
8,278,757 B2 10/2012 Crain et al.
8,449,950 B2 5/2013 Aksay et al.
8,891,247 B2 11/2014 Pnld’homme et al.
9,039,938 B2 5/2015 Crain et al.
2004/0261928 A1 1/2004 Imhoff et al.
2012/0244433 A1 9/2012 Aksay et al.
2012/0255607 A1 10/2012 Aksay et al.

FOREIGN PATENT DOCUMENTS
EP 1950328 7/2008
GB 2009/0720 6/1999

OTHER PUBLICATIONS
Office Action for European Application No. 10753968.6, mailed Aug. 16, 2013, 3 pages.
Office Action for European Application No. 10753966.0, mailed May 29, 2013, 3 pages.

* cited by examiner
REINFORCED POLYMERIC ARTICLES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/234,654, entitled “Reinforced Polymeric Materials,” filed Sep. 16, 2011, which is a continuation of International Application No. PCT/US10/27440, filed Mar. 16, 2010, which claims priority to, and the benefit of U.S. Provisional Application No. 61/610,590, filed on Mar. 16, 2009, entitled “Reinforced Polymeric Articles,” the disclosures of each of which are incorporated by reference herein in their entirety.

This application is also related to pending U.S. application Ser. No. 13/234,602, entitled “Polymeric Fibers and Articles Made Therefrom,” filed on Sep. 16, 2011 and U.S. application Ser. No. 13/234,668, entitled “Tire Cords,” filed on Sep. 16, 2011, the disclosures of each of which are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

The present invention relates to polymeric articles reinforced with a reinforcing agent made from compositions comprising at least one polymer and graphene sheets.

BACKGROUND

The physical properties of polymeric fibers (which can include, depending on the polymeric material, high modulus, high strength, high toughness, high stiffness, high fatigue resistance (including bending and expansion/compression fatigue resistance), dimensional stability, abrasion resistance, shrinkage, thermal degradation stability, and chemical resistance, among other attributes) can be improved by using them to reinforce many polymeric articles, including mechanical rubber goods, belts, membrane fabrics, hoses, diaphragms, and the like. Their high weight and ease of processing have allowed polymeric fibers to replace metals partially or wholly in many applications.

It would, however, be desirable to obtain polymeric fibers having further improved properties, including one or more of modulus, strength, dimensional stability, fatigue resistance, impact resistance, and shrinkage.

Improved modulus and/or strength per unit weight could, for example, allow for the construction of lighter polymeric goods. Improved modulus and/or strength could also permit the replacement of metals (such as steel) or the reduction of the amount of metal used in certain applications. For example, alternative warp and/or weft cord constructions could be used for some reinforcing applications.

For example, alternative warp and/or weft cord constructions in a belt could be used to decrease the reinforcement weight per unit area, which could offer goods (including mechanical rubber goods) such as belts having lower operating and end-use costs. Bending resistance and warp crimp requirements could be improved, improving the hysteresis and/or dynamic elongation properties of reinforcing agents and reinforced articles.

Increased impact resistance and shock absorptivity of reinforcing agents and reinforced articles could lower maintenance costs and reduce performance. Increased thermal and/or electrical conductivity could offer more end-use possibilities for reinforced polymeric goods, such as self-cleaning articles and applications where static dissipativity is important.

Thermal shrinkage and dimensional stability of reinforced polymeric goods (including mechanical goods) (such as braided hoses, wrapped hoses, membranes, profiles, and diaphragms) could increase their durability (particularly under flexing) and useful lifetime. Control of shrinkage forces can be important when processing articles, particularly those having complex shapes.

SUMMARY OF THE INVENTION

Disclosed and claimed herein are articles comprising at least one polymeric component and at least one reinforcing component, wherein the reinforcing component includes a composition that has a polymer and graphene sheets.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a plot of the storage modulus vs. temperature of monofilaments comprising poly(ethylene terephthalate) containing 0.25 wt. % graphene sheets and of commercial PET monofilaments.

DETAILED DESCRIPTION

Articles described herein comprise at least one polymeric component and at least one reinforcing component. The reinforcing component includes a composition that comprises at least one polymer and graphene sheets. The reinforcing component can be in any suitable form, such as fibers, yarns, cords, fabrics, strips, tapes, plies, etc.

Fibers described herein comprise a composition including a polymer and graphene sheets. The fibers can be in the form of polyamides, polyesters, acrylics, acetates, modacryls, spandex, lyocells, and the like. Such fibers (also referred to herein as filaments) can take on a variety of forms, including staple fibers (also referred to as spun fibers), monofilaments, multifilaments, and the like. The fibers can have a number of different average diameters. For example, in some embodiments the fibers can have a number average diameter of about 1 μm to about 1.5 μm or of about 15 μm to about 1.5 mm.

The fibers can be of any cross-sectional shape. For example, they can have a circular or substantially circular cross-section, or have cross-sections that are, for example, oval, star-shaped, trilobal (including trilobal), square, rectangular, polygonal, irregular, etc. They can also be hollow in their entirety or in part and can have a foam-like structure. The fibers can be crimped, bent, twisted, woven or the like.

Fibers can be in the form of a multicomponent (such as a bicomponent) composite structure (these are also referred to as conjugate fibers), including, for example, multilayered structures comprising two or more concentric and/or eccentric layers (including inner core and outer sheath layers), a side-by-side structure, or the like. These can be obtained, for example, by extruding two or more polymers from the same spinnerette.

In one embodiment, each of the components of the structures include a form of the composition. In another embodiment, at least one of the components include a form of the composition and another of the components include a material without the composition. For example, other components (such as layers) may comprise other polymeric materials.

Examples of bicomponent structures include fibers comprising a polyester core and a copolyester sheath, a polyester core and a polyethylene sheath, a polyester core and a polyamide sheath, a poly(ethylene terephthalate) core and a sheath of another polyester, a polyamide core and a copolyamide
The fibers can be formed in fabrics that comprise at least one fiber of the present invention. The fibers can also be formed in fabrics that comprise at least one fiber of the present invention and can optionally comprise other fibers. The fabrics can be in the form of filament yarns, spun yarns, and the like. The fabrics can additionally be formed into cords that comprise at least one yarn and/or filament of the present invention. Fabrics may be formed from one or more fibers, cords, yarns, etc.

The fibers, yarns, and/or cords can be formed in fabrics having enhanced tensile properties and strengths and tenacities. The fabrics can be woven fabrics, non-woven fabrics (including spunbonded, spunlaid, spun laced, etc. fabrics), knit fabrics, and the like and can include additional components such as, for example, fibers, yarns, and/or cords other than those comprising the polymer or yarn. The fibers can also be formed into microfiber fabrics.

The polymers can be of any suitable type, including thermoplastics, elastomers, non-melt-processible polymers, thermoset polymers, etc. Examples of polymers include, but are not limited to: polyamides, polyesters, polyolefins (such as polyethylene, ethylene/propylene, low linear density polyethylene, low density polyethylene, high density polyethylene, propylene, and olefin copolymers), cellulose, cellulose acetate, acrylics, poly(methyl methacrylate) and other acrylic polymers, poly(phenylene sulfide) (PPS), poly(acrylonitrile) and poly(acrylonitrile) copolymers (such as copolymers with vinyl acetate, methyl acrylate, and/or methyl methacrylate), melamine polymers, polynylbenzimidazoles (PBI), polyurethanes (including thermoplastics and thermosets), poly(p-phenylene-2,6-benzobisoxazole) (PBO), polypheylene benzoisothiazole, poly[2,6-dimethyl[4,5-b:4,5-c,5,6-diphenyldi- 2,5-dihydroxyphenylene]] (PMDA), liquid crystalline polymers, aramids (such as those sold by DuPont under the trademarks Kevlar® and Nomex®, including poly(p-phenylene isophthalamide) and poly(p-phenylene terephthalamide), and copolymers of the foregoing. Preferred polyamides include polyamide 6,6; polyamide 6; and copolymers of polyamide 6 and polyamide 6.6. The polyamide 6,6 may have a relative viscosity of at least about 65 when measured in 96% formic acid. The polyamide 6 may have a relative viscosity of at least about 85 when measured in 96% formic acid.

Examples of suitable polyesters include, but are not limited to, semiaromatic polyesters, such as poly(ethylene terephthalate) (PET), poly(ethylene adipate) (PDA), and poly(ethylene terephthalate) (PPT), poly(ethylene naphthalate) (PEN), and poly(cyclohexanedimethanol terephthalate) (PCT), aliphatic polyesters (such as poly(lactic acid), and copolymers thereof. Preferred polyesters are PET, PPT, and PEN. Particularly preferred is PET. Polymers can include copolyetheresters. Preferred polyesters have an intrinsic viscosity of at least about 0.8 when measured in ortho-chlorophenol.

The graphene sheets are graphite sheets preferably having a surface area of at least about 100 m²/g to about 2,630 m²/g. In some embodiments, the graphene sheets may be, almost completely, or completely comprise fully exfoliated single sheets of graphene (these are approximately 1 nm thick and are often referred to as "graphene"), while in other embodiments, they can comprise partially exfoliated graphene sheets, in which two or more sheets of graphene have not been exfoliated from each other. The graphene sheets may comprise mixtures of fully and partially exfoliated graphene sheets.

One method of obtaining graphene sheets is from graphite and/or graphite oxide (also known as graphitic acid or graphene oxide). Graphite can be treated with oxidizing and intercalating agents and exfoliated. Graphite can also be treated with intercalating agents and electrochemically oxidized and exfoliated. Graphite sheets can be formed by ultrasonically exfoliating suspensions of graphite and/or graphite oxide in a liquid. Exfoliated graphite oxide dispersions or suspensions may be subsequently reduced to graphene sheets. Graphite sheets can also be formed by mechanical treatment (such as grinding or milling) to exfoliate graphite oxide (which would subsequently be reduced to graphene sheets).

Graphite oxide can be reduced to graphite by chemical reduction using hydrogen gas or other reducing agents.
Examples of useful chemical reducing agents include, but are not limited to, hydrazines (such as hydrazine, N,N-dimethylhydrazine, etc.), sodium borohydride, hydroquinone, citric acid, etc. For example, a dispersion of exfoliated graphite oxide in a carrier (such as water, organic solvents, or a mixture of solvents) can be made using any suitable method (such as ultrasonication and/or mechanical grinding or milling) and reduced to graphite sheets.

One method of exfoliation includes thermal exfoliation and ultrasonic dispersion of suspensions. The graphite can be any suitable type, including natural, Kish, and synthetic/polymeric graphites and graphitic materials such as, for example, graphitic carbon fibers (including those derived from polymers), and highly oriented pyrolytic graphite.

In one method of preparing graphite sheets, graphite is first oxidized to graphite oxide, which is then thermally exfoliated to form high surface area graphite sheets in the form of thermally exfoliated graphite oxide. Such a method is generally described in U.S. Patent Pub. No. 2007/0092432, entitled “Thermally Exfoliated Graphite Oxide” by Prad‘Homme et al., the disclosure of which is incorporated herein by reference. The thusly formed thermally exfoliated graphite oxide may display little or no signature corresponding to graphite or graphite oxide in its X-ray diffraction pattern.

Graphite oxide may be produced by any method known in the art, such as by a process that involves oxidation of graphite using one or more chemical oxidizing agents and, optionally, intercalating agents such as sulfuric acid. Examples of oxidizing agents include nitric acid, sodium and potassium nitrates, perchlorates, hydrogen peroxide, sodium and potassium permanganates, phosphorus pentoxide, bisulfites, and the like. Preferred oxidants include KClO₄, HNO₃, and KClO₃; KMnO₄ and/or NaMnO₄; KMnO₄ and Na₂SO₄; K₂S₂O₈ and PO₃; and KMnO₄ and HNO₃; and HNO₃. A preferred intercalation agent includes sulfuric acid. Graphite can also be treated with intercalating agents and electrochemically oxidized.

The graphite sheets preferably have an average aspect ratio of about 100 to 100,000 (where “aspect ratio” is defined as the ratio of the longest dimension of the sheet to the shortest dimension of the sheet).

The graphite sheets preferably have a surface area of from about 100 m²/g to about 2,630 m²/g, or more preferably of from about 200 m²/g to about 2,630 m²/g, or yet more preferably of from about 300 m²/g to about 2,630 m²/g, or even more preferably from about 350 m²/g to about 2,630 m²/g, or still more preferably of from about 400 m²/g to about 2,630 m²/g, or further more preferably of from about 500 m²/g to about 2,630 m²/g. In another preferred embodiment, the surface area is about 300 m²/g to about 1,100 m²/g. A single graphite sheet has a maximum calculated surface area of 2,630 m²/g. The surface area includes all values and subvalues therebetween, especially including 400, 500, 600, 700, 800, 900, 100, 110, 1,200, 1,300, 1,400, 1,500, 1,600, 1,700, 1,800, 1,900, 2,000, 2,100, 2,200, 2,300, 2,400, 2,500, and 2,630 m²/g.

Surface area can be measured using either the nitrogen adsorption/BET method at 77 K or a methylene blue (MB) dye method in a liquid solution. The dye method is carried out as follows. A known amount of graphite sheets is added to a flask. At least 1.5 g of MB per gram of graphite sheets is then added to the flask. Ethanol is added to the flask and the mixture is ultrasonicated for about fifteen minutes. The ethanol is then evaporated and a known amount of water is added to the flask to re-dissolve the free MB. The undissolved material is allowed to settle, preferably by centrifuging the sample. The concentration of MB in solution is determined using a UV-vis spectrophotometer by measuring the absorption at λₑₑₑ = 298 nm relative to that of standard concentrations.

The difference between the amount of MB that was initially added and the amount present in solution as determined by UV-vis spectrophotometry is assumed to be the amount of MB that has been adsorbed onto the surface of the graphite sheets. The surface area of the graphite sheets is then calculated using a value of 2.54 m²/g from equation: 1.05 kg/m³ to at least about 200 kg/m³. The bulk density includes all values and subvalues therewithin, especially including 0.5, 1, 5, 10, 15, 20, 25, 30, 35, 50, 75, 100, 125, 150, and 175 kg/m³.

The graphite sheets can be functionalized with, for example, oxygen-containing functional groups (including, for example, hydroxyl, carboxyl, and epoxy groups) and typically have an overall carbon to oxygen molar ratio (C/O ratio), as determined by elemental analysis of at least about 1:1, or more preferably, at least about 2:1. Examples of carbon to oxygen ratios include from about 3:2 to about 85:15; about 3:2 to about 20:1; about 3:2 to about 30:1; about 3:2 to about 40:1; about 3:2 to about 60:1; about 3:2 to about 80:1; about 3:2 to about 100:1; about 3:2 to about 200:1; about 3:2 to about 500:1; about 3:2 to about 1000:1; about 3:2 to greater than 1000:1; about 10:1 to about 30:1; about 80:1 to about 100:1; about 20:1 to about 100:1; about 20:1 to about 500:1; about 20:1 to about 1000:1. In some embodiments of the invention, the carbon to oxygen ratio is at least about 10:1, or at least about 20:1, or at least about 35:1, or at least about 50:1, or at least about 75:1, or at least about 100:1, or at least about 200:1, or at least about 300:1, or at least about 400:1, or at least about 500:1, or at least about 750:1, or at least about 1000:1, or at least about 1500:1, or at least about 2000:1. The carbon to oxygen ratio also includes all values and subvalues between these ranges.

The surface of the graphite sheets can be modified by the addition of molecules including hydrocarbons, and those containing neutral or charged functional groups, such as oxygen-, nitrogen-, halogen-, sulfur-containing functional groups. Examples of functional groups include hydroxyl groups, amine groups, ammonium groups, sulfates, sulphonates, epoxy groups, carboxylate and carboxylic acid groups, esters, anhydrides, and the like. The modifying molecules may be bound to the surface of the graphite sheets covalently, ionically, via hydrogen bonding, electrostatically, via physical adsorption, and the like.

The graphite sheets can contain atomic scale kinks due to the presence of lattice defects in the honeycomb structure of the graphite basal plane. These kinks can be desirable to prevent the stacking of the single sheets back to graphite oxide and/or other graphite structures under the influence of van der Waals forces. Kinks may also be desirable for adjusting the modulus of the sheets in the composite applications where at low strains the kinks yield at low stress levels and thus provide a gradually increasing modulus (75 to 250 GPa), and at high strains modulus as high as 1 TPa may be attained. The kinks can also be desirable for mechanical interlocking in the composite structures.

The compositions can optionally further include additional polymers and/or additional additives, including stabilizers (such as thermal, oxidative, and/or UV light resistant stabilizers), nucleating agents, colorants (such as pigments, dyes, and the like), other nano fillers (such as nanoclay), other carbon-based fillers (such as carbon nanotubes, carbon black, graphite, and the like), lustersents, delusterants (e.g., titanium dioxide), lubricants, dye-adhesion promoters, and the like.
The compositions preferably include at least about 0.0001 wt % graphene sheets, based on the total weight of the graphene sheets and polymer. The graphene sheets can be present in at least about 0.005 wt %, in at least about 0.01 wt %, in at least about 0.1 wt %, in at least about 0.2 wt %, or in at least about 0.25 wt % (where all weight percentages are based on the total weight of the graphene sheets and polymer).

Preferred ranges in which the graphene sheets are present include from about 0.0001 wt % to about 3 wt %, from about 0.001 wt % to about 3 wt %, from about 0.005 wt % to about 3 wt %, from about 0.01 wt % to about 3 wt %, from about 0.025 wt % to about 2 wt %, from about 0.05 wt % to about 2 wt %, from about 0.05 wt % to about 1 wt %, from about 0.1 wt % to about 0.5 wt %, from about 0.1 wt % to about 1 wt %, from about 0.1 wt % to about 0.5 wt %, and from about 0.1 wt % to about 0.3 wt % (where all weight percentages are based on the total weight of the graphene sheets and polymer).

If the polymer is melt processable, the compositions can be made prior to fiber formation using any suitable melt-blending method, including using a single or twin-screw extruder, a blender, a kneader, or a Banbury mixer. In one embodiment, the compositions are melt-mixed blends wherein the non-polymeric ingredients are well-dispersed in the polymer matrix, such that the blend forms a unified whole.

The compositions can also be formed by dry blending polymer and a master batch containing polymer and graphene sheets prior to melt spinning. In such a method, the master batch preferably comprises up to about 50 wt % graphene sheets, or more preferably from about 2 wt % to about 20 wt % graphene, based on the total weight of the master batch.

The compositions can also be made by combining graphene sheets (and optionally, additional components) with monomers that are polymerized to form the polymer.

The fibers can be formed by any suitable method such as, for example, extrusion, melt spinning, solvent (wet) spinning, dry spinning, gel spinning, reaction spinning, electrospinning, and the like. For example, when spinning, suitable nozzles (such as spinnerettes) may be selected to form monofilament or multifilament fibers.

When melt spinning, a quench zone can be used for the solidification of the filaments. Examples of quench zones include cross-flow, radial, horizontal, water bath, and other cooling systems. A quench delay zone that may be heat or unheated can be used. Temperature control may be done using any suitable medium, such as a liquid (e.g. water), a gas (e.g. air), and/or the like.

Filaments and/or yarns can be subjected to one or more drawing and/or relaxation operations during and/or subsequent to the spinning process. Drawing and/or relaxation processes can be combined with the spinning processes (such as by using a spin draw process), or can be done using separate drawing equipment to pre-spin fibers in form of monofilament or multifilament yarns. The drawing process can be done, for example, by using different speed single or duo gojets or rolls, with heating (hot drawing), without heating (cold drawing), or both. The draw ratio can be controlled by heating and/or annealing during the quench delay zone. Heating can be achieved using heated gojets, one or more hot boxes, etc. Relaxation can be done with heating (hot drawing), without heating (cold drawing), or both.

The spinning speed, spinline tension, spinline temperature, number of drawing stages, draw ratio, relaxation ratio, speed ratios between each relaxation and drawing step, and other parameters can vary. The parameters of the drawing and/or relaxation processes can be selected according to the polymer or polymers used, the polymer structures, processability requirements, and/or desired physical and/or chemical properties of the fibers and/or filaments.

Spinning and/or drawing processes can affect one or more of the degree of crystallization, crystallization rates, crystal structure and size, crystaline orientation, amorphous orientation, and the like. Filament and yarn properties (such as tensile modulus and strength) may vary as a function of spinning and/or drawing processes. In certain cases it is possible that the functionalized graphene sheets increase orientation and crystallization of the polymer structure during the spinning processes.

A spin finish oil may optionally be applied to the filament after quenching, but before any drawing and/or relaxation steps. A finish oil may also be optionally applied to fibers before or during subsequent processes such as twisting, weaving, dipping, and the like.

The fibers can be electrically conductive, meaning that they may have a conductivity of at least about 10^{-5} S/m. In some embodiments, the fibers preferably have a conductivity of at least about 10^{-4} S/m, or more preferably of about 10^{-3} S/m to about 10^{0} S/m. In other embodiments, the fibers have a conductivity of at least about 100 S/m, or at least about 1000 S/m, or at least about 10 S/m, or at least about 10^{0} S/m.

The reinforcing component can be treated with an adhesive prior to being incorporated into the article. Examples of adhesives include RFL (resorcinol formaldehyde latex) dips, cement, isocyanates, epoxies, and the like.

Examples of the polymeric component include, but are not limited to, resins comprising one or more of rubbers, elastomers, polyurethanes, polyolefins (such as ethylene and including substituted polyolefins and copolymers (random and block), such as styrene-isoprene-styrene and styrene-butadiene-styrene copolymers, chloropolymers (such as poly(vinyl chloride) (PVC)), fluoropolymers, etc. The resins may comprise additional components, such as additives.

Example of rubbers used in the articles of the invention include, but are not limited to, natural rubber, butyl rubber, polybutadiene, styrene-butadiene rubber, isobutylene-isoprene rubber, chlorobutyl rubber, bromobutyl rubber, neoprene, polyisoprene, chloroprene rubber, nitrile rubber, etc.

Examples of reinforced articles include, but are not limited to, belts (such as conveyor belts, transmission belts, timing belts, v-belts, power transmission belts, pump belts, antistatic belts, etc.), diaphragms and membrane fabrics (such as those used in diaphragms, air brakes, roofing, and the like), hoses (such as automotive under-hood hoses, high pressure hoses, and the like), air springs, textile architectural components, etc. The articles include manufactured rubber goods. Examples of belts include, but are not limited to, belts for open or closed mining operations, belts for transporting luggage and cargo (as in airports, for example), belts used in factory production, belts used in shopping check-out areas, belts used in construction, belts used in power plant operations, man lifts, etc.

**EXAMPLES**

Example 1

Graphene sheets are added to poly(ethylene terephthalate) (PET) by melt compounding in an extruder to yield a PET composition comprising about 0.25 weight percent graphene sheets. The PET composition is then solid phase polymerized at 215° C. to an IV of about 1 dl/g. The composition is spun into monofilaments that are then post drawn to a draw ratio of about 4 to 5. After drawing, the filaments have a diameter of...
about 120 microns. The storage modulus of the monofilaments is then measured as a function of temperature using a dynamic mechanical analyzer (DMA). The results are given in Table 1 and in FIG. 1.

Comparative Example 1

The storage modulus of commercial PET monofilaments having an IV of about 0.6 to 0.8 dL/g and a diameter of about 250 microns is measured using a DMA. The commercial PET and the PET of Example 1 have similar tenacities. The results are given in Table 1 and FIG. 1.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th></th>
<th>Comparative Ex. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage modulus</td>
<td>Example 1</td>
<td></td>
</tr>
<tr>
<td>(GPa)</td>
<td>32° C.</td>
<td>17.7</td>
</tr>
<tr>
<td></td>
<td>52° C.</td>
<td>22.9</td>
</tr>
<tr>
<td></td>
<td>70° C.</td>
<td>21.8</td>
</tr>
<tr>
<td></td>
<td>90° C.</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>110° C.</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>130° C.</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>150° C.</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>170° C.</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>190° C.</td>
<td>9.82</td>
</tr>
<tr>
<td></td>
<td>210° C.</td>
<td>8.89</td>
</tr>
</tbody>
</table>

What is claimed is:

1. An article comprising: a polymeric component and a reinforcing component, the reinforcing component including a composition having a polymer and graphene sheets, wherein the reinforcing component has a diameter of about 120 μm to about 1.5 mm.

2. The article of claim 1, wherein the polymer is one or more selected from the group consisting of polyamides, polyesters, polyolefins, aramids, cellullosic polymers, and rayon.

3. The article of claim 2, wherein the polymer is a polyamide.

4. The article of claim 3, wherein the polyamide is one or more of polyamide 6,6; polyamide 6; and polyamide 6,6/polyamide 6 copolymers.

5. The article of claim 2, wherein the polymer is a polyester.

6. The article of claim 5, wherein the polyester is one or more of poly(ethylene terephthalate), poly(ethylene naphthalate), and poly(ethylene terephthalate)/poly(ethylene naphthalate) copolymers.

7. The article of claim 2, wherein the polymer is an aramid.

8. The article of claim 2, wherein the polymer is rayon.

* * * * *