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(54) Title: HEAT RESISTANCE USING TITANIUM DIOXIDE NANOFIBERS

(57) Abstract: A composite structure includes a resin and a plurality of titanium dioxide fibers provided in the resin.



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IMPROVED HEAT RESISTANCE USING TITANIUM DIOXIDE NANOFIBERS

TECHNICAL FIELD

The disclosure relates to structures having a high heat resistance which are suitable for aerospace applications. More particularly, the disclosure relates to structures having titanium dioxide nanofibers which impart improved heat resistance to the structures and a method of fabricating the structures.

BACKGROUND

It may be desirable for insulation blankets which are used in the lower half of an aircraft fuselage to be more heat-resistant. The challenge for the aerospace industry is to develop new structures that exhibit the desired mechanical and heat-resistant properties without imposing a significant weight penalty. Therefore, insulation blanket cover films with improved heat resistance properties have been developed. Existing cover film structures which meet the new heat resistance requirements may be characterized as heavier than desired.

Accordingly, there is a need for insulation blankets that have improved mechanical and heat-resistant properties by incorporating a cover film that has improved heat resistance properties on the blankets that overcome the challenges discussed above.

SUMMARY

The disclosure is generally directed to improving heat resistance of various structures while maintaining light weight of the structures by incorporating titanium dioxide nanofibers into the structures. The disclosure is further generally directed to methods of fabricating structures having enhanced heat resistance.

In some illustrative embodiments, a composite structure 1 with enhanced heat resistance may include a resin 2 and a plurality of titanium dioxide fibers 3 provided in the resin 2.

In some illustrative embodiments, an insulation blanket batting 6 with enhanced heat resistance may include a blanket body 9 having a plurality of titanium dioxide fibers 3.

- 5 In some illustrative embodiments, an insulation blanket cover film 12 with enhanced heat resistance may include a cover film outer layer 13 and at least one layer of titanium dioxide fibers 3 provided on the cover film outer layer 13.

In some illustrative embodiments, a method of fabricating a structure with enhanced heat resistance 600 may include providing a plurality of titanium dioxide fibers 602; providing a resin
10 602b; impregnating the titanium dioxide fibers with the resin 606; and forming a composite structure by thermoforming the resin 608.

In some illustrative embodiments, a method of fabricating an insulation blanket with enhanced heat resistance 700 may include providing insulation blanket batting 702; providing an insulation
15 blanket cover layer on the insulation blanket batting 704; providing a plurality of titanium dioxide fibers 706; and incorporating the plurality of titanium dioxide fibers in at least one of the insulation blanket batting and the insulation blanket cover layer 708.

In some illustrative embodiments, a method of fabricating a paper mat having enhanced heat resistance 800 may include providing a plurality of titanium dioxide fibers 802 and fabricating
20 the plurality of titanium dioxide fibers into a paper mat 804.

In some illustrative embodiments, a composite structure 1 with enhanced heat resistance may include a resin 2 selected from the group consisting of phenolic, benzoxazine and bis-phenol

cyanate ester and having a thickness of about 0.080 inch; a plurality of titanium dioxide fibers 3 having an average diameter of about 10 nanometers provided in the resin 2; and the plurality of titanium dioxide fibers 3 are doped with anions to enhance electrical conductivity of the plurality of titanium dioxide fibers 3.

- 5 In some illustrative embodiments, a method of fabricating a structure with enhanced heat resistance 600 may include providing a plurality of titanium dioxide fibers having an average diameter of about 10 nanometers 600; enhancing electrical conductivity of the plurality of titanium dioxide fibers by doping the plurality of titanium dioxide fibers with anions 602a; providing a resin selected from the group consisting of phenolic, benzoxazine and bis-phenol
10 cyanate ester and having a thickness of about 0.080 inch 602b; impregnating the titanium dioxide fibers with the resin 606; forming a composite structure by thermoforming the resin 608; and fabricating the aircraft structure using the composite structure 610.

7. An insulation blanket batting, comprising:

a blanket body comprising a plurality of titanium dioxide fibers.

- 15 8. The insulation blanket batting of claim 7 further comprising a plurality of other fiber types provided in said blanket body.

9. The insulation blanket batting of claim 7 further comprising a plurality of fiberglass fibers provided in said blanket body.

- 20 10. The insulation blanket of claim 9 wherein said plurality of titanium dioxide fibers comprises at least one distinct layer of said plurality of titanium dioxide fibers in said blanket body.

11. The insulation blanket of claim 7 wherein said plurality of titanium dioxide fibers comprises a plurality of dyed titanium dioxide fibers.

12. An insulation blanket cover film, comprising:

a cover film outer layer; and

at least one layer of titanium dioxide fibers provided on said cover film outer layer.

13. The insulation blanket cover film of claim 12 wherein said cover film outer layer
5 comprises metal.

14. The insulation blanket cover film of claim 13 wherein said metal comprises aluminum.

18. A method of fabricating an insulation blanket with enhanced heat resistance, comprising:

10 providing insulation blanket batting;
providing an insulation blanket cover layer on said insulation blanket batting;
providing a plurality of titanium dioxide fibers; and
incorporating said plurality of titanium dioxide fibers in at least one of said insulation blanket batting and said insulation blanket cover layer.

15 19. A method of fabricating a paper mat having enhanced heat resistance, comprising:
providing a plurality of titanium dioxide fibers; and
fabricating said plurality of titanium dioxide fibers into a paper mat.

20. The method of claim 19 further comprising:

20 providing a resin;
pre-impregnating said paper mat with said resin;
forming a composite structure by thermoforming said resin; and
fabricating a structure using said composite structure.

21. The method of claim 20 wherein said fabricating a structure using said composite structure comprises fabricating a light block under window reveal in an aircraft sidewall panel.

25 22. A composite structure, comprising:

a resin selected from the group consisting of phenolic, benzoxazine and bis-phenol cyanate ester and having a thickness of about 0.080 inch;

a plurality of titanium dioxide fibers having an average diameter of about 10 nanometers provided in said resin; and

5 said plurality of titanium dioxide fibers are doped with anions to enhance electrical conductivity of said plurality of titanium dioxide fibers.

23. A method of fabricating a structure with enhanced heat resistance, comprising:

 providing a plurality of titanium dioxide fibers having an average diameter of about 10 nanometers;

10 enhancing electrical conductivity of said plurality of titanium dioxide fibers by doping said plurality of titanium dioxide fibers with anions;

 providing a resin selected from the group consisting of phenolic, benzoxazine and bis-phenol cyanate ester and having a thickness of about 0.080 inch;

 impregnating said titanium dioxide fibers with said resin;

15 forming a composite structure by thermoforming said resin; and

 fabricating said aircraft structure using said composite structure.

BRIEF DESCRIPTION OF THE ILLUSTRATIONS

FIG. 1 is a cross-sectional view of an illustrative embodiment of a composite structure having
20 titanium dioxide fibers.

FIG. 2 is a cross-sectional view of an illustrative embodiment of an insulation blanket batting having titanium dioxide fibers.

FIG. 3 is a cross-sectional view of an illustrative embodiment of an insulation blanket batting having titanium dioxide fibers and fiberglass fibers.

FIG. 4 is a cross-sectional view of an illustrative embodiment of an insulation blanket cover film having titanium dioxide fibers.

FIG. 5 is a cross-sectional view of an illustrative embodiment of a paper mat having titanium dioxide fibers.

- 5 FIG. 5A is a cross-sectional view of an illustrative embodiment of a composite structure fabricated using the paper mat shown in FIG. 5.

FIG. 6 is a flow diagram which illustrates an illustrative method of fabricating an aircraft structure with enhanced heat resistance using a composite structure having titanium dioxide fibers.

- 10 FIG. 7 is a flow diagram which illustrates an illustrative method of fabricating an insulation blanket batting with enhanced heat resistance.

FIG. 8 is a flow diagram which illustrates an illustrative method of fabricating a paper mat having enhanced heat resistance.

- FIG. 8A is a flow diagram which illustrates an illustrative method of fabricating a light block
15 under a window panel reveal in a sidewall panel using a composite structure having enhanced heat resistance.

FIG. 9 is a flow diagram of an aircraft production and service methodology.

FIG. 10 is a block diagram of an aircraft.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the described embodiments or the application and uses of the described embodiments. As used herein, the word “exemplary” or “illustrative” means “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” or “illustrative” is not necessarily to be construed as preferred or advantageous over other implementations. All of the implementations described below are exemplary implementations provided to enable persons skilled in the art to make or use the embodiments of the disclosure and are not intended to limit the scope of the embodiments of the disclosure which are defined by the claims. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

Referring initially to FIG. 1, a composite structure 1 with enhanced heat resistance is shown. The composite structure 1 may be used in the fabrication of interior aircraft fuselage components such as sidewall panels, ceiling panels and/or cargo liners, for example and without limitation. The composite structure 1 may include a mat or paper 2a which is impregnated with a resin 2 which may be a low heat release resin, for example and without limitation. Resins which are suitable for the resin 2 may include, for example and without limitation, phenolics; benzoxazine and bis-phenol cyanate esters.

The mat or paper 2a may include a meshwork or weave of titanium dioxide (TiO_2) fibers 3 which extend throughout the resin 2. The titanium dioxide fibers 3 may be fabricated using a hydrothermal heating process and may be obtained from the IP2BIZ® LLC of Atlanta, Ga. Each of the titanium dioxide fibers 3 may have an average diameter of about 10 nanometers. In some applications, the titanium dioxide fibers 3 may be dyed titanium dioxide fibers. The dyed titanium dioxide fibers 3 may be necessary in some applications because the darkened fiber

absorbs visible light more efficiently and may help to minimize light bleed-through. This type of structure property may be necessary in applications in which the titanium fibers 3 are to be incorporated into a light block used beneath a window reveal in an aircraft, for example and without limitation.

5 In some applications, the electrical conductivity of the titanium dioxide fibers 3 may be tailored by doping of the titanium dioxide with different anions of nitrogen, carbon and sulfur, for example and without limitation. Doping of the titanium dioxide with anions may significantly enhance conductivity of the titanium dioxide fibers 3. Enhancing the electrical conductivity of the titanium dioxide fibers 3 may be useful in applications in which the composite structure 1 is
10 used in the fabrication of at least a portion of the outside portion of an aircraft fuselage, for example and without limitation. The FIGURES tend to show a high resin quality to make it easier to view the titanium dioxide fibers 3. The actual composite structure 1 may include a thin layer of resin 2 with the titanium dioxide fibers 3 incorporated therein.

The composite structure 1 may be fabricated by, for example and without limitation, randomly
15 incorporating the titanium dioxide fibers 3 into random or non-random mat or paper form; pre-impregnating the mat or paper form with the resin 2; and thermally forming the resin into the composite structure 1 by, for example and without limitation, heating the resin 2 while forming or shaping the resin 2 and the paper mat 2a using a suitable tool or dye (not illustrated) in the conventional manner. The thickness 4 (FIG. 1) of the mat or paper form may generally
20 correspond to the thickness of the component which will be fabricated using the composite structure 1. In some applications, the thickness of the mat or paper form may not exceed about 0.080 inches to impart the optimum thickness to the aircraft fuselage sidewall panel; ceiling panel; cargo liner; and/or other component which incorporates the composite structure 1.

The composite structure 1 may be used in the fabrication of any of a variety of interior aircraft fuselage components including but not limited to interior sidewall panels, ceiling panels and cargo liners. In some applications, the composite structure 1 may be used in the fabrication of the outer portion of an aircraft fuselage. Accordingly, the titanium dioxide fibers 3 in the composite structure 1 may impart improved heat resistance to the composite structure 1 without adding significant weight to the aircraft fuselage. Moreover, the titanium dioxide fibers 3 may improve electrical conductivity at the outer surface of the aircraft fuselage.

Referring next to FIG. 2, an illustrative embodiment of an insulation blanket batting 6 with enhanced heat resistance is shown. The insulation blanket batting 6 may include a blanket body 9 having a network or weave of titanium dioxide fibers 3. In some embodiments, other fiber types 3a may be mixed or weaved into the blanket body 9. The other fiber types 3a may be carbon fibers and/or fiberglass fibers, for example and without limitation. Accordingly, the titanium dioxide fibers 3 may impart improved heat resistance without adding significant weight to the insulation blanket batting 6 when the insulation blanket batting 6 is used as an insulation blanket in aerospace or other applications.

Referring next to FIG. 3, an alternative illustrative embodiment of the insulation blanket batting 6a has a blanket body 9 which may include a network or weave of fiberglass fibers 8. At least one distinct layer of titanium dioxide fibers 3 may form a fire-resistant barrier within the fiberglass fibers 8 in the blanket body 9. The insulation blanket batting 6 or the insulation blanket batting 6a may be processed to promote a suitable amount of lofting.

Referring next to FIG. 4, an illustrative embodiment of an insulation blanket cover film 12 with enhanced heat resistance is shown. The insulation blanket cover film 12 may be provided on insulation blanket batting 15. The insulation blanket batting 15 may include the insulation

blanket batting 6 having titanium dioxide fibers 3, as was heretofore described with respect to FIG. 2. Alternatively, the insulation blanket batting 15 may include the insulation blanket batting 6a with fiberglass fibers 8 and a distinct layer of titanium dioxide fibers 3, as was heretofore described with respect to FIG. 3. Still further in the alternative, the insulation blanket
5 15 may be a conventional insulation blanket batting having fiberglass fibers only.

As shown in FIG. 4, the insulation blanket cover film 12 may include a cover film outer layer 13. The cover film outer layer 13 may be a metal such as aluminum, for example and without limitation. At least one layer of multiple titanium dioxide fibers 3 may be bonded to the cover film outer layer 13. Accordingly, the insulation blanket cover film 12 may enhance the heat
10 resistance of the insulation blanket 15 in aerospace or other applications.

Referring next to FIG. 5, an illustrative embodiment of a paper mat 18 with enhanced heat resistance is shown. The paper mat 18 may include a binder 20 and titanium dioxide fibers 3 provided in the binder 20. The paper mat 18 may be fabricated using conventional paper-forming techniques known to those skilled in the art.

15 Referring next to FIGS. 5 and 5A, in some applications, the paper mat 18 with heat resistance which was heretofore described with respect to FIG. 5 may be used in the fabrication of a thin composite structure 22 which is shown in FIG. 5A. The composite structure 22 may be suitable for light-blocking purposes, for example and without limitation. Accordingly, the titanium dioxide fibers 3 in the paper mat 18 (FIG. 5) which is used to fabricate the composite structure
20 22 may be dyed titanium dioxide fibers, for example and without limitation. The paper mat 18 of FIG. 5 may be impregnated with a resin 23 (FIG. 5A). Resins which are suitable for the resin 23 may include phenolics; benzoxazine and bis-phenol cyanate esters, for example and without limitation. The paper mat 18 and resin 23 may then be thermoformed into the composite

structure 22 shown in FIG. 5A. Thermoforming may be accomplished by, for example and without limitation, heating the resin 23 while forming or shaping the paper mat 18 and resin 23 using a suitable tool or dye (not illustrated) in a conventional manner. The composite structure 22 may then be used as a light block beneath a window reveal in a sidewall panel of an aircraft fuselage (not shown), for example and without limitation.

Referring next to FIGS. 1, 5 and 6, a flow diagram 600 which illustrates an illustrative method of fabricating an aircraft structure, for example and without limitation, with enhanced heat resistance using a composite structure 1 (FIG. 1) having titanium dioxide fibers is shown. In block 602 of the flow diagram 600, titanium dioxide nanofibers 3 are provided. The titanium dioxide nanofibers 3 may have an average diameter of about 10 nanometers. In block 602a, the titanium dioxide fibers may be doped with anions to enhance the electrical conductivity of the anions. In block 602b, a resin 2 is provided. In block 604, the titanium dioxide nanofibers 3 may be fabricated into a paper mat 18 (FIG. 5) or paper form. In block 606, the paper mat 18 or form may be impregnated with the resin 2. Resins which are suitable for the purpose may include phenolics, benzoxazine and bis-phenol cyanate esters, for example and without limitation. In block 608, the resin 2 may be thermoformed into a composite structure 1. In block 610, an interior sidewall; a ceiling panel; and/or a cargo liner of an aircraft fuselage, for example and without limitation, may be fabricated using the composite structure 1.

Referring next to FIGS. 2, 4 and 7, an illustrative method of fabricating an insulation blanket batting 6 (FIG. 2) and/or insulation blanket cover film 12 (FIG. 4) with enhanced heat resistance is shown. In block 702, insulation blanket batting 6 is provided. In block 704, an insulation blanket cover layer 12 is provided on the insulation blanket batting 6. In block 706, titanium nanofibers 3 are provided. In block 708, the titanium nanofibers 3 are incorporated into an

insulation blanket cover film 12 and/or an insulation blanket batting 6. In block 710, the insulation blanket batting 6 may be processed to promote suitable lofting.

Referring next to FIGS. 5 and 8, a flow diagram 800 which illustrates an illustrative method of fabricating a paper mat 18 (FIG. 5) having enhanced heat resistance is shown. In block 802 of the flow diagram 800, titanium dioxide nanofibers 3 are provided. In block 804, the titanium dioxide nanofibers 3 are fabricated into a paper mat 18.

Referring next to FIGS. 1, 5 and 8A, a flow diagram 800A (FIG. 8A) which illustrates an illustrative method of fabricating a thin composite structure 22 (FIG. 5A) which may be used to fabricate a light block under a window panel reveal in a sidewall panel, for example and without limitation, is shown. In block 802a, a paper mat 18 (FIG. 5) with titanium dioxide nanofibers 3 is provided. In block 804a, the paper mat 18 with titanium dioxide nanofibers 3 is impregnated with a resin 23 (FIG. 5A). Resins which are suitable for the purpose may include phenolics, benzoxazine and bis-phenol cyanate esters, for example and without limitation. In block 806a, the thin composite structure 22 may be thermoformed into a composite structure 1 (FIG. 1). In block 808a, a light block under a window reveal in a sidewall panel of an aircraft fuselage may be fabricated using the composite structure 1.

Referring next to FIGS. 9 and 10, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method 78 as shown in FIG. 9 and an aircraft 94 as shown in FIG. 10. During pre-production, exemplary method 78 may include specification and design of the aircraft 94 and structure procurement 82. During production, component and subassembly manufacturing 84 and system integration 86 of the aircraft 94 takes place. Thereafter, the aircraft 94 may go through certification and delivery 88 in order to be placed in service 90. While in service by a customer, the aircraft 94 may be scheduled for routine

maintenance and service 92 (which may also include modification, reconfiguration, refurbishment, and so on).

Each of the processes of method 78 may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system
5 integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in FIG. 10, the aircraft 94 produced by exemplary method 78 may include an airframe
10 98 with a plurality of systems 96 and an interior 100. Examples of high-level systems 96 include one or more of a propulsion system 102, an electrical system 104, a hydraulic system 106, and an environmental system 108. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the automotive industry.

15 The apparatus embodied herein may be employed during any one or more of the stages of the production and service method 78. For example, components or subassemblies corresponding to production process 84 may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft 94 is in service. Also, one or more apparatus
20 embodiments may be utilized during the production stages 84 and 86, for example, by substantially expediting assembly of or reducing the cost of an aircraft 94. Similarly, one or more apparatus embodiments may be utilized while the aircraft 94 is in service, for example and without limitation, to maintenance and service 92.

Although the embodiments of this disclosure have been described with respect to certain exemplary embodiments, it is to be understood that the specific embodiments are for purposes of illustration and not limitation, as other variations will occur to those of skill in the art.

CLAIMS

What is claimed is:

1. A composite, comprising:

5 a resin; and
 a plurality of titanium dioxide fibers provided in said resin.

2. The composite structure of claim 1 wherein said titanium dioxide fibers define a paper
mat.

10

3. The composite structure of claim 2 wherein said titanium dioxide fibers are randomly
incorporated into said paper mat.

4. The composite structure of claim 2 wherein said titanium dioxide fibers are non-
15 randomly incorporated into said paper mat.

5. The composite structure of claim 1 wherein said plurality of titanium dioxide fibers
comprises a plurality of dyed titanium dioxide fibers.

"

20 6. The composite structure of claim 1 wherein said plurality of titanium dioxide fibers
comprises a plurality of titanium dioxide fibers with enhanced electrical conductivity.

7. A method of fabricating a structure with enhanced heat resistance, comprising:

 providing a plurality of titanium dioxide fibers;

25 providing a resin;

impregnating said titanium dioxide fibers with said resin; and
forming a composite structure by thermoforming said resin.

8. The method of claim 7 further comprising fabricating an aircraft structure using said
5 composite structure.

9. The method of claim 8 wherein said fabricating said structure using said composite
structure comprises fabricating at least one of an interior sidewall, a ceiling panel and a cargo
panel using said composite structure.

10

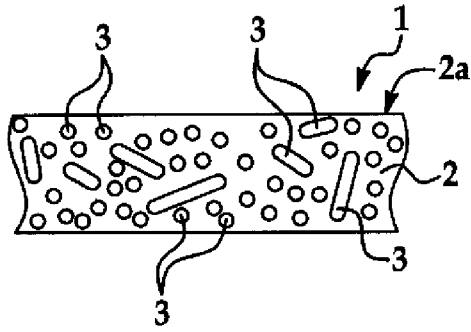


FIG. 1

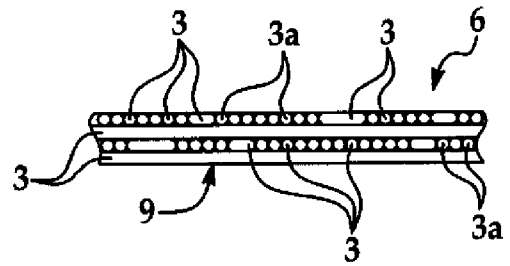


FIG. 2

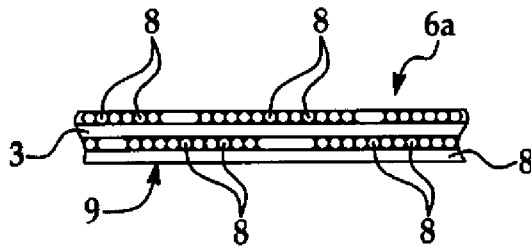


FIG. 3

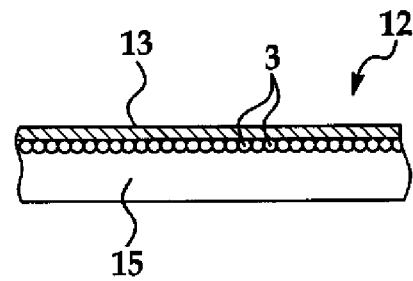


FIG. 4

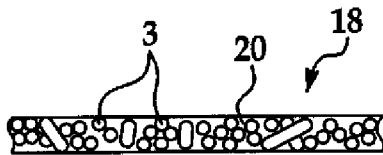


FIG. 5

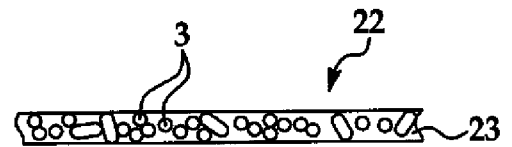


FIG. 5A

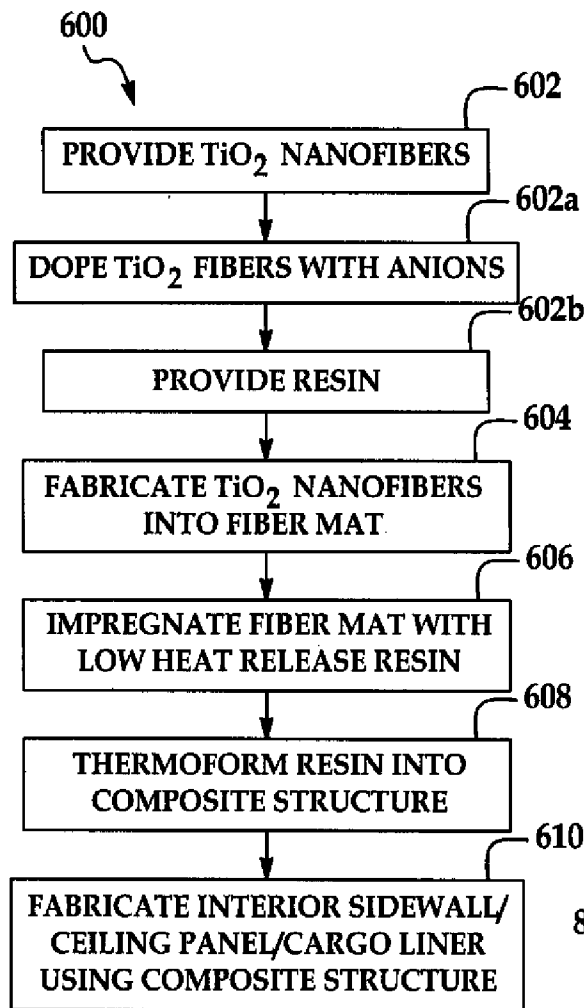


FIG. 6

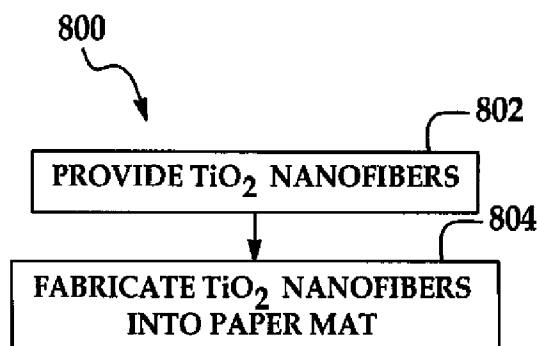


FIG. 8

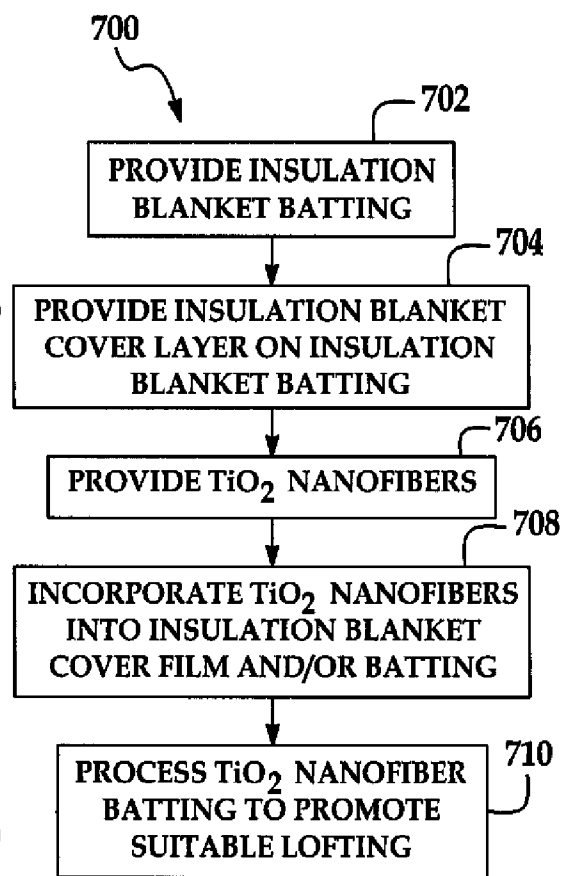


FIG. 7

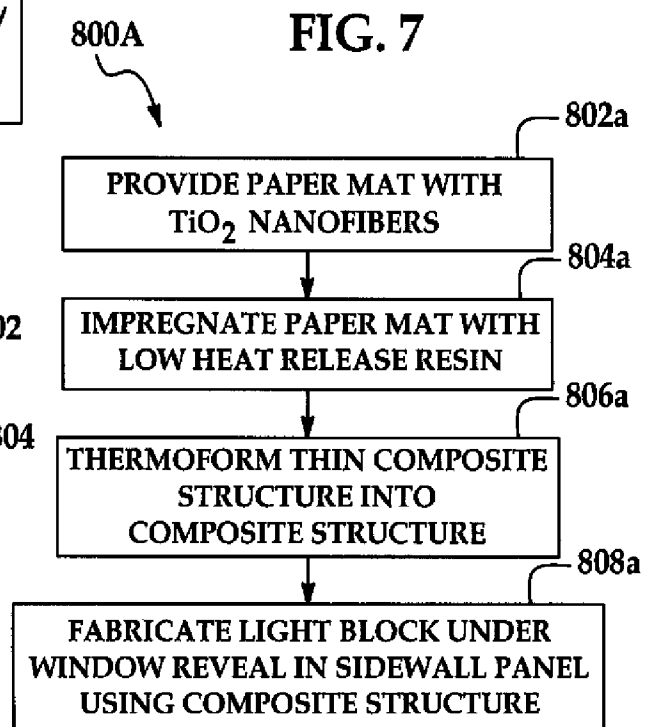


FIG. 8A

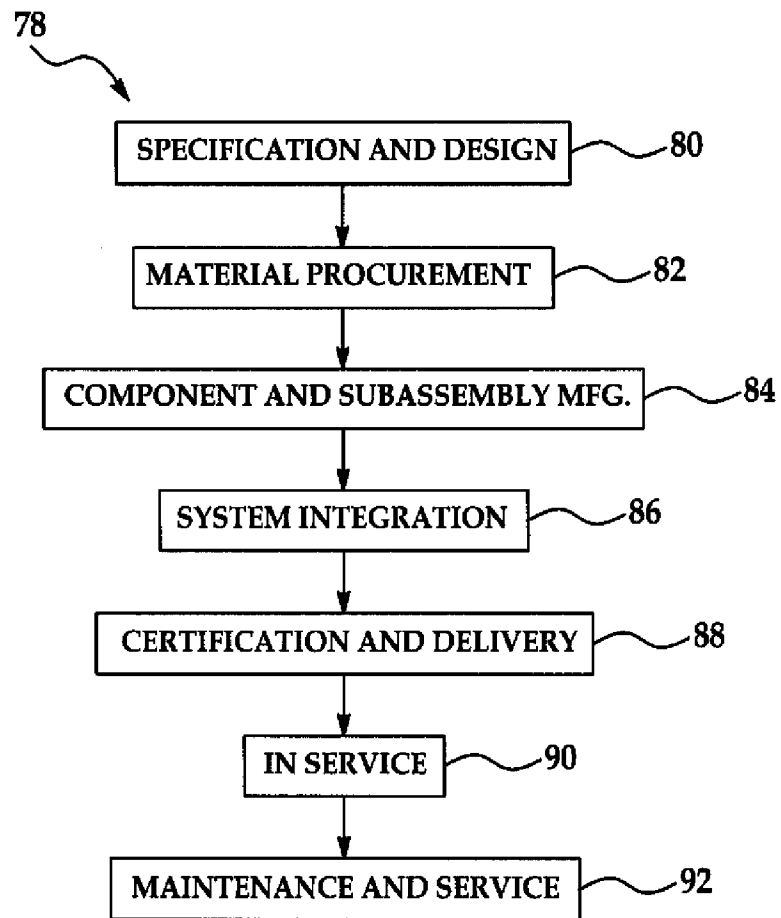


FIG. 9

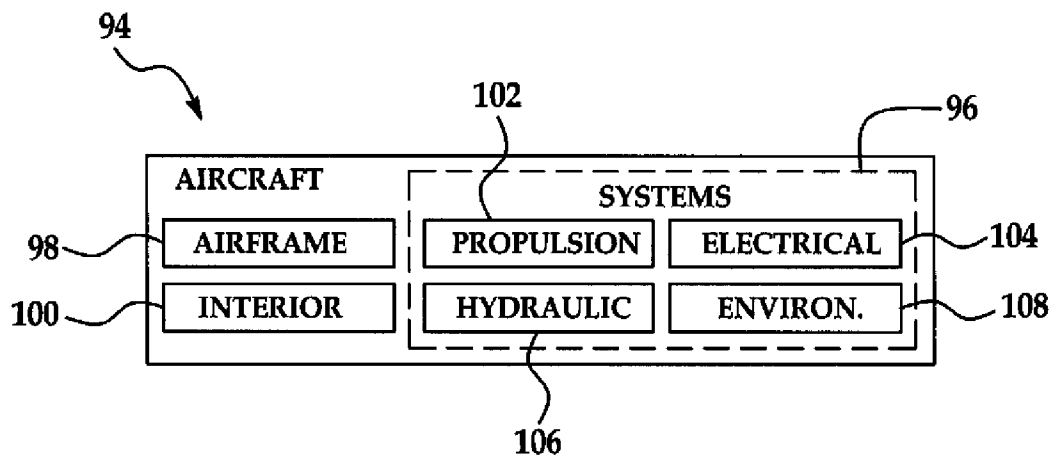


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/060241

A. CLASSIFICATION OF SUBJECT MATTER

INV. C08K7/08 D21H23/00

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)

C08K D21H

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 practical, 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.
X	DATABASE WPI Week 199621 Thomson Scientific, London, GB; AN 1996-205321 XP002558058 & JP 08 073220 A (OTSUKA KAGAKU YAKUHHN KK) 19 March 1996 (1996-03-19) abstract	1
Y	US 2008/166937 A1 (GARVEY CHAD E [US]) 10 July 2008 (2008-07-10) example 1	2-9
Y	DE 19 00 064 A1 (BAYER AG) 27 August 1970 (1970-08-27) page 1, paragraph 2	2-9



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

30 November 2009

Date of mailing of the international search report

07/12/2009

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Siemens, Thomas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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