

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 November 2010 (04.11.2010)

PCT

(10) International Publication Number
WO 2010/127074 A1

(51) International Patent Classification:

C04B 38/00 (2006.01) **C04B 35/636** (2006.01)
C04B 35/195 (2006.01)

(21) International Application Number:

PCT/US2010/032907

(22) International Filing Date:

29 April 2010 (29.04.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

12/433,365 30 April 2009 (30.04.2009) US

(71) Applicant (for all designated States except US): **CORNING INCORPORATED** [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **HOU, Jun** [US/US]; 123 Fieldview Drive, Painted Post, New York 14870 (US). **LAUDERDALE, Susan C** [US/US]; 8 Timber Lane, Painted Post, New York 14870 (US). **PESANSKY, Jonathan D** [US/US]; 2619 Morrcrest Drive, Corning, New York 14830 (US).

(74) Agents: **DOUGLAS, Walter M** et al.; CORNING INCORPORATED, Intellectual Property Department, SP-TI-3-1, Corning, New York 14831 (US).

(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, 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, PE, PG, PH, PL, PT, RO, RS, RU, 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, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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))

(54) Title: SELECTED BINDERS FOR THE EXTRUSION OF ULTRA-THIN WALL CELLULAR CERAMICS

(57) Abstract: The disclosure provides for a mixture suitable for extrusion and firing to form a ceramic honeycomb substrate, said mixture comprising a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition, an optional pore former material; a binder material and water; wherein said binder is a methyl ether of cellulose binder having a count of less than 300 water-insoluble fibers per gram of binder material.



WO 2010/127074 A1

SELECTED BINDERS FOR THE EXTRUSION OF ULTRA-THIN WALL CELLULAR CERAMICS

Cross-reference to Related Applications

[0001] This application claims the benefit of priority of U.S. Application Serial No. 12/433365 filed on April 30, 2009.

Field

[0002] The field of the invention is ultra-thin wall ceramic honeycombs substrates made of cordierite or aluminum titanate, and in particular to selected binders for making such substrates.

Background

[0003] Ceramic honeycombs, for example cordierite or aluminum titanate honeycombs, are made by extrusion of a ceramic paste. The ceramic paste is prepared by mixing dry raw materials followed by the addition, with further mixing, of liquid components and plasticizing the resulting mixture using an auger or twin screw mixing system. After plasticizing, the ceramic paste is pushed through an extruder die to form a honeycomb "green body" that is further processed. The overall process can be summarized as providing a plasticized ceramic honeycomb precursor batch material comprising inorganic ceramic-forming components, optional pore forming materials (for example a starch or graphite material), liquid components (for example, water), lubricating materials (to aid in extrusion) and binders; plasticizing the mixture; forming a green body having the desired shape, size and cells density from the plasticized ceramic precursor batch material; optionally drying the green body to remove excess moisture and prevent slumping during firing; and firing the dried green body under conditions sufficient to convert the green body into a ceramic honeycomb. Depending on the choice of inorganic materials, the fired honeycomb can be a cordierite or aluminum titanate honeycomb. In the above process one problem that is frequently encountered is the plugging of the die during the extrusion

process, particularly when ultra-thin wall honeycomb substrates are formed. The present invention presents a solution to the plugging process.

Summary

[0004] In one aspect of the present invention there is provided a method for producing a porous ceramic honeycomb article, comprising the steps of providing inorganic ceramic-forming ingredients; adding a polymeric organic binder material, a solvent and a pore forming agent to the inorganic ceramic-forming ingredients, wherein the organic binder is a polymeric material having less than 300 insoluble polymeric fiber or fiber-like particles per gram (<300 fibers/g) as determined using a 1wt% aqueous binder solution; mixing the inorganic ceramic-forming ingredients, the binder, the solvent and the pore forming agent to form a precursor batch; forming the precursor batch into a green body; and firing the green body at a temperature sufficient to produce a porous ceramic article. In one embodiment the number of insoluble fibers is less than 200/g. In a further embodiment the number of insoluble fibers is less than 65/g. A preferred binder material for use in the present invention is a water soluble cellulose ether binder (an alkyl cellulose ether) component selected from the group consisting of methyl cellulose, water soluble methyl cellulose derivatives (for example, hydroxypropyl methyl cellulose, hydroxyethyl methyl cellulose), water soluble ethyl cellulose derivatives (for example, hydroxyethyl cellulose) and combinations thereof. In some embodiments the binder material is selected from the group consisting of methyl cellulose, hydroxypropyl methyl cellulose, hydroxyethyl cellulose and hydroxyethyl methyl cellulose.

[0005] In one embodiment the invention is directed to a method for preparing a ceramic honeycomb comprising the steps of:

- providing a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition;
- optionally providing a pore former material;
- providing a binder material and water;

mixing the batch composition with the pore former, binder, and water to form a plasticized extrudable paste;
extruding the paste to form a honeycomb green body; and
firing the green body to form a honeycomb comprising a ceramic material selected from the group consisting of cordierite and aluminum titanate;
wherein providing a binder means providing a water soluble alkyl ether of cellulose binder having a count of less than 300 insoluble fibers per gram of binder material as measured for a 1 wt% aqueous solution of binder material.

[0006] In one embodiment the invention is directed to a mixture suitable for extrusion and firing to form a ceramic honeycomb substrate, said mixture comprising:

a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition;

optionally, a pore former material;

a binder material; and

water;

wherein said binder is a water soluble alkyl ether of cellulose binder having a count of less than 300 water-insoluble fibers per gram of binder material.

Detailed Description

[0007] Herein the term "ultra-thin wall" means honeycomb substrates that have a wall thickness of less than 4 mil (<0.102 mm); for example, the 600 and 900 cpsi (cells per sq. in.) substrates made by Corning Incorporated that have wall thicknesses of ~3 mil (0.076 mm) and ~2 mil (0.05 mm), respectively. "Thin wall" substrates such as those made by Corning Incorporated have a thickness greater than 4 mil (>0.102 mm) and less than 6 mil. Standard wall substrates (Corning Incorporated) have a thickness in the range of 0.165 mm to 0.280 mm. As also used herein the term "honeycomb" means any ceramic cellular substrate having any number of cells per square inch or centimeter and channels through the substrate from one end to the opposite end. Further, herein the terms "fibers per gram" and "fibers/g" means insoluble fibers per gram of binder as determined by optical microscopy using a 100x microscope and a 1 wt% aqueous binder solution (1 gram of

binder and 99 grams water). Alternatively, suspended fiber may be measured with a particle size analyzer such as a Multisizer™ 3 COULTER COUNTER®.

[0008] Ceramic honeycomb substrates are typically made by an extrusion process; and descriptions of the materials and the extrusion processes used to prepare ceramic honeycomb substrates can be found in numerous patents and patent applications. Examples of ceramic batch material compositions and processes for forming cordierite honeycombs that can be used in practicing the present invention are disclosed in U.S. Pat. Nos. 3,885,977; RE 38,888; 6,368,992; 6,319,870; 6,210,626; 5,183,608; 5,258,150; 6,432,856; 6,773,657; 6,864,198; and U.S. Patent Application Publication Nos. 2004/0029707, 2004/0261384, and 2005/0046063. Examples of ceramic batch material compositions and processes for forming aluminum titanate that can be used in practicing the present invention are those disclosed in U.S. Pat. Nos. 4,483,944; 4,855,265; 5,290,739; 6,620,751; 6,942,713; 6,849,181; U.S. Patent Application Publication Nos.: 2004/0020846; 2004/0092381; and in PCT Application Publication Nos. WO 2006/015240; WO 2005/046840; and WO 2004/011386.

[0009] By way of an example without limitation, a cordierite-forming composition is formed using talc, clay, silica, and alumina, a binder material, and addition materials such as water, plasticizers, lubricants, and other materials as is known in the art to make compositions that are then used to form porous cellular ceramic honeycomb structures. The materials are mixed and plasticized, and the resulting composition is pushed through a die to form a honeycomb green body as has been indicated above. However, one problem encountered during formation of the green body is that large particles, fibers and agglomerates that may be present in the batched materials limit the ability to push the composition through dies that have narrow slots; for example dies that are used to make ultra-thin wall honeycombs. Screens having sufficiently small openings to filter-out the particles, fibers and agglomerates, and thus protect the die slots from plugging, significantly raised the pressure required to push the paste through the extrusion system and the dies themselves were quickly plugged. In addition, fibrous materials (for example, cellulose-derived materials and other polymeric materials) were found to orient themselves

in the direction of flow and pass through the screens. As a result, while the screens would hold back particles and agglomerates (or cause them to break up on the screen surface due to the applied pressure), the fibrous materials pass through the screens and plug the narrow die slots used for making ultra-thin wall honeycombs.

[0010] As is known to the art, the formation of ceramic honeycombs requires that the ceramic precursor composition be formed by some means to the desired shape and then subsequently treated to form and unify the composition into the final form of the article or part. In an extrusion process components of the ceramic material are combined with a "binding agent" and then introduced into a die to impart a particular form upon the combined ceramic and the binding agent. The binding agent, also known to the art as a "binder" imparts a certain degree of dimensional stability and form retention to the mixture, which is a necessary feature of the extrusion process to prevent slumping of the green body before it is fired. After the green body has been formed it is then fired to form the final article. In one embodiment the green body is dried to remove excess moisture prior to firing. The drying, by removing excess moisture, results in a green body that is less likely to slump as it is transported to a firing oven and heated to a temperature sufficient to convert the composition into a ceramic material. During the firing process the binder is driven off leaving a formed honeycomb that is essentially free from any organic materials. Many polymeric materials have been used as a binder and some of these materials are not completely soluble in water. Cellulose-derived materials such as methyl cellulose, water soluble derivatives of methyl cellulose, and water soluble derivatives of ethyl cellulose are preferred binders for use in making ceramic honeycomb substrates because of their ready availability, low cost, ease of use and safety in handling the material. The resulting aqueous "solution" of such polymeric materials may consist of particles that are partially soluble in water or contain both soluble and insoluble fractions. It is the insoluble fractions that create problems during the extrusion of ultra-thin walled honeycomb substrates. Herein methyl cellulose will be used as the binder material exemplifying the invention.

[0011] Cellulose is a natural, long chain polymer made by the linking of β -D-glucose molecules by the elimination of water. The length of the chain varies greatly, from a few hundred units in wood pulp to over 6000 for cotton. Cellulose contains many polar -OH groups that form many hydrogen bonds with OH groups on adjacent chains, bundling the chains together. The chains also pack regularly in places to form hard, stable crystalline regions that give the bundled chains even more stability and strength. As a result cellulose is insoluble in water and many organic solvents. However, when cellulose is treated to form alkyl cellulose ethers, many of these alkyl ethers, and/or their derivatives, are water soluble. In particular, alkyl cellulose ethers, for example, methyl cellulose and hydroxypropyl methyl cellulose, and derivatives are water soluble.

[0012] Chemically, methyl cellulose is a methyl ether of cellulose, arising from substituting the hydrogen atoms of cellulose's hydroxyl groups (-OH) with methyl groups (-CH₃) to form ether groups (-OCH₃). This process un-bundles the cellulose chains to an extent and imparts water solubility to the product. However, in the process of making methyl cellulose some portion of the cellulose remains un-reacted or has not been fully reacted and is therefore water insoluble. When the product is dispersed in water insoluble cellulosic fibers resulting from incomplete reaction are present in the resulting solution of methyl cellulose. When these fibers exceed 300 fibers per gram (300 fiber/g) of binder (measured using a 1 wt% aqueous binder solution), screen plugging and die plugging occur much more rapidly than when insoluble fibers are less than 300 fibers/g of binder. As a result, when the insoluble fiber level is greater than 300 fibers/g, problems arise in the making of ultra-thin wall substrates; that is, substrates having a wall thickness of less than 4 mils (< 0.101 mm). When very narrow slot dies (less than 0.101 mm) are used for extrusion, even with screens in front of the dies, the dies rapidly become plugged. When insoluble fibers exceed 100 per gram of binder, plugging problems can be expected in dies with 0.05mm slot widths, whereas binders with less than 100 insoluble fibers per gram of binder have been observed to perform well. Plugging in the die results in non-knits that are breaks in cellular structure that tends to limit the physical strength of the parts. By choosing a binder that has been more fully reacted so that the number of insoluble fibers per gram is less than 300 fiber/g, the plugging is minimized. This eliminates need for

frequent changing/cleaning of the screens and dies, maintains good cell integrity (eliminates or minimizes non-knits to an acceptable level), and therefore provides for good physical strength in the finished parts.

[0013] A number of methods have been used to differentiate lots/grades of methyl cellulose binder for level of insoluble fibers. One such method involves preparation of a 1% aqueous solution of the binder. A drop is quantitatively transferred to a clean microscope slide. Using an optical microscope having 100x magnification, the number of insoluble fibers on the slide is counted. It is preferred that several slides be prepared and evaluated. From those counts, fibers/g of binder per gram can be calculated. Lots with fiber counts less than 200/gc are suitable for extrusions through 2.85 mils and wider slots. Fiber counts of less than 60/g are suitable for extrusion through dies with slots as narrow as 2.0 mils. The relative number of insoluble fibers has been correlated with extrusion pressure and plug rates of both screens and dies and it has been found that the lower the fibers/g, the lower the extrusion pressure and plug rates of both screens and dies.

Cordierite Example

[0014] A cordierite honeycomb substrate, made using a methyl cellulose binder having less than 300 fiber/g as described herein, can be made as described in U.S. Patent No. 5,296,423 (the '423 patent). Summarizing the '423 patent, a plasticizable admixture is prepared for use in making a substrate having cordierite as its primary phase so that, by weight on an analytical oxide basis, the admixture comprises about 11.5-16.5% MgO, about 33-41% Al₂O₃ and about 46.6-53.0% SiO₂. The sources of the magnesia, alumina and silica are described in the '423 patent, the magnesia source being kaolin generally having an average particle diameter of not greater than about two microns. The kaolin, preferably calcined kaolin, is used in the amount of about 15 to about 39 weight percent, based on total minerals in the batch. The minerals of which the plasticizable admixture is comprised are combined in a mixing step sufficient to produce intimate mixing of the raw material phases to allow complete reaction in thermal processing. Water and extrusion aids, such as binders and lubricants, are added at this stage to help create an extrudable admixture that is formable or moldable. Sufficient extrusion aids well known in the art,

such as binders (e.g., methyl celluloses) and lubricants (e.g., stearates), are added to give plastic formability and green strength prior to firing. Binder materials are added to the admixture in an amount of in the range of 2-4 weight percent based on inorganics in the admixture. Sodium stearate was used as the lubricant and was added in an amount in 0.4 - 1.0 weight percent based on inorganics in the admixture. Water aids in plastic formability and may be controlled to benefit the specific composition. Generally, the batch raw materials utilized in this composition require between about 28 and 35 weight % water based on the dry batch (total organics and inorganics). Variations may be required to accommodate a change in raw materials or particle sizes.

[0015] The extrudable admixture prepared as described above can be formed into the desired structure by conventional ceramic forming processes. Herein an extrusion process was used to form a honeycomb substrate green body having ultra-thin walls. Using a methyl cellulose binder having less than 300 insoluble fibers/g the extrusion process went smoothly without plugging of the screens of a die having <3mil slots. The green structure was dried, dielectrically, for a period of about 5-20 minutes prior to firing. After drying the green body was fired at a temperature in the range of 1340-1450 °C to form a cordierite honeycomb substrate.

Aluminum Titanate Example

[0016] An aluminum titanate honeycomb substrate, made using a methyl cellulose binder having less than 300 fiber/g as described herein, can be made as described in U.S. Patent No. 7,258,120 (the '120 patent). The process of the '120 patent may be summarized as comprising the steps of first formulating a batch of inorganic raw materials comprising sources of silica, alumina, titania, and an alkaline earth metal (preferably at least one selected from the group consisting of strontium, calcium and barium). A rare earth metal oxide is also added to the batch of raw materials to lower the firing temperature at which the bodies can be processed, lower the CTE, and increase the porosity, all without substantially reducing the strength of the final fired body. In addition, lowering the firing temperature significantly increases furnace furniture life. The batch of raw materials is further mixed together with processing aids selected from the group consisting of

plasticizers, lubricants, binders, pore formers, and solvents (such as water). In accordance with the present invention, the preferred binder is methyl cellulose having less than 300 fibrous particles per gram. The batch components and processing aids are mixed together to form a preferably homogeneous and plasticized mixture, which is thereafter shaped into a green body. The shaping step can be performed according to well-known ceramic processing techniques, and is most preferably formed by extrusion of the plasticized mixture through an extrusion die. In one embodiment the plasticized mixture is extruded through a die to form a green body preferably having a honeycomb structure formed of intersecting cell walls. The green body is optionally dried, and then preferably fired to a maximum (top) temperature of less than 1500 °C, preferably between 1400-1450°C to form a predominant phase of aluminum titanate.

[0017] Accordingly, in one embodiment the invention is directed to a method for preparing a ceramic honeycomb comprising the steps of providing a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition; providing a pore former material, a binder material and water; mixing the batch composition with the pore former, binder, and water to form a plasticized extrudable paste; extruding the paste to form a honeycomb green body; and firing the green body to form a honeycomb comprising a ceramic material selected from the group consisting of cordierite and aluminum titanate; wherein providing a binder means providing a water soluble alkyl ether of cellulose binder having a count of less than 300 insoluble fibers per gram of binder material as measured for a 1 wt% aqueous solution of binder material. In one embodiment the alkyl cellulose is selected from the group consisting of methyl cellulose, methyl cellulose derivatives, ethyl cellulose, and ethyl cellulose derivatives and combinations thereof. In another embodiment the binder is selected from the group consisting of methyl cellulose and hydroxypropyl methyl cellulose. In a further embodiment the count of insoluble fibers is less than 200 fibers per gram of binder material. In another embodiment the count of insoluble fibers of the alkyl cellulose or alkyl cellulose derivative is less than 65 fibers per gram of binder material.

[0018] In another embodiment the invention is directed to a mixture suitable for extrusion and firing to form a ceramic honeycomb substrate, said mixture comprising a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition; a pore former material; a binder material; and water; wherein said binder is a methyl ether of cellulose binder having a count of less than 300 water-insoluble fibers per gram of binder material. In a further embodiment the methyl ether of cellulose has a count of less than 200 water-insoluble fibers per gram of binder material. In an addition embodiment the methyl ether of cellulose has a count of less than 65 water-insoluble fibers per gram of binder material. In another embodiment the methyl ether of cellulose is selected from the group consisting of methyl cellulose, hydroxyethyl methyl cellulose and hydroxypropyl methyl cellulose.

[0019] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein.

We claim:

1. A method for preparing a ceramic honeycomb comprising the steps of:
 - providing a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition;
 - optionally providing a pore former material;
 - providing a binder material and water;
 - mixing the batch composition with the pore former, binder, and water to form an plasticized extrudable paste;
 - extruding the paste to form a honeycomb green body; and
 - firing the green body to form a honeycomb comprising a ceramic material selected from the group consisting of cordierite and aluminum titanate;wherein providing a binder means providing a water soluble alkyl ether of cellulose binder having a count of less than 300 insoluble fibers per gram of binder material as measured for a 1 wt% aqueous solution of binder material.
2. The method according to claim 1, wherein the alkyl ether of cellulose binder is selected from the group consisting of methyl cellulose, and methyl cellulose derivatives and ethyl cellulose derivatives that are water soluble, and combinations thereof.
3. The method according to claim 1, wherein the alkyl ether of cellulose binder is a water soluble ether selected from the group consisting of methyl cellulose, hydroxyethyl methyl cellulose, hydroxyethyl cellulose and hydroxypropyl methyl cellulose, and combinations thereof.
4. The method according to claim 1, where the count of insoluble fibers is less than 200 fibers per gram of binder material.
5. The method according to claim 2, where the count of insoluble fibers is less than 200 fibers per gram of binder material.

6. The method according to claim 3, where the count of insoluble fibers is less than 200 fibers per gram of binder material.
7. The method according to claim 1, where the count of insoluble fibers is less than 65 fibers per gram of binder material.
8. The method according to claim 2, where the count of insoluble fibers is less than 65 fibers per gram of binder material.
9. The method according to claim 2, where the count of insoluble fibers is less than 65 fibers per gram of binder material.
10. A mixture suitable for extrusion and firing to form a ceramic honeycomb substrate, said mixture comprising:
 - a batch composition selected from the group consisting of a cordierite batch composition and an aluminum titanate batch composition;
 - optionally, a pore former material;
 - a binder material; and
 - water;wherein said binder is a water soluble alkyl ether of cellulose binder having a count of less than 300 water-insoluble fibers per gram of binder material.
11. The mixture according to claim 10, wherein said alkyl ether of cellulose has a count of less than 200 water-insoluble fibers per gram of binder material.
12. The mixture according to claim 10, wherein said alkyl ether of cellulose has a count of less than 65 water-insoluble fibers per gram of binder material.

13. The mixture according to claim 7, wherein the alkyl ether of cellulose is selected from the group consisting of methyl cellulose, and methyl cellulose derivatives and ethyl cellulose derivatives that are water soluble, and combinations thereof.

14. The mixture according to claim 10, wherein the alkyl ether of cellulose is selected from the group consisting of methyl cellulose, hydroxyethyl methyl cellulose, ethyl cellulose, hydroxyethyl methylcellulose, hydroxypropyl methyl cellulose, and combinations thereof.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/032907

A. CLASSIFICATION OF SUBJECT MATTER INV. C04B38/00 C04B35/195 C04B35/636 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) C04B		
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, INSPEC, 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	EP 1 852 406 A2 (IBIDEN CO LTD [JP]) 7 November 2007 (2007-11-07) claims 1-24; examples 1-9	1-14
X	US 5 660 904 A (ANDERSEN PER JUST [US] ET AL) 26 August 1997 (1997-08-26) claims 1-82; examples 1-145	1-14
X	US 2008/254254 A1 (OHNO KAZUSHIGE [JP] ET AL) 16 October 2008 (2008-10-16) claims 1-25; examples 1-9	1-14
X,P	EP 2 105 192 A1 (IBIDEN CO LTD [JP]) 30 September 2009 (2009-09-30) claims 1-11; examples 1-4	1-14
X	WO 99/64371 A1 (CORNING INC [US]) 16 December 1999 (1999-12-16) claims 1-28; examples 1-11; tables I-III	1-14
☐ 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 document 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 another 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. 'Z' 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 August 2010		02/09/2010
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Fortunati, Taddiano

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2010/032907

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1852406	A2	07-11-2007	NONE
US 5660904	A	26-08-1997	US 6180037 B1 30-01-2001 US 5879722 A 09-03-1999
US 2008254254	A1	16-10-2008	CN 101400626 A 01-04-2009 WO 2007129430 A1 15-11-2007 KR 20080096538 A 30-10-2008
EP 2105192	A1	30-09-2009	WO 2009118872 A1 01-10-2009 US 2009247403 A1 01-10-2009
WO 9964371	A1	16-12-1999	AT 247080 T 15-08-2003 AT 247081 T 15-08-2003 AU 4327399 A 30-12-1999 AU 4412899 A 30-12-1999 BR 9910951 A 06-03-2001 BR 9910952 A 20-03-2001 CN 1304389 A 18-07-2001 CN 1308593 A 15-08-2001 DE 69910385 D1 18-09-2003 DE 69910392 D1 18-09-2003 EP 1089953 A1 11-04-2001 EP 1093447 A1 25-04-2001 JP 2002517374 T 18-06-2002 JP 2002517375 T 18-06-2002 WO 9964370 A1 16-12-1999