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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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, 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.

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[Continued on next page]

(54) Title: PROCESS OF DEBUNDLING CARBON FIBER TOW AND MOLDING COMPOSITIONS CONTAINING SUCH FIBERS

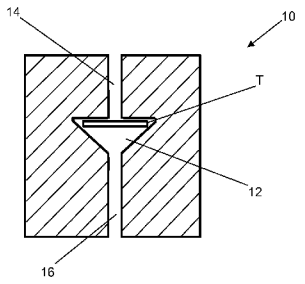

FIG. 1A

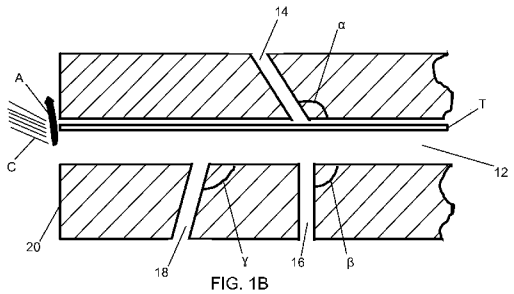

FIG. 1B

(57) Abstract: A process for debundling a carbon fiber tow into dispersed chopped carbon fibers suitable for usage in molding composition formulations is provided. A carbon fiber tow is fed into a die having fluid flow openings, through which a fluid impinges upon the side of the tow to expand the tow cross sectional area. The expanded cross sectional area tow extends from the die into the path of a conventional fiber chopping apparatus to form chopped carbon fibers, or through contacting tines of a mechanical debundler. Through adjustment of the relative position of fluid flow openings relative to a die bore through which fiber tow passes, the nature of the fluid impinging on the tow, the shape of the bore, in combinations thereof, an improved chopped carbon fiber dispersion is achieved. The chopped carbon fiber obtained is then available to be dispersed in molding composition formulations prior to formulation cure.

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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, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

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

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

PROCESS OF DEBUNDLING CARBON FIBER TOW AND MOLDING COMPOSITIONS CONTAINING SUCH FIBERS

Cross-Reference to Related Application

[0001] This application claims priority of United States Provisional Patent Application Serial No. 61/641,136 filed May 1, 2012, which is incorporated herein by reference.

Field of the Invention

[0002] The present invention in general relates to a process for debundling carbon fiber tow and in particular, to a process for producing chopped and disbursed carbon fibers amenable to inclusion molding compositions.

Background of the Invention

[0003] The use of fiber inclusions to strengthen a matrix is well known to the art. Well established mechanisms for the strengthening include slowing and elongating the path of crack propagation through the matrix, as well as energy distribution associated with pulling a fiber free from the surrounding matrix material. In the context of sheet molding composition (SMC) formulations and bulk molding composition (BMC) formulations; hereafter referred to collectively as "molding compositions", fiber strengthening has traditionally involved usage of chopped glass fibers. There is a growing appreciation in the field of molding compositions that replacing in part, or all of the glass fiber in molding compositions with carbon fiber. However, this effort has met with limited success owing to differences between glass and carbon fibers. Specifically, these differences include fiber diameter with glass fibers used in molding compositions having typical diameters of between 16 and 30 microns while carbon fibers typically have diameters of between 2 and 10 microns. Additionally, whereas glass roving fabrics, or bundles typically have tens to hundreds of individual fibers, carbon fiber tows typically come in bundles of thousands and even tens of thousands of individual fibers. A still further difference exists in the fiber-fiber interactions where glass fibers tend to scatter and debundle upon chopping, Van der waals bonding and other interfiber surface interactions tend to make carbon fiber disinclined from debundling after chopping into desired lengths for use as reinforcement in a molding composition. While the debundling of carbon fiber tows is addressed in laboratory scale moldings through manual manipulation, problems exist for production scale debundling of carbon fiber tow into separate chopped carbon fibers.

[0004] Thus, there exists a need for a process to debundle carbon fiber tow into separated chopped carbon fibers in a continuous manner. There further exists a need to facilitate

interaction of carbon fibers with molding composition components to enhance the strength of a resulting SMC or BMC

Summary of the Invention

[0005] An improved device and method for debundling a large number of carbon fibers collectively forming a tow into dispersed chopped carbon fibers suitable for usage in molding composition formulations is provided. According to an embodiment of the present invention, a carbon fiber tow is fed into a die having fluid flow openings, through which a fluid impinges upon the side of the tow to expand the tow cross sectional area. The expanded cross sectional area tow extends from the die into the path of a conventional fiber chopping apparatus to form chopped carbon fibers. Through adjustment of the relative position of fluid flow openings relative to a die bore through which fiber tow passes, the nature of the fluid impinging on the tow, the shape of the bore, in combinations thereof, an improved chopped carbon fiber dispersion is achieved, compared to existing processes. The chopped carbon fiber obtained according to the present invention is then available in certain embodiments to be dispersed in molding composition formulations prior to formulation cure. Through control of the molding composition monomer polarity, still further dispersion and anisotropy of the chopped carbon fibers is obtained.

[0006] A mechanical debundler that accepts tow like material, such as carbon fiber tow, as input in a top feed area between two opposing rollers with tines, where the first roller spins clockwise and the second roller spins counter clockwise so as to pull the tow inward towards a lower tined roller that rotates faster than the upper two rollers, and as the tow goes through it gets pulled open and kinked to expand the tow to about 5 times in height. In embodiments, the mechanical debundler may also be used simultaneously with heating, air blowing, or plasma. In the embodiment where plasma is used, the tines are charged to create plasma in region that tow is being teased open.

[0007] In an alternative embodiment of the present invention, a conventionally chopped fiber tow is dispersed in a polar monomer containing molding composition.

Brief Description of the Drawings

[0008] The subject matter that is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other

objects, features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0009] Fig. 1A is a transverse cross sectional view of a die according to the present invention operative in debundling carbon fiber tow;

[0010] Fig. 1B is a longitudinal cross sectional view of the die shown in Fig. 1A; and

[0011] Fig. 2 is a second embodiment of a die operative in the present invention for debundling carbon fiber tow.

[0012] Fig. 3 illustrates a mechanical debundler according to an embodiment of the invention.

Detailed Description of the Invention

[0013] The present invention has utility in debundling a large number of carbon fibers collectively forming a tow into dispersed chopped carbon fibers suitable for usage in molding composition formulations. According to the present invention, a carbon fiber tow is fed into a die having fluid flow openings, through which a fluid impinges upon the side of the tow to expand the tow cross sectional area. The expanded cross sectional area tow extends from the die into the path of a conventional fiber chopping apparatus to form chopped carbon fibers. Through adjustment of the relative position of fluid flow openings relative to a die bore through which fiber tow passes, the nature of the fluid impinging on the tow, the shape of the bore, in combinations thereof, an improved chopped carbon fiber dispersion is achieved, compared to existing processes. The chopped carbon fiber obtained according to the present invention is then available in certain embodiments to be dispersed in molding composition formulations prior to formulation cure. Through control of the molding composition monomer polarity, still further dispersion and anisotropy of the chopped carbon fibers is obtained.

[0014] In an alternative embodiment of the present invention, a conventionally chopped fiber tow is dispersed in a polar monomer containing molding composition.

[0015] Referring now to Figs. 1A and 1B, an inventive die is shown generally at 10. The die 10 has a bore 12 that is dimensionally larger than the cross sectional area of the carbon fiber tow T passed there through. At least two fluid flow openings 14, 16, and 18 as shown in Figs. 1A and 1B are provided to allow fluid communication into the bore 12 and onto the side of the carbon fiber tow T. The bore 12 is depicted having a triangular cross section. It is appreciated that the bore of an inventive die has other cross sectional shapes such as circular, oval, hourglass-shape, and other polygonal cross sectional shapes. The fluid openings 14, 16, and 18 allow for a fluid to be injected into the bore 12 so as to impact the side of the carbon fiber tow T

and induce debundling so as to increase the cross sectional area of the bundle T. According to the present invention at least two fluid openings are provided. It is appreciated that the fluid ingress need only occur through the fluid openings as the fluid is able to leave the die 10 from the terminal die face 20 that is proximal to a fiber chopping apparatus A. Through the control of feed rate of the tow T and the operational speed of the chopper A, a controlled length debundled chopped fiber C is obtained.

[0016] As fluid impingement the fluid openings 14, 16, and 18 each intersect with the bore 12 at an angle, alpha (α), beta (β), and gamma (γ), respectively. Each of these angles is independently variable. In specific embodiments, the angles alpha, beta, and gamma are each independently between 30 and 150 degrees, although it should be appreciated that other angles are operative herein.

[0017] Without intending to be bound to a particular theory, it is believed that, the fluid enters the bore 12 under conditions such that the fluid penetrates into the tow T creating a larger void volume in the resultant expanded cross sectional area bundle. Fluid entering the bore 12 that as an expanding fluid tends to travel along a path of least resistance, the conditions are preferably established that favor fluid penetration through the tow T thereby increasing the cross section of the tow T prior to the fluid exiting through a lower pressure fluid flow opening than the one through which the fluid entered alone or in combination with exiting through the terminal die face 20. As best shown in Fig. 1B, it should be appreciated that fluid flow openings need not all exist in a single plane where fluid flow outlet 18 is downstream from openings 14 and 16 relative to the movement of the tow T.

[0018] Another embodiment of an inventive die is shown in Fig. 2 generally at 30 with a circular bore 12' and fluid openings 14' and 16';

[0019] As used herein, the term "fluid" is intended to include gasses, liquids, and aerosol atomized fluids. Fluids operative herein for debundling carbon fiber tow illustratively include air, nitrogen, noble gasses, carbon dioxide, carbon monoxide, and steam. It is appreciated that organic molecules, and silanes, above the respective boiling temperature of each are also operative herein as gaseous fluids used to debundle carbon fiber filaments. Liquid fluids suitable for debundling carbon fiber tow illustratively include high polarity liquids with a relative polarity of greater than about 0.5. In addition to a simple fluid, a fluid according to the present invention also carries an additive such as particulate, radicals, coupling agents, and combinations thereof. Particulate suitable for entrainment within a fluid impinging upon a carbon fiber tow illustratively include carbon black, calcium carbonate, colloidal silica, titanium dioxide, and

combinations thereof. Coupling agents operative herein illustratively include epoxies, organo-titanates, organo-zirconates, hydroxyl methyl resorcinol, and combinations thereof. Radicals operative as additive; especially gaseous fluids illustratively include ozone, singlet oxygen, and plasma. It is appreciated that control of factors such as cross sectional area of the bore, the shape of the bore, inlet pressure of fluid, and relative position of fluid exit openings affect the degree of carbon fiber tow debundling, to produce dispersed carbon fiber strands after being chopped from the tow by a chopping apparatus A is readily achieved.

[0020] As shown in Fig. 2 where like numerals correspond to the meanings ascribed thereto with respect to Figs. 1A and 1B, another die as part of an inventive process is provided. Without intending to be bound to a particular theory, simultaneously impinging upon a carbon fiber tow from two fluid flow openings as shown in Fig. 2, under conditions that limit the twisting of the carbon fiber tow is suitable in inventive embodiments for successful debundling.

[0021] Fig. 3 illustrates an inventive mechanical debundler 40 that accepts tow like material, such as carbon fiber tow, as input in a top feed area between two opposing rollers with tines 48, where the first roller 42 spins clockwise and the second roller 44 spins counter clockwise so as to pull the tow inward towards a lower tined roller 46 that rotates faster than the upper two rollers (42, 44), and as the tow goes through it gets pulled open and kinked to expand the tow to about 5 times in height. In embodiments, the mechanical debundler may also be used simultaneously with heating, air blowing, or plasma to separate the tow. In certain embodiments, heat is applied that is sufficient to remove any sizing or other conventional surface coatings on the surface of the carbon fibers. In still other embodiments heat is applied under an inert or reducing atmosphere to promote pyrolysis of the sizing from the core carbon fibers. A plasma is readily generated with a conventional plasma generator source to treat the tow fibers prior to, during, or subsequent to engagement with the second roller 44. In the embodiment where plasma is used, the tines are charged to create plasma in the region that the tow is being teased open. It is appreciated that a tow is contacted with a mechanical debundler in concert with air debundling or as a stand alone process.

[0022] An inventive process after a carbon fiber tow has been fed through a die with impingement of fluid onto the side of the tow and penetrating the carbon fiber tow so as to increase the cross sectional area, or through the mechanical debundler, the tow is then chopped into preselected lengths of carbon fiber strands. The resultant strands are then dispersed in an SMC, BMC or RTM formulation for subsequent molding and cure. It has been found that such chopped fiber strands tend to disperse and achieve a greater degree of both fiber debundling and

anisotropy when the molding composition is more polar. In specific embodiments of the present invention, the chopped carbon fibers so produced are dispersed in a methyl methacrylate monomer. Other suitable monomers from which a molding composition formulation is produced illustratively include unsaturated polyesters, epoxies, and combinations thereof. A molding composition formulation based on epoxy illustratively includes bis-phenol-A and Novolac based epoxy terminated resins. Suitable curing agents for such an epoxy based molding composition formulation illustratively include anhydrides such as trimellitic anhydride, methyl tetrahydrophthalic anhydride (MTHPA), nadic methyl anhydride (NMA), di- and tri-functional amines, and combinations thereof.

[0023] An alternative embodiment of the present invention involves dispersing conventional chopped and bundled carbon tow in a molding composition monomer or solution containing monomer with a relative polarity of greater than 0.26, and in certain embodiments greater than 0.5, and in still other embodiments between 0.5 and 0.8. Relative polarity is defined per Christian Recihardt, Solvents and Solvent Effects in Organic Chemistry, Wiley-VCH, 3rd edition, 2003.

[0024] The chopped carbon fibers produced according to an inventive process are readily dispersed in molding composition formulations prior to cure as a substitute for, or in combination with glass fibers. As a result of debundling carbon fiber tow according to an inventive process, a reinforced SMC, BMC or resin transfer molding (RTM) cured article is formed that has a lower density overall, and a lower percentage by weight loading of fibers. Additionally, through the use of coupling agents superior tensile strength is achieved. Additionally, it is of note that the inventive process as a continuous process for producing chopped carbon fibers is amenable to usage with production scale manufacture.

[0025] The resulting chopped and debundled carbon fibers find particular utility in an SMC having an inner portion containing from 10 to 40% by weight carbon fibers of the inner portion, with an outer skin of SMC based on the commercially available TCA (Continental Structural Plastics) containing glass fiber containing between 10 and 60% glass fiber by weight of the TCA portion, as embodied in U.S. Patent 7,655,297. The ratio of thickness of the inner portion to the outer skin ranges from 01-10:1. The resulting SMC inner portion and outer skin layers are either cured separately and joined or cured in contact with one another. Such a dual layer SMC with an inner portion containing carbon fibers is noted to have a density that is 10, 20, 30 and even 40% lower than the comparable article formed wholly from TCA. In this way a lightweight article is formed that retains the high surface glass of a class-A surface associated with TCA.

[0026] Patent documents and publications mentioned in the specification are indicative of the levels of those skilled in the art to which the invention pertains. These documents and publications are incorporated herein by reference to the same extent as if each individual document or publication was specifically and individually incorporated herein by reference.

The foregoing description is illustrative of particular embodiments of the invention, but is not meant to be a limitation upon the practice thereof. The following claims, including all equivalents thereof, are intended to define the scope of the invention.

Claims

1. A process for debundling carbon fiber tow into chopped carbon fibers comprising:

feeding the carbon fiber tow defined by a bundle cross sectional area and a tow surface into a die having a bore, the die having at least two fluid flow openings, where the bore is sized larger than the bundle cross sectional area with the proviso that if the at least two fluid flow openings are two openings, that the two openings are not diametrically positioned through a circular cross sectional bore;

impinging on the carbon fiber tow through a first opening of the at least two fluid flow openings with a fluid at a flow rate to expand carbon fiber tow to an expanded cross sectional area greater than the bundle cross sectional area within said bore;

chopping the expanded cross sectional area carbon fiber tow upon exiting said die to form the chopped carbon fiber.

2. The process of claim 1 wherein the carbon fiber tow has at least 1,000 carbon fibers therein.

3. The process of claim 1 wherein the carbon fiber tow has at least 10,000 carbon fibers therein.

4. The process of claim 1 wherein chopping occurs proximal to a terminal face of said die.

5. The process of claim 1 wherein the bore is a cross sectional shape of triangular, circular, oval, or polygonal.

6. The process of claim 1 wherein the at least two fluid flow openings are laterally displaced along a length of the bore.

7. The process of claim 1 wherein at least one of the fluid flow openings defines a fluid exhaust.

8. The process claim 1 wherein the fluid is air.

9. The process of claim 1 wherein the fluid is gaseous and further comprises particulate.

10. The process of claim 9 wherein said particulate is at least one of carbon black, calcium carbonate, silica, or titanium dioxide.

11. The process of claim 1 wherein the fluid is gaseous and further comprises radicals.

12. The process of claim 11 wherein said radicals comprise singlet oxygen, or plasma.

13. The process of claim 1 wherein the fluid is gaseous and further comprises a coupling agent.

14. The process of claim 13 wherein said coupling agent is at least one of epoxy, a titanate, or a zirconate.

15. The process of claim 1 further comprising dispersing the chopped carbon fiber in a molding composition prepolymer formulation.

16. The process of claim 15 wherein said molding composition prepolymer comprises polar monomers.

17. The process of claim 16 wherein said polar monomers comprise a majority by weight of said molding composition absent fiber and fillers.

18. The process of claim 16 wherein said polar monomer is at least one of methyl methacrylate.

19. A process for debundling carbon fiber tow into chopped carbon fibers comprising:

chopping the carbon fiber tow to a chopped tow; and dispersing the chopped tow in a monomer, or in a molding composition containing said monomer with a relative polarity of greater than 0.25.

20. The process of claim 19 wherein the relative polarity is greater than 0.5.

21. The process of claim 19 wherein the relative polarity is between 0.5 and 0.8.

22. The process of any of claims 1 to 21 further comprising contacting said tow with a plurality of rotating tines.

23. The process of claim 1 further comprising contacting said tow with a plurality of rotating tines while simultaneously exposing said tow to at least one of heat or plasma.

24. The process of claim 23 wherein heat is applied under an inert or reducing environment.

25. An article comprising:

a cured inner portion of sheet molding composition reinforced predominantly with chopped carbon fibers; and

a cured outer skin of a second sheet molding composition reinforced predominantly with glass fiber.

26. The article of claim 22 wherein said cured inner portion is substantially devoid of glass fiber.

27. The article of claim 22 or wherein said outer skin has an automotive surface quality finish..

28. The article of claim 24 wherein said outer skin is substantially devoid of chopped carbon fiber.

29. The article of claim 22 wherein said outer skin has a class-A finish.

30. The article of claim 22 wherein said inner portion has an inner layer thickness and said outer skin has an outer skin thickness and the ratio of the inner layer thickness to outer skin thickness is between 01-10:1.

31. A process for debundling carbon fiber tow into chopped carbon fibers comprising:

feeding the carbon fiber tow defined by a bundle cross sectional area and a tow surface into a mechanical debundler comprising: a feed area that accepts said tow between two opposing rollers with tines, where a first roller of said two opposing rollers spins clockwise and a second roller of said two opposing rollers spins counter clockwise so as to pull the tow inward towards a lower tined roller that rotates faster than the upper two rollers;

expanding said tow to about 5 times in loft.

32. The process of claim 31 further comprising chopping the expanded cross sectional area carbon fiber tow upon exiting said die to form the chopped carbon fiber.

33. The process of claim 31 further comprising applying at least one of blowing air, heat or plasma to said tow in a region between said lower tined roller and the upper two rollers.

34. A mechanical debundler comprising:

a top feed area that accepts tow material, such as carbon fiber tow, between two opposing rollers with tines, where a first roller of said two opposing rollers spins clockwise and a second roller of said two opposing rollers spins counter clockwise so as to pull the tow inward towards a lower tined roller that rotates faster than the upper two rollers; and

a plasma source forming a plasma in proximity to one of said upper two rollers or said lower tined roller.

35. The debundler of claim 34where the tines are charged to create the plasma.

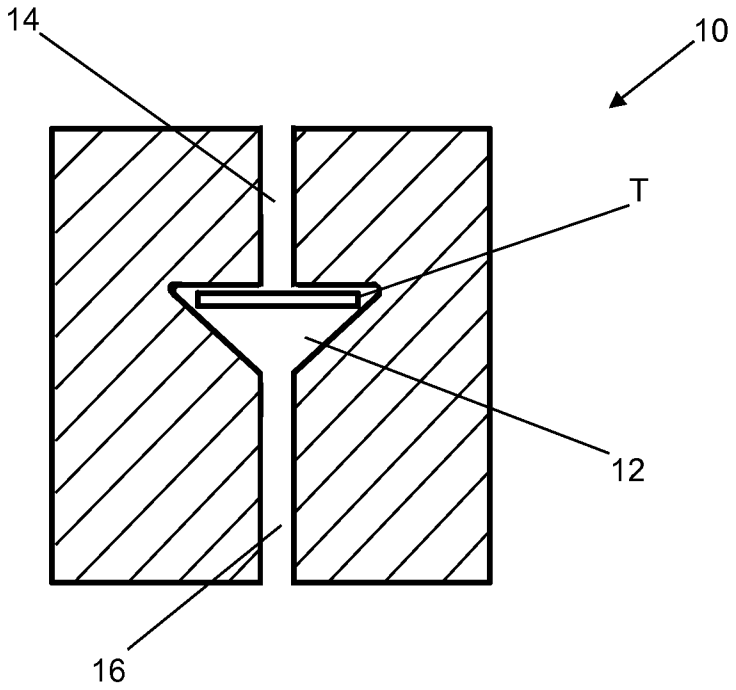

FIG. 1A

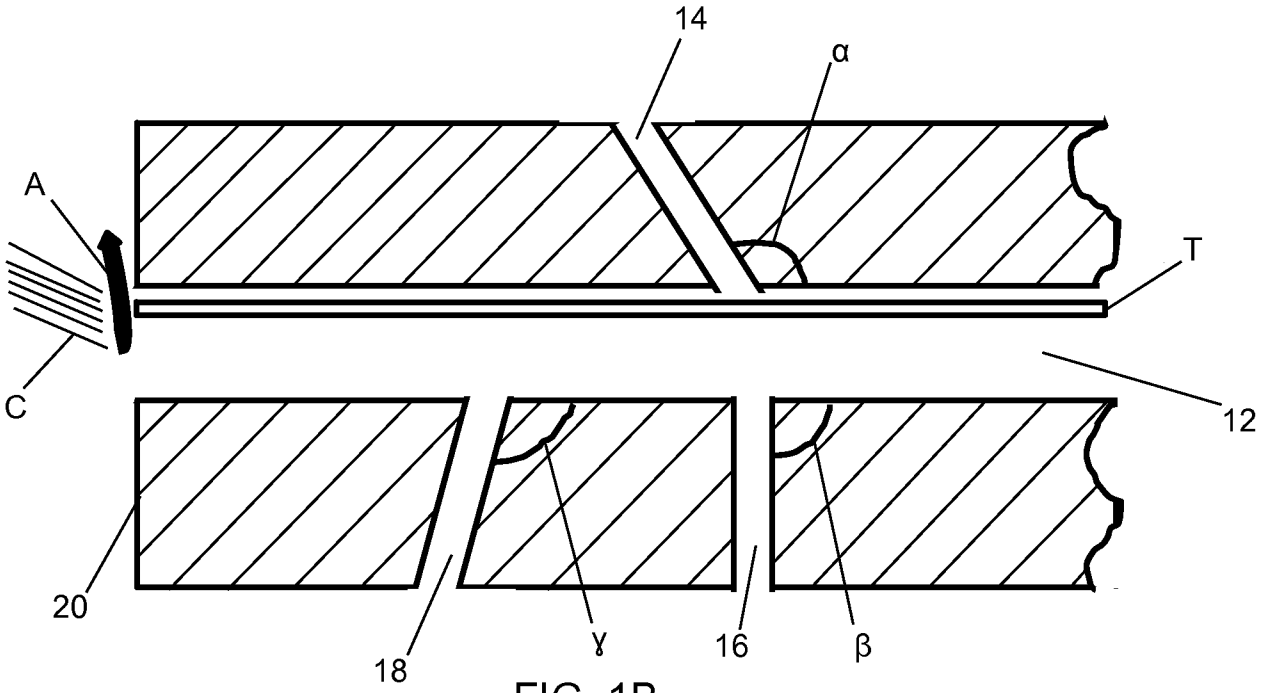

FIG. 1B

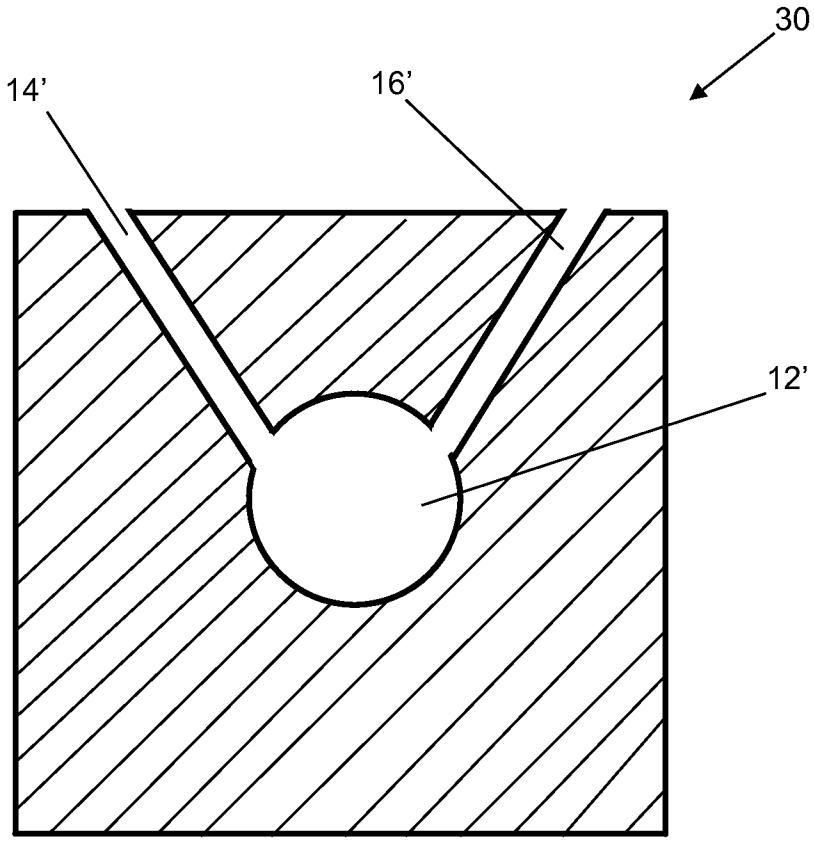

FIG. 2

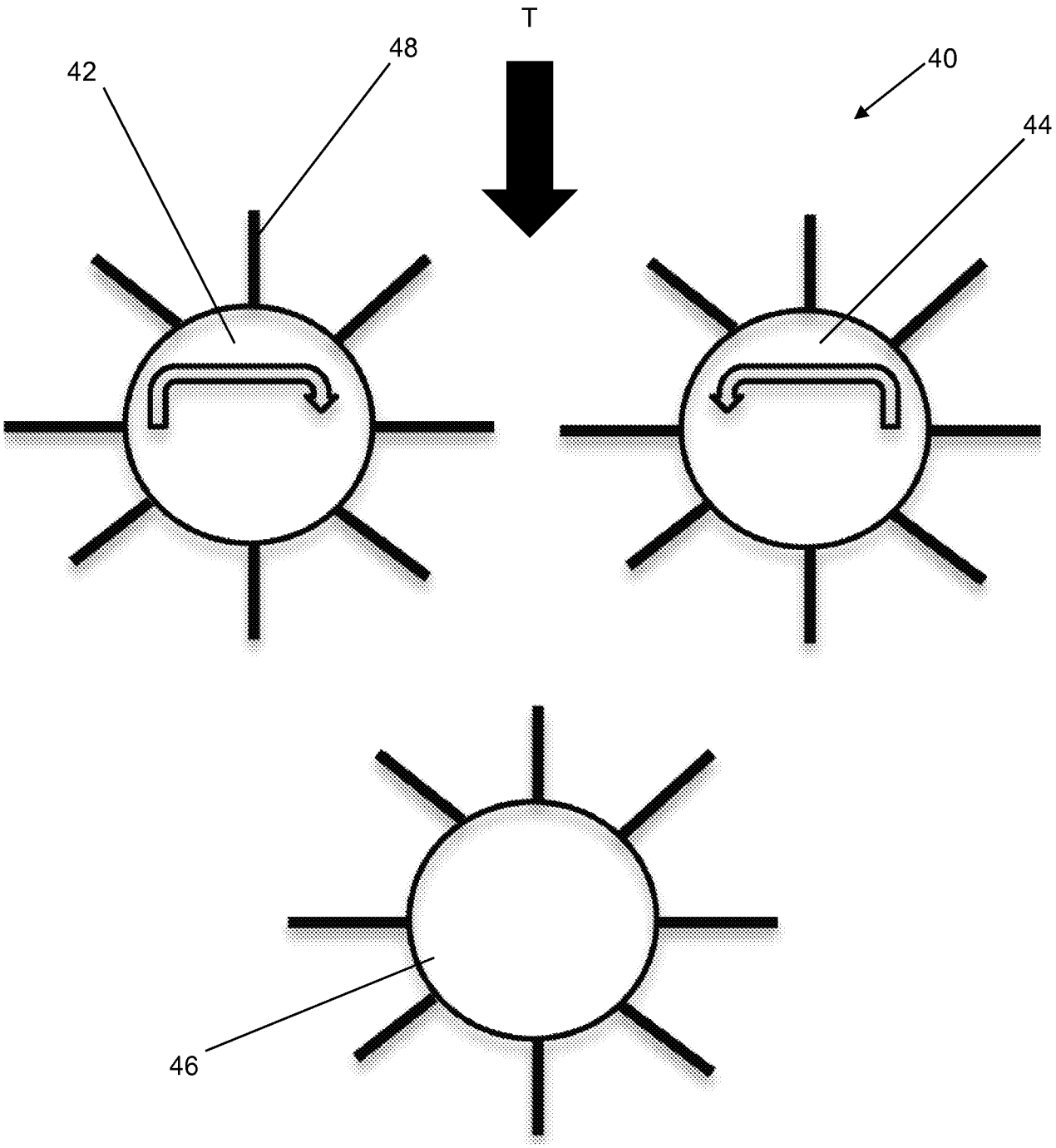

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/039041

A. CLASSIFICATION OF SUBJECT MATTER

D02J 1/18(2006.01)i, D01G 9/00(2006.01)i, D01G 1/04(2006.01)i, C08J 5/04(2006.01)i

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)
D02J 1/18; B32B 17/04; C01B 31/00; B01F 3/18; B28C 5/40; B29C 47/14; B32B 5/08; D01F 9/145; D01G 9/00; D01G 1/04; C08J 5/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: carbon fiber, debundle, tow, chop, die, monomer, disperse, mold, glass fiber, roller, plasma

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-0302243 B1 (SK CHEMICALS. CO., LTD.) 20 June 2002 See abstract; claims 1, 4; and figure 1.	25
A		1-24,31,33-35
X	JP 61-157335 A (IRIE HEKIZAI: KK.) 17 July 1986 See claim 1; figure 1.	31
A	EP 0881312 A2 (TORAY INDUSTRIES, INC.) 2 December 1998 SEe abstract; claims 1, 7.	1-24,31,33-35
A	US 2007-0132126 A1 (SHAO, R. L. et al.) 14 June 2007 See abstract; claims 1-24.	1-24,31,33-35
A	KR 1020070107015 A (OWENS CORNING) 6 November 2007 See abstract; claims 1-18.	25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2013 (25.09.2013)	**25 September 2013 (25.09.2013)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/039041

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 26-30, 32
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
See supplemental box.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group 1, claims 1-24, 31, 33-35, is drawn to a process for debundling carbon fiber and a mechanical debundler.
Group 2, claim 25, is drawn to an article comprising a cured inner portion of sheet molding composition reinforced predominantly with chopped carbon fibers; and a cured outer skin of a second sheet molding composition reinforced predominantly with glass fiber.

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/039041

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Box No. II

Claims 26-30 relate to an article, but claims 26-30 are dependent on claims 22, 24 which are related to a process. As claims 26-30 do not clearly define the matter for which protection is sought, these claims do not meet the requirement of PCT Article 6.

Claim 32 is unclear since the term 'die' of claim 32 is not found in claim 31 to which claim 32 refers (PCT Article 6).