



(43) International Publication Date
8 September 2017 (08.09.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/151701 A1

- (51) **International Patent Classification:**
D06M 13/17 (2006.01) *C08J 5/04* (2006.01)
D06M 13/419 (2006.01)
- (21) **International Application Number:**
PCT/US2017/020080
- (22) **International Filing Date:**
1 March 2017 (01.03.2017)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/303,090 3 March 2016 (03.03.2016) US
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- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** CARBON FIBER SIZING AGENTS FOR IMPROVED INTERFACIAL SHEAR STRENGTH

(57) **Abstract:** The present invention provides aqueous sizing compositions for carbon fibers comprising, as solids, from 85 to 99.5 wt.% of one or more ethoxylated bisphenol A having a weight average of from 2 to 30 ethylene oxide groups and from 0.5 to 15 wt.% of ethoxylated oleamides having a weight average of from 2 to 30 ethylene oxide groups or, preferably, from 3 to 20 ethylene oxide groups, as well as the carbon fibers sized with the aqueous sizing compositions. The aqueous sizing compositions enable one to provide sized carbon fiber containing epoxy resin articles having improved interfacial shear strength (IFSS) between fiber and matrix resin.



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CARBON FIBER SIZING AGENTS FOR IMPROVED INTERFACIAL SHEAR STRENGTH

The present invention relates to aqueous compositions for sizing carbon fibers comprising ethoxylated bisphenol A and ethoxylated oleamide, as well as to carbon
5 fibers treated therewith and epoxy resin compositions containing the thus treated carbon fibers. More particularly, the present invention relates to aqueous sizing compositions comprising ethoxylated bisphenol A and ethoxylated oleamide having a solids content of from 0.1 to 5.0 wt.%, wherein the amount of ethoxylated oleamide, based on total aqueous sizing composition solids, ranges from 0.5 to 15 wt.%, as
10 well as to sized carbon fibers treated with from 0.1 to 3 wt.% of the composition solids, for example, chopped carbon fibers, and epoxy resin compositions containing the sized carbon fibers.

Carbon fibers are brittle and require sizing materials on their surface as lubricants to enable improved fiber processing and to protect the fibers from damage
15 during handling and the fabrication of fiber intermediates, e.g. fabric. Acceptable sizing compositions provide low friction and consistent handling that allow for easy processing and that prevent residual sizing and/or fiber build-up on processing equipment. In addition, carbon fibers are used to reinforce or fill resin matrix materials; thus, the sizing compositions must be compatible with resin matrix
20 materials formulated to contain the sized carbon fibers.

Japanese laid open patent publication (Kokai) H1-272867A, to Toray (Tore K.K.) discloses that ethoxylated and propoxylated bisphenol A can be used as sizing agents for carbon fibers. Toray discloses that relatively low levels of the sizing agents can allow the thus treated carbon fiber to be processed without fraying.
25 However, while such carbon fibers treated with an ethoxylated bisphenol A sizing composition can be processed without any fraying and can exhibit improved fiber bundle break up upon chopping, the compositions of Toray fail to provide acceptable interfacial shear stress (IFSS) between the fiber and an epoxy resin.

The present inventors have endeavored to provide sizing compositions for carbon
30 fibers that allow for acceptable carbon or graphite fiber processing without fraying, that enable acceptable resin matrix infusion into the fibers, e.g. bundles, and that provide improved interfacial bonding between the fibers and the resin matrix.

STATEMENT OF THE INVENTION

1. In accordance with the present invention, aqueous compositions for sizing carbon fibers comprise from 85 to 99.5 wt.%, or, preferably, from 90 to 99.5 wt.%, or, more preferably, from 95 to 99 wt.%, or, even more preferably, from 97 to 99 wt.%,
5 based on the total solids in the aqueous sizing composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30 ethylene oxide groups, or, preferably, from 3 to 20 ethylene oxide groups, or, more preferably, 3 to 16 ethylene oxide groups and from 0.5 to 15 wt.%, or, preferably, from 0.5 to 10.0 wt.%, or, more preferably, from 1 to 5 wt.%, or, even more preferably, from 1 to 3 wt.%, based on
10 the total solids in the composition, of an ethoxylated oleamide.

2. In accordance with the present invention as in item 1, above, wherein the ethoxylated oleamide has a weight average of from 2 to 30 ethylene oxide groups, or, preferably, from 3 to 20 ethylene oxide groups, or, more preferably, 3 to 16 ethylene oxide groups.

15 3. In accordance with the present invention as in item 1, above, wherein the ethoxylated oleamide comprises the ethoxylated reaction product of oleic acid or its salt with an amine that contains one or more hydroxyl groups, preferably, one or more primary hydroxyl groups, such as an alkanolamine, a dialkanolamine or a trialkanolamine.

20 4. In accordance with the present invention as in any one of items 1, 2, or 3, above, wherein each of the ethoxylated bisphenol A and the ethoxylated oleamide has the same weight average number of ethylene oxide groups, or each has a weight average of from 3 to 20 ethylene oxide groups, or, preferably, each has a weight average of from 3 to 16 ethylene oxide groups.

25 5. In accordance with the present invention as in any one of items 1, 2, 3, or 4, above, wherein the total solids content in the aqueous compositions ranges from 0.1 to 5 wt.%, or, preferably, from 0.2 to 5 wt.% or, preferably, from 0.2 to 3 wt.%, or, more preferably, 2 wt.% or less, or, more preferably, 0.35 wt.% or more.

30 6. In accordance with the present invention in any one of items 1, 2, 3, 4, or 5, above, wherein the composition has a viscosity at 20 °C as determined with a fluids rheometer (ARES RFSIII, TA Instruments- Waters LLC, New Castle, DE) equipped with a cup and bob fixture and taking the intersection between two sets of data, one taken from an experiment that varied shear rates, in steady shear flow, of from 0.03

to 300/s, and a second one at varied oscillation frequencies, in oscillatory shear flow, of from 100 to 0.1 rad/s of from 0.8 to 100 centipoises (cPs), or, preferably, from 0.8 to 20 cPs, or, more preferably, from 1 to 10 cPs.

7. In another aspect of the present invention, carbon fiber compositions
5 comprise sized carbon fibers treated with a sizing composition in the amount of from 0.1 to 5 wt.% as solids, or, preferably, from 0.2 to 5 wt.% as solids, or, preferably, from 0.2 to 3 wt.% as solids, or, more preferably, 2 wt.% or less and/or 0.35 wt.% or more as solids, based on the total weight of the thus treated fibers, the sizing composition containing from 85 to 99.5 wt.%, or, preferably, from 90 to 99.5 wt.%, or,
10 more preferably, from 95 to 99 wt.%, or, even more preferably, from 97 to 99 wt.%, based on the total solids in the sizing composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30 ethylene oxide groups, or, preferably, from 3 to 20 ethylene oxide groups, or, more preferably, 3 to 16 ethylene oxide groups and from 0.5 to 15 wt.%, or, preferably, from 0.5 to 10.0 wt.%, or, more preferably, from 1
15 to 5 wt.%, or, even more preferably, from 1 to 3 wt.%, based on the total solids in the sizing composition, of an ethoxylated oleamide.

8. In accordance with the present invention as in item 7, above, wherein the ethoxylated oleamide has a weight average of from 2 to 30 ethylene oxide groups, or, preferably, from 3 to 20 ethylene oxide groups, or, more preferably, 3 to 16
20 ethylene oxide groups.

9. In accordance with the present invention as in any one of items 7, or 8, above, wherein the ethoxylated oleamide comprises the ethoxylated reaction product of oleic acid or its salt with an amine that contains one or more hydroxyl groups, preferably, one or more primary hydroxyl groups, such as an alkanolamine, a
25 dialkanolamine or a trialkanolamine.

10. In accordance with the present invention as in any one of items 7, 8, or 9, above, wherein each of the ethoxylated bisphenol A and the ethoxylated oleamide has the same number of ethylene oxide groups, or each has a weight average of from 3 to 20 ethylene oxide groups, or, preferably, each has a weight average of
30 from 3 to 16 ethylene oxide groups.

11. In accordance with the present invention as in any one of items 7, 8, 9, or 10, above, wherein the fibers comprise carbon fibers as continuous carbon fibers, carbon fiber bundles or chopped carbon fibers.

12. In yet another aspect of the present invention, epoxy resin compositions comprise one or more epoxy resins, for example, bisphenol A or bisphenol F epoxy resin, epoxy hybrid resins or epoxy resin blends, and sized carbon fibers treated with from 0.1 to 5 wt.% or, preferably, from 0.2 to 5 wt.%, or, preferably, from 0.2 to 3
5 wt.%, or, more preferably, up to 2 wt.% and/or 0.35 wt.% or more, based on the total weight of the thus sized carbon fibers, of a sizing composition of from 85 to 99.5 wt.%, or, preferably, from 90 to 99.5 wt.%, or, more preferably, from 95 to 99 wt.%, or, even more preferably, from 97 to 99 wt.%, based on the total solids in the sizing composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30
10 ethylene oxide groups, or, preferably, a weight average of from 3 to 20 ethylene oxide groups, or, more preferably, a weight average of from 3 to 16 ethylene oxide groups and from 0.5 to 15 wt.%, or, preferably, from 0.5 to 10.0 wt.%, or, more preferably, from 1 to 5 wt.%, or, even more preferably, from 1 to 3 wt.%, based on the total solids in the sizing composition, of an ethoxylated oleamide.

15 13. In accordance with the present invention as in item 12, above, wherein the ethoxylated oleamide in the sizing composition has a weight average of from 2 to 30 ethylene oxide groups, or, preferably, a weight average of from 3 to 20 ethylene oxide groups, or, more preferably, a weight average of 3 to 16 ethylene oxide groups.

20 14. In accordance with the present invention as in item 12 or 13, above, wherein each of the ethoxylated bisphenol A and the ethoxylated oleamide in the sizing composition has the same weight average number of ethylene oxide groups, or each has a weight average of from 3 to 20 ethylene oxide groups, or, preferably, each has a weight average of from 3 to 16 ethylene oxide groups.

25 15. In accordance with the present invention as in any one of items 12, 13, or 14, above, wherein the compositions comprise from 65 to 400 phr or, preferably, from 90 to 300 phr or, more preferably, from 95 to 300 phr of the sized carbon fibers.

30 16. In accordance with the present invention as in any one of items 12, 13, 14 or 15, above, wherein the fibers comprise continuous carbon fibers or chopped carbon fibers.

17. In accordance with the present invention in any one of items 12, 13, 14, 15 or 16, above, wherein the compositions comprise a prepreg, a sheet molding compound of chopped carbon or graphite fibers, an extruded bulk molding

compound of carbon or graphite fibers, a woven or non-woven article of continuous carbon or graphite fibers or a non-woven article of chopped or random carbon or graphite fibers.

18. In accordance with the present invention as in any one of items 7 to 17,
5 above, wherein the carbon fibers comprise carbon or graphite fibers.

19. In accordance with the present invention as in item 18, above, wherein the carbon fibers have a first layer of surface oxidation and as second layer, the sizing composition.

Unless otherwise indicated, conditions of temperature and pressure are room
10 temperature and standard pressure, also referred to herein as "ambient conditions".

The singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise.

The endpoints of all ranges directed to the same component or property are inclusive of the endpoint and independently combinable. Thus, for example, a
15 disclosed range of from 0.5 to 15 wt.%, or, preferably, from 0.5 to 10.0 wt.%, or, more preferably, from 1 to 3 wt.% means any and all of from 0.5 to 15 wt.%, or, preferably, from 0.5 to 10.0 wt.%, or, more preferably, from 1 to 3 wt.%, or from 0.5 to 1 wt.%, or from 0.5 to 3 wt.%, or, preferably, from 3 to 10 wt.%, or, preferably, from 1 to 10 wt.%, or from 1 to 15 wt.%, or from 3 to 15 wt.%, or from 10 to 15 wt.%.

20 As used herein, the term "aqueous" means water or water mixed with up to 50 wt.%, or up to 25 wt.%, or, preferably, from 0 to 10 wt.%, based on the total weight of a mixture of water and solvent, of one or more water miscible solvents which is volatile under ambient conditions, such as a lower alkanol, an ether, or a ketone.

As used herein, the term "phr" means per hundred parts resin, by weight.

25 Unless otherwise indicated, the resin refers to the total amount of resin in a given composition, including blends and combinations of more than one different resin, as well as curing agents and reactive diluents.

As used herein, the term "polyamine" means any amine containing compound having three or more amine groups including terminal amine groups.

30 As used herein, the term "solids" or "total solids" excludes organic solvents and refers to the non-volatile content of a composition, wherein volatiles comprise anything that boils or is a gas at 100 °C, such as water, ammonia or methyl ethyl ketone.

As used herein, unless otherwise indicated, the term “weight average number of ethylene oxide groups” means that amount determined by measuring the weight average molecular weight of a given compound by gel permeation chromatography (GPC) against poly(ethylene glycol) standards sufficient to resolve the number of ethylene oxide groups to within a single such group, subtracting the molecular weight (formula weight) of the groups other than ethylene oxide groups, for example, bisphenol A, from the weight average molecular weight, and then dividing the result by the molecular weight of ethylene oxide.

As used herein, the term “wt. %” refers to weight percent.

The present inventors have found that a layer of a sizing composition of ethoxylated oleamide and ethoxylated bisphenol A on a carbon fiber leads to an improvement in the interfacial shear strength (IFSS) between the sized carbon fiber and an epoxy resin matrix containing the sized carbon fiber. At the same time, the sizing composition provides fiber processability and reduced fluff while ensuring compatibility with the epoxy resin compositions that can be used as matrix resins without a need for epoxy resin in the sizing composition.

The aqueous sizing compositions of the present invention are made by simple combination or mixing of one or more ethoxylated oleamides (for example, the number of ethylene oxide groups and the amine containing portions thereof can vary) in the amount of 15 wt. % or less, or, preferably, less than 5 or less than 3 wt. %, based on total solids in the sizing composition, with the remainder of an ethoxylated bisphenol A. In the aqueous sizing compositions, too much of the ethoxylated oleamide can reduce the compatibility of the sized carbon fiber with matrix resin.

The ethoxylated oleamides of the present invention can be made by reaction of oleic acid or its salts with an amine containing one or more hydroxyl groups, preferably, one or more primary hydroxyl groups, such as, a hydroxy functional amine, a hydroxy functional diamine, for example, ethanol amine, diethanol amine, followed by ethoxylation in a conventional manner.

The ethoxylated oleamides of the present invention can be purchased, for example, the SERDOX NXC series of specialty materials from Elementis Specialties, Netherlands B.V.

The ethoxylated bisphenol A of the present invention can be made in a conventional fashion by reacting the alkali salt of bisphenol A with ethylene oxide.

The ethoxylated bisphenol A of the present invention can be purchased, for example, the SYN FAC 9000 series of bisphenol A ethoxylates from Milliken Chemicals, Inc, Greenville, SC.

5 The ethoxylated oleamides and the ethoxylated bisphenol A compounds of the present invention are water dispersible. Thus, the aqueous sizing composition of the present invention can be made by simple mixing of the ingredients with or in an aqueous medium.

10 The aqueous sizing compositions of the present invention can include up to 15 wt.%, based on total weight solids, of one or more formulation chemicals. Suitable formulation chemicals can comprise nonionic surfactants, emulsifiers, water dispersible epoxy resins, thermoplastic resins and antifoaming agents, such as silicone containing oils.

15 Suitable carbon fibers in the present invention can be any such as Type I (high modulus - HM) and Type II (high tensile strength - HT) carbon fiber, and can also include graphite fibers. Carbon fibers can be formed in a conventional fashion from polyacrylonitrile (PAN), pitch or hydrocarbon feedstocks, and RayonTM cellulosic polymer feedstocks, for example, any such polymers having high strength and high moduli of elasticity. Such carbon fibers can have a tensile modulus of elasticity preferably ranging from 165 GPa to 800 GPa and further preferably ranging from 200
20 GPa to 800 GPa at room temperature.

Preferably, for increased adhesion of the sizing composition of the present invention to a given carbon fiber, the carbon fibers of the present invention are preferably subject to surface oxidation treatment and thereby have a first layer of surface oxidation. The suitable carbon fibers may be subjected to liquid phase or
25 vapor phase surface oxidization treatment in advance of sizing. Suitable methods for surface oxidization treatment may include subjecting carbon fiber to electrochemical oxidation using the carbon fiber as the anode, with an electrolyte solution of an oxidant compound having any of a hydroxyl (C-OH) group, carbonyl (C=O) group, carboxyl (COOH) group, an ammonium bicarbonate as the electrolyte
30 and using varied current densities [31]. Oxidation treatment in an electrolytic aqueous solution is preferable because of its advantages, including its convenience. Solutions for electrolytic treatment are not particularly limited, and may be a sulfuric acid solution or an ammonium carbonate solution, for example. To minimize

damage to the carbon fiber, an appropriate example of electricity for electrolytic treatment ranges from 0 (no treatment) to 100 coulombs per gram of carbon fiber.

The carbon fiber sizing methods of the present invention may comprise the surface oxidation treatment and then treating the carbon fibers with a sizing
5 composition as a second layer, for example, in an aqueous bath, followed by drying the thus treated carbon fibers.

The aqueous sizing compositions of the present invention can be applied to the carbon fibers as sizing solution bath at an elevated temperature, e.g. of from 30 to 100 °C. In a sizing bath, the amount of size retained on the carbon fibers and the
10 effectiveness of the bath depend on sizing residence times, bath temperature, sizing line speeds, and carbon fiber tension.

The drying of the sized carbon fibers of the present invention may comprise drying at room temperature or heating to elevated temperatures to remove water or solvent in air or inert atmosphere.

15 The sized carbon fibers of the present invention can then be processed by winding, such as around a bobbin, and then chopping to make chopped carbon fibers, by weaving so as to form a fabric, or spreading the fibers such as for use in forming tape.

The sized carbon fibers of the present invention, whether chopped or continuous,
20 can be further processed by contacting them with a matrix resin comprising epoxy resin compositions (as in a prepreg), or by laying chopped random carbon fibers on an epoxy resin composition film, as in sheet molding compounds (SMC), or by extruding the carbon fiber or a spread fiber array with the epoxy resin compositions as in bulk molding compounds (BMC), or by compression molding which comprises
25 placing the sized carbon fiber as a fabric in a mold, injecting the matrix epoxy resin compositions and pressing, or by filament winding of resin infused fibers onto a substrate, such as a pressure vessel. In such further processing, the prepreg, resin infused fiber, the chopped random fiber or SMC materials are intermediates that can later be cured and yet even further processed, such as by compression molding.
30 Any of the intermediates can be made as or formed into a specific three dimensional shape for further processing.

The epoxy resin compositions of the present invention can further comprise the sized carbon fibers of the present invention in combination with other reinforcing

fibers to provide strength to the polymer matrix for reinforcement. Fibers suitable for epoxy resin matrix reinforcement include, for example, ceramic fibers, synthetic organic fibers, natural fibers, mineral fibers, metal fibers, and other forms of fibers.

Suitable epoxy resins for use in making the epoxy resin compositions of the present invention include any epoxy resin compositions, for example, bisphenol A or bisphenol F epoxy resin, novolac epoxy resins, as well as epoxy hybrid resins, e.g. acrylic epoxy hybrids or polyester epoxy hybrids or urethane epoxy hybrids, or epoxy resin blends.

The epoxy resin compositions of the present invention can comprise a prepreg, a sheet molding compound of chopped carbon or graphite fibers, an extruded bulk molding compound of carbon or graphite fibers, a woven or non-woven article of continuous carbon or graphite fibers, or a non-woven article of chopped or random carbon or graphite fibers.

Epoxy resins used in the present invention may be combined with an appropriate curing agent, such as an aromatic or aliphatic amine, internal mold release agent, viscosity modifiers such as diluents or thickeners. Epoxy resins are formulated to achieve desired processing characteristics, such as, for example, infusion of epoxy resin formulation into the carbon fiber intermediate, such as chopped fiber or fabric; to achieve desired processing characteristics of epoxy and carbon fiber intermediates, such as uncured (B-staged) carbon fiber and epoxy mixtures intermediates such as prepregs and sheet molding compounds with appropriate tack for handling and viscosity for molding; or to achieve final desired molded composite article performance attributes, such as glass transition temperature, composite tensile and flexural strength and fiber volume fraction.

EXAMPLES

The following examples serve to better illustrate the invention, which is not intended to be limited by the examples.

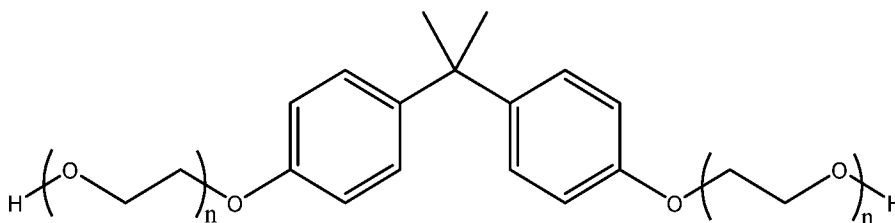
The following materials were used in the examples:

Unsize carbon fibers are 12K A42 carbon fiber (DowAksa, Yalova, Turkey).

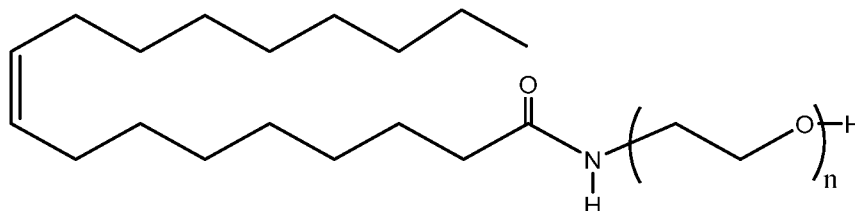
After a conventional carbon fiber graphitization process, the carbon fiber was treated with a basic electrolyte.

Ethoxylated bisphenol A (BPAEO) sizing material of the following formula:

Number of ethylene oxide groups (weight avg.) = 15 total, n=8



Ethoxylated oleamides having ethylene oxide groups, include SERDOX NXC3 materials with 3 such ethylene oxide groups (Elementis Specialties, Netherlands B.V.), SERDOX NXC6 materials with 6 ethylene oxide groups (Elementis), and SERDOX NXC14 with 14 ethylene oxide groups (Elementis). For example, the ethoxylated oleamide sold under the name SERDOX NXC 3 has the following formula, wherein $n = 3$:



An epoxy matrix resin was formulated from a blend of 87 wt.% of D.E.R. 354 diglycidyl ether of bisphenol-F liquid epoxy resin (Olin Corporation, Clayton, MO) and 13 wt.% of D.E.H. 26 (an aliphatic polyamine hardener, tetraethylenepentamine (TEPA), The Olin Corporation).

Interfacial Shear Strength (IFSS): The formulated matrix resin and sized fibers were subject to a microbond test to determined IFSS. The microbond test measures the force required to displace a drop of the indicated epoxy resin that has been cured so that it adheres around a single carbon fiber filament sized with the indicated composition. See, for example, J. L. Thomason and L. Yang, "*Temperature dependence of the interfacial shear strength in glass-fibre polypropylene composites*," Composites Science and Technology, 71 (2011) at 1600-1605. In the test, the sized fiber is glued to a paper tab and the cured resin droplet is adhered on the free end of the sized fiber. The IFSS test fixture is installed in the grips of a tension test instrument (TA.XT PLUS Texture Analyzer, Stable Micro Systems, Godalming, Surrey, UK). The cured resin droplet is suspended from the test fixture, consisting of a metal slit ~25 μm in width and having approximately parallel edges,

with the fiber hanging through the slit. The paper tab is clamped into immovable grips below the test fixture; the Texture Analyzer is actuated to displace the cured resin droplet (bead length L) from the sized fiber (fiber diameter D), and the peak force (F_P) is recorded. The IFSS is then calculated using Formula (I), below:

5 (I)
$$\tau = \frac{F}{\pi DL}$$

Comparative Example A

The formulated epoxy matrix resin, described above, was applied on to unsized carbon fiber to form beads adhered on the surface of the fiber. The samples were
10 cured at 60 °C for 4 hr to cure the resin before microbond testing. The IFSS of the unsized carbon fiber with the composite matrix resin was 37.1 MPa.

Example 1

Ethoxylated bisphenol A (BPAEO) having a weight average of 15 ethylene oxide groups was first mixed with ethoxylated oleamide having a weight average of 3
15 ethylene oxide groups to prepare a mixture with 97 wt% BPAEO and 3 wt% of ethoxylated oleamide. The mixture was then diluted with water to prepare a sizing solution with 0.388 wt% of BPAEO and 0.012 wt% of ethoxylated oleamide in water. The aqueous sizing composition had a viscosity of 1.2 cPs at 20 °C.

Using a continuous process, unsized carbon fiber was pulled by a 5 roller feed
20 Godet set roller unit (model FR-N0.6-SRV, Izumi International, Inc. Greenville, SC) from the creel stand of the roller unit and then fed through a bath of the aqueous sizing composition at room temperature (~20 °C) for a sizing application time of 10 seconds. The sized carbon fiber tow is pulled by a tension controlled winder from the sizing bath through a dryer, maintained between 100 to 102 °C via a controller, at
25 a line speed of 1 m/min, for a total drying time of 128 sec to remove the water and produce sized carbon fiber. The dried carbon fiber tow is collected on the spool of the winder. The fiber tension was monitored between the dryer and the winder, using a hand held tension meter (ELECTROMATIC DTMB-1K, Electromatic Equipment Co., INC), and found at the winder to be 873 g.

30 The formulated epoxy matrix resin was applied onto the sized carbon fiber to form beads adhered on the surface of the carbon fiber. The samples were cured at 60 °C for 4 hr to cure the resin before microbond testing. The IFSS of the sized carbon fiber with the composite matrix resin was 57.8 MPa. Therefore, the addition

of ethoxylated oleamide (SERDOX) in BPAEO sizing material resulted in a significant improvement in IFSS between carbon fiber and composite resin matrix materials.

We claim:

1. An aqueous composition for sizing carbon fibers comprise from 85 to 99.5 wt.%, based on the total solids in the composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30 ethylene oxide groups, and from 0.5 to 15 wt.%, based on the total solids in the composition, of an ethoxylated oleamide.
2. The aqueous composition as claimed in claim 1, wherein the composition comprises from 0.1 to 5 wt.%, based on the total solids in the composition, of the ethoxylated oleamide.
3. The aqueous composition as claimed in claim 1, wherein the ethoxylated oleamide has a weight average of from 2 to 30 ethylene oxide groups.
4. The aqueous composition as claimed in claim 1, wherein the ethoxylated oleamide has a weight average of from 3 to 20 ethylene oxide groups.
5. The aqueous composition as claimed in claim 1, wherein the total solids content in the aqueous composition ranges from 0.2 to 5 wt.%.
6. The aqueous composition as claimed in claim 1, wherein the ethoxylated bisphenol A has a weight average of from 3 to 20 ethylene oxide groups.
7. A carbon fiber composition comprising sized carbon fibers treated with a sizing composition of from 0.1 to 5 wt.% as solids, based on the total weight of the thus treated fibers, the sizing composition containing from 85 to 99.5 wt.%, based on the total solids in the sizing composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30 ethylene oxide groups, and from 0.5 to 15 wt.%, based on the total solids in the sizing composition, of an ethoxylated oleamide.
8. The carbon fiber composition as claimed in claim 7, wherein the ethoxylated oleamide has a weight average of from 2 to 30 ethylene oxide groups.
9. The carbon fiber composition as claimed in claim 7, wherein the sizing composition comprises from 0.2 to 5.0 wt.%, based on the total solids in the sizing composition, of the ethoxylated oleamide.
10. An epoxy resin composition comprising one or more epoxy resins, epoxy hybrid resins or epoxy resin blends, and sized carbon fibers treated with from 0.1 to 3 wt.%, based on the total weight of the thus sized carbon fibers, of a sizing composition of from 85 to 99.5 wt.%, based on the total solids in the sizing composition, of an ethoxylated bisphenol A having a weight average of from 2 to 30

ethylene oxide groups, and from 0.5 to 15 wt.%, based on the total solids in the sizing composition, of an ethoxylated oleamide.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/020080

A. CLASSIFICATION OF SUBJECT MATTER
INV. D06M13/17 D06M13/419 C08J5/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D06M C08J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104 928 933 A (CHINA PETROLEUM & CHEMICAL; SINOPEC SHANGHAI RES INST PETROCHEMICAL TE) 23 September 2015 (2015-09-23) abstract examples	1-10
A	JP 2001 207380 A (TAKEMOTO OIL & FAT CO LTD) 3 August 2001 (2001-08-03) abstract examples	1-10
A	JP 2013 127132 A (TORAY INDUSTRIES) 27 June 2013 (2013-06-27) abstract examples	1-10
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

8 May 2017

Date of mailing of the international search report

16/05/2017

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/020080

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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