(19) DANMARK

(10) DK/EP 3942141 T3

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

(51) Int.Cl.: ***E 06 B 3/66 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2024-08-05**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2024-05-15**

(86) Europæisk ansøgning nr.: **20709187.7**

(86) Europæisk indleveringsdag: **2020-03-05**

(87) Den europæiske ansøgnings publiceringsdag: **2022-01-26**

(86) International ansøgning nr.: **EP2020055862**

(87) Internationalt publikationsnr.: **WO2020187584**

(30) Prioritet: **2019-03-19 EP 19163703**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **AGC Glass Europe, Avenue Jean Monnet 4, 1348 Louvain-La-Neuve, Belgien**
AGC Inc., Shin Marunouchi Building, 1-5-1 Marunouchi, Chiyoda-ku, Tokyo 100-8405, Japan
AGC Flat Glass North America, Inc., 11175 Cicero Drive, Suite 400, Alpharetta, 30022-1167, USA
AGC Vidros do Brasil Ltda, Estrada Municipal Fazenda São Pedro, 500 , Jardim Vista Alegre, CEP 12523-671 Guaratinguetá São Paulo, Brasilien

(72) Opfinder: **BEN TRAD, Abderrazek, Rue Louis Blériot 12, 6041 Gosselies, Belgien**
WANG, Minwei, Hoegaardsestraat 27, 3000 LEUVEN, Belgien

(74) Fuldmægtig i Danmark: **RWS Group, Europa House, Chiltern Park, Chiltern Hill, Chalfont St Peter, Bucks SL9 9FG, Storbritannien**

(54) Benævnelse: **ASYMMETRISK VAKUUMISOLERET RUDEENHED**

(56) Fremdragne publikationer:
EP-A1- 1 033 352
EP-A1- 1 630 344
WO-A1-2019/145332
JP-A- 2001 316 138
US-A1- 2015 354 264
Agc Glass Uk Ltd.: "Performance Summary Tables", , 30 December 2008 (2008-12-30), pages 380-407, XP055373270, http://www.euglass.com/products/index.php? dir=agc_glaverbel%2F Retrieved from the Internet: URL:http://www.euglass.com/products/agc_gl averbel/Summary-tables.pdf [retrieved on 2017-05-16]

DESCRIPTION

Description

Technical Field

[0001] The invention relates to a vacuum-insulated glazing unit provided with a low emissivity coating and having low stress levels induced by negative and positive temperature differences.

Background Art

[0002] Vacuum-insulated glazing (VIG) units are recommended because of their high performance thermal insulation. A vacuum-insulated glazing unit is typically composed of at least two glass panes separated by an internal space in which a vacuum has been generated. In general, in order to achieve a high-performance thermal insulation, the Thermal transmittance, U, being $U<1.2\ W/m^2K$. The absolute pressure inside the glazing unit is typically 0.1mbar or less and generally at least one of the two glass pane may be covered with a low emissivity coating. To obtain such a pressure inside the glazing unit, a hermetically bonding seal is placed on the periphery of the two glass panes and the vacuum is generated inside the glazing unit by virtue of a pump. To prevent the glazing unit from caving in under atmospheric pressure, due to the pressure difference between the interior and exterior of the glazing unit, discrete spacers are placed between the two glass panes.

[0003] Typical VIG units are symmetric VIG units made of two glass panes having the same glass thickness. The highly insulating properties of vacuum-insulated glazing together with the non-flexible hermetical bonding seals lead to higher thermal strain when there are large differences in temperature between the exterior ant the interior of a building. JP 2001316137 A therefore teaches to configure an asymmetric vacuum-insulated glazing unit wherein the inner glass pane disposed on the indoor side is thicker than the outer glass pane, to achieve thermal strain levels under strong sunlight that are lower than in a comparable symmetric VIG unit. While these asymmetric glazings reduce deformation in summer situations, they risk being submitted to higher stress than comparable symmetric VIG units in winter situations.

[0004] JP 2001316138 A teaches the opposite asymmetric VIG construction wherein the outer glass pane disposed on the outdoor side is thicker than the inner glass pane, for improved shock resistance and acoustic performances.

[0005] US 2015/0354264 A1 teaches a reduced pressure double glazed glass panel with a

low-E film with an emissivity of 0.067 or less on the second glass surface of the outside glass, i.e. the glass surface of the outside glass that is oriented to face the gap portion, to provide sufficient heat insulating and heat shielding properties. The Low-E film is a stack of lower dielectric layer, metal layer, sacrificial layer and upper dielectric layer, preferably formed by magnetron sputtering.

[0006] WO 2016/063007 A1 discloses a vacuum-insulated glazing unit with a low emissivity coating on the exterior facing surface for anti-condensation properties.

[0007] EP 1630344 A1 teaches to provide a low emissivity coating of less than 0.2 emissivity on the interior surfaces of the glass panes of vacuum-insulated glazing unit. Examples of convenient low emissivity coating are sputtered coating stacks of the type dielectric/silver/sacrificial/dielectric or are chemical vapour deposition coatings based on doped tin oxide layers. While the addition of coatings is also interesting for the optimization of insulating or solar control properties of a VIG, these coatings however also modify the thermal stress imposed on the VIG.

[0008] However, none of the art addresses the technical problem of reducing the thermally induced stress in asymmetric VIG units wherein one or more glass panes are bearing low emissivity solar control or insulating coatings and are subjected to temperature difference between exterior and interior environments. Furthermore, none of the art addresses the technical problem of atmospheric pressure induced stress at the pillar locations of such VIG units and even less how to design such a vacuum-insulated glazing unit demonstrating improved combined, thermal and pressure induced stress levels while maintaining high performance thermal insulation.

[0009] Indeed none of the art addresses the technical problem of reducing the combined induced stress, and the resulting breakage risk, of VIG units bearing infrared reflecting coatings, both in summer situations, where the interior is colder than the exterior and also in winter situations where the exterior is colder than the interior, in particular in situations where the winter conditions are more severe than the summer conditions.

Summary of invention

[0010] The aim of the present invention is to provide a vacuum-insulated glazing, bearing on the first glass pane's inner face an **infrared reflecting coating** that faces the interior volume and having a low overall stress-related risk of breakage in summer situations, where the interior is colder than the exterior, as well as in winter situations where the exterior is colder than the interior, in particular in situations where the winter conditions are more severe than the summer conditions. The infrared reflecting coating in the present invention may be an insulating coating or a solar control coating.

[0011] The inventors have surprisingly found that the combination of certain dimensions and

thicknesses for the inner and outer glass panes, together with a certain pitch of the spacers as well as particular positioning of coatings and energetical properties of the glass panes led to a significantly reduced overall risk of stress-related breakage in vacuum-insulated glazings that are exposed to both mild summer situations, where the interior is colder than the exterior, as well as to severe winter situations where the exterior is colder than the interior. With the present invention asymmetric VIGs have their overall induced stress lowered, in particular embodiments stress is lowered in winter conditions to a level lower than that of their equivalent symmetric VIGs. Their equivalent symmetric VIG are identical in all regards, in particular regarding external dimensions of length, width and overall thickness, with the exception that the first and second glass sheets' thicknesses are the same. Symmetric VIGs are well established on the market and naturally form a reference for new developments in the field. They are known to generally reach their highest combined induced stress levels in winter conditions. An equivalent symmetric VIG's maximum combined induced stress level, whether reached in winter or summer conditions, thus forms a useful reference value for comparison to an asymmetric VIG. In certain particular embodiments of the present invention, asymmetric VIGs' overall induced stress values in both winter and summer conditions are lower than the maximum induced stress levels, tolerated, in summer or winter conditions, by their equivalent symmetric VIGs.

[0012] The present invention relates to a vacuum insulating glazing unit extending along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Z and having a width, W, measured along the longitudinal axis, X, and a length, L, measured along the vertical axis, Z. The length of the vacuum insulating glazing unit, L, is comprised between 300 and 4000 mm, (300 mm ≤ L ≤ 4000 mm) and the width of the vacuum insulating glazing unit, W, is equal comprised between 300 and 1500 mm, (300 mm ≤ W ≤ 1500 mm). In certain preferred embodiments of the present invention, L is comprised between 300 and 3000 mm to further reduce stress. The vacuum insulating glazing unit comprises:

1. a. a first glass pane having a thickness Z_1 and an energetic absorptance EA_1 , and
2. b. a second glass pane having a thickness Z_2 and an energetic absorptance EA_2,
3. c. wherein Z_1 is equal to or greater than 5 mm, and
4. d. wherein a thickness difference ΔZ, of the thickness of the first glass pane, Z_1, and the thickness of the second glass pane, Z_2, is equal to or greater than 1 mm ($\Delta Z = Z_1 - Z_2 \geq 1$ mm).
5. e. a set of discrete spacers positioned between the first and second glass panes, maintaining a distance between the first and the second glass panes and forming an array having a pitch, λ. The pitch, λ, is comprised between 10 mm and 35 mm (10 mm ≤ λ ≤ 35 mm).
6. f. a hermetically bonding seal (4) sealing the distance between the first and second glass panes over a perimeter thereof;
7. g. 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 a vacuum of absolute pressure of less than 0.1 mbar
8. h. an infrared reflecting coating having an emissivity of at most 0.4 on the face facing the

inner volume of the first glass pane.

[0013] By convention, to describe the position of a pane surface in an insulating glazing unit, the surfaces of the two or more glass panes are numbered starting from the pane surface that faces the exterior (Position 1) towards the pane surface that faces the interior (Position 4 in a double glazing). For the purpose of the vacuum insulated glazings of the present invention, the pane surface numbering of the VIG is maintained even in embodiments where this VIG is combined with additional glass panes. Furthermore, the thicknesses are measured in the direction normal to the plane, P. For the purpose of the present invention the glass thicknesses are rounded to the nearest millimetre.

[0014] The vacuum-insulated glazing unit of the present invention, bears an infrared reflecting coating in position 2, that is on the face of the first, outer glass pane that is oriented towards the inner volume. Low overall induced stress is obtained when the weighted difference of energetic absorptance between the outer glass pane and the inner glass pane ΔEA is at most $0.0033\ \Delta Z^2\ /mm^2 - 0.0468\ \Delta Z\ /mm + 0.7702$ ($\Delta EA \leq 0.0033\ \Delta Z^2\ /mm^2 - 0.0468\ \Delta Z/mm + 0.7702$; $\Delta EA = EA_1 - 2*EA_2$).

[0015] Other aspects and advantages of the embodiments will become apparent from the following detailed description taken in conjunction with the accompanying drawing which illustrates, by way of example, the principles of the described embodiments.

Brief description of drawings

[0016] This and other aspects of the present invention will now be described in more detail, with reference to the appended drawing showing an exemplifying embodiment of the invention.

Figure 1 shows a cross sectional view of an asymmetric vacuum-insulated glazing unit according to one embodiment of the present invention.

Description of embodiments

[0017] It is an object of the present invention to provide a vacuum-insulated glazing unit (hereinafter referred as VIG) which demonstrates low thermally induced stress when exposed to high positive and negative temperature differences between the exterior and interior environment, provides thermal insulating properties, is highly sustainable over its life time and can be produced in an efficient and cost effective manner.

[0018] It is in particular an object of the present invention to provide a vacuum-insulated glazing unit (hereinafter referred to as VIG) which demonstrates high performance thermal insulation or solar control and improved resistance to the stress induced by the combination of a temperature difference between interior and exterior environments and of atmospheric pressure.

[0019] These objectives are realized by a vacuum-insulated glazing unit of the present invention which is asymmetric, i.e. wherein the first glass pane is thicker than a second glass pane (Z1>Z2), and carefully dimensioned by a specific size including length (L) range and a width (W) range, a specific interval between the spacers (λ), and a specific thickness of the second glass pane (Z2) and where the first glass pane carries an infrared reflecting coating facing the inner volume, when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met:
$\Delta EA \leq 0.0033\ \Delta Z^2/mm^2 - 0.0468\ \Delta Z/mm + 0.7702$; $\Delta EA = EA_1 - 2^*EA_1$,
wherein
$300\ mm \leq L \leq 4000\ mm$,

$300\ mm \leq W \leq 1500\ mm$,

$Z_1 \geq 5\ mm$, $Z_2 \geq 3\ mm$,

$\Delta Z = Z_1 - Z_2 \geq 1\ mm$,
and
$10\ mm \leq \lambda \leq 35\ mm$.

[0020] The thicker, first glass pane is destined to face the outside of the building, the thinner, second glass pane is destined to face the inside of the building. Such a combination of different thicknesses improves the stress related to winter conditions, also with an infrared reflecting coating in position 2. Surprisingly, also in summer situations, low induced stress can be obtained on an such an asymmetric VIG, bearing an infrared reflecting coating in position 2. To achieve this, it was in fact found to be critical to adapt the first and second glass panes' energetic absorptance levels in view of the VIG's critical dimensions.

[0021] The invention relates to a vacuum-insulated glazing unit typically comprising a first glass pane and a second glass pane that are associated together by way of set of discrete spacers that holds said panes a certain distance apart, typically in the range of between 50 µm and 1000 µm, preferably between 50 µm and 500 µm and more preferably between 50 µm and 150 µm, and between said glass panes, an internal space comprising at least one first cavity, in which cavity there is an absolute vacuum less than 0.1 mbar, said space being closed with a peripheral hermetically bonding seal placed on the periphery of the glass panes around said internal space. For the present invention the pitch of the spacers it is understood to mean the shortest distance separating any given spacer from its nearest neighbouring spacer. Preferably the spacers are spaced apart in a regular pattern, for example a square, hexagonal, or triangular pattern.

[0022] As illustrated in Figure 1, the vacuum insulating glazing unit (10) extending along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Y. The VIG of the present invention comprises:

1. a. a first glass pane (1) having an inner pane face (12) and an outer pane face (13) and having a thickness Z_1, and a second glass pane (2) having an inner pane face (22) and an outer pane face (23) and having a thickness, Z_2. The thicknesses are measured, to the nearest mm, in the direction normal to the plane, P.
2. b. a set of discrete spacers (3) positioned between the first and second glass panes and maintaining a distance between the first and the second glass panes;
3. c. a hermetically bonding seal (4) sealing the distance between the first and second glass panes over a perimeter thereof;
4. d. 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 a vacuum of absolute pressure of less than 0.1 mbar.

[0023] The vacuum-insulated glazing unit of the present invention will be hereinafter referred to as the "asymmetric VIG".

[0024] Within the VIG, the first glass pane has an inner pane face (12) and an outer pane face (13). The second glass pane has an inner pane face (22) and an outer pane face (23). The inner pane faces are facing the internal volume, V, of the asymmetric VIG. The outer pane faces are facing the exterior and interior of a building for example.

[0025] As illustrated in Figure 1, the inner pane face (12) of the first glass pane (1) of the asymmetric VIG of the present invention is provided with an infrared reflecting coating (hereinafter referred to as IR-coating).

[0026] The IR-coating (5) of the present invention has an emissivity of not more than 0.2, in particular less than 0.1, less than 0.05 or even less than 0.04. The IR-coating of the present invention may comprise a metal based low emissive IR-coating; these coatings typically are a system of thin layers comprising one or more, for example two, three or four, functional layers based on an infrared radiation reflecting material and at least two dielectric coatings, wherein each functional layer is surrounded by dielectric coatings. The IR-coating of the present invention may in particular have an emissivity of at least 0.010. The functional layers are generally layers of silver with a thickness of some nanometres, mostly about 5 to 20nm. Concerning the dielectric layers, they are transparent and traditionally each dielectric layer is made from one or more layers of metal oxides and/or nitrides. These different layers are deposited, for example, by means of vacuum deposition techniques such as magnetic field-assisted cathodic sputtering, more commonly referred to as "magnetron sputtering". In addition to the dielectric layers, each functional layer may be protected by barrier layers or improved by deposition on a wetting layer.

[0027] The IR-coatings in the present invention may have anti-solar or solar control properties that may reduce the risk of overheating, for example, in an enclosed space with large glazed surfaces and thus reduce the power load to be taken into account for air-conditioning in summer. In this case the glazing must allow the least possible amount of total solar energy radiation to pass through, i.e. it must have the lowest possible solar factor (SF or g). Often, it is highly desirable that the glazing guarantees a certain level of light transmission (LT) in order to provide a sufficient level of illumination inside the building. These somewhat conflicting requirements express the wish to obtain a glazing unit with a high selectivity (S) defined by the ratio of light transmission to solar factor. The IR-coatings in the present invention may also be insulating coatings with a low emissivity tuned to reduce a building's heat loss through longer wavelength infrared radiation. Thus, they improve the thermal insulation of glazed surfaces and reduce energy losses and heating costs in cold periods.

Particular embodiments

[0028] The following particular embodiments of combinations of glass pane thicknesses, pitch ranges and dimensions were found to provide combined induced stress levels, in both winter and summer conditions, lower than the maximum combined stress level induced, in summer or winter conditions, in their equivalent symmetric vacuum-insulated glazing, of the same overall thickness. EA_1 and EA_2 designate the first and second glass panes' energetic absorptances respectively.

[0029] In particular the present invention's stress resistance in summer conditions is evaluated in comparison to its equivalent symmetric VIG. For the purpose of the present invention, the equivalent symmetric VIG of an asymmetric VIG is a VIG having all the values of W, L, λ, having the same overall thickness Z_1+Z_2, but wherein the thickness of the first pane is the same as the thickness of the second pane $Z_1=Z_2$.

[0030] In particular, in both winter and summer conditions, combined induced stress levels lower than the maximum combined stress level induced in an equivalent symmetric vacuum-insulated glazing, of the same overall thickness, are reached for a vacuum-insulated glazing wherein Z_2 = 3mm and 10 mm ≤ λ ≤ 25 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq 0.0084\ \Delta Z^2/mm^2 - 0.1545\ \Delta Z/mm + 0.6966$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0031] In particular, in both winter and summer conditions, combined induced stress levels lower than the maximum combined stress level induced in an equivalent symmetric vacuum-insulated glazing, of the same overall thickness are reached for a vacuum-insulated glazing wherein Z_2 = 4mm and 10 mm ≤ λ ≤ 25 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq - 0.0214$

ΔZ /mm + 0.5696; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0032] In particular, in both winter and summer conditions, combined induced stress levels lower than the maximum combined stress level induced in an equivalent symmetric vacuum-insulated glazing, of the same overall thickness are reached for a vacuum-insulated glazing wherein Z_2 = 5mm and 10 mm ≤ λ ≤ 35 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq 0.0033\ \Delta Z^2/mm^2 - 0.0468\ \Delta Z/mm + 0.7434$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0033] In particular, in both winter and summer conditions, combined induced stress levels lower than the maximum combined stress level induced in an equivalent symmetric vacuum-insulated glazing, of the same overall thickness are reached for a vacuum-insulated glazing wherein Z_2 = 6mm and 10 mm ≤ λ ≤ 35 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq 0.0033\ \Delta Z^2/mm^2 - 0.0468\ \Delta Z/mm + 0.7702$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0034] In particular, in both winter and summer conditions, combined induced stress levels lower than the maximum combined stress level induced in an equivalent symmetric vacuum-insulated glazing, of the same overall thickness are reached for a vacuum-insulated glazing wherein Z_2 = 4mm and 25 mm < λ ≤ 30 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq - 0.0308\ \Delta Z/mm + 0.5294$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0035] In one embodiment of the present invention, the thickness of the first glass pane, Z_1, of the asymmetric VIG, may be equal to or greater than 5 mm ($Z_1 \geq 5$ mm), preferably may be equal to or greater to 6 mm, ($Z_1 \geq 6$mm), preferably equal to or greater to 8 mm, ($Z_1 \geq 8$ mm). Typically, the thickness of the first glass pane, Z_1, will be not more than 12 mm, preferably no more than 10 mm. In another embodiment, the thickness of the second glass pane, Z_2, of the asymmetric VIG, may typically be equal to or greater than 3 mm ($Z_2 \geq 3$mm), preferably may be equal to or greater to 4 mm, ($Z_2 \geq 4$ mm), preferably equal to or greater to 5 mm, ($Z_2 \geq 5$ mm). Typically, the thickness of the second glass pane, Z_2, will be not more than 10 mm, preferably no more than 8 mm. However, in order to improve the mechanical resistance of the asymmetric VIG of the present invention, it is preferred to keep the thickness of the second pane, Z_2, to a minimum.

[0036] In another embodiment of the present invention, the present invention also applies to any type of glazing unit comprising glass panes (two, three or more) bounding insulating or

non-insulating internal spaces (also called multiple glazing units) provided that a partial vacuum is generated in at least one of these internal spaces. Therefore, in one embodiment, to improve the mechanical performances of the asymmetric VIG of the present invention, a third additional glass pane can be coupled to at least one of the outer pane faces (13 and/or 23) of the first and second glass pane along the periphery of the VIG via a peripheral spacer bar creating in insulating cavity sealed by a peripheral edge seal. Said peripheral spacer bar maintained a certain distance between the third glass pane and the at least one of the outer pane face one of the first and second glass panes. Typically said spacer bar comprises a desiccant and has typically a thickness comprised between 6 mm to 20 mm, preferably 9 to 15mm. In general, said second internal volume is filled with a predetermined gas selected from the group consisting of air, dry air, argon (Ar), krypton (Kr), xenon (Xe), sulfur hexafluoride (SF6), carbon dioxide or a combination thereof. Said predetermined gas are effective for preventing heat transfer and/or may be used to reduce sound transmission.

[0037] When the asymmetric VIG is used to close an opening within a partition separating the interior and exterior spaces, it is preferred to the third glass pane faces the exterior space. It is further preferred that the third glass pane is provided with at least a pyrolytic TCO-based coating on at least one of its surfaces. Such specific glazing unit provides higher mechanical performance while improving the emissivity performances and/or reducing the formation of condensation. In particular and for safety reasons, the outer face of the second glass pane (23) facing the interior environment may be additionally laminated to at least one glass sheet by at least one polymer interlayer forming a laminated assembly.

[0038] In one embodiment of the present invention, at least one of the outer pane faces (13 and/or 23) of the first and the second glass pane may be further laminated to at least one additional glass sheet by at least one polymer interlayer forming a laminated assembly, for safety and security reasons.

[0039] Within the laminate assembly, the at least one additional glass sheet preferably has a thickness, Z_S, equal to or greater than 0.5 mm ($Z_S \geq 0.5$ mm). The thickness is measured in the direction normal to the plane, P. The at least one polymer interlayer is a transparent or translucent polymer interlayer comprising a material selected from the group consisting ethylene vinyl acetate (EVA), polyisobutylene (PIB), polyvinyl butyral (PVB), polyurethane (PU), polyvinyl chlorides (PVC), polyesters, copolyesters, assembly polyacetals, cyclo olefin polymers (COP), ionomer and/or an ultraviolet activated adhesive and others known in the art of manufacturing glass laminates. Blended materials using any compatible combination of these materials can be suitable, as well.

[0040] Reinforced acoustic insulation with acoustic laminated glass are also compatible with the present concept to improve the performances of the window or door. In such case, the polymer interlayer comprises at least one additional acoustic material inserted between two polyvinyl butyral films. Glass panes with electrochromic, thermochromic, photochromic or photovoltaic elements are also compatible with the present invention.

[0041] The first and second glass panes of the asymmetric VG of the present invention can be chosen among float clear, extra-clear or colored glass technologies. The term "glass" is herein understood to mean any type of glass or equivalent transparent material, such as a mineral glass or an organic glass. The mineral glasses used may be irrespectively one or more known types of glass such as soda-lime-silica, aluminosilicate or borosilicate, crystalline and polycrystalline glasses. The glass pane can be obtained by a floating process, a drawing process, a rolling process or any other process known to manufacture a glass pane starting from a molten glass composition. The glass panes can optionally be edge-ground. Edge grinding renders sharp edges into smooth edges which are much safer for people who could come in contact with the vacuum-insulating glazing, in particular with the edge of the glazing. Preferably, the glass pane according to the invention is a pane of soda-lime-silica glass, aluminosilicate glass or borosilicate glass. More preferably and for reasons of lower production costs, the glass pane according to the invention is a pane of soda-lime-silica glass. Typically, the first and second glass panes of the present invention are annealed glass panes. Preferably, the composition for the first and second glass panes of the asymmetric VIG of the invention comprises the following components in weight percentage, expressed with respect to the total weight of glass (Table 1, Comp. A). More preferably, the glass composition (Table 1, 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.

Table 1

	Comp. A	Comp. B
SiO_2	40 to 78%	60 to 78 %
Al_2O_3	0 to 18%	0 to 8 %,
		preferably 0 to 6 %
B_2O_3	0 to 18%	0 to 4 %,
		preferably 0 to 1 %
Na_2O	0 to 20%	5 to 20 %,
		preferably 10 to 20 %
CaO	0 to 15%	0 to 15 %,
		preferably 5 to 15 %
MgO	0 to 10%	0 to 10%,
		preferably 0 to 8 %
K_2O	0 to 10%	0 to 10 %
BaO	0 to 5%	0 to 5 %,
		preferably 0 to 1 %.

[0042] Other particular glass compositions for the first and second glass panes of the asymmetric VIG of the invention, comprises the following components of Table 2 in weight

percentage, expressed with respect to the total weight of glass.

Table 2

Comp. C	Comp. D	Comp. E
$65 \leq SiO_2 \leq 78$ wt%	$60 \leq SiO_2 \leq 78$ %	$65 \leq SiO_2 \leq 78$ wt%
$5 \leq Na_2O \leq 20$ wt%	$5 \leq Na_2O \leq 20$ %	$5 \leq Na_2O \leq 20$ wt%
$0 \leq K_2O < 5$ wt%	$0.9 < K_2O \leq 12$ %	$1 \leq K_2O < 8$ wt%
$1 \leq Al_2O_3 < 6$ wt%,	$4.9 \leq Al_2O_3 \leq 8$ %	$1 \leq Al_2O_3 < 6$ wt%
pref $3 < Al_2O_3 \leq 5$ %		
$0 \leq CaO < 4.5$ wt%	$0.4 < CaO < 2$ %	$2 \leq CaO < 10$ wt%
$4 \leq MgO \leq 12$ wt%	$4 < MgO \leq 12$ %	$0 \leq MgO \leq 8$ wt%
$(MgO/(MgO+CaO)) \geq 0.5$, preferably		$0.1 \leq K_2O/(K_2O+Na_2O) \leq 0.7$
$0.88 \leq [MgO/(MgO+CaO)] < 1$		

[0043] In particular, examples of base glass matrixes for the composition according to the invention are described in published in PCT patent applications WO 2015/150207 A1, WO 2015/150403 A1, WO 2016/091672 A1, WO 2016/169823 A1 and WO 2018/001965 A1.

[0044] The second and first glass panes can be of the same dimensions or of different dimensions and form thereby a stepped VIG. In a preferred embodiment of the present invention, the first and the second glass panes comprise first and second peripheral edges, respectively and wherein the first peripheral edges are recessed from the second peripheral edges or wherein the second peripheral edges are recessed from the first peripheral edges. This configuration allows to reinforce the strength of the hermetically bonding seal.

[0045] In one embodiment, to provide a VIG with higher mechanical performances and/or to improve further the safety of the VIG, it can be contemplated to thermally or chemically pre-stress the first and/or second glass pane(s) of the present invention. In this instance, it is required that both the first and second glass panes are treated by the same pre-stress treatment to provide the same resistance to thermal induced load. Therefore, if pre-stress treatment occurs on the glass panes, then it requires that the first glass pane and the second glass pane are both heat strengthened glass panes, or that the first glass pane and the second glass pane are both thermally toughened glass panes or that the first glass pane and the second glass pane are both chemically strengthened glass panes.

[0046] Heat strengthened glass is heat treated using a method of controlled heating and cooling which places the glass surface under compression and the glass core under tension. This heat treatment method delivers a glass with a bending strength greater than annealed glass but less than thermally toughened safety glass.

[0047] Thermally toughened safety glass is heat treated using a method of controlled high temperature heating and rapid cooling which puts the glass surface under compression and the glass core 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.

[0048] 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.

[0049] As depicted in Figure 1, the vacuum-insulated glazing unit of the present invention comprises a plurality of discrete spacers (3), also referred to as pillars, sandwiched between the first and second glass panes (1, 2) so as to maintain the internal volume, V. As per invention, the discrete spacers are positioned between the first and second glass panes, maintaining a distance between the first and the second glass panes and forming an array having a pitch, λ, comprised between 10 mm and 35 mm (10 mm ≤ λ ≤ 35 mm). By pitch, it is meant the interval between the discrete spacers. In a preferred embodiment, the pitch is comprised between 20 mm and 35 mm (20 mm ≤ λ ≤ 35 mm). The array within the present invention is typically a regular array based on an equilateral triangular, square or hexagonal scheme, preferably a square scheme.

[0050] The discrete spacers can have different shapes, such as cylindrical, spherical, filiform, hour-glass shaped, 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. The discrete spacers are typically made of a material having a strength endurable against pressure applied from the surfaces of the glass panes, capable of withstanding high-temperature process such as burning and baking, and hardly emitting gas after the glass panel is manufactured. Such a material is preferably a hard 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, or a ceramic material such as corundum, alumina, mullite, magnesia, yttria, aluminum nitride, silicon nitride or the like.

[0051] As shown in Figure 1 , the internal volume, V, delimited between the glass panes (1, 2)

of the vacuum-insulated glazing (10) of the present invention is closed with a hermetically bonding seal (4) placed on the periphery of the glass panes around said internal space. The said hermetically bonding seal is impermeable and hard. Such as used here and unless otherwise indicated, the term "impermeable" is understood to mean impermeable to air or any other gas present in the atmosphere.

[0052] 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 panels of the glazing unit. The use of this type of seal limits the choice of low-E layers to those that are not degraded by the thermal cycle required to implement the solder glass, i.e. to those that are able to withstand a temperature possibly as high as 250° C. In addition, since this type of solder-glass-based seal is only very slightly deformable, it does not allow the effects of differential expansion between the interior-side glass panel of the glazing unit and the exterior-side glass panel of the glazing unit when said panels are subjected to large temperature differences to be absorbed. Quite substantial stresses are therefore generated at the periphery of the glazing unit and may lead to breakage of the glass panels of the glazing unit.

[0053] 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. One substantial advantage of this second type of seal relative to the first type of seal is that it is able to partially deform in order to partially absorb the differential expansion created between the two glass panels. There are various types of tie underlayers on the glass panel.

[0054] Patent application WO 2011/061208 A1 describes one example embodiment of a peripheral impermeable seal of the second type for a vacuum-insulated glazing unit. In this embodiment, the seal is a metal strip, for example made of copper, that is soldered by means of a solderable material to an adhesion band provided on the periphery of the glass panes.

[0055] 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 asymmetric VIG of the present invention.

[0056] The internal volume of the asymmetric VIG of the present invention, can comprise a gas, for example, but not exclusively, air, dry air, argon (Ar), krypton (Kr), xenon (Xe), sulfur hexafluoride (SF 6), carbon dioxide or a combination thereof. The transfer of energy through an insulating panel having this conventional structure is decreased, because of the presence of the gas in the internal volume, relative to a single glass pane.

[0057] The internal volume may also be pumped of any gas, creating therefore a vacuum glazing unit. Energy transfer through a vacuum-insulated insulating glazing unit is greatly decreased by the vacuum. To generate the vacuum in the internal space of the glazing unit, a

hollow glass tube bringing the internal space into communication with the exterior is generally provided on the main face of one of the glass panes. Thus, the partial vacuum is generated in the internal space by pumping out gases present in the internal space by virtue of a pump connected to the exterior end of the glass tube.

[0058] To maintain for the duration a given vacuum level in a vacuum-insulated glazing unit, a getter may be used in the glazing panel. Specifically, the internal surfaces of the glass panes making up the glazing panel may release over time gases absorbed beforehand in the glass, thereby increasing the internal pressure in the vacuum-insulated glazing panel and thus decreasing the vacuum performance. Generally, such a getter consists of alloys of zirconium, vanadium, iron, cobalt, aluminium, 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 of the glazing panel so as not to be seen (for example hidden by an exterior enamel or by a portion of the peripheral impermeable seal). The getter forms, on its surface, a passivation layer at room temperature, and must therefore be heated in order to make the passivation layer disappear and thus activate its alloy gettering properties. The getter is said to be "heat activated".

Table 3

Ref.#	Feature
10	Vacuum-insulated glazing unit
1	First glass pane
12	Inner pane face of the first glass pane
13	Outer pane face of the first glass pane
2	Second glass pane
22	Inner pane face of the second glass pane
23	Outer pane face of the second glass pane
3	Discrete spacers
4	Hermetically bonding seal
5	lowE coating
V	Internal volume

Examples

[0059] In order to evaluate the breakage risk, the combined stress resulting from atmospheric pressure stress, due to the vacuum in the inner volume V, and of the thermal induced stress, due to the temperature difference on both sides of the glazing, was calculated.

[0060] Because of the vacuum maintained between the two panes of the VIG, the atmospheric pressure causes permanent tensile stresses at the external surfaces of the glass panes of the VIG at each pillar location. It is known by the skilled person that for small pillars, the tensile

stress induced by the pillars at the external surfaces of the glass panes is independent of the size of its external circumference. By small pillars, it is generally meant pillars having 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.

[0061] In those instances and for regular arrays based on an equilateral triangular, square or hexagonal scheme, this atmospheric pressure induced stress also referred to as tensile stress, can be calculated for a glass pane by the following formula: $\sigma_p \leq 0.11x\ \lambda^2/Z^2$ [*MPa*], wherein λ [m] and Z [m] are respectively, the pitch between the spacers and the glass pane's thickness. By "pitch", it is understood to mean the shortest distance separating any spacer from its neighbours. In particular, for square based regular arrays, the tensile stress is maximum and therefore follows the following formula : $\sigma_p = 0.11x\ \lambda^2/Z^2$ [*MPa*].

[0062] The maximum atmospheric pressure stress is calculated for each of the VIG's first and second glass sheets, σ_{p1} and σ_{p2}.

[0063] Thermal induced tensile stress on the external surface of a glass pane of a VIG occurs as soon as there is a temperature difference between the first glass pane (1, T_1) and the second glass panes (2, T_2) and increases with increasing differences between T_1 and T_2. The temperature difference (ΔT) is the absolute difference between the mean temperature, T_1, calculated for the first glass pane (1) and the mean temperature, T_2, calculated for the second glass pane (2) The mean temperature of a glass pane may for example be calculated from numerical simulations known by the skilled person in the art. For the present invention the temperature difference between the two glass panes was calculated using the calculation software "Window 7.4" which is based on the method proposed by the American National Fenestration Rating Council NFRC that is consistent with the ISO 15099. Thermal induced stress may lead to breaking the VIG, when such absolute temperature difference between the glass panes reaches 30°C and even more when the absolute temperature difference is higher than 40°C in severe conditions. The temperature of the interior environment is typically from 20°C to 25°C whereas the temperature of the exterior environment can extend from -20°C in the winter to +35°C in the summer. Therefore, the temperature difference between the interior environment and the exterior environment can reach more than 40°C in severe conditions. Therefore, the temperature difference (ΔT) between the mean temperature, T=, calculated for the first glass pane (1) and the mean temperature, T_2, calculated for the second glass pane (2) can reach more than 40°C as well. Numerical simulation is used to calculate the maximum thermal stress σ_T induced on the external surface of each glass pane of the VIG. A finite element analysis (FEA) model by commercial software Abaqus2017 (formerly referred to by ABAQUS) has been built to stimulate the behaviour of a VIG when exposed to different temperature conditions. The calculations were achieved with glass panes being meshed using C3D8R elements with 5 integrations points on glass thickness. The global mesh size used was 1cm. In order to achieve the ΔT of the present invention, initial and uniform temperature was imposed on both glass panes then uniform temperature variation has been imposed on one of

the glass pane, while maintaining the other glass pane at the initial temperature. Mechanical coupling was imposed between the two glass panes to force equal displacement of the two touching glass surfaces. Other boundary conditions have been set to prevent rigid body motion of the assembly. Calculations were performed for all glazings having free, unconstrained edges.

[0064] The hard winter temperature conditions used for the purpose of the present invention were: an outside air temperature of -20°C, an inside air temperature of 20°C, giving a Maximum temperature difference between outside and inside of 40°C.

[0065] The inventors found that as thermal induced stress and atmospheric pressure stress occur simultaneously in a glass pane, it is the combined stress (σ_c), which is the combination of thermal induced stress and atmospheric pressure induced stress, that needs to be considered when dimensioning a VIG. The term "combined induced stress" or "the combination of induced stresses" is understood to mean the sum of the thermal induced stress and the atmospheric pressure induced stress ($\sigma_c = \sigma_p + \sigma_T$). The combined stress can be calculated for the chosen winter conditions o_{cw} and for the chosen summer conditions σ_{cs}.

[0066] It was found that in winter conditions, when the VIG is asymmetric with a thicker first glass pane and a thinner second glass pane, the highest combined winter stress σ_{cwmax}, which is the highest value between the combined winter stress of the first glass pane ($\sigma_{cw1} = \sigma_{p1} + \sigma_{Tw1}$) and the combined winter stress of the second glass pane ($\sigma_{cw2} = \sigma_{p2} + \sigma_{Tw2}$) ($\sigma_{cwmax} = \max(\sigma_{cw1}, \sigma_{cw2})$ is reduced. In particular for an asymmetric VIG respecting the following dimensional criteria :

$300\ mm \leq L \leq 4000\ mm$,

$300\ mm \leq W \leq 1500\ mm$,

$Z_1 \geq 5\ mm$, $Z_2 \geq 3\ mm$,

$\Delta Z = Z_1 - Z_2 \geq 1\ mm$,
and
$10\ mm \leq \lambda \leq 35\ mm$,
the highest combined winter stress is lower than the highest combined winter stress of an equivalent symmetric VIG having the same overall thickness.

[0067] The mild summer temperature conditions used for the purpose of the present invention were: an outside air temperature of 32°C, an inside air temperature of 24°C, and a solar flux of 783 W/m^2.

[0068] In summer conditions, the highest combined summer stress σ_{csmax}, is the highest value between the combined summer stress of the first glass pane ($\sigma_{cs1} = \sigma_{p1} + \sigma_{Ts1}$) and the combined summer stress of the second glass pane ($\sigma_{cs2} = \sigma_{p2} + \sigma_{Ts2}$) ($\sigma_{csmax} = \max(\sigma_{cs1},$

σ_{cs2}). It was found in summer condition that in order to be acceptable, the highest combined summer stress σ_{csmax} in an asymmetric VIG should be less than or equal to the maximum combined induced stress, which is either σ_{cwmax} or $\sigma_{csmax,,}$ of its equivalent symmetric VIG in . When this relationship is respected, then the breakage risk due to combined atmospheric and thermal induced stresses, in both hard winter and mild summer conditions, is never higher for the asymmetric VIG than for its equivalent symmetric VIG.

[0069] It was found that an asymmetric VIG respecting this combined induced stress limitation could be made by balancing the energetic absorptance of the first and the second glass panes as well as their thicknesses for different sets of L,W and λ parameter ranges.

[0070] In the following particular embodiments A to E of the present invention the asymmetric VIG respects the following relationships:
σ_{cw2} (asymmetric VIG) < σ_{cw2} (equivalent symmetric VIG)
and
σ_{cs1}(asymmetric VIG) ≤ σ_{cw2} (equivalent symmetric VIG)

[0071] Embodiment A: Asymmetric VIG wherein Z_2 = 3mm and 10 mm ≤ λ ≤ 25 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq 0.0084\ \Delta Z^2/mm^2 - 0.1545\ \Delta Z/mm + 0.6966$; wherein $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0072] Embodiment B: Asymmetric VIG wherein Z_2 = 4mm and 10 mm ≤ λ ≤ 25 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: $\Delta EA \leq -0.0214\ \Delta Z/mm + 0.5696$; wherein $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0073] Embodiment C: Asymmetric VIG wherein Z2 = 5mm and 10 mm ≤ λ ≤ 35 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: wherein $\Delta EA \leq 0.0033\ \Delta Z^2/mm^2 - 0.0468\ \Delta Z/mm + 0.7434$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0074] Embodiment D: Asymmetric VIG wherein Z2 = 6mm and 10 mm ≤ λ ≤ 35 mm when the following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: wherein $\Delta EA \leq 0.0033\ \Delta Z^2/mm^2 - 0.0468\ \Delta Z/mm + 0.7702$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0075] Embodiment E: Asymmetric VIG wherein Z_2 = 4mm and 25 mm < λ ≤ 30 mm when the

following condition on the weighted difference of energetic absorption of the first and the second glass pane is met: wherein $\Delta EA \leq - 0.0308\ \Delta Z/mm + 0.5294$; $\Delta EA = EA_1 - 2*EA_2$, wherein 300 mm $\leq L \leq$ 3000 mm, 300 mm $\leq W \leq$ 1500 mm, $Z_1 \geq 5$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm.

[0076] Indeed it was found that these limitations of the energetical absorptances of the first and second panes of an asymmetric VIG led to temperature differences in the first and second glass panes that kept the combined stress levels below the required limits.

[0077] For summer conditions inventors found that there was a correlation between the energetic absorptances of the glass panes and the temperature differences obtained. The follow relation was established based on the example coatings mentioned above positioned on the inner face of the first glass pane of the VIG:
ΔT /°C = 37.386 x ΔEA + 6.2068; $\Delta EA = EA_1 - 2*EA_2$ and $\Delta T = T_1 - T_2$.
Energetic absorptances EA of the glass panes are determined according to standard ISO15099 referring to EN410:2011, for the glass panes when they are in the VIG. The pillars are not taken into account for the calculation of EA.

[0078] These stress calculations were performed for a large number of glass dimensions, thicknesses and infrared reflective coatings. In particular the following infrared reflective coatings commercialized by the Asahi Glass Company (AGC) were used: Stopray Ultra 50 (U50), Stopray Vision 50 (V50), I-plus Top 1.1(I+), Stopray Vision 40 (V40), Stopray Vision 72 and Energy N (EN). All of these coatings provide an emissivity <0.4. For the calculations the glazing are considered free and unconstrained at all edges.

[0079] Soda lime clear glass Planibel Clearlite (CL) was used for most glass panes. Soda lime extra-clear low-iron glass Planibel Clearvision (CV) as well as Dark Grey Glass (DG) has been used for some glass panes.

[0080] Comparative examples are labelled 'C.Ex.', examples according to the present invention are labelled 'Ex.'.

[0081] In the examples and comparative examples, the space between the glass sheets is 100µm and the array of pillars is a regular square array and the size W x L is 1.5m x 3m.
Table 4

	VIG composition					
	Outer glasspane			Inner glass pane		Pitch
	Type	thickn. (mm)	Coating in p2	Type	thickn. (mm)	(mm)
Ex.1	CL	7	U50	CL	3	25
Ex.2	CL	7	I+	CL	3	25
C. Ex. 1	CL	5	I+	CL	5	25
Ex.3	CL	8	V50	CL	4	25

	VIG composition					
	Outer glasspane			Inner glass pane		Pitch
	Type	thickn. (mm)	Coating in p2	Type	thickn. (mm)	(mm)
C.Ex.2	DG	8	U50	CL	4	25
Ex.4	CL	10	U50	CL	4	30
Ex.5	CL	10	EN	CL	4	30
C.Ex.3	CL	7	EN	CL	7	30
Ex.6	CL	12	U50	CL	4	25
Ex.7	CL	12	V72	CL	4	25
Ex.8	CL	11	V40	CL	5	25
C.Ex.4	DG	11	U50	CV	5	25
C.Ex.5	CL	8	V72	CL	8	25
C.Ex.6	CL	8	V40	CL	8	25
Ex.9	CL	11	V40	CL	5	30
C.Ex.7	DG	11	U50	CV	5	30
C.Ex.8	DG	8	U50	CV	8	30
C.Ex.9	CL	8	V40	CL	8	30
Ex. 10	CL	11	V40	CL	5	35
C.Ex.10	DG	11	U50	CV	5	35
C.Ex.11	DG	8	U50	CV	8	35
C.Ex.12	CL	8	V40	CL	8	35
Ex.11	CL	12	V40	CL	6	25
C.Ex.13	DG	12	U50	CV	6	25
C.Ex.14	DG	9	U50	CV	9	25
C.Ex.15	CL	9	V40	CL	9	25
Ex.12	CL	12	V40	CL	6	30
C.Ex.16	DG	12	U50	CV	6	30
C.Ex.17	DG	9	U50	CV	9	30
C.Ex.18	CL	9	V40	CL	9	30

	VIG composition					
	Outer glasspane			Inner glass pane		Pitch
	Type	thickn. (mm)	Coating in p2	Type	thickn. (mm)	(mm)
Ex.13	CL	12	V40	CL	6	35
C.Ex.19	DG	12	U50	CV	6	35
C.Ex.20	DG	9	U50	CV	9	35
C.Ex.21	CL	9	V40	CL	9	35

[0082] Table 5 below shows for the examples and comparative examples of the table 4 above the maximum allowable ΔEA according to the present invention and the calculated ΔEA of the respective example or comparative example. Comparative examples present too high ΔEA values and therefore present a higher breakage risk, their ΔEA value is higher than the ΔEA value permitted as per the present invention. Examples Ex. 2 to 13 in particular present a lower breakage risk than the corresponding equivalent symmetric vacuum insulating glazing.

Table 5

	Max ΔEA allowed	ΔEA	ΔT_{summer} (°C)	ΔT_{winter} (°C)
Ex.1	0.636	0.443	22.4	40
Ex. 2	0.636	0.131	11.0	40
C.Ex.1		0.070	8.7	40
Ex.3	0.636	0.429	22.0	40
C.Ex.2	0.636	0.948	39.9	40
Ex.4	0.608	0.491	24.6	40
Ex.5	0.608	0.289	17.1	40
C.Ex.3		0.227	14.5	40
Ex.6	0.607	0.520	26.0	40
Ex.7	0.607	0.313	18.3	40
Ex.8	0.608	0.427	22.6	40
C.Ex.4	0.608	0.956	41.0	40
C.Ex.5		0.240	15.0	40
C.Ex.6		0.381	20.3	40
Ex.9	0.608	0.427	22.6	40
C.Ex.7	0.608	0.956	41.0	40

	Max ΔEA allowed	ΔEA	ΔT_{summer} (°C)	ΔT_{winter} (°C)
C.Ex.8		0.949	39.9	40
C.Ex.9		0.381	20.3	40
Ex. 10	0.608	0.427	22.6	40
C.Ex.10	0.608	0.956	41.0	40
C.Ex.11		0.949	39.9	40
C.Ex.12		0.381	20.3	40
Ex.11	0.608	0.437	23.1	40
C.Ex.13	0.608	0.956	41.4	40
C.Ex.14		0.950	40.4	40
C.Ex.15		0.391	21.0	40
Ex.12	0.608	0.437	23.1	40
C.Ex.16	0.608	0.956	41.4	40
C.Ex.17		0.950	40.4	40
C.Ex.18		0.391	21.0	40
Ex.13	0.608	0.437	23.1	40
C.Ex.19	0.608	0.956	41.4	40
C.Ex.20		0.950	40.4	40
C.Ex.21		0.391	21.0	40

[0083] The table 6 below shows the induced stresses obtained in the examples and comparative examples in summer and winter conditions. The pressure induced stresses in a first or second glass pane above the pillars is noted σ_{p1} and σ_{P2} respectively. The winter temperature stress is denoted σ_{Tw1} and σ_{Tw2} respectively, the summer temperature stress is denoted σ_{Ts1} and σ_{Ts2} respectively. The combined summer stress is denoted σ_{cs1} ($\sigma_{cs1} = \sigma_{p1} + \sigma_{Ts1}$) and σ_{cs2} ($\sigma_{cs2} = \sigma_{p2} + \sigma_{Ts2}$)respectively, the combined winter stress is denoted σ_{cw1} ($\sigma_{cw1} = \sigma_{p1} + \sigma_{Tw1}$) and σ_{cw2} ($\sigma_{cw2} = \sigma_{p2} + \sigma_{w2}$) respectively. The highest of combined winter stress and the highest combined summer are denoted σ_{cwmax} ($\sigma_{cwmax} = \max(\sigma_{cw1} + \sigma_{cw2})$) and σ_{csmax} ($\sigma_{cwmax} = \max(\sigma_{cs1} + \sigma_{cs2})$) respectively. The highest combined induced stress, which occurs in either summer or winter conditions is denoted, σ_{cmax}. The measurement unit for all stresses is MPa. The maximum combined stress value for each example is underlined and corresponds thus to σ_{cmax}.

[0084] As can be seen in table 6 below, in symmetric VIG's the highest combined stress values are, with few exceptions, reached in winter conditions on the second glass pane. The maximum stress value reached in any condition, serves as a reference point to compare an asymmetric VIG with its equivalent symmetric VIG. Furthermore it was found that when the VIG is asymmetric with a thicker first glass pane and a thinner second glass pane the highest combined winter stress σ_{cwmax} is reduced and in particular for an asymmetric VIG respecting the following dimensional criteria : 300 mm ≤L ≤ 4000 mm, 300 mm ≤ W ≤ 1500 mm, $Z_1 \geq 5$ mm, $Z_2 \geq 3$ mm, $\Delta Z = Z_1 - Z_2 \geq 1$ mm, and 10 mm ≤ λ ≤ 35 mm, the highest combined winter stress is lower than for the equivalent symmetric VIG having the same overall thickness.

[0085] It can also be seen in the table 6 below that in summer conditions the highest combined summer stress σ_{csmax} is higher in an asymmetric VIG than in its equivalent symmetric VIG. In particular embodiments of the present invention, that is in the examples marked with an asterisk, the highest combined summer stress, σ_{csmax} in the examples of the present invention was found to be acceptable, the highest combined summer stress σ_{csmax} being less than or equal to highest combined stress (winter or summer) of its equivalent symmetric VIG, that is the combined winter stress σ_{cw2} of the second glass pane in its equivalent symmetric VIG.

Table 6

	Outer pane stresses (MPa)					Inner pane stresses (MPa)				
	σ_{Ts1}	σ_{Tw1}	σ_{p1}	σ_{cs1}	σ_{cw1}	σ_{Ts2}	σ_{Tw2}	σ_{p2}	σ_{cs2}	σ_{cw2}
Ex.1	6.48	1.66	1.40	7.88	3.07	7.87	2.08	7.64	15.51	9.72
Ex.2*	3.18	1.66	1.40	4.58	3.07	3.87	2.08	7.64	11.50	9.72
C.Ex.1	2.04	9.14	2.75	4.79	11.89	1.99	9.36	2.75	4.74	12.11
Ex.3*	6.44	0.04	1.07	7.51	1.11	5.70	4.09	4.30	10.00	8.38
C.Ex.2	11.68	0.04	1.07	12.75	1.11	10.34	4.09	4.30	14.64	8.38
Ex.4	6.95	0.00	0.99	7.94	0.99	6.50	2.78	6.19	12.69	8.97
Ex.5*	4.83	0.00	0.99	5.82	0.99	4.52	2.78	6.19	10.71	8.97
C.Ex.3	3.35	2.73	2.02	5.37	4.75	0.99	9.25	2.02	3.01	11.27
Ex.6	6.91	0.00	0.48	7.39	0.48	7.05	1.71	4.30	11.35	6.01
Ex.7*	4.86	0.00	0.48	5.34	0.48	4.96	1.71	4.30	9.26	6.01
Ex.8*	6.46	0.00	0.57	7.02	0.57	4.44	4.41	2.75	7.19	7.16
C.Ex.4	11.71	0.00	0.57	12.28	0.57	8.06	4.41	2.75	10.81	7.16
C.Ex.5	3.43	0.89	1.07	4.50	1.97	0.34	9.15	1.07	1.41	10.22
C.Ex.6	4.64	0.89	1.07	5.72	1.97	0.45	9.15	1.07	1.53	10.22

	Outer pane stresses (MPa)					Inner pane stresses (MPa)				
	σ_{Ts1}	σ_{Tw1}	σ_{p1}	σ_{cs1}	σ_{cw1}	σ_{Ts2}	σ_{Tw2}	σ_{p2}	σ_{cs2}	σ_{cw2}
Ex.9*	6.46	0.00	0.82	7.27	0.82	4.44	4.41	3.96	8.40	8.37
C.Ex.7	11.71	0.00	0.82	12.53	0.82	8.06	4.41	3.96	12.02	8.37
C.Ex.8	9.12	0.89	1.55	10.67	2.44	0.89	9.15	1.55	2.44	10.69
C.Ex.9	4.64	0.89	1.55	6.19	2.44	0.45	9.15	1.55	2.00	10.69
Ex.10*	6.46	0.00	1.11	7.57	1.11	4.44	4.41	5.39	9.83	9.80
C.Ex.10	11.71	0.00	1.11	12.82	1.11	8.06	4.41	5.39	13.45	9.80
C.Ex.11	9.12	0.89	2.11	11.23	3.00	0.89	9.15	2.11	3.00	11.25
C.Ex.12	4.64	0.89	2.11	6.75	3.00	0.45	9.15	2.11	2.56	11.25
Ex.11*	6.59	0.00	0.48	7.07	0.48	3.23	5.51	1.91	5.14	7.42
C.Ex.13	11.81	0.00	0.48	12.29	0.48	5.80	5.51	1.91	7.71	7.42
C.Ex.14	9.12	0.00	0.85	9.97	0.85	0.00	9.03	0.85	0.85	9.88
C.Ex.15	4.74	0.00	0.85	5.59	0.85	0.00	9.03	0.85	0.85	9.88
Ex.12*	6.59	0.00	0.69	7.28	0.69	3.23	5.51	2.75	5.98	8.26
C.Ex.16	11.81	0.00	0.69	12.50	0.69	5.80	5.51	2.75	8.55	8.26
C.Ex.17	9.12	0.00	1.22	10.35	1.22	0.00	9.03	1.22	1.22	10.26
C.Ex.18	4.74	0.00	1.22	5.96	1.22	0.00	9.03	1.22	1.22	10.26
Ex. 13 *	6.59	0.00	0.94	7.53	0.94	3.23	5.51	3.74	6.98	9.25
C.Ex.19	11.81	0.00	0.94	12.75	0.94	5.80	5.51	3.74	9.54	9.25
C.Ex.20	9.12	0.00	1.66	10.79	1.66	0.00	9.03	1.66	1.66	10.70
C.Ex.21	4.74	0.00	1.66	6.41	1.66	0.00	9.03	1.66	1.66	10.70

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not

form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP2001316137A [0003]
- JP2001316138A [0004]
- US20150354264A1 [0005]
- WO2016063007A1 [0006]
- EP1630344A1 [0007]
- WO2015150207A1 [0043]
- WO2015150403A1 [0043]
- WO2016091672A1 [0043]
- WO2016169823A1 [0043]
- WO2018001965A1 [0043]
- WO2011061208A1 [0054]

Patentkrav

1. Vakuumisolerende rudeenhed (10), der er forsynet med én infrarødreflekterende coating, med en længde L med 300 mm ≤ L ≤ 4000 mm og en bredde W med 300 mm ≤ W ≤ 1500 mm, og som omfatter:
a. en første glasrude (1) med en indvendig rudeflade (12) og en udvendig rudeflade (13) og som har en tykkelse Z_1 og bærer den infrarødreflekterende coating på den indvendige rudeflade, idet den coatede første glasrude har en energiabsorption EA_1, og
b. en anden glasrude (2) med en indvendig rudeflade (22) og en udvendig rudeflade (23) og med en tykkelse Z_2, hvor tykkelserne er målt i retningen vinkelret på planet P, idet den anden glasrude har en energiabsorption EA_2
c. et sæt diskrete afstandsstykker (3), der er placeret mellem den første og den anden glasrude, og som opretholder en afstand mellem den første og den anden glasrude og danner et net med en afstand λ, idet afstanden λ ligger mellem 10 mm og 35 mm
d. en hermetisk klæbende tætning (4), der forsegler afstanden mellem den første og den anden glasrude over en omkreds af denne
e. et indvendigt volumen V, der afgrænses af den første og den anden glasrude og sættet af diskrete afstandsstykker, og som lukkes af den hermetisk klæbende tætning, og hvori der er et vakuum med et absolut tryk på mindre end 0,1 mbar, og
f. hvor de indvendige rudeflader af den første og den anden glasrude vender mod det indvendige volumen V,
g. kendetegnet ved, at den første glasrude er tykkere end den anden glasrude ($Z_1 > Z_2$), ved, at $\Delta EA \leq 0{,}0033\ \Delta Z^2/mm^2 - 0{,}0468\ \Delta Z/mm + 0{,}7702$, hvor $\Delta EA = EA_1 - 2*EA_2$, ved, at $Z_1 \geq 5$ mm, $Z_2 \geq 3$ mm, og $\Delta Z = (Z_1 - Z_2) \geq 1$ mm, samt ved, at 10 mm ≤ λ ≤ 35 mm.

2. Vakuumisolerende rudeenhed ifølge krav 1, hvor Z_2 = 3 mm og 10 mm ≤ λ ≤ 25 mm, når følgende betingelse om den vægtede forskel af den første og den anden glasrudes energiabsorption er opfyldt: $\Delta EA \leq 0{,}0084\ \Delta Z^2/mm^2 - 0{,}1545\ \Delta Z/mm + 0{,}6966$, hvor $\Delta EA = EA_1 - 2*EA_2$, og 300 mm ≤L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm.

3. Vakuumisolerende rudeenhed ifølge krav 1, hvor Z_2 = 4 mm og 10 mm ≤ λ ≤ 25 mm og $\Delta EA \leq - 0{,}0214\ \Delta Z/mm + 0{,}5696$ og 300 mm ≤

L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm.

4. Vakuumisolerende rudeenhed ifølge krav 1, hvor Z_2 = 5 mm og 10 mm ≤ λ ≤ 35 mm og ΔEA ≤ 0,0033 $\Delta Z^2/mm^2$ - 0,0468 ΔZ/mm + 0,7434 og 300 mm ≤ L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm.

5. Vakuumisolerende rudeenhed ifølge krav 1, hvor Z_2 = 6 mm og 10 mm ≤ λ ≤ 35 mm og ΔEA ≤ 0,0033 $\Delta Z^2/mm^2$ - 0,0468 ΔZ/mm + 0,7702 og 300 mm ≤ L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm.

6. Vakuumisolerende rudeenhed ifølge krav 1, hvor Z_2 = 4 mm og 25 mm < λ ≤ 30 mm og ΔEA ≤ -0,0308 ΔZ/mm + 0,5294 og 300 mm ≤ L ≤ 3000 mm, 300 mm ≤ W ≤ 1500 mm.

7. Vakuumisolerende rude ifølge et hvilket som helst af de foregående krav, hvor den infrarødreflekterende coating omfatter et metalbaseret funktionelt lavemissionslag, der tilvejebringer en emissionseffekt på højst 0,04, fortrinsvis højst 0,02.

8. Vakuumisolerende rudeenhed ifølge et hvilket som helst af de foregående krav, hvor mindst én af de udvendige rudeflader (13; 23) af den første og den anden glasrude er lamineret til mindst én glasplade ved hjælp af mindst ét polymer-mellemlag, hvorved der dannes en lamineret enhed.

9. Vakuumisolerende rudeenhed ifølge et hvilket som helst af de foregående krav, hvor mindst én af de udvendige rudeflader (13; 23) af det første og det andet glas er koblet til en tredje glasrude langs periferien af den vakuumisolerende rudeenhed gennem et perifert afstandsstykke, hvorved der dannes et isolerende hulrum, der er forseglet med en perifer kanttætning.

10. Skillevæg, der afgrænser et udvendigt rum og et indvendigt rum, hvilken skillevæg omfatter en åbning, der er lukket med en vakuumisolerende rudeenhed ifølge et af de foregående krav, hvor den første glasrude vender mod det udvendige rum.

11. Anvendelse af en vakuumisoleret rudeenhed ifølge et hvilket som helst af kravene 1 til 9 til at lukke åbningen af en skillevæg, der afgrænser et udvendigt rum og et indvendigt rum, hvor den første glasrude vender mod det udvendige rum.

DRAWINGS

Drawing

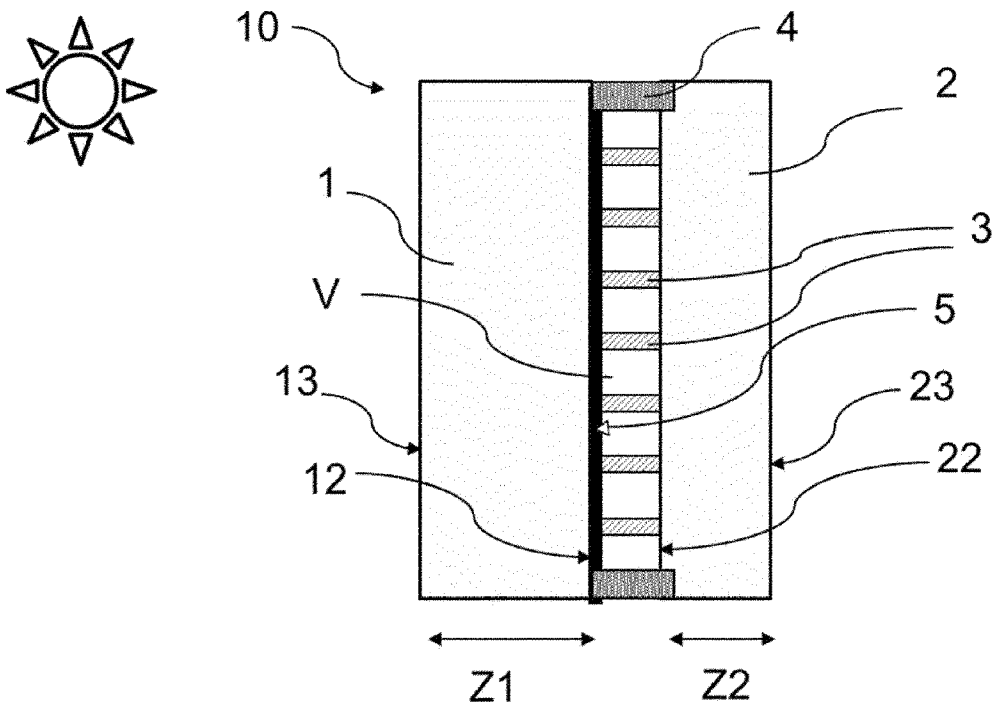

Figure 1