In a vacuum-insulated glass building component comprising first and second glass panes which are supported with respect to each other by spacers and are closed along their edges by a vacuum-tight edge connection so as to enclose between them a thin evacuated intermediate space, the edge connection is formed by first and second metal foil strips which are connected to the edge areas of the first and, respectively, second glass panes in a vacuum-tight manner and the areas of the first and second metal foil strips projecting beyond the edges of the respective glass panes are welded together to join the glass panes.
BACKGROUND OF THE INVENTION

[0001] The invention relates to a vacuum-insulated glass building element that is to a vacuum-insulated glass pane and also to other building components consisting of a combination of vacuum insulated glass including for example a solar module. The invention also resides in a method and an apparatus for the manufacture of such vacuum-insulated building elements.

[0002] A building element of the type with which the present invention is concerned comprises at least two glass panes or other areal glass structures with or without the inclusion of another areal body which are joined together with a thin evacuated space therebetween.

[0003] Vacuum-insulated glass as such is known. It differs from conventional insulated glass in that the space between the panes is evacuated whereas, in conventional insulated glass, it is filled with a noble gas. Furthermore, the space between the glass panes of vacuum insulated glass is substantially thinner than in normal insulated glass, that is, it has a thickness of only about 0.7 mm or less since, in vacuum insulated glass, there is no convection in the space between the individual glass panes. The two individual glass panes are supported with respect to each other by way of supports distributed over the glass surface in a grid-like pattern so that the ambient air pressure cannot press the panes together. At their circumference, they are joined by a vacuum-sealed edge connection.

[0004] In accordance with the known state of the art, vacuum insulated glass panels are manufactured in that spacers are placed in the predetermined grid-like pattern onto a first individual glass pane and fixed by cementing and the second individual glass pane is then placed on top. The top glass pane is provided at its edge with a bore including a sealed-in evacuation nipple which is fixed in position by glass solder or which is cemented and to which a suction hose with a vacuum pump can be connected. The two glass panes are then laser-welded along their edges under atmospheric conditions using glass solder. To this end, the top glass pane is dimensioned so as to be smaller than the bottom pane by several millimeters so that the edge of the top pane is recessed with respect to the edge of the bottom pane disposed below. In this way, the two glass panes can be laser-welded together using glass solder by a laser beam directed onto the arrangement from the top.

[0005] After the laser welding of the panes, the space between the panes is evacuated via the suction nipple. Evacuation is performed for about two hours or longer during which the glass composite is maintained at a temperature of about 400° C. to about 450° C. Only in this way, volatile materials, mainly water, which are adhering to the glass surfaces can be removed from the space between the glass panes and a vacuum of sufficient quality can be established.

[0006] This long period of evacuation at high temperature does not only result in an expensive manufacturing process for the vacuum glass but also detrimentally affects the product quality. Usually a reflective surface layer is vapor-deposited on the glass surfaces facing the intermediate space if the glass panel is to be used as a window panel in order to reflect heat radiation for improved heat protection. However, because of the high temperatures used during evacuation over a long period, highly effective coatings with a low emission degree (soft coatings) cannot be used. As a result, conventional vacuum glass panels of the two-pane construction can reach heat insulation values comparable only with good conventional insulated glass panels.

[0007] In addition, a high-temperature of about 450° C. maintained during evacuation over a period of about 2 hours results in the de-tempering of single pane safety glass so that it substantially loses its safety glass property.

[0008] From EP 0 771 313, it is known to perform the laser welding of the two individual panes of a vacuum insulated panel, which are separated by an intermediate space and held in spaced relationship by spacers arranged in the intermediate space, in a vacuum chamber, so that the subsequent evacuation of the intermediate space is no longer necessary. This printed publication however recommends that during the welding of their edges within the vacuum chamber the whole individual glass panes are heated to, or slightly above, their annealing temperature in order to avoid tension cracks. As a result, the problem that none of the effective coatings for achieving low degrees of emission can be used and safety glass single panes are also in this case de-tempered.

[0009] However, whether the two single panes are welded together in an atmospheric chamber with subsequent evacuation of the intermediate space or in a vacuum chamber, in connection with conventional vacuum-insulated glass panels, there is always the substantial problem that the composite rigid glass panel formed by the welding of the individual panes will not withstand the stresses to which it is subjected during use: The two individual panes separated by the evacuated intermediate space during use assume different temperatures since the glass pane facing the room is warm and the pane facing the outside air is cooler, wherein the use of a coating for the reduction of heat losses by radiation increases that temperature difference substantially. The temperature difference between the individual panes generated in this way results in substantial mechanical tensions. This means that conventional vacuum-insulated glass panels are limited in size to certain maximum formats. Such vacuum-panels permit only a certain relatively small window size. In addition, no reliable information is available concerning vacuum insulation glass panels used under conditions where they are subjected to high mechanical tensions.

[0010] It is therefore the object of the present invention to provide vacuum-insulated glass building elements which reach heat insulating values which are substantially better than those obtained by good double pane insulation glass, but which, on the other hand, require manufacturing expenditures which are at least not essentially higher than the manufacturing expenditures for a good double pane insulating glass panel, and which can accommodate mechanical tensions occurring between the two individual panes by temperature differences therebetween substantially better than conventional vacuum insulated glass panels and which therefore promise a reliable long lifespan.

SUMMARY OF THE INVENTION

[0011] In a vacuum-insulated glass building component comprising first and second glass panes which are supported with respect to each other by spacers and are closed along their edges by a vacuum-tight edge connection so as to enclose between them a thin evacuated intermediate space, the edge connection is formed by first and second metal foil strips which are connected to the edge areas of the first and,
respectively, second glass panes in a vacuum tight manner and the areas of the first and second metal foil strips projecting beyond the edges of the respective glass panes are welded together to join the glass panes.

[0012] A particularly advantageous method for the manufacture of the vacuum insulated glass building element according to the invention and a respective suitable and advantageous arrangement therefore are also part of the present invention.

[0013] Since in the arrangement according to the present invention, the two individual panes are provided at their edges each with a metal foil strip and the metal foil strips of the two individual panes are welded together, a durably vacuum-tight connection between the individual panes is established which however is not rigid but which can accommodate relative thermal expansions of the two individual panes. Such expansion movements are accommodated, without tensions, by the metal foil strips which are interconnected by welding. In this way, a vacuum-tight non-rigid edge connection of the two individual panes of the vacuum-insulated glass building element is provided which, during use, remains essentially free from mechanical stresses also when the individual panes are subjected to high temperature differences. For such an arrangement also a reliable long life for the edge connection can be considered to be no problem and the formation of cracks as a result of thermal effects on the panes which could lead to a loss of the vacuum between the panes is avoided.

[0014] As essential advantages of the arrangement according to the invention, not only a predictably long life of the vacuum-insulated glass panel according to the invention is obtained in this way, but also a limitation of the panel to small formats is eliminated as it exists in connection with the rigid edge connections of conventional vacuum-insulated glass panels obtained by glass-welding of the two individual panes.

[0015] The glass panes can be joined along their edges with the metal foil strips either with the aid of glass solder by melt welding or by "cold" welding by means of ultrasound. In this connection, ultrasound welding is preferred since it causes no thermal stresses. In addition, the ultrasound welding procedure is simpler than the melt welding with glass solder.

[0016] This results in a further substantial advantage of the vacuum-insulated glass building element according to the invention in that the ultrasound welding causes no thermal stresses, and does not detrimentally affect the glass panes. If one of the glass panes consists of safety glass, the glass pane is not de-tempered by the effects of heat and the safety glass structure remains unchanged. In addition, highly effective low-emission coatings can be used which are not affected by the manufacture of the edge joint so that very high heat insulation values are obtained for the vacuum insulated building element.

[0017] The manufacture of the edge connection is possible by a relatively simple process. The ultrasound welding (or also the glass solder welding) of the glass pane edges with the metal strip can occur under atmospheric conditions. The subsequent welding of the metal foil strip areas which project from the glass pane edges and are connected to the glass pane edges can be performed in a vacuum chamber by laser welding so that subsequent evacuation of the space between the glass panes is not necessary. Subsequently, outside the vacuum chamber, the welded excess metal foil strip areas can be bent over toward one or the other side and the edge joint is completed.

[0018] The metal foil strips are preferably arranged at the sides of the glass panes which face each other. Before the welding of the metal foil strips in the vacuum chamber expeditiously a getter material is applied to one side of the metal strips which, with respect to the welding seam to be formed, faces the interior of the space between the panes for the absorption of moisture molecules possibly still present in the space between the glass panes.

[0019] An exemplary embodiment of a vacuum-insulated glass building element according to the invention and a method and an apparatus for the manufacture thereof will be described below in greater detail with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 shows in cross-section an edge area of a vacuum insulated glass building element according to the invention.

[0021] FIG. 2 shows the two individual glass panes of the building element with metal foil strips attached thereto before the assembly thereof.

[0022] FIG. 3 shows the assembled individual glass panes after the welding of the projecting areas of the metal foil strips.

[0023] FIG. 4 shows schematically a cross-section of the edge area of a vacuum insulated glass building element according to the invention forming a solar module.

[0024] FIG. 5 shows a variation of the arrangement according to FIG. 1.

[0025] FIG. 6 shows schematically a diagram which clarifies the manufacturing procedure of vacuum insulated building elements according to the invention.

[0026] FIG. 7 shows schematically the cleaning step of the method according to the invention in a first vacuum chamber, and

[0027] FIG. 8 shows schematically the laser welding stage of the method in a second vacuum chamber.

DESCRIPTION OF PARTICULAR EMBODIMENTS OF THE INVENTION

[0028] FIG. 1 shows, in cross-section, the edge area of a vacuum insulated glass building element in the form of a vacuum insulated glass panel with a finished edge connection. The arrangement comprises a cover pane 1 (outer pane) and a bottom pane 2 (inner pane), which are separated from each other by an intermediate pane space 3. In the intermediate pane space 3, there is a vacuum. The two panes 1 and 2 are held at a predetermined distance from each other by spacers 4 which are fixed to the bottom pane 2 in a grid-like pattern for example by cementing and on which the cover pane 1 is supported. The spacers may be small glass cylinders as shown but they may also be in the form of balls and they may also consist of metal.

[0029] The cover pane 1 and the bottom pane 2 each may have a thickness of 4 mm and the intermediate space 3 may have a thickness which is preferably in the range of 0.7 mm to 1 mm.

[0030] At the edge of each of the two panes 1, 2, a metal foil strip 5 is attached in a vacuum-tight manner. Preferably, the metal foil strips 5 are attached at the sides of the two panes 1, 2 facing the intermediate space 3.

[0031] The metal foil strips 5 may be connected to the respective panes either by welding by means of a glass solder,
preferably however by ultrasound welding. The ultrasound welding occurs with the interposition of a thin aluminum foil strip 6 between the respective metal foil strip 5 and the glass surface, wherein the aluminum is tightly joined to the glass surface and also to the other metal of which the metal foil 5 consists, preferably stainless steel. The areas of the metal foil strip 5 which are attached to the two panes and which project over the glass pane edges are compressed and welded together preferably by laser welding. Herein, a getter material 8 is arranged inward of the welding seam 7 between the metal foil strips 5 that is still within the intermediate space between the panes which getter material has been applied to the lower metal foil strip before the welding. The welded projecting area of the metal foil strips 5 is bent onto the edge surface of the lower pane 2. The getter material does not need to be arranged between the panes as shown (where with a thin intermediate space, there is generally no space), but it may be disposed in the bent over area of the welded metal foil strips.

Fig. 2 and 3 show pre-stages of the finished edge connection of the vacuum insulated glass building element according to Fig. 1.

Fig. 2 shows the two still individual panes, that is the cover pane 1 and the bottom pane 2, each with the metal foil strip 5 welded to the respective edge areas. On the bottom pane 2, furthermore, the spacers 4 are already in place.

Fig. 3 shows the joined arrangement of the top pane 1 and the bottom pane 2 with the metal foil strips 5 welded thereto, wherein the areas of the metal foil strips 5 projecting beyond the pane edges are welded together by a welding seam 7. By bending the welded projecting areas of the metal foil strips 5 onto the edge surfaces of the bottom pane 2, the edge connection is completed as it is shown in Fig. 1.

Fig. 4 shows an arrangement as it is shown in Fig. 1, wherein however the bottom pane 2 is combined with an additional module (or is formed as such), here with a solar photo voltaic module 10. Herein, the solar photo voltaic module 10 forms with the bottom pane 2, a compound arrangement. If as shown in the embodiment of Fig. 4, the additional module consists fully or partially of glass, the metal foil strips may also be attached as shown in Fig. 4 or, like in the basic embodiment according to Fig. 1, to the side walls of the cover pane 1 and the bottom pane 2 or, respectively, the additional module which faces the intermediate space 3 between the panes. However, if the additional module is not suitable for a vacuum-tight attachment of the respective metal foil strips 5, the arrangement as shown in Fig. 5 and described below may be selected. Generally, however the particular pane, in this case, the bottom pane will form the additional module by integration of a particular function.

Fig. 5 shows a modified embodiment of the vacuum sealed edge jointure of the arrangement according to Fig. 1. It differs from the embodiment of Fig. 1 in that the metal foil strip 5 is not attached to the facing surfaces of the individual glass panes 1 and 2, but to their outer surfaces. This embodiment according to Fig. 5 is possible and equally good with respect to the quality of the vacuum sealed edge connection as the embodiment of Fig. 1, but in that case, the outer surfaces of the finished vacuum insulated glass element is not smooth fully to the outer edge thereof but has a raised edge area because of the metal foil strips 5 extending along the edge. This could be objectionable for some applications, which is why this embodiment appears to be less preferred.

The preferred material for the edge foil strips 5 in all embodiments is stainless steel.

As apparent from Figs. 1 to 3, the outer gap between the individual panes 1 and 2 and the metal foil strips 5 attached thereto can be sealed in the area between the respective individual outer pane edges and the connection or, respectively, weld areas to the glass pane surface by a filler material 9. This filler material has two functions. It ensures a long-term vacuum sealing by protecting the weld between the metal foil strips and the glass from outside influences and it also reduces mechanical stresses. Furthermore, it protects the pane edges from mechanical stresses during the bending over of the welded metal foil strips.

Fig. 6 shows the procedure of a preferred manufacturing method for the above-described vacuum insulated building elements in a schematic block diagram.

In a first method step A, the two individual glass panes are prepared under atmospheric conditions. This includes the connection of the metal foil strips to the individual glass panes and the attachment of the spacers to the bottom pane as well as the application of the getter material, if used.

The second method step B resides in the cleaning of the two individual panes, particularly the removal of water molecules from the pane surfaces. Special coatings of the panes bind water molecules which are difficult to remove therefrom. Conventionally, this requires heating to high temperatures over an extended period, which, however, is undesirable since high temperatures, particularly when effective over an extended period, destroy high quality coatings for reducing the degree of emission (so-called low E-layers) and also the glass structure, for example, that of safety glass, as mentioned already earlier. This cleaning step is performed with the method according to the invention, without temperature effects, by ion scattering, wherein the ions absorb the moisture molecules and carry them away, or by plasma cleaning which is also called plasma etching. This method step is performed in a first vacuum chamber under constant suction in order to remove any moisture released from the pane surfaces. It is very important herein that, in each case, both sides of each individual pane are cleaned that the moisture is removed also from that side which does not delimit the evacuated space between the panes. This is necessary because any moisture input into the high vacuum chamber, in which the laser welding of the metal foil strips takes place must be carefully avoided since otherwise the high vacuum is detrimentally affected.

Fig. 7 shows schematically the cleaning stage according to the method step B in the first vacuum chamber by ion scattering, or, respectively, vacuum etching on both sides of the plate wherein the ion scattering or, respectively, the vacuum etching occurs along a line over the whole width of the pane while the glass pane is moved on a transport means through the first vacuum chamber.

The third method step C is the laser welding of the metal foil strips in a second vacuum chamber 13, which is schematically shown in Fig. 8 in a sectional view. Herein, first, the lower pane 2 is introduced into the vacuum chamber 13 and subsequently the upper pane is introduced and placed onto the lower pane. The vacuum chamber 13 is provided at its topside along all four corner areas with a, in each case, line-like window 14 which, of course, is interrupted by bridge areas of supporting material as necessary for the integrity of the top wall of the vacuum chamber 13. A laser cannon 15 is arranged on the outside, that is, above the vacuum chamber 13 and movable along the window 14 in order to direct the laser
beam through the window 14 onto the metal foil strips to be welded. The pane arrangement is disposed within the vacuum chamber 13 on a corresponding carriage which is movable in the plane of the pane since, because of the design-based interruptions of the window 14, a certain movability of the pane arrangement is necessary in addition to the movability of the laser cannon.

[0044] This arrangement has essential advantages. Since the laser cannon 15 is arranged outside the vacuum chamber 13 and is movable along the window 14, no mirror or any other optical elements or mechanisms are needed within the vacuum chamber so that the vacuum chamber can have a minimum volume. The required length and width of the vacuum chamber is based on the dimensions of the largest pane arrangement to be welded therein and the height of the vacuum chamber is determined only by the thickness of the pane arrangement and the height required for the carriage by which it is supported. Because of the movability of the laser cannon 15 also complicated laser-optical equipment, particularly mirror mechanisms, are not needed outside the vacuum chamber either, which simplifies the arrangement.

[0045] In the last method step D, after the removal of the pane arrangement with the welded metal foil strips out of the second vacuum chamber 13, a final treatment of the edge areas is performed, that is, the application of a filler material 9 and the bending of the laser-welded projecting areas of the metal foil strips, and, if desired, the installation of a protective cover on the finished edge connection.

What is claimed is:

1. A vacuum insulated glass building element, comprising a first glass pane (1) and a second glass pane (2), spacer elements (4) arranged between the glass panes (1, 2) so as to support the glass panes (1, 2) in spaced relationship relative to each other, first and second metal foil strips (5) connected to the edges of the respective first and second glass panes (1, 2) in a vacuum-tight manner, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges.

2. A vacuum insulated glass building element according to claim 1, wherein the metal foil strip (5) is connected to the respective glass panes (1, 2) by ultrasound welding wherein, between the respective metal foil strip (5) and the respective glass pane (1, 2), a thin aluminum foil strip (6) is interposed which, by the ultrasound welding, is on one side connected to the glass surface in a vacuum-tight manner and, on the other side to the metal foil strip (5) in a vacuum-tight manner.

3. A vacuum insulated glass building element according to claim 1, wherein the metal foil strips (5) are connected to the respective glass panes (1, 2) by welding via glass solder.

4. A vacuum insulated glass building element according to claim 1, wherein a getter material (8) is applied to at least one of the metal foil strips (5), so that, after the welding of the metal foil strips, it is disposed on the side of the evacuated intermediate space (3) between the two glass panes (1, 2) of the welding seam (7) of the metal foil strips (5).

5. A vacuum insulated glass building element according to claim 1, wherein the metal foil strips (5) are connected to the two glass panes (1, 2) at the sides which face each other.

6. A vacuum insulated glass building element according to one of claims 1, wherein the metal foil strips (5) consist of stainless steel.

7. A vacuum insulated glass building element according to claim 1, wherein gap spaces between the metal foil strip (5) and the respective glass surfaces outside the respective metal foil strip-glass surface weld areas are filled with a filler material (9).

8. A vacuum insulated glass building element according to claim 1, wherein one of the first and the second glass pane is combined with an additional element, that is, one of a solar module, a photovoltaic module and another element or is in the form of such an element.

9. A method for the manufacture of a vacuum insulated glass building element, comprising a first glass pane (1) and a second glass pane (2), spacer elements (4) arranged between the glass panes (1, 2) so as to support the glass panes (1, 2) in spaced relationship relative to each other, first and second metal foil strips (5) connected to the edges of the respective first and second glass panes (1, 2) in a vacuum-tight manner, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges.

10. The method according to claim 9, wherein, before their introduction into the vacuum chamber (13) in which the metal foil strips (5) are welded together, the two glass-panes (1, 2) are cleaned in another vacuum chamber (12) on both sides by one of ion sputtering or plasma etching for the removal of moisture.

11. An apparatus for performing the method for the manufacture of a vacuum insulated glass building element, comprising a first glass pane (1) and a second glass pane (2), spacer elements (4) arranged between the glass panes (1, 2) so as to support the glass panes (1, 2) in spaced relationship relative to each other, first and second metal foil strips (5) connected to the edges of the respective first and second glass panes (1, 2) in a vacuum-tight manner, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges, said first and second metal foil strips (5) having edge areas extending beyond the circumferential edges of the respective glass panes (1, 2) to which they are welded and being joined at their projecting edges.
are transparent to laser radiation, a laser cannon (15) which is movable along the windows (14), and a carriage arranged in the vacuum chamber (13) for the limited movement of the pane arrangement formed by the glass panes (1, 2) disposed on top of one another in the vacuum chamber (13) on the carriage.

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