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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 October 2022 (27.10.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/223586 A1

(51) International Patent Classification:
B32B 17/10 (2006.01) *E06B 3/66* (2006.01)
B32B 27/32 (2006.01) *E06B 5/16* (2006.01)

(21) International Application Number:
PCT/EP2022/060369

(22) International Filing Date:
20 April 2022 (20.04.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
21169721.4 21 April 2021 (21.04.2021) EP

(71) Applicants: **AGC GLASS EUROPE** [BE/BE]; Avenue Jean Monnet 4, 1348 Louvain-la-Neuve (BE). **AGC INC.** [JP/JP]; Shin-Marunouchi Building 1-5-1 Marunouchi Chiyoda Ku, Tokyo, 100-8405 (JP). **AGC FLAT GLASS NORTH AMERICA, INC.** [US/US]; 11175 Cicero Drive Suite 400, Alpharetta, 30022-1167 (US). **AGC VIDROS DO BRASIL LTDA** [BR/BR]; Estrada Municipal Doutor Jaime Eduardo Ribeiro Pereira, 500 Jardim Vista Alegre, CEP 12523-671 São Paulo (BR).

(72) Inventors: **CARLEER, Pierre**; Avenue de Tancarville 21, 1410 Waterloo (BE). **LEYBROS, Perrine**; Rue Saint-Donat 145, 5002 Saint-Servais (BE). **JEANFILS, Julien**; Rue du Bois de Buis 4, 1457 Walhain (BE).

(74) Agent: **AGC GLASS EUROPE**; Rue Louis Blériot 12, 6041 Gosselies (BE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,

(54) Title: NOVEL LAMINATION PROCESS TO PRODUCE LAMINATED VACUUM INSULATING GLAZING ASSEMBLY

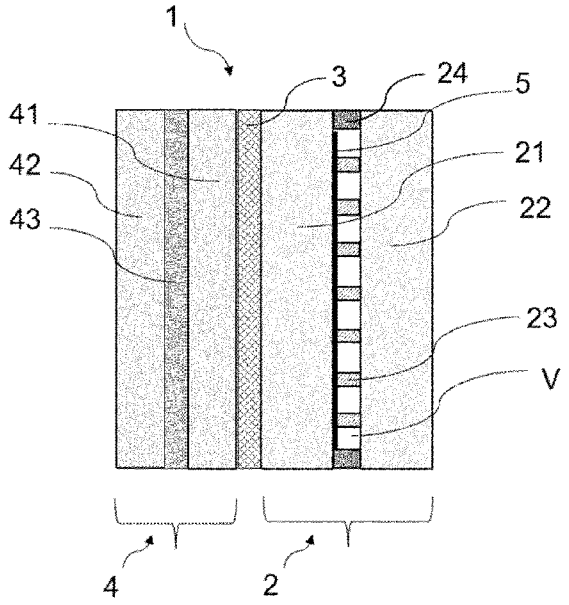


Figure 1

(57) Abstract: The present invention concerns a process for the production of a laminated vacuum insulating glazing assembly (1) that comprises at least one vacuum insulating glazing (2), at least one interunit polymer (3) and at least one functional unit (4); that have been made separately. The functional unit has been produced at a processing pressure (PP) from 5.5 bar to 15.0 bar (5.5 bar ≥ PP ≥15.0 bar).The process for the production of a laminated vacuum insulating glazing assembly (1) that complieswith the High Temperature Test of the norm ISO12543-4:2011; comprises at least the following steps :1) Stacking the vacuum insulating glazing (2), the interunit polymer (3) and the functional unit (4); thereby creating a pre-assembly; 2) Inserting the pre-assembly into a vacuum ring or vacuum bag; 3) Processing the pre-assembly into a laminated VIG assembly by at least the following sub-steps:a. Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar, within the vacuum ring or vacuum bag, b. Heating the pre-assembly

WO 2022/223586 A1

[Continued on next page]

DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *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))*

to a temperature ranging from 50°C to 200°C, preferably from 75°C to 175°C, more preferably from 90°C and 150°C.c. Pressurizing the pre-assembly under an overpressure (OP) equal to or lower than 4.5bar (OP ≤ 4.5 bar); and 4) Releasing the evacuation 3)a), the heating 3)b) and the overpressure 3)c).

NOVEL LAMINATION PROCESS TO PRODUCE LAMINATED VACUUM INSULATING GLAZING ASSEMBLY

FIELD OF THE INVENTION

[0001] The present invention relates to a novel production process of a laminated vacuum insulating glazing assembly that provides an additional performance such as acoustic, safety, security, fire resistance and/or decoration.

BACKGROUND OF THE INVENTION

[0002] Vacuum insulating glazing do respond to the market's need of higher thermal insulation. They are typically composed of at least two glass panes separated by an internal space in which a vacuum has been generated and wherein discrete spacers are placed to prevent direct contact between the glass panes under atmospheric pressure. In addition to the insulation performance, the glass market seeks to add to the vacuum insulating glazing additional benefits such as safety, security, acoustic, fire resistance, decoration...

[0003] Such additional benefits are typically brought to the vacuum insulating glazing by a lamination process. Nearly all of the lamination processes require pressurized autoclave finishing treatment at pressures above 10 atmospheres and temperatures up to 150°C in order to make acceptable quality laminated glass. Indeed, during lamination, temperatures typically are elevated up to about 150°C to soften the interlayer, helping conform it to the surface of the glass substrate and flow the interlayer into areas where the substrate spacing may be uneven. Once the interlayer is conformed, the mobile polymer chains of the interlayer develop adhesion with the glass. Elevated temperatures also accelerate the diffusion of residual air and/or moisture pockets from the glass/intermediate layer interface into the intermediate layer. Pressure appears to play two critical roles in the production of glass laminates. Firstly, pressure promotes the intermediate layer flow. Secondly, it suppresses bubbles formation that otherwise would be caused by the combined vapor pressure of water and air trapped in the system. Water and air trapped in a pre-press (i. e. , the layered assembly of unbonded glass and intermediate layer) tend to expand into bubbles when the pre-press assembly is heated at atmospheric pressure to finishing temperatures greater than about 100°C. To suppress bubbles formation, heat accompanied with overwhelming pressure typically is applied to the assembly in an autoclave vessel, so as to counteract the expansion forces generated when air and water trapped within the pre-press are heated. Finally, time ultimately plays an important role in lamination. While

temperature and pressure can accelerate lamination, a certain critical time must always elapse in order to produce good quality laminated glass.

[0004] However, because of the high pressure and/or of the high temperature requirements, such conventional lamination process cannot be used on vacuum insulating glazing. In particular, the pressurized treatment step is not compatible with the intrinsic nature of the vacuum insulating glazing: the discrete spacers placed between the two glass panes of the vacuum insulating glazing might not resist to the required pressure and/or micro cracks can appear on the glass panes around these discrete spacers, impairing substantially the mechanical strength of the vacuum-insulating glazing and its thermal performance.

[0005] Therefore, lamination at atmospheric pressure or under very low pressure has been used to laminate an additional glass sheet to a vacuum insulating glazing. For example, WO2020203550 discloses a method of laminating a transparent plate to a vacuum insulating glazing via an intermediate film. The vacuum insulating glazing comprises a first glass panel, a second glass panel, a vacuum space located between the first and the second glass panels and a plurality of spacers made of resin. The processing pressure to laminate together the vacuum insulating glazing and the transparent plate is smaller than the compressive strength of the plurality of spacers.

[0006] However, such low pressure requirement significantly reduces the flexibility of the choice of the additional benefit that could be added to the vacuum insulating glazing. Most of the additional benefits brought by functional units do indeed require high temperature and/or high pressure, processed directly on the vacuum insulating glazing because of the vacuum insulating glazing mechanical resistance.

[0007] Therefore, the skilled person in the art is looking for a novel lamination process to bring an additional superior benefit to a vacuum insulating glazing that allows to combine the benefits of the vacuum insulating glazing with the performance of a functional unit without impairing the mechanical and functional properties of the vacuum-insulating glazing. Hence, in order to resist to a lamination process whereby an additional benefit is added via a functional unit to the vacuum insulating unit, the vacuum insulating unit should be designed to resist to the following loads :

(1) the intrinsic load (L_{int}) being all stresses inherent to the vacuum insulating glazing design itself such as the mechanical resistance of the discrete spacers, the thickness of the glass panes, the atmospheric pressure,...;

(2) the lamination load (L_{lam}) being all stresses brought by a lamination process to the vacuum insulating glazing; and

(3) the use load (L_{use}) being all stresses caused by the conditions of use of the vacuum insulating glazing, such as the temperature difference between the inside and outside environment, the wind,...

[0008] Therefore, it is an object of the present invention to provide a novel production process that allows to add to the benefits of the vacuum insulating glazing, the performance of a functional unit without impairing the mechanical and functional properties of both the vacuum-insulating glazing and the functional unit, while keeping the production process, cost-effective and simple.

SUMMARY OF THE INVENTION

[0009] The present invention relates to a process for the production of a laminated vacuum insulating glazing assembly that complies with the High Temperature Test of the norm ISO12543-4:2011. The process comprises at least the following steps :

1) Stacking a vacuum insulating glazing, an interunit polymer and a functional unit; thereby creating a pre-assembly. The functional unit has been processed at a processing pressure (PP) from 5.5 bar to 15.0 bar (5.5 bar ≥ PP ≥15.0 bar), preferably from 7.5 bar to 14.0 bar (7.5 bar ≥ PP ≥ 14.0bar), more preferably from 10.0 bar to 14.0 bar (10.0 bar ≥ PP ≥ 14.0 bar)
2) Inserting the pre-assembly into a vacuum ring or vacuum bag, preferably into a vacuum bag;
3) Processing the pre-assembly into a laminated VIG assembly by at least the following sub-steps:
    a. Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar, within the vacuum ring or vacuum bag,
    b. Heating the pre-assembly to a temperature ranging from 50°C to 200°C, preferably from 75°C to 175°C, more preferably from 90°C and 150°C,
    c. Pressurizing the pre-assembly under an overpressure (OP) equal to or lower than 4.5 bar (OP ≤ 4.5 bar); and
4) Releasing the evacuation 3)a), the heating 3)b) and the overpressure 3)c);

[0010] In a preferred embodiment, the functional unit comprises at least 2 sheets, preferably at least one of the sheets is a glass sheet, more preferably the at least 2 sheets are glass sheets.

[0011] In a preferred embodiment, the overpressure of sub-step3)c) is equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5 bar), preferably equal to or less than to 1.0bar (OP ≤ 1.0bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

[0012] In a preferred embodiment, the sub-steps of the processing step 3) are achieved in the following processing order: the evacuation sub-step 3)a), the heating sub-step 3)b) and the pressurization sub-step 3)c); preferably the heating sub-step 3)b) and the pressurization sub-step 3)c) are started simultaneously.

[0013] In a preferred embodiment, the evacuation sub-step 3)a) of the processing step 3) is started at ambient temperature for a period of 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min.

[0014] In a preferred embodiment, the releasing step 4) is achieved by releasing the heating first and then releasing the evacuation, preferably releasing the evacuation and pressurization together, preferably when the temperature of the VIG laminated assembly has reached 50°C to 60°C, more preferably ambient temperature.

[0015] In a preferred embodiment, the heating release step within step (4) is run at a rate of 1-10°C/min, preferably 2-9°C/min, preferably 3-8°C/min, preferably 4-7°C/min, more preferably 5-6°C/min, preferably in the temperature range of 130°C to 30°C. This is especially preferred when the interunit polymer is an ethylene vinyl acetate and/or an ionomer, preferably is ethylene vinyl acetate.

[0016] In a preferred embodiment, the laminated vacuum insulating glazing assembly complies with the following load equation: $L_{lam} \leq [L_{int} (SF-1)] + [L_{use} \times SF]$ wherein:

- L_{lam} is the lamination load being all stresses brought by a lamination process to the vacuum insulating glazing;
- L_{int} is the intrinsic load being all stresses inherent to the vacuum insulating glazing design per se;
- SF is the security factor; and
- L_{use} is the use load being all stresses caused by the vacuum insulating glazing use conditions.

[0017] In a preferred embodiment, the interunit polymer is selected from the group consisting of ethylene vinyl acetate (EVA), cyclo polyolefin polymer (COP),autoclave-free polyvinyl butyral

(Autoclave-free PVB), polyurethane (PU), and/or ionomers, preferably is selected from ethylene vinyl acetate (EVA) and/or autoclave-free polyvinyl butyral (Autoclave-free PVB).

[0018] In a preferred embodiment wherein the interunit polymer is an autoclave-free polyvinyl butyral, the temperature of the heating sub-step b) of the Processing Step 3) ranges from 90°C to 150°C, preferably from 115°C to 150°C, preferably from 135°C to 145°C, more preferably is 140°C; preferably for a period ranging from 20 to 180 min, more preferably for 60 min.

[0019] In a preferred embodiment wherein the interunit polymer is a polyurethane, the temperature of the heating sub-step b) of the processing step 3) ranges from 90°C to 150°C, preferably from 110°C to 120°C; preferably for a period ranging from 20 to 180 min, more preferably for 60 min. In a preferred embodiment, the pressurizing sub-step 3)c) is done under an overpressure (OP) comprised between 2.0 bar and 4.5 bar (2.0 bar ≤ OP ≤ 4.5 bar), preferably between 2.0 bar and 4.0 bar (2.0 bar ≤ OP ≤ 4.0 bar), more preferably is 3.0 bar.

[0020] In a preferred embodiment wherein the interunit polymer is an ethylene vinyl acetate and/or a cyclo polyolefin polymer, preferably is an ethylene vinyl acetate; the temperature of the heating sub-step b) of the processing Step 3) ranges from 90°C to 150°C, preferably from 110°C to 145°C.

[0021] In a preferred embodiment wherein the interunit polymer is an ethylene vinyl acetate, the processing step (3) comprises a further sub-step b*) before the sub-step b), of heating at an intermediate temperature ranging from 75°C to 95°C; preferably for a period of 10 to 60 min, more preferably from 15 min to 40 min.

[0022] In a preferred embodiment wherein the interunit polymer is an ethylene vinyl acetate, the sub-steps of processing step (3) are achieved in the following processing order :

a) Evacuating at room temperature for a period of 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min;

b*) Heating to an intermediate temperature ranging from 75°C to 95°C, preferably for a period of 10 to 60 min, more preferably from 15 min to 40 min;

b) Heating to a temperature ranging from 110°C and 145°C, preferably from 130°C to 140°C for a period of 45 min to 300 min;

c) Pressurizing under an overpressure (OP) equal to or lower than 2.0 bar (OP ≤ 2.0bar), preferably equal to or lower than 1.5 bar (OP ≤ 1.5 bar) preferably equal to or lower than 1.0

bar (OP ≤ 1.0bar), preferably equal to or lower than 0.5 bar (OP ≤ 0.5 bar), more preferably under no overpressure of 0 bar (OP = 0 bar)

wherein preferably the sub-step b) and sub-step c) are simultaneous.

[0023] In a preferred embodiment wherein the interunit polymer is an ionomer and wherein the heating sub-step b) of the processing step (3) is run under a temperature from 90°C to 150°C, preferably from 130°C to 135°C; preferably for a period of 45 to 75 min, more preferably for 60 min.

[0024] In a preferred embodiment, the functional unit comprises at least 2 glass sheets laminated by a polyvinyl butyral polymer interlayer.

[0025] In a preferred embodiment, the functional unit comprises at least one structural plastic sheet, preferably a polycarbonate sheet and at least one glass sheet laminated by at least one polyvinyl butyral polymer interlayer and at least one polyurethane polymer interlayer.

[0026] In a preferred embodiment, the polyvinyl butyral polymer interlayer is an acoustic polyvinyl butyral polymer interlayer and/or the sheets are of different thicknesses.

[0027] In a preferred embodiment, the functional unit comprises at least 2 glass sheets separated by intumescent material, preferably hydrated alkali metal silicates. In a preferred embodiment, the functional unit comprises further a peripheral spacer thereby creating a space between the 2 glass sheet to comprise the intumescent material, and wherein the heating sub-step b) of the processing step 3) is achieved under a temperature equal to or lower than 120°C, preferably equal to or lower than 110°C, preferably equal to or lower than 100°C, more preferably equal to or lower than 90°C.

[0028] In a preferred embodiment, the at least one of the first and/or second glass pane of the vacuum insulating glazing and/or at least one of the sheets of the functional unit, is a heat strengthened glass, a thermally toughened safety glass, or a chemically strengthened glass.

[0029] In a preferred embodiment, the discrete spacers of the vacuum insulting glazing are made of metal material, quartz glass, a ceramic material and/or resin, preferably resin, more preferably polyimide resin.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Figure 1 shows a cross sectional view of a laminated vacuum insulating assembly according to one embodiment of the present invention, wherein the vacuum insulating glazing is laminated by an interunit polymer to a functional unit comprising 2 sheets.

DETAILED DESCRIPTION

[0031] The present invention relates to a production process of a "laminated vacuum insulating glazing assembly", herein after referred to as "laminated VIG assembly", that comprises at least 2 separate units: a vacuum insulating glazing hereinafter referred to as "VIG" and a functional unit.. The VIG and functional unit are made separately, before being stacked together with an interunit polymer, into a pre-assembly that is laminated to form the laminated VIG assembly within the production process of the present invention.

[0032] It is well understood by persons skilled in the art that, as used herein the terms "a", "an" or "the" means at least "one" and should not be limited to "only one" unless explicitly indicated to the contrary.

The process

[0033] The objective of the present invention is to produce a laminated vacuum-insulating glazing assembly that combines the excellent thermal insulation properties, the thinness and weight characteristics of a vacuum insulating glazing with some other functionality such as safety, security, acoustic, fire resistance, decoration… properties brought by a functional unit, without impairing the functional or mechanical properties of the vacuum insulating glazing unit, nor of the functional unit.

[0034] A further objective of the present invention is to obtain such superior performance while avoiding the overdesigns of the VIG, of the functional unit and/or of the entire laminated VIG assembly since overdesign brings unnecessary complexity, costs and may impair the laminated VIG assembly thermal performance, light transparency, weight, thickness, processability and transport…

[0035] Regular lamination processes whereby high temperature and/or high pressure conditions are applied have been found to impair in some instances, the mechanical properties and/or the thermal performance of the vacuum insulating glazing. It has been surprisingly found that the process of the present invention whereby the vacuum insulating glazing and the functional unit are produced

separately and then laminated together under gentle overpressure conditions allows to maintain the vacuum insulating glazing integrity and to bring superior functional properties to the laminated VIG assembly that could not otherwise be brought to the vacuum insulation glazing.

[0036] The present invention is therefore addressing how a laminated VIG assembly should be designed and processed to support the different loads : the intrinsic load, the use load and the lamination load. It has been found that the laminated VIG assembly and its production process should be designed such that :

(1) the laminated VIG assembly resists to the intrinsic load (L_{int}) and use load (L_{use}) both complemented with a certain design Security Factor: Design load ≥ (Lint + Luse) x SF; and

(2) the laminated VIG assembly resists as well to the combined intrinsic and lamination loads : Design Load ≥ Lint + Llam.

Therefore, the lamination load complies with the following equation : Llam ≤ [Lint (SF-1)] + [Luse x SF]

[0037] In order to resist to the charges brought by the lamination process (L_{lam}) as per above equation and therefore to avoid damaging the functional or mechanical properties of the vacuum insulating glazing, different routes are offered to the person skilled in that art:

(1) One potential route would be to increase the use load. However, if the laminated VIG assembly would be designed to resist to a higher use load, it would be unnecessarily overdesigned.

(2) Another potential route would be to increase the Security Factor such increasing the thickness of the glass panes of the VIG. Here again, the laminated VIG assembly would be unnecessarily overdesigned and this would deteriorate the advantageous properties of thickness and light weight of the VIG.

(3) Another technical approach would be to increase the numbers of discrete spacers to would allow to reduce the intrinsic load and to reduce the lam load. However such route would significantly reduce the thermal performance of the VIG and would be unnecessarily overdesigned.

Such overdesigns are to be avoided since they bring unnecessary complexity, costs and may impair the laminated VIG assembly thermal performance, light transparency, weight, thickness, processability and transport...

(4) Finally, the last potential route is therefore to design a production process whereby the lamination load is reduced, i.e. a production process at lower pressure and/or lower

temperature. However, such production process would not allow to make use of all functional units that require indeed high pressure and/or high temperature conditions to be made.

[0038] As indicated above, overdesigning the vacuum insulating glazing is not an economically viable option. Lamination at lower pressure would exclude functional units that require indeed high pressure and/or high temperature conditions. Such functional unit typically are processed at a processing pressure (PP) from 5.5bar to 15.0bar. Therefore, there is still a need to develop a production process that combines and maintains the excellent thermal properties of the VIG as well as the functional properties of the added functional unit. It has been found that the novel production process of the present invention whereby the functional unit and VIG are made in separate steps and then laminated together under gentle overpressure provides the greatest flexibility in additional technical performance to a VIG while avoiding overdesigning of the VIG component and/or reducing the thermal performance. Indeed, the present invention allows to add a functional unit that has been processed at high pressure to a VIG via a lamination process at low pressure.

[0039] Moreover, the novel production process for the laminated VIG assembly can be performed in a single stage within a single industrial equipment and therefore is easy, simple, efficient and cost effective.

[0040] The laminated VIG assembly can comprise at least one VIG and at least one functional unit. Typically the laminated VIG assembly comprises one VIG and one functional unit. However, in some embodiments, the laminated VIG assembly can comprise more than one functional units added to the same side of the VIG or to both sides of the VIG. It could also be contemplated embodiments wherein the laminated VIG assembly comprise more than one VIGs with one or more functional units. All combinations of VIG(s) and functional unit(s) are herein encompassed.

[0041] In a preferred embodiment of the present invention, the laminated VIG assembly comprises one VIG and one functional unit.

[0042] The laminated VIG assembly, the VIG and functional unit, as well as the panes of the VIG and the sheets of functional unit, extend along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Z. Each of these elements have a thickness measured in the direction normal to the plane, P and have a surface extending along the place, P.

[0043] The present invention relates a process for making a laminated VIG assembly (1) comprising a VIG (2) and a functional unit (4) wherein the VIG and functional units have been made in separate steps. Suitable interunit polymer to be used in the process of the present invention to laminate the functional unit and the VIG, to form the laminated VIG assembly of the present invention, is a polymer that it capable of providing suitable mechanical adhesion by lamination at gentle overpressure.

[0044] During stacking, the interunit polymer can be deposited onto the surface of the VIG and/or of the functional unit and is located between the vacuum insulating glazing and the functional unit thereby creating the pre-assembly.

[0045] By suitable mechanical adhesion by lamination, it is meant that the resulting laminated VIG assembly does comply with the High Temperature test (also known to as Bake test) within the durability section of the norm NBN EN ISO 12543 dated October 2011, Glass in building – Laminated glass and laminated safety glass – Part 4: Test methods for durability (ISO12543-4:2011)

[0046] By overpressure, it is meant an additional pressure over the atmospheric pressure. By gentle overpressure, it is meant an overpressure equal to or less than to 4.5 bar (OP ≤ 4.5 bar), preferably equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5bar), preferably equal to or less than to 1bar (OP ≤ 1bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

[0047] Hence, suitable interunit polymers to be used in the process of the present invention are those providing proper mechanical adhesion between the functional unit and the VIG so that the resulting laminated VIG assembly does comply with the High Temperature Test ISO12543-4:2011 at an overpressure equal to or less than to 4.5bar (OP ≤ 4.5bar), preferably equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5bar), preferably equal to or less than to 1bar (OP ≤ 1bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

[0048] In a preferred embodiment, suitable interunit polymers to be used in the process of the present invention are selected from the group consisting of ethylene vinyl acetate (EVA), cyclo olefin

polymers (COP), autoclave-free polyvinyl butyral (herein after referred to as Autoclave-free PVB), polyurethane (PU), ionomers like SentryGlas™ and combinations thereof.

[0049] The present invention relates to a process for the production of a laminated vacuum insulating glazing assembly that complies with the High Temperature Test of the norm ISO12543-4:2011, comprising at least the following steps :

1) Stacking a vacuum insulating glazing, an interunit polymer and a functional unit, thereby creating a pre-assembly. The interunit polymer is located between the VIG and the functional unit in order for the pre-assembly to be further laminated into a laminated VIG assembly.
2) Inserting the pre-assembly in a vacuum ring or vacuum bag, preferably into a vacuum bag.
3) Processing the pre-assembly into a laminated VIG assembly by at least the following sub-steps:
    a) Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar, within the vacuum ring or vacuum bag,
    b) Heating the pre-assembly to a temperature ranging from 50°C to 200°C, preferably from 75°C to 175°C, more preferably from 90°C and 150°C,
    c) Pressurizing the pre-assembly under an overpressure (OP) equal to or lower than 4.5 bar (OP ≤ 4.5 bar); and
4) Releasing the evacuation 3)a), the heating 3)b) and the overpressure 3)c).

[0050] The functional unit herein has been processed at high pressure to provide superior benefits. i.e. at a processing pressure (PP) from 5.5 bar to 15.0 bar (5.5 bar ≥ PP ≥15.0 bar), preferably from 7.5 bar to 14.0 bar (7.5bar ≥ PP ≥14.0bar), more preferably from 10.0 bar to 14.0 bar (10.0bar ≥ PP ≥14.0bar). The functional unit preferably comprises at least 2 sheets, preferably at least one of the sheets is a glass sheet, more preferably the at least 2 sheets, are glass sheets.

[0051] In a preferred embodiment of the process of the present invention, the overpressure of sub-step b) of the processing step 3) is equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0 bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5bar), preferably equal to or less than to 1.0bar (OP ≤ 1.0bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

[0052] It is well understood by persons skilled in the art, that when the process of the present invention is run at an overpressure equal to 0 bar, it is run without additional overpressure, i.e. at atmospheric pressure and that no release of the overpressure is required.

[0053] It is well understood by persons skilled in the art that any other vacuum device can be used in place of the vacuum bag or vacuum ring, such as a vacuum chamber, to achieve the same purpose of subjecting the pre-assembly to vacuum, especially in the method of the present invention wherein no overpressure is used (OP = 0bar). When the vacuum bag is used, it is preferred to surround the pre-assembly by a breather frame to increase the de-airing phenomena.

[0054] Preferably the process of the present invention will be is free of a system of pressure rollers or calander (single or double) so that the overpressure is not achieved via a calander rolls, nip-rollers or any other roller, to avoid impairing the mechanical resistance and to maintain the integrity of the laminated VIG assembly.

[0055] The sub-steps of the processing Step 3) being the evacuation a), the heating b) and the pressurization c) can be started in any order. However, in a preferred embodiment of the present invention, the sub-steps of the processing step 3) are achieved in the following processing order: the evacuation sub-step 3)a), the heating sub-step 3)b) and the pressurization sub-step 3)c); preferably the heating sub-step 3)b) and the pressurization sub-step 3)c) are started simultaneously. It has been found that such preferred embodiment improves the evacuation of air at low temperature. Increasing the pressure will help the evacuation and the heating will cause edge sealing of the assembly preventing the air to return the structure.

[0056] In a preferred embodiment of the present invention, the evacuation sub-step a) of the processing step 3) is started at ambient temperature for a period of 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min before the heating sub-step 3)b) is started. It has been found that such preferred embodiment allows smooth air evacuation caught between the interunit polymer and the VIG and/or functional unit.

[0057] In a further preferred embodiment of the present invention, the releasing step 4) of the process of the present invention is achieved by releasing the heating first and then releasing the evacuation, preferably releasing the evacuation and pressurization together. Such preferably when the temperature of the VIG laminated assembly has reached 50°C to 60°C, more preferably has reached ambient temperature. Indeed, cooling under vacuum is advantageous since it reduces the formation of air pockets and cloudiness in the laminated VIG assembly.

[0058] In a further preferred embodiment of the present invention, the heating release sub-step of step (4) of the process, is run to achieve a diminution of 1-10°C/min, preferably 2-9°C/min, preferably 3-8°C/min, preferably 4-7°C/min, more preferably 5-6°C/min, especially in the temperature range of 130°C to 30°C. It is indeed especially preferred in the embodiment wherein the interunit polymer used to form the laminated VIG unit is EVA, COP and/or ionomer. The cooling step of the process of the present invention will preferably be run fast to avoid the appearance of haze. Convention cooling, by means of flow of cooling gas such as with a fan with or without a heat exchanger, or conduction cooling can be used.

[0059] Typically, the processes of the invention is achieved within a clean room to respect specific temperature and the low moisture level when required, as well as to avoid contamination.

[0060] In a preferred embodiment, suitable interunit polymers to be used in the process of the present invention are selected from the group consisting of ethylene vinyl acetate (EVA), cyclo olefin polymers (COP), autoclave-free polyvinyl butyral (herein after referred to as Autoclave-free PVB), Polyurethane (PU) and/or ionomers like SentryGlas™.

Process with Autoclave-free PVB

[0061] In the process of the present invention wherein the interunit polymer used to form the laminated VIG assembly is a autoclave-free PVB, an initial step of preconditioning the autoclave-free PVB to a specific relative humidity and temperature conditions is preferably added. This is preferred to obtain a good quality of the laminated VIG assembly after the lamination cycle and in particular avoid bubbles formation at the edges of the laminated VIG assembly. Such autoclave-free PVB typically requires specific humidity conditions for the storage and processing such as to present a moisture content of less than 20%, preferably less the 15%, more preferably less than 10% and temperature between 15°C and 30°C, preferably between 18°C and 25°C. Therefore, in this embodiment wherein the interunit polymer is a autoclave-free PVB, the process of the present invention preferably comprises an initial step of preconditioning the autoclave-free PVB for at least 10hours, preferably at least 12 hours at ≤ 10% relative humidity and 25°C.

[0062] In this embodiment, the heating sub-step b) of the processing step 3) of the process of the present invention will preferably heat the pre-assembly at temperature of from 90°C to 150°C, preferably from 115°C to 150°C, preferably from 135°C to 145°C, more preferably is 140°C. Such is preferably achieved for a period ranging from 20 to 180 min, preferably for 60 min.

[0063] Therefore, in a preferred embodiment of the present invention, the sub-steps a) and b) of the processing Step (3) of the process of the present invention are achieved in the following processing order:

a. Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar within the vacuum ring or vacuum bag; at room temperature for a period ranging from 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min;
b. Heating at a temperature between from 90°C and 150°C, preferably from 115°C to 150°C, preferably from 135°C to 145°C, more preferably is 140°C; preferably for a period ranging from 20 to 180 min, preferably for 60 min.

[0064] In a further preferred embodiment, the pressurizing sub-step 3)c) is done under an overpressure (OP) equal to or lower than 2.0 bar (OP ≤ 2.0 bar), preferably equal to or lower than 1.5 bar (OP ≤ 1.5 bar) preferably equal to or lower than 1.0 bar (OP ≤ 1.0 bar), preferably equal to or lower than 0.5 bar (OP ≤ 0.5 bar), and more preferably under no overpressure of 0 bar (OP = 0 bar).

[0065] Preferably, the heating sub-step b) and pressurization sub-step c) of the processing step 3) are started simultaneously.

[0066] All these preferred features are combined within a more preferred process of the present invention wherein the interunit polymer is autoclave free PVB.

Process with PU

[0067] In the process of the present invention wherein the interunit polymer used to form the laminated VIG assembly is polyurethane (PU), the heating sub-step b) of the processing step 3) of the process of the present invention will preferably heat the pre-assembly at temperature of from 90°C to 150°C, preferably from 110°C to 120°C. Such is preferably achieved for a period ranging from 20 to 180 min, more preferably for 60 min.

[0068] Therefore, in such preferred embodiment of the present invention, the sub-steps a) and b) of the processing Step (3) of the process of the present invention are achieved in the following processing order:

a. Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar within the vacuum ring or vacuum bag; at room temperature for a period ranging from 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min;

b. Heating at a temperature between from 90°C and 150°C, preferably from 110°C to 120°C; preferably for a period ranging from 20 to 180 min, preferably for 60 min.

[0069] In a further preferred embodiment, the pressurizing sub-step 3)c) is done under an overpressure (OP) comprised between 2.0 bar and 4.5 bar (2.0 bar ≤ OP ≤ 4.5 bar), preferably between 2.0 bar and 4.0 bar (2.0 bar ≤ OP ≤ 4.0 bar), more preferably is around 3.0 bar.

[0070] Preferably, the heating sub-step b) and pressurization sub-step c) of the processing step 3) are started simultaneously.

[0071] All these preferred features are combined within a more preferred process of the present invention wherein the interunit polymer is a polyurethane (PU).

Process with EVA and/or COP

[0072] In the process of the present invention, a preferred interunit polymer to form the laminated VIG assembly is selected from EVA and/or COP, more preferably is EVA.

[0073] In the process of the present invention wherein the interunit polymer used to form the laminated VIG assembly is EVA and/or COP, specific care should be brought to the quality of the vacuum and the temperature profile. The temperature range and its duration are easily adapted by person skilled in that art depending on the parameters of the laminated VIG assembly such as total thickness, glass thermal inertia, glass volume…

[0074] Therefore, in a preferred embodiment wherein the interunit polymer used to form the laminated VIG unit is EVA and/or COP, the heating sub-step b) of the processing step 3) of the process of the present invention will preferably comprise the initial step of pre-bonding the EVA interunit polymer by heating under a temperature between 75°C to 95°C, preferably for a period of 10 to 60 min, more preferably from 15 min to 40 min, to provide the elimination of the imprisoned air between the EVA or COP interunit polymer and the glass surface of the VIG and functional unit thanks to the obtained optimal viscosity of the EVA polymer or of the cyclo olefin polymer.

[0075] In the embodiment wherein the interunit polymer used to form the laminated VIG unit is EVA and/or COP, the heating sub-step b) of the processing Step 3) of the process of the present invention will preferably be run under a temperature of 90°C and 150°C, more preferably under a temperature

of 110°C to 145°C. The temperature ranges allow optimal cross-linking of the interunit polymer thereby optimal adhesion and durability.

[0076] In the embodiment wherein the interunit polymer used to form the laminated VIG unit is EVA and/or COP, the sub-steps of processing step (3) are achieved in in the following processing order :

a) Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar within the vacuum ring or vacuum bag; at room temperature for a period of 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 to 30min;

b*) Heating to an intermediate temperature ranging from 75°C to 95°C; preferably for a period of 10 to 60 min, more preferably from 15 min to 40 min;

b) Heating to a temperature ranging from 110°C and 145°C, preferably from 130°C to 140°C for a period of 45 min to 300 min.

[0077] In a further preferred embodiment, the pressurizing sub-step 3)c) is done under an overpressure (OP) equal to or lower than 2.0 bar (OP ≤ 2.0 bar), preferably equal to or lower than 1.5 bar (OP ≤ 1.5 bar) preferably equal to or lower than 1.0 bar (OP ≤ 1.0 bar), preferably equal to or lower than 0.5 bar (OP ≤ 0.5 bar), and more preferably under no overpressure of 0 bar (OP = 0 bar).

[0078] Preferably, the heating sub-step b) and pressurization sub-step c) of the processing step 3) are started simultaneously.

[0079] All these preferred features are combined within a more preferred process of the present invention wherein the interunit polymer is EVA and/or COP, preferably is EVA.

Process with Ionomer

[0080] In the process of the present invention wherein the interunit polymer used to form the laminated VIG assembly is an ionomer, special care should be brought to the storage of such ionomer in the humidity and temperature conditions recommended by the supplier, typically a relative humidity of less than or equal to 15%.

[0081] The process of the present invention wherein the interunit polymer is an ionomer, preferably requires a degassing step and an edge pre-sealing step. Indeed, it is preferred that the air located at the VIG and functional unit interface with the interunit polymer is evacuated and then the edges are pre-sealed to avoid air penetration during the processing step of the process of the present invention.

Such initial degassing step can be achieved by a system of pressure rollers or calander (single or double), or by a vacuum process. The vacuum process is herein preferred to avoid to impairing the mechanical resistance and maintaining the integrity of the laminated VIG assembly.

[0082] In this embodiment, the heating sub-step b) of the processing step (3) is preferably run under a temperature from 90°C to 150°C, more preferably from 130°C to 135°C; preferably for a period of 45 to 75 min, more preferably for 60 min.

The interunit polymer

[0083] In a preferred embodiment, suitable interunit polymers to be used in the process of the present invention are selected from the group consisting of ethylene vinyl acetate (EVA), Cyclo olefin polymers (COP), autoclave-free polyvinyl butyral (herein after referred to as Autoclave-free PVB), polyurethane (PU), ionomers like SentryGlas™ and combinations thereof. In a more preferred embodiment, the interunit polymer is selected from the group consisting of ethylene vinyl acetate (EVA) and/or autoclave-free PVB.

[0084] The thickness of the interunit polymer is not particularly limited as long as the laminated VIG assembly does comply with the High Temperature Test ISO12543-4:2011 at an overpressure equal to or lower than 4.5 bar and as long as the transparency of the laminated VIG assembly is maintained, but may be for example, from 0.25 mm to 5 mm, preferably from 0.3 mm to 4 mm, preferably 0.3 to 3mm more preferably from 0.3mm to 2mm.

[0085] Preferably for use in the process of the present invention, the interunit polymer is the autoclave-free PVB. As well understood by persons skilled in that art, an autoclave-free PVB is a PVB that is effective in lamination processes even at gentle over pressure, i.e; at an overpressure equal to or less than to 4.5bar (OP ≤ 4.5bar), preferably equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5bar), preferably equal to or less than to 1.0bar (OP ≤ 1.0bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

[0086] Suitable autoclave-free PVB is the PVB interlayer described in WO2003/057478 by Eastman in the paragraphs [0020] to [0026] having a lowered water content below 0.35% by weight, a working

range temperature of 120-150°C, preferably 135°C and allowing the lamination process to be achieved without the autoclave finishing treatment. Such autoclave-autoclave-free PVB sheet is commercially available from Eastman , as "Saflex@"interlayer. Other suitable autoclave-free PVB are commercially available from Kuraray : Trosifol® PVB films are recommended for autoclave-free processing – particularly suitable is Trosifol® HR.

[0087] Furthermore, it has been found that using autoclave-free PVB as the suitable interunit polymer, it provides the required lamination property at gentle overpressure but as well is excellent in transparency, provides improved strength for safety and security performance.

[0088] Preferably for use in the process of the present invention, the interunit polymer is a polyurethane (PU). Suitable commercially available PU is Krystalflex® TPU Films (PE399 or PE900) by Huntsman, a high performance aliphatic polyether film intended for glass, polycarbonate, acrylic, CAB lamination applications and recommended for aerospace, transportation, security, and architectural markets. It provides low temperature impact resistance, excellent adhesion to glass, polycarbonate (PC) and polymethylmethacrylate (PMMA), moisture resistance, low lamination temperature compatible with PMMA and even lamination possible, even with complex surfaces with double degree of curvature.

[0089] Preferably for use in the process of the present invention, the interunit polymer is ethylene vinyl acetate. EVA is preferable because it is excellent in transparency and flexibility as well as it provides improved scattering resistance. Furthermore, it can also be used at lower process temperature.

[0090] Suitable commercially available EVAs are :

- From GLAAST supplier: the EVA-based lamination films are Specifically Designed for 'Glass Lamination' wherein the DAYLIGHT EV200 series features very high performance in ageing, high static load capability, adhesion, flow and impact resistance, clarity, high light transmission and exceptional UV cut features.
- Another suitable EVA for use in the process of the present invention is the STRATO® PLUS EVA from the Satinal supplier. It provides a completely natural and neutral-looking glass thanks to its high degree of transparency and UV protection without problems of distortions or air bubbles ensuring, at the same time, the highest degree of transparency even with low temperature lamination.

- Also suitable is Evalam Visual by the supplier HORNOS Pujol.

[0091] Preferably for use in the process of the present invention, the interunit polymer is a cyclo olefin polymer. COP are fully amorphous and highly transparent thermoplastic resins. Commercially available COP are sold by the supplier Zeon under the name Zeonx®. Those provide high transparency and low optical birefringence, low haze, extremely low water absorption and moisture permeation, high heat resistance, high mechanical stiffness, outstanding dimensional stability, good impact resistance and good moldability, high flowability, low mold shrinkage.

[0092] Preferably for use in the process of the present invention, the interunit polymer is an ionomer. Ionomer contains no plasticizer and are based on ionoplast chemistry. Ionomer provides structural performance over a range of temperatures because of the unique chemistry. Ionomer is preferable thanks to its excellent mechanical properties, high strength, strong stability, moisture resistance. Ionomer laminated glass is colorless, transparent and anti-ultraviolet.

[0093] Suitable commercially available ionomer is SentryGlas® ionomer. It is up to 100 times stiffer and 5 times stronger than traditional interlayers, helping thinner laminates meet specified wind loads or structural requirements. Laminated glass made with stiff SentryGlas® can tolerate high stress loads.

The functional unit

[0094] The functional unit has been processed in a separate process than the process for the production of the laminated VIG assembly. It has been processed at a processing pressure (PP) from 5.5 bar to 15.0 bar (5.5 bar ≥ PP ≥15.0 bar), preferably from 7.5 bar to 14.0 bar (7.5 bar ≥ PP ≥ 14.0 bar), more preferably from 10.0 bar to 14.0 bar (10.0 bar ≥ PP ≥ 14.0 bar).

[0095] As described below, the functional unit (4) of the laminated VIG assembly of the present invention typically comprises at least 1 sheet and a functional layer (43), preferably at least 2 sheets (41, 42) separated by the functional layer (43). In a preferred embodiment, at least one of the sheets is a glass sheet, more preferably the at least 2 sheets, are glass sheets. The functional layer is typically a polymer interlayer and/or an intumescent material. Such functional unit provides therefore a functional benefit such safety, security, acoustic interlayer solar control and/or fire resistance, ...

[0096] It has been found that the functional unit that are indeed produced under a high pressure lamination process cannot be directly laminated to a VIG since the VIG cannot be further processed at such high pressure to preserve its physical integrity and functionality. Hence, the process of the present invention allows to design a laminated VIG assembly that provides a very efficient functional benefit in addition to the high thermal insulating properties of the VIG that would otherwise not be possible to obtain with a low pressure lamination process. Indeed, the present invention allows to add a functional unit that has been processed at high pressure to a VIG via a lamination process at low pressure. In addition, it has been found that such process at gentle overpressure maintains the performance and properties of the functional unit.

[0097] Depending on the performance expected from the laminated VIG assembly of the present invention, different functional units can be laminated to the VIG to provide different functions. It is for example highly desirable to combine the fire resistance and anti-blast properties for boat application or to combine the acoustic and safety performance for city windows. Hence, several of the same or different functional units can be laminated to one or both sides of the VIG.

[0098] The functional unit can be prepared according to any of the known method in the art.

[0099] In one embodiment of the invention, the functional unit is a safety and/or security functional unit.

The main function of safety and security glasses is to absorb energy, such as caused by a blow from an object, without allowing penetration through the opening, thus minimizing damage or injury to the objects or persons within an enclosed area. Therefore, safety and/or security laminated units provide protection from injury due to accidental impact, protection from falls of through glass, and protection against break-ins and vandalism.

[0100] Depending on the expected performance, the safety and/or security functional unit can comprise two of more glass sheets, each separated by a polymer interlayer. Typically, the skilled person will design the safety and/or security functional unit with a number of glass sheets ranging from 2 to 8, preferably from 2 to 4; with the thickness of the glass sheets ranging from 0.2mm, preferably from 0.5mm, preferably from 1mm, more preferably from 3mm to 12mm, preferably to 6 mm and with the thickness of the polymer interlayer ranging from 0.2mm, preferably from 0.35mm to 5mm, preferably 2.5mm.

[0101] Typical polymer interlayer to be used in such functional unit comprises a material selected from the group consisting ethylene vinyl acetate (EVA), polyisobutylene (PIB), polyvinyl butyral (PVB), polyurethane (PU), polyvinyl chlorides (PVC), polyesters, copolyesters, polyacetals, cyclo olefin polymers (COP), ionomers and/or an ultraviolet activated adhesive, and others known in the art of manufacturing glass laminates. Preferably, the polymer interlayer is polyvinyl butyral. Reinforced acoustic insulation can be provided with a polymer interlayer with specific acoustic performance, such as specific PVBs.

[0102] Standard EN 356 defines eight performance levels based on tests representing the ability of laminated glass pane to resist throwing objects : levels P1A to P5A to comply with protection against impacts including vandalism and burglary attempts and levels P6B to P8B to comply with reinforced protection against burglary attempts. Typically, in the event of impacts from outer environment, a security functional unit has a P1A security level thanks to a laminated unit comprising two glass sheets of 3 mm each bonded by a polymer interlayer of polyvinyl butyral of 0.76mm thick. Typical P2A level will be obtained with a security functional unit comprising a polyvinyl butyral interlayer of 0.76 mm thick and two glass sheets of 4mm each. The thickness of the polyvinyl butyral interlayer can be increased to 1.52 mm thick for P4A, to 2.28 for P5A level. For passing levels P6B to P8B of standard EN 356, the security functional unit typically have glass panes of thickness greater than 8mm.

[0103] In other embodiments, the security functional unit to the used in the process of the present invention can comprise 2 glass sheets of 4mm each, or 6mm each or even 8mm each laminated by 0.76mm of PVB. Such units can be laminated through the process of the present invention to a VIG comprising typically two glass panes of a thickness of 4mm and/or 6mm.

[0104] <u>In one embodiment of the invention, the functional unit is an acoustic functional unit.</u>
In the embodiment of the present invention where the process is used to make an acoustic laminated VIG assembly, it is preferred that the VIG and/or the acoustic functional unit is made of glass panes / glass sheets of different thicknesses. Indeed, the asymmetric configuration helps to interrupt sound wave intrusion around critical sound frequency of the glass, it is meant resonant frequency that will cause glass to vibrate spontaneously.

[0105] Typical acoustic functional unit could also comprise two or more glass sheets separated by a polymer interlayer with specific acoustic performance, such as specific Polyvinyl Butyral components: e.g. Saflex® acoustic PVB interlayer from Eastman or Trosifol® acoustic PVB layer from Kuraray.

[0106] Typically the acoustic functional unit comprises two glass sheets, preferably glass sheets of a different thickness ranging from 0.2mm, preferably from 0.5mm, from 1mm, from 3mm, from 4mm to 12mm, to 8mm, to 6mm. The thickness of the polymer interlayer ranges from 0.2mm, preferably from 0.35mm to 5 mm, preferably to 3 mm.

[0107] In some embodiments, the acoustic functional unit to the used in the process of the present invention can comprise 2 glass sheets of 4mm each, or 6mm each or even 8mm, preferably of different thicknesses, each laminated by 0.76mm of an acoustic PVB. Such units can be laminated through the process of the present invention to a VIG comprising two glass panes of a typical thickness of 4mm and/or 6mm, preferably of the different thickness of 4mm and 6mm.

[0108] In another embodiment of the present invention, the functional unit is an anti-bullet or anti-blast unit

In order to achieve reinforced security protection such as against burglary attempts in compliance with standard EN 356 and even against firearms and explosions in compliance with Standards EN 1063 and EN 13541 respectively, it is conventional that functional glass units are designed with a number of glass sheets potentially combined with structural plastic sheets, often of different thicknesses, assembled with several PVB and/or polyurethane polymer interlayers.

[0109] Such anti-bullet and anti-blast functional unit typically comprise from 2 to 10 sheets, preferably from 2 to 7 sheets and at least corresponding layers of polymer interlayers. Preferably the sheets are glass sheets or structural plastic sheets, preferably a polycarbonate sheets. Typical polymer interlayer to be used in such application comprises a material selected from the group consisting ethylene vinyl acetate (EVA), polyisobutylene (PIB), polyvinyl butyral (PVB), polyurethane (PU), polyvinyl chlorides (PVC), polyesters, copolyesters, polyacetals, cyclo olefin polymers (COP), ionomers and/or an ultraviolet activated adhesive, and others known in the art of manufacturing glass laminates. Preferably, the polymer interlayer is polyurethane and/or polyvinyl butyral. Reinforced acoustic insulation can be provided with a polymer interlayer with specific acoustic performance, such as specific PVBs. Typical thicknesses for these polymer interlayer are from 0.2mm, preferably from 0.3 mm, more preferably 0.75mm to 4,5 mm preferably to 3.0 mm, more preferably to 1.75 mm.

[0110] In one embodiment, the functional unit comprises at least one structural plastic sheet, preferably a polycarbonate sheet, more preferably a polycarbonate having a thickness of at most 2.0 mm and at least one glass sheet laminated by at least one polyvinyl butyral polymer interlayer and at

least one polyurethane polymer interlayer. Preferably the polymer interlayer has a thickness of at least 0.76mm.

[0111] In one embodiment of the invention, the functional unit is special solar control functional unit The functional unit can provide solar benefits that cannot be brought by the existing coating layers that are typically provided on the glass sheet. Special solar functional interlayer polymer can provide protection from UV radiation, or allow the full natural spectrum of solar radiation for botanical application, or can absorb infrared (IR) light wavelength from the sun.

[0112] The solar functional unit typically comprises at least 2 glass sheets separated a solar functional interlayer polymer. Typically, the solar functional unit will comprise from 2 to 8, preferably from 2 to 4 glass sheets; with the thickness of the glass sheets ranging from 0.2mm, preferably 0.5mm, preferably 1mm, more preferably 3mm to 12mm, preferably 6mm and with the thickness of the solar interlayer polymer ranging from 0.2mm, preferably 0.35mm to 5mm, preferably 2.5mm.

[0113] Suitable solar functional interlayer polymer are for example XIR Foil (metallic coating on PET laminated between layers of poly vinyl butyrate) encompassed within layers of PVB and the IR-Cut PVBs (Particles of indum tin oxide (ITO) or cesium tungsten oxide (ceWox) particles dispersed in a layer of poly vinyl butyrate). Commercially available solar functional interlayer polymer are the Saflex® Solar range interlayers from the supplier Eastman; the Southwall's XIR® Laminated products encapsulating XIR "heat rejecting" film between two layers of PVB and glass and S-LEC™ Sound and Solar Film from the Sekisui supplier.

[0114] Preferably, the laminated VIG assembly produced by the process of the present invention will combine several functions : safety/security, acoustic, anti-bullet/anti-blast and/or special solar control, preferably safety/security and acoustic. Therefore, in a preferred embodiment, the functional unit comprises at least 2 glass sheets laminated by a polyvinyl butyral polymer interlayer. Preferably, in another preferred embodiment, the functional unit comprises at least one polycarbonate sheet and at least one glass sheet laminated by at least one polyvinyl butyral polymer interlayer and at least one polyurethane polymer interlayer. Preferably, the polyvinyl butyral polymer interlayer is an acoustic polyvinyl butyral polymer interlayer and/or the sheets are of different thicknesses.

[0115] In one embodiment of the invention, the functional unit is a fire resistant functional unit.

The fire resistant functional unit typically comprises at least 2 sheets of glass separated by layers of intumescent materials. The weight and thickness of fire resistant glazing may become high depending on the fire resistance performance level required, that defines the number of glass sheets and layers of intumescent material. The layers of intumescent material are most often composed of hydrated alkali metal silicates. Organic and/or inorganic hydrogels may alternatively be used. The intumescent materials under the effect of heat, expand by forming a foam opaque to radiation, that keeps the glass walls in position even when the latter are fragmented under the effect of heat.

[0116] The use of hydrated alkali metal silicates in the manufacture of fire resistant functional unit is mainly carried out according to two distinct modes. The first mode is known as the "drying process" since such fire resistant functional unit are typically processed in 2 stages comprising a first drying stage followed by an autoclave stage typically at temperature around 110°C and pressure around 11-13bar.

[0117] In the first mode, the layer of intumescent material is obtained by applying solutions of these silicates over a glass pane and by carrying out a more or less prolonged drying step until a solid layer is obtained. Several assemblies layer/glass pane can be piled up to obtain products having the desired fire resistance performances. The last layer of intumescent material formed is typically covered by a final glass sheet.

[0118] In such first mode, the fire resistant functional unit comprises preferably from 2 to 9 glass sheets, more preferably from 3 to 5 glass sheets. Such glass sheets are preferably from 3mm to 8mm thick and the layer of intumescent material is preferably from 1 to 8mm, preferably from 1 to 5mm, more preferably from 1mm to 4mm thick.

[0119] In In one preferred embodiment, the fire resistant functional unit comprises 3 glass sheets and 2 layers of intumescent material. Typically such fire resistance unit will comprise a first glass sheets of 3mm + 1.5-2mm of intumescent material + a second glass sheet of 8mm + 1.5-2mm of intumescent material + a third glass sheet of 3mm. Typically such fire resistance unit can be laminated via an interunit polymer such as 0.76mm of EVA, to a VIG such as a VIG comprising 2 glass panes of 6mm each.

[0120] In another preferred embodiment, the fire resistant functional unit is comprises 5 glass sheets and 4 layers of intumescent material. Typically such fire resistance unit will comprise a first

glass sheet of 3mm + 1.5-2mm of intumescent material + a second glass sheet of 3mm + 1.5-2mm of intumescent material + a third glass sheet of 8mm and again 2 glass sheets of 3mm separated by 1.5-2mm of intumescent material. Typically such fire resistance unit can be laminated via an interunit polymer such as 0.76mm of EVA, to a VIG such as a VIG comprising 2 glass panes of 6mm each.

[0121] In another preferred embodiment, the fire resistant unit comprises 2 glass sheets and 1 layer of intumescent material being two glass panes of 3mm each separated by a layer of 1.5-2mm of intumescent material. Typically such fire resistance unit can be laminated via an interunit polymer such as 0.76mm of EVA, to a VIG such as a VIG comprising 2 glass panes of 6mm each.

[0122] For improved acoustic properties, it could be contemplated to use glass panes and glass sheets of different thickness.

[0123] A second mode known as the "cast-in-place process" since such fire resistant functional units are typically processed in 2 stages comprising a first assembly stage typically at ambient temperature wherein a double glazing with a peripheral spacer is created at pressure up to 20bar thereby creating a space wherein the intumescent material is poured, followed by reticulation of the intumescent material stage typically at temperature around 70-90°C and atmospheric pressure.

[0124] In such second mode fire resistant function unit, the silicate solution is modified by the addition of products qualified as "hardeners", "crosslinking agents" or in yet another way; to promote gelling of the silicate solution. They are chosen carefully so that, after their addition to the silicate solution, the latter, when left at rest, spontaneously hardens over a relatively short time into an intumescent layer, without being necessary to carry out a drying step. For these products, before formation of the gel, the solution and its eventual additives, is poured in a cavity between two glass panes. The glass panes are joined at their periphery by a spacer which keeps them at a distance from each other, and which, with the two glass panes, defines a leaktight cavity in which the solution is poured.

[0125] In such second mode, the fire resistant functional unit comprises preferably from 2 to 4 glass sheets. Such glass sheets are preferably from 3mm to 6mm thick and the layer of intumescent material is preferably from 3 to 30mm thick.

[0126] In one preferred embodiment of such second more, the fire resistant functional unit comprises 2 glass sheets and 1 layer of intumescent material. Typically such fire resistance unit will

comprise a first glass sheet, preferably tempered, of 6mm + 4-6mm of intumescent material + a second glass sheet, preferably tempered, of 6mm. Typically such fire resistance unit can be laminated via an interunit polymer such as 0.76mm of EVA, to a VIG such as a VIG comprising 2 glass panes of 6mm each.

[0127] In the process of the present invention wherein the functional unit is a fire-resistant functional unit second mode, i.e. comprising at least 2 glass sheets separated by a peripheral spacer thereby creating a space comprising the intumescent material, then the heating sub-step b) of the processing step 3) is preferably achieved under a temperature equal to or lower than 120°C, preferably equal to or lower than 110°C, preferably equal to or lower than 100°C, more preferably equal to or lower than 90°C.

Other functional units.

[0128] Some other additional benefits can be provided within functional units encompassing rather delicate technology that would not withstand to be further processed at high temperature and/or pressure and could be produced as well by the process of the present invention.

[0129] Such are the functional unit panes with electrochromic, thermochromic, photochromic or photovoltaic elements are also compatible with the present invention. Other suitable electronic functional units to be used in the present invention are comprise LEDs (Light-emitting diodes) – either monochrome or RGB (red, green, blue) – are powered via a super-efficient, transparent conductive layer. Further electronic functional unit can comprise display, antennae system able to receive or transmit electromagnetic signal, touch functions,... Other are those decorative functional unit comprising decorative inserts in paper, fabric, stone mimics film into typically a PVB frame.

THE VIG

[0130] The vacuum insulating glazing (2) of the laminated VIG assembly (1) produced by the process of the present invention typically comprise:

- a first glass pane (21) and a second glass pane (21);
- a set of discrete spacers (23) positioned between the first and second glass panes, maintaining a distance between the first and the second glass panes;
- a hermetically bonding seal (24) sealing the distance between the first and second glass panes over a perimeter thereof;

- an internal volume, V, defined by the first and second glass panes and the set of discrete spacers and closed by the hermetically bonding seal and wherein there is an absolute vacuum of pressure of less than 0.1 mbar.

[0131] In general, in order to achieve a high-performance thermal insulation (Thermal transmittance, U, being U<1.2 W/m^{2}K, preferably U<0.8 W/m^{2}K), the pressure inside the glazing unit is typically 0.1mbar or less and generally at least one of the two glass panes is covered with a low-E coating.

Method of manufacturing glass panel unit

[0132] There are different processes for assembling a VIG. An illustrative assembly process is described in EP2851351A1 comprising three main steps which may overlap. First, a first glass pane is placed horizontally, the glass frit is deposited, the pillars are placed and a second pane are disposed on top, a first heating period (up to 450°C) allows the hermetical sealing of both glass panes at their outer edges, leaving a space in between. The second step is the pumping of inside gases down to a residual pressure of not more than 0.1 mbar. With respect to the formation of the vacuum in the internal space of the glass unit, a hollow glass tube connecting the internal space to the outside is generally provided on the main face of one of the glass sheets. The vacuum is thus created in the internal space by pumping the gases present into the internal space by means of a pump connected to the outer end of the glass tube. EP1506945A1 for example describes the use of such a glass tube, which is welded in position in a through-hole provided in the main face of one of the glass sheets. During this second step, the temperature decreases in some extent and the glass panes come closer up to reaching the pillars which define the autoclave-free space. The final space between the two glass panes is not greater than 2 mm. The third step comprises a second heating period up to 465°C, allowing the pillars to adhere to the glass panes and also finalizing the hermetic sealing. This technique impairs the aesthetic appearance of the glass panel as no visible protrusion on the surface of one of the glass sheet is formed.

[0133] Also suitable is the manufacturing method described in WO2019/230220 comprising a bonding step [0011] to [0025], an insertion step [0026] to [0027], a depressurization step [0028] to [0043], and a sealing step [0044] to [005] as well as the modifications of such steps described thereafter. The temperature of the process is around 300°C or below, allowing to process vacuum insulating glazing comprising heat strengthened and thermally toughened glass panes.

Spacers

[0134] The discrete spacers (also referred to as "pillars") are positioned between the first and second glass panes, maintaining a distance there between and forming an array having a pitch, λ, comprised between 10 mm and 100 mm (10 mm ≤ λ ≤ 100 mm). By pitch, it is meant the interval between the discrete spacers. In a preferred embodiment, the pitch is comprised between 20 mm and 80 mm (20 mm ≤ λ ≤ 80 mm), more preferably between 20 mm and 50 mm (20 mm ≤ λ ≤ 50 mm). The array within the present invention is typically a regular array based on an equilateral triangular, square or hexagonal scheme, preferably based on a square scheme. The discrete spacers can have different shapes, such as cylindrical, spherical, filiform, hourglass, C-shaped, cruciform, prismatic shape... It is preferred to use small pillars, i.e. pillars having in general a contact surface to the glass pane, defined by its external circumference, equal to or lower than 5 mm^2, preferably equal to or lower than 3 mm^2, more preferably equal to or lower than 1 mm^2 . These values may offer a good mechanical resistance whilst being aesthetically discrete.

[0135] Typical discrete spacers are made of a material having a strength endurable against the pressure and high-temperature making process of the VIG and hardly emitting gas after the glass pane is manufactured. Such a material is preferably a hard material such as metal material, quartz glass or a ceramic material, in particular a metal material such as iron, tungsten, nickel, chrome, titanium, molybdenum, carbon steel, chrome steel, nickel steel, stainless steel, nickel-chromium steel, manganese steel, chromium-manganese steel, chromium-molybdenum steel, silicon steel, nichrome, duralumin or the like. Another such material is a ceramic material such as corundum, alumina, mullite, magnesia, yttria, aluminum nitride, silicon nitride or the like. However, if such material provides higher mechanical resistance, they provide rather poor performance in thermal conductivity. Therefore, preferred discrete spacers for the VIG element of the laminated VIG assembly of the present invention are made of material of lower conductivity profile such as resins, preferably made of polyimide resin. In this case, it is possible to suppress the thermal conductivity of the spacer and heat is hardly transferred via the discrete spacers in contact with the first and the second glass sheets.

The hermetically Bonding Seal

[0136] The internal volume of the VIG is closed with such hermetically bonding seal placed on the periphery of the glass panes around said internal space. The hermetically bonding seal is impermeable to air or any other gas present in the atmosphere. Various hermetically bonding seal technologies exist. A first type of seal (the most widespread) is a seal based on a solder glass for which the melting point is lower than that of the glass of the glass panes of the glazing unit. Typically lower than 500°C,

preferably lower 450°C, more preferably lower than 400°C. Examples are low melting point glass frits such as bismuth based glass frits, lead based glass frits, and vanadium based glass frits and mixtures thereof. A second type of seal comprises a metal seal, for example a metal strip of a small thickness (<500 µm) soldered to the periphery of the glazing unit by way of a tie underlayer covered at least partially with a layer of a solderable material such as a soft tin-alloy solder.

Internal volume

[0137] A vacuum of absolute pressure less than 0.1 mbar, preferably less than 0.01mbar is created, within the internal volume, V, defined by the first and second glass panes and the set of discrete spacers and closed by the hermetically bonding seal within the VIG. To maintain for the duration a given vacuum level in a vacuum-insulating glazing unit a getter may be used. Generally, such a getter consists of alloys of zirconium, vanadium, iron, cobalt, aluminum, etc., and is deposited in the form of a thin layer (a few microns in thickness) or in the form of a block placed between the glass panes.

PANES and SHEETS

[0138] The panes of the VIG and the sheet(s) of the functional unit can be chosen among glass, metal sheets or structural plastic sheets, such as polycarbonate sheets for reduced weight, and preferably are chosen among float clear, extra-clear or colored glass. The glass panes optionally be edge-ground for safety. Preferably, the panes of the VIG and the sheets of functional unit according to the invention are made of glass, typically soda-lime-silica glass, aluminosilicate glass or borosilicate glass; preferably soda-lime-silica glass. Textured, structured, printed glass are suitable.

For acoustic performance, it is preferred that the glass panes of the VIG and/or the sheets of the functional interunit are of different thickness. Furthermore, to improve the resistance to induced thermal stress in VIG in use wherein glass panes are subjected to temperature difference between exterior and interior environments, and therefore to reduce the L_{use}, it is also preferred that the glass panes of the VIG are of different thicknesses.

[0139] Typically, the glass panes / sheets are annealed glass panes / sheets. However, to provide laminated VIG assemblies with higher mechanical performances and/or to improve further the safety of the VIG and/or the functional unit, it can be contemplated to use prestressed glass for one or more glass pane(s) of the laminated VIG assembly and/or one or more glass sheets of the functional unit. By prestressed glass, it is meant herein a heat strengthened glass, a thermally toughened safety glass, or a chemically strengthened glass.

[0140] Heat strengthened glass is heat treated using a method of controlled heating and cooling which places one glass surface under compression and the other glass surface under tension. This heat treatment method delivers a glass with a bending strength greater than annealed glass but less than thermally toughened safety glass.

[0141] Thermally toughened safety glass is heat treated using a method of controlled heating and cooling which puts one glass surface under compression and the other glass surface under tension. Such stresses cause the glass, when impacted, to break into small granular particles instead of splintering into jagged shards. The granular particles are less likely to injure occupants or damage objects.

[0142] The chemical strengthening of a glass article is a heat induced ion-exchange, involving replacement of smaller alkali sodium ions in the surface layer of glass by larger ions, for example alkali potassium ions. Increased surface compression stress occurs in the glass as the larger ions "wedge" into the small sites formerly occupied by the sodium ions. Such a chemical treatment is generally carried out by immerging the glass in an ion-exchange molten bath containing one or more molten salt(s) of the larger ions, with a precise control of temperature and time. Aluminosilicate-type glass compositions, such as for example those from the products range DragonTrail® from Asahi Glass Co. or those from the products range Gorilla® from Corning Inc., are also known to be very efficient for chemical tempering.

[0143] Preferably, the composition for the glass pane / sheet comprises the following components in weight percentage, expressed with respect to the total weight of glass (Comp. A). More preferably, the glass composition (Comp. B) is a soda-lime-silicate-type glass with a base glass matrix of the composition comprising the following components in weight percentage, expressed with respect to the total weight of glass.

	Comp. A	Comp. B
SiO2	40 - 78%	60 - 78 wt%
Al2O3	0 - 18%	0 - 8 wt%, pref 0 - 6 wt%
B2O3	0 - 18%	0 - 4 wt%, pref 0 - 1 wt%
Na2O	0 - 20%	5 – 20 wt%, pref 10 - 20 wt%
CaO	0 - 15%	0 - 15 wt%, pref 5 - 15 wt%
MgO	0 – 15%	0 – 10 wt%, pref 0 - 8 wt%

K2O	0 – 15%	0 – 10 wt%
BaO	0 – 5%	0 – 5 wt%, pref 0 - 1 wt%.

[0144] Other preferred glass comprises the following components in weight percentage, expressed with respect to the total weight of glass:

Comp. C	Comp. D	Comp. E
65 ≤ SiO2 ≤ 78 wt%	60 ≤ SiO2 ≤ 78 %	65 ≤ SiO2 ≤ 78 wt%
5 ≤ Na2O ≤ 20 wt%	5 ≤ Na2O ≤ 20 %	5 ≤ Na2O ≤ 20 wt%
0 ≤ K2O < 5 wt%	0.9 < K2O ≤ 12 %	1 ≤ K2O < 8 wt%
1 ≤ Al2O3 < 6 wt%, pref 3 < Al2O3 ≤ 5 %	4.9 ≤ Al2O3 ≤ 8 %	1 ≤ Al2O3 < 6 wt%
0 ≤ CaO < 4.5 wt%	0.4 < CaO < 2 %	2 ≤ CaO < 10 wt%
4 ≤ MgO ≤ 12 wt%	4 < MgO ≤ 12 %	0 ≤ MgO ≤ 8 wt%
(MgO/(MgO+CaO)) ≥ 0.5, pref 0.88 ≤ [MgO/(MgO+CaO)] < 1.		K2O/(K2O+Na2O) : 0.1 - 0.7.

[0145] In some embodiments of the present invention, films such as low emissivity films, solar control films (a heat ray reflection films), anti-reflective films, anti-fog films, preferably a heat ray reflection film or a low emissivity film, can be provided on at least one of the glass pane of the VIG eventually on a glass sheet within the functional block.

[0146] Figure 1 illustrates a laminated VIG assembly (1) comprising a VIG (2) and a functional unit (4), laminated via a interunit polymer (3) by the process of the present invention. The VIG (2) comprises a first glass pane (21) and a second glass pane (21) and a set of discrete spacers (23) positioned between the first and second glass panes, maintaining a distance between them. It is closed by a hermetically bonding seal (24) sealing the distance between the first and second glass panes over a perimeter thereof and so defined an internal volume, V wherein there is an absolute vacuum of pressure of less than 0.1 mbar. A low emissivity film or a heat ray reflection film (5) is provided on the of inner face pane of the second glass pane of the VIG. The functional unit (4) comprises a first glass sheet (41) laminated to a second glass sheet (42) by a interlayer polymer (43).

[0147] The person skilled in the art realizes that the present invention is by no means limited to the preferred embodiments described above. On the contrary, many modifications and variations are

possible within the scope of the appended claims. It is further noted that the invention relates to all possible combinations of features, and preferred features, described herein and recited in the claims.

[0148] The following examples are provided for illustrative purposes, and are not intended to limit the scope of this invention.

EXAMPLES

Example 1 : Acoustic laminated VIG assembly

[0149] An acoustic functional unit comprising two standard soda-lime silica glass sheets (thickness of 8 mm each) and an acoustic polyvinyl butyral (thickness of 0,76mm) was produced with a standard lamination process with a nip-roller and an autoclave technology at temperature of 140°C and at a pressure of 12bar.

[0150] A VIG comprising 2 standard soda-lime silica glass panes (thickness of 6 mm each), pillars of resin material at a pitch of 20mm, sealed by a glass frit. The thermal performance of such VIG (U) is 0.7W/m^2K.

[0151] The acoustic laminated VIG assembly was produced by the following steps within an autoclave:

1) Preparing an pre-assembly by stacking the VIG, 0.76 mm of the interunit polymer EVA (deposited on a surface of the functional unit) and the functional unit;
2) Inserting the pre-assembly into a vacuum bag;
3) Processing the pre-assembly into a laminated VIG assembly :
    - ✓ Evacuating to a vacuum of -1 bar at ambient temperature for 30minutes,
    - ✓ Heating at an intermediate temperature of 85-90°C for 30 min under continued vacuum,
    - ✓ Heating at a temperature of 130°C for 105 min under continued vacuum,
    - ✓ Overpressure of 0.2bar (OP = 0.2bar);
4) Releasing the vacuum and releasing the heating so that the laminated VIG assembly reaches ambient temperature in 35 min. Releasing the overpressure at ambient temperature

[0152] The acoustic laminated VIG assembly produced via the process of the present invention passes the High Temperature Test of the norm ISO12543-4:2011 and demonstrates the superior properties

of maintaining the physical integrity of the VIG, especially no sign of micro cracks around pillars, nor compressed pillars; maintenance of the superior thermal performance; excellent acoustic property and so at a very limited thickness.

[0153] In particular, Table I below shows that the acoustic laminated VIG assembly obtained by the process of the present invention provides excellent acoustic properties: better than the acoustic performance of the VIG alone and even better than a double glazing comprising the same two units of acoustic functional unit and VIG.

[0154] According to ISO 10140-2:2010 : Acoustics — Laboratory measurement of sound insulation of building elements — Part 2: Measurement of airborne sound insulation : Rw (C; Ctr) wherein Rw represents weighted sound reduction index, C and Ctr are correction factors, namely C for the medium frequency range and Ctr for the low frequency range. Increasing the Rw by one translates to a reduction of approximately 1db in noise level.

Table I

structure	Acoustic performance index - Rw in dB	Thickness
VIG	36 (-1;-2)	12mm
A double glazing comprising the acoustic functional unit and the VIG, separated by a 24mm peripheral spacer	43 (-3;-6)	52.76mm
The laminated acoustic VIG assembly obtained by the process of the present invention	44 (-1;-3)	29.52 mm

Example 2 : Security laminated VIG assembly

[0155] A security functional unit comprising 2 standard soda-lime silica glass sheets having each a thickness of 4mm, laminated by 6 layers of PVB of 0.38mm thickness each, was produced with a standard lamination process with a nip-roller and an autoclave technology at a temperature of 140°C and at a pressure of 12bar.

[0156] A VIG comprising 2 standard soda-lime silica glass panes (Thickness of 4 mm each), pillars of resin material at a pitch of 20mm, sealed by a glass frit. The thermal performance of such VIG (U) is 0.7 W/m^2K.

[0157] The security laminated VIG assembly was produced by the following steps within an oven under no overpressure :

1) Preparing an pre-assembly by stacking the VIG, 0.76 mm of the interunit polymer EVA (deposited on a surface of the functional unit) and the functional unit;
2) Inserting the pre-assembly into a vacuum bag;
3) Processing the pre-assembly into a laminated vacuum insulating glazing assembly :
   - ✓ Evacuating to a vacuum of -1 bar at ambient temperature for 30minutes,
   - ✓ Heating at an intermediate temperature of 85-90°C for 30 min under continued vacuum,
   - ✓ Heating at a temperature of 130°C for 80 min under continued vacuum,
   - ✓ No overpressure (OP = 0 bar);
4) Releasing the vacuum and releasing the heating so that the laminated VIG assembly reaches ambient temperature in 30 min.

[0158] The security laminated VIG assembly produced via the process of the present invention passes the High Temperature Test of the norm ISO12543-4:2011 and demonstrates the superior properties of maintaining the physical integrality of the VIG, especially no sign of micro cracks around pillars, nor compressed pillars; maintenance of the superior thermal performance; and excellent security property.

[0159] In particular, Table II below shows that the laminated VIG assembly obtained by the process of the present invention provides excellent security properties. The VIG made of 2 glass sheets of 4 mm each, shows no mechanical performance according to the EN 356 norm. When laminated to the security functional unit, the laminated VIG assembly produced by the process of the present demonstrates a P5A classification within the Security norm Ref. No. EN 356:1999 E.

Table II

Structure	EN 356
VIG	No performance
security laminated VIG assembly	P5A

CLAIMS

1. A process for the production of a laminated vacuum insulating glazing assembly (1) complying with the High Temperature Test of the norm ISO12543-4:2011 and comprising at least the following steps :

   1) Stacking a vacuum insulating glazing (2), an interunit polymer (3) and a functional unit (4); thereby creating a pre-assembly, wherein the functional unit has been processed at a processing pressure (PP) from 5.5bar to 15.0bar (5.5bar ≥ PP ≥ 15.0bar), preferably from 7.5bar to 14.0bar (7.5bar ≥ PP ≥ 14.0bar), more preferably from 10.0bar to 14.0bar (10.0bar ≥ PP ≥ 14.0bar);
   2) Inserting the pre-assembly into a vacuum ring or vacuum bag, preferably into a vacuum bag;
   3) Processing the pre-assembly into a laminated VIG assembly by at least the following sub-steps:
      a. Evacuating to a vacuum of minus 0.1bar to minus 1bar, preferably minus 0.5bar to minus 1bar, within the vacuum ring or vacuum bag,
      b. Heating the pre-assembly to a temperature ranging from 50°C to 200°C, preferably from 75°C to 175°C, more preferably from 90°C and 150°C,
      c. Pressurizing the pre-assembly under an overpressure (OP) equal to or lower than 4.5bar (OP ≤ 4.5bar); and
   4) Releasing the evacuation 3)a), the heating 3)b) and the overpressure 3)c).

2. The process for the production of a laminated vacuum insulating glazing assembly according to claim 1 wherein the functional unit comprises at least 2 sheets, preferably at least one of the sheets is a glass sheet, more preferably the at least 2 sheets are glass sheets.

3. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the claims 1 to 2 wherein the overpressure of sub-step 3)c) is equal to or less than to 4.0bar (OP ≤ 4.0bar), preferably equal to or less than to 3.0bar (OP ≤ 3.0bar), preferably equal to or less than to 2.0bar (OP ≤ 2.0bar), preferably equal to or less than to 1.5bar (OP ≤ 1.5 bar), preferably equal to or less than to 1.0bar (OP ≤ 1.0bar), preferably equal to or less than to 0.5bar (OP ≤ 0.5bar); more preferably is equal to 0bar (OP = 0bar).

4. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the sub-steps of the processing step 3) are achieved in the following processing order: the evacuation sub-step 3)a), the heating sub-step 3)b) and the

pressurization sub-step 3)c); preferably the heating sub-step 3)b) and the pressurization sub-step 3)c) are started simultaneously.

5. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the evacuation sub-step 3)a) of the processing step 3) is started at ambient temperature for a period of 5 min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min.

6. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the releasing step 4) is achieved by releasing the heating first and then releasing the evacuation, preferably releasing the evacuation and pressurization together, preferably when the temperature of the VIG laminated assembly has reached 50°C to 60°C, more preferably ambient temperature.

7. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the heating release step within step (4) is run at a rate of 1-10°C/min, preferably 2-9°C/min, preferably 3-8°C/min, preferably 4-7°C/min, more preferably 5-6°C/min, preferably in the temperature range of 130°C to 30°C.

8. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the laminated vacuum insulating glazing assembly complies with the following load equation: $L_{lam} \leq [L_{int} (SF-1)] + [L_{use} \times SF]$ wherein:

- L_{lam} is the lamination load being all stresses brought by a lamination process to the vacuum insulating glazing;
- L_{int} is the intrinsic load being all stresses inherent to the vacuum insulating glazing design per se;
- SF is the security factor; and
- L_{use} is the use load being all stresses caused by the vacuum insulating glazing use conditions.

9. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein interunit polymer is selected from the group consisting of ethylene vinyl acetate (EVA), cyclo polyolefin polymer (COP), autoclave-free polyvinyl butyral (Autoclave-free PVB), polyurethane (PU), and/or ionomers, preferably is selected from ethylene vinyl acetate (EVA) and/or autoclave-free polyvinyl butyral (Autoclave-free PVB).

10. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the interunit polymer is an autoclave-free polyvinyl butyral, and wherein the temperature of the heating sub-step b) of the Processing Step 3) ranges from 90°C to 150°C, preferably from 115°C to 150°C, preferably from 135°C to 145°C, more preferably is 140°C; preferably for a period ranging from 20 to 180 min, more preferably for 60 min.

11. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the claims 1 to 9 wherein the interunit polymer is a polyurethane, wherein the temperature of the heating sub-step b) of the processing step 3) ranges from 90°C to 150°C, preferably from 110°C to 120°C; preferably for a period ranging from 20 to 180 min, more preferably for 60 min.

12. The process for the production of a laminated vacuum insulating glazing assembly according to claim 11 wherein the pressurizing sub-step 3)c) is done under an overpressure (OP) comprised between 2.0bar and 4.5bar (2.0bar ≤ OP ≤ 4.5bar), preferably between 2.0bar and 4.0bar (2.0bar ≤ OP ≤ 4.0bar), more preferably is 3.0bar.

13. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims 1-9, wherein the interunit polymer is an ethylene vinyl acetate and/or a cyclo polyolefin polymer, preferably is an ethylene vinyl acetate, and wherein the temperature of the heating sub-step b) of the processing Step 3) ranges from 90°C to 150°C, preferably from 110°C to 145°C.

14. The process for the production of a laminated vacuum insulating glazing assembly according to claim 13 wherein the processing step (3) comprises a further sub-step b*) before the sub-step b): of heating at an intermediate temperature ranging from 75°C to 95°C; preferably for a period of 10 min to 60 min, more preferably from 15 min to 40 min.

15. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims 13 to 14 wherein the sub-steps of processing step (3) are achieved in the following processing order :

a) Evacuating at room temperature for a period of 5min to 40 min, preferably from 10 min to 30 min, more preferably from 20 min to 30 min;

b*) Heating to an intermediate temperature ranging from 75°C to 95°C, preferably for a period of 10 to 60 min, more preferably from 15 min to 40 min;

b) Heating to a temperature ranging from 110°C and 145°C, preferably from 130°C to 140°C for a period of 45 min to 300 min;

c) Pressurizing under an overpressure (OP) equal to or lower than 2.0bar (OP ≤ 2.0bar), preferably equal to or lower than 1.5bar (OP ≤ 1.5bar) preferably equal to or lower than 1.0bar (OP ≤ 1.0bar), preferably equal to or lower than 0.5bar (OP ≤ 0.5bar), more preferably under no overpressure of 0bar (OP = 0bar)

wherein preferably the sub-step b) and sub-step c) are simultaneous.

16. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims 1 to 9, wherein the interunit polymer is an ionomer and wherein the heating sub-step b) of the processing step (3) is run under a temperature from 90°C and 150°C, preferably from 130°C to 135°C; preferably for a period of 45 to 75 min, more preferably for 60 min.

17. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the functional unit comprises at least 2 glass sheets laminated by a polyvinyl butyral polymer interlayer.

18. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims 1 to 16 wherein the functional unit comprises at least one structural plastic sheet, preferably a polycarbonate sheet and at least one glass sheet; laminated by at least one polyvinyl butyral polymer interlayer and at least one polyurethane polymer interlayer.

19. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the claims 17 to 18 wherein the polyvinyl butyral polymer interlayer is an acoustic polyvinyl butyral polymer interlayer and/or wherein the sheets are of different thicknesses.

20. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims 1 to 16 wherein the functional unit comprises at least 2 glass sheets separated by intumescent material, preferably hydrated alkali metal silicates.

21. The process for the production of a laminated vacuum insulating glazing assembly according to claim 20 wherein the functional unit comprises further a peripheral spacer thereby creating a

space between the 2 glass sheet to comprise the intumescent material, and wherein the heating sub-step b) of the processing step 3) is achieved under a temperature equal to or lower than 120°C, preferably equal to or lower than 110°C, preferably equal to or lower than 100°C, more preferably equal to or lower than 90°C.

22. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the vacuum insulating glazing comprising a first and a second glass pane and wherein at least one of the first and/or second glass pane of the vacuum insulating glazing and/or at least one of the sheets of the functional unit, is a heat strengthened glass, a thermally toughened safety glass, or a chemically strengthened glass.

23. The process for the production of a laminated vacuum insulating glazing assembly according to any one of the preceding claims wherein the vacuum insulating glazing comprises a first glass pane and a second glass pane and a set of discrete spacers positioned between the first and second glass panes, maintaining a distance between the first glass pane and the second glass pane and wherein such discrete spacers are made of metal material, quartz glass, a ceramic material and/or resin, preferably resin, more preferably polyimide resin.

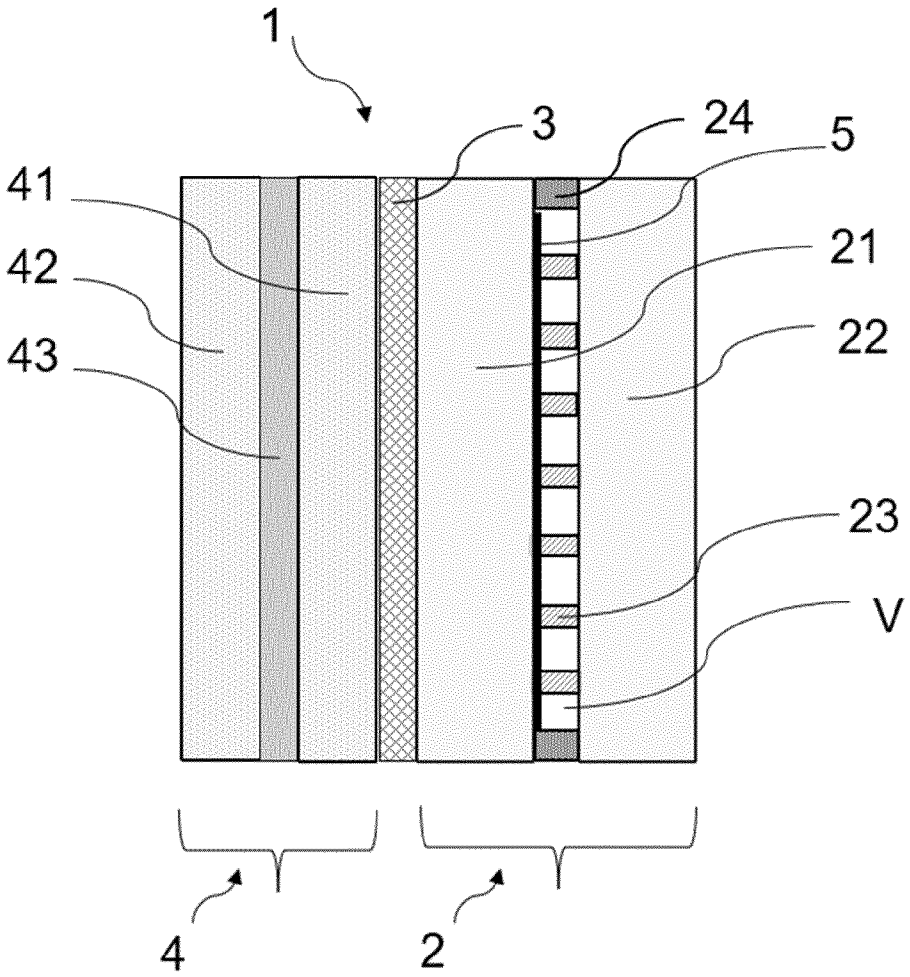


Figure 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/060369

A. CLASSIFICATION OF SUBJECT MATTER
INV. B32B17/10 B32B27/32 E06B3/66 E06B5/16
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)
B32B E06B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 173 668 A (HENTZELT WALTHER E [DE] ET AL) 6 November 1979 (1979-11-06) column 5, line 53 - column 6, line 27; example 1 figure 1	1-23
A	WO 2019/224363 A1 (VKR HOLDING AS [DK]) 28 November 2019 (2019-11-28) claims 1,22 figures 1,22 page 56, line 11 - line 21	1-23

☐ 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 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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 August 2022	18/08/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Flores de Paco, M

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2022/060369

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4173668 A	06-11-1979	AT 346009 B	25-10-1978
		BE 835890 A	25-05-1976
		CA 1026075 A	14-02-1978
		CH 606750 A5	15-11-1978
		DE 2457037 A1	10-06-1976
		DK 526075 A	04-06-1976
		FR 2293566 A1	02-07-1976
		GB 1518958 A	26-07-1978
		IT 1051311 B	21-04-1981
		JP S5178023 A	07-07-1976
		JP S5834638 B2	28-07-1983
		NL 7513835 A	08-06-1976
		US 4173668 A	06-11-1979
WO 2019224363 A1	28-11-2019	EP 3802126 A1	14-04-2021
		EP 3802127 A1	14-04-2021
		EP 3802128 A1	14-04-2021
		EP 3802129 A1	14-04-2021
		US 2021197533 A1	01-07-2021
		US 2021291506 A1	23-09-2021
		US 2021293077 A1	23-09-2021
		US 2021293078 A1	23-09-2021
		WO 2019224358 A1	28-11-2019
		WO 2019224361 A1	28-11-2019
		WO 2019224362 A1	28-11-2019
		WO 2019224363 A1	28-11-2019