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(54) **STRUCTURE OF THERMAL INSULATION OF GLAZING**

WÄRMEDÄMMUNGSSTRUKTUR FÜR EINE VERGLASUNG

STRUCTURE D'ISOLATION THERMIQUE DE VITRAGE

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Description

Field of the invention

[0001] The object of the invention is the structure of thermal insulation of glazing, especially windows with insulated glass consisting of two transparent, rigid panes with a transparent gaseous medium and invisible for the user transparent elements between them, in the form of nanofibrous tulle screens that are stretched, parallel to the panes, and invisible to the unaided eye.

This is a completely transparent thermal insulation, i.e. not diffusing, not refracting and not reflecting visible radiation, and also, not distorting the view through the glazing.

Background of the invention

[0002] Several well known and commonly used heat insulating materials owe their high heat resistance, in some cases exceeding the resistance of pure, free gas to their specific fine-pore structure, which encloses and separates fundamental, small portions of such gas (usually air) from each other. Since gas is a far greater insulator when it is being held motionless, such division of volume is intended to reduce any movements of a fluid medium, making the development of thermal convection difficult. Traditional thermal insulating pore-structured materials have, however, several disadvantages. In thicker layers they are opaque which rejects them from many applications. The reason for this occurrence is the contrast between the optical properties of the gas medium, which fills the pores and the polymer frame with the light diffraction coefficient, which is significantly greater than the gas. Even though the polymer is completely transparent, as a result of repeated reflection and refraction of rays on numerous porewalls located on ray's way, light cannot get through the insulation.

Attempts were made to design a thermal insulating material with a structure of empty spaces in it, feasible for a wide range of applications, i.e. one that would have high heat resistance and would be transparent at the same time. Three different directions of research have been followed.

First of all, the size of the elements of the frame of porous materials is being attempted to be reduced so that their size is far smaller than the length of a visible light wave. This resulted in the invention of cutting-edge thermal insulating material - aerogel. Aerogel is a fine porous material from an amorphous silica or polymer, with size of pores in the range of 20 nanometers, fractally limited by an organized network of chain-like filaments (fibers) and membranes of thickness of about 2 nanometers for the lowest-order structures.

[0003] Aerogel exhibits a number of favorable properties: very high thermal resistance, low specific weight, near-zero reflection of light from the surface. What is important, it is translucent, in thin layers, almost completely

transparent. In thicker layers, however, it scatters light, similarly to tobacco smoke, and thus, sometimes it is called frozen smoke. Number of commercially available glazing structures with aerogel plates have been developed (e.g. Aspen Systems Inc., Airglass)

[0004] The main obstacles for using these kinds of systems are very high price of aerogel, its sophisticated technology of production, extremely high fragility that makes shipping and handling difficult, and limited visibility. Light layer of fog and its bluish or yellowish tone, which is visible especially in windows directed towards south, where the sun strikes the window greatest, eliminates this material for applications where the quality of view plays a significant role - exhibition windows, sight-windows, etc.

[0005] Secondly, attempts were made to produce a highly organized structure with patterned macroscopic geometry similar to a capillary plate, honey strip or a structure of parallel, contactless flat partitions (windows with several window panels in it, several compartments or one, two or even three sheets of Mylar type foil, covered with lowemissive layer as in Southwall Technologies'- Heat Mirror® technology.

[0006] Optimal separation between window panels was determined experimentally, and depending on the gas used it is oscillating between 5 and 16 mm. This space is a compromise between suppressing thermal convection, obtained by reducing interspaces and rising conductive heat transfer through decreasing gas layer thickness. Making the separation between window panels greater does not necessarily increase thermal resistance of the glazing. As a matter of fact, it does quite the opposite.

In order to increase thermal resistance of the glazing with the space between the window panels exceeding 16 mm it is necessarily to introduce additional, possibly transparent elements. Commercially available fillings of such type include capillary plates, fine-ducted plates or honey strip plates. Their most common orientation is perpendicular to the surface of the window panel (WO 94/02313, DE 19 815 969, US 5 092 101). Sometimes they are slanted with respect to the surface of the window panel (EP 1 072 752, DE 41 032 47). Other commercially available fillings include coarse-celled foamed PMMA (US 4 443 391) and structures with several window panels or sheets of film. (US 4 433 712; explained in Elmahdy & Cornick, 1990, "Emerging window technology" Construction Canada, 32 (1) p, 46-48).

[0007] Such glazing is a compromise solution. It is not entirely satisfactory in both thermal and optical fields. Massive polymer or glass frame and/or large dimensions of fundamental spaces and ducts result in poor thermal insulation properties - there are numerous massive heat leakage bridges in the material and the convection is developing in the macroscopic spaces filled by gas. The heat transfer coefficient (λ) for this type of plates is about 0.07-0.1 W / (m K). It is similar as in multilayer insulated glass units. However, with several window panels or equipped with additional sheets of polymer film,

which is parallel to window panels, they are expensive and heavy. Such solution also results in absorption of large amount of visible radiation and the repeated reflection disturbs the visual quality of the view.

Interference of the rays on the surface of all the additional elements worsens the quality of vision through the glazing. The structure absorbs and scatters substantial amount of light that falls on the insulation. For that reason, usage of such type of glazings is usually limited to less optically demanding sheds, greenhouses, sun collectors and similar.

[0008] Interestingly enough, fibrous or meshlike structures, which are optically profitable and commonly used for different purposes, have not been proposed so far to improve thermal insulation of insulated glass units. Such structures are installed in windows as a sun protecting meshlike window-blinds.

[0009] An invisible nanofibrous, openwork thermal insulation structure that is proposed in this application, from the point of view of settling two contradictory constraints - mechanical and optical, is similar to another macroscopic engineering structure - a mosquito screen. Mosquito screens are currently being optimized by a number of producers in order to make them less visible or even invisible (compare Lauren Hunter's review "A fine Mesh. Low-visibility window screens let the sun shine". Remodeling Magazine, November 2008). Several patent-protected solutions are used in the market products (e.g. US 6 763 875, "Reduced visibility insect screen" by Andersen Corp.). Other virtually 'invisible' mosquito screens that are present on the market include polyester GORE™ inLighten, a product of Harvey Building Products and other mosquito screens made of glass fibre offered by chinese producers.

[0010] A microscopic fibrous structure that is even more scale-similar to the one proposed in this application was compiled by the company Karl Mayer. A new textile product, "Newconer" which is produced by the company STING, is a very thin polyester material. It is also described as a filtrating mesh. Such a net, when installed in windows is transparent enough to freely observe the environment, lets the sufficient amount of light into the room, and protects against the dust or pollens through (Grebowski J., "Nowości w dziewiarstwie". Przegląd WOS 3/2009). Transparent, woven and metallized electromagnetic screens (e.g. net VeilShield® Responsible Textiles Lab's advertised as an almost invisible) are mounted in the window openings in order to protect the premises from radio waves and microwaves, which are harmful and interfere with the work of electronic equipment.

[0011] Spider webs are also worth mentioning. Because of the evolutionary pressure, these structures are completely optimized in terms of mechanical and optical properties. These nanofibrous structures are spanned by a number of spiders from very flexible, more resistant to tension than steel or UHMWPE fibers, sub-micron 'threads' (even 10 nanometers in thickness for some spe-

cies). Spider webs, which are often stretched out in window openings, are dry and clean right after they are spanned. They are almost invisible for insects as well as for human eye (even those greater than a micrometer in diameter).

[0012] Similarly directed attempt was made in order to overcome poor optical properties of multilayered structures such as Heat-Mirror. The source of problem in this case is a very high coefficient of absorption and reflection of low-emissive coatings. Because of that, the overall transmission of visible light radiation through the glazing is relatively low. It was proposed to replace a solid, continuous and conducting layer with a netlike or fibrous structures made of conducting nanowires. Such nanowires would be a mirror for mid infrared. For such not continuous layers made of e.g. nanowires of conducting oxides, but spread over a solid foundation (Ravenbrick, "Low-emissivity window films and coatings incorporating nanoscale wire grids" US Patent Application 20090128893 or described in John C. C. Fan's, Frank J. Bachner's, and R. A. Murphy's, 1976 "Thin-film conducting microgrids as transparent heat mirrors" Appl. Phys. Lett. 28, 440), the reflectivity and absorption of the visible light still remains high.

The main reason for that is the reflection and absorption of light, which also occurs in the foundation of the mirror, i.e. on the entire surface of the solid plate, its inside and on its opposite surface.

[0013] It was proposed that flat polymer or glass panes would be included in transparent glazing or reflective plates. Such panels would create a structure of equilateral spaces, oriented similarly to the window-blinds (EP 1 072 752). In some instances of the invention, the angle of the panels can be adjusted (US 4 245 435). Such division of space between window panels is significant in terms of heat resistance of the glazing. In these designs, however, the spaces are big and almost isometric in cross-section. Also, the transparent (or reflective in other designs) partitions, which are limiting the spaces and are suspended on the flexible connectors, have to be rigid and thus heavy. Including mentioned transparent or reflective "window-blinds" is not very significant in terms of reducing heat resistance of the windows. It does, however worsen the visibility.

Third direction was concerned with removing air from the gap between the window panels. This would result in creation of a layer of vacuum.

Vacuous glazing pieces (US 4 928 444, US 6 291 036 and the publications cited in there, WO 01/61135), are being tested as functional prototypes by a few window manufacturers in the world. In the Saint Gobain's labs and on the Ulster University in Belfast such glazing types are being commercialized. Another research conducted by R. E. Collins from the University of Sydney successfully commercialized window panels SPACIA, a property of "Nippon Sheet Glass Ltd.", which is still developing this technology in their own laboratories (US 6 105 336). Similarly, "Guardian Industries Corp." is conducting re-

search on commercialization of vacuum windows and has a patent regarding this technology (US 6 291 036, US 6 541 084). Vacuum windows seem to be most promising from all proposed technologies regarding development of transparent thermal insulations.

[0014] The advantage of vacuum glazing and windows is their decent quality of view, low and fairly high thermal resistance. It is not, however, an ideal solution for a number of reasons. Necessity to fabricate and maintain high quality vacuum for many years requires use of a perfectly hermetic seal that would be impenetrable for defunding gases throughout the entire length of the edge of the glazing. Gaskets made of indium, its alloys, or glass welds that were initially used for this type of glazing have poor thermal properties and serve as heat leakage bridges. Such heat leakage bridge is a substantial source of losses. An attempt to solve this problem is to manufacture the edge of the window panel (e.g. US 6 291 036), as foamed, flexible gaskets with spacers that would control the distance between the window panels.

[0015] Atmospheric pressure (100kN/mkw) requires a placement of some structure of supports between the window panels. Without any support the window would simply implode. Usually they are placed according to a regular pattern (SPACIA) or randomly (US 4 786 344) and have shapes of columns, cylinders or spheres. They are usually made of glass, rarely of metal or monocrystals (WO 01/61135). A Gardian company's patent that was mentioned before, proposed spacers made of polymers. To some extent they worsen the visual aspect of the window, but most importantly they form a structure of heat leakage bridges. Moreover, the effect of condensation occurs on the surface of the window panel around the supports in supersaturated conditions. This worsens the quality of view through the window. The overall heat transfer coefficient of a VIG is measured to be equal to $U \sim 0.7$ and the measurement is taken at the center of a window panel. Such value of U is very close to the overall heat transfer coefficient of a triple glazing window of standard construction filled with xenon. Because of the supports that must be used in VIGs, however, the actual overall heat transfer coefficient of the entire window is significantly higher than the one measured at the center of the window panel.

[0016] A bundle of solutions proposed in the patent application (PTC/PL03/00028, published as WO 03/104599 A1) "A system of gaseous thermal insulation, especially of insulated glass units" is an attempt to satisfy both contradictory conditions, great optical characteristics and a high thermal insulation.

[0017] This invention solves the problem of placing an invisible blocking system into a space, filled with a transparent, colorless gas, between the transparent partitions, especially window panels. Such blocking system prevents the development of thermal convection in the medium or gives the entire structure geometry that blocks thermal convection.

[0018] Gaseous thermal insulation structure, in the cit-

ed solution has an inner thermal convection blocking arrangement that consists of at least one chamber, separated by paralleled transparent walls placed between the outer window panels angled with respect to the horizontal. The longer side of the bottom edge of a chamber is sealed to the colder window pane - placed in the lower temperature area. The upper edge is sealed to the warmer window pane, where the temperature is higher. Yet another variant would be to introduce a periscope window construction, where the convection blocking occurs more stably. In this case a density stratification of the gas that fills a hermetic window chamber consisting of mirrors angled by 45 degrees takes place.

This solution, however, has some disadvantages linked with the necessity to change the orientation of the chamber. The condition is that the orientation of chamber has to be changed with respect to the colder or warmer window panel, according to the desired function - improvement of thermal effectiveness or protection between high temperature amplitudes of short time (e.g. day to night temperature change).

Disclosure of the invention

[0019] The object of the invention is to introduce a new generation thermal insulation glazings of an extreme, so far unachievable thermal and optical properties at once. ($R > 20$ $U < 0.05$ and $> 70\%$ visible sunlight transmission). These properties enable realization of passive house conditions, enjoying comfort of a regular window of classic construction at the same time, without season changes of the glazing..

[0020] Structure of thermal insulation of glazing refers to two-compartment insulation glass, mounted in a vertical position, consisting of two outer transparent panes of glass, between which there is a transparent gas medium and invisible transparent, positioned in parallel elements.

The structure according the invention has the transparent partitions which take the form of pre-stressed tulle screens of nanofibers with an openwork design, consisting of at least two of the following three layers of tulle: (i) a frame carrier of mechanically strong, flexible or textured nanofibers, (ii) a conductive layer of nanofibers or nanowires stretched over a frame carrier, and (iii) a covering and densifying veil made of nanofibers, 5-25 nanometers in diameter.

The distance between the screens depends on the type of gas used, and in the case of standard glazing thickness of 16 to 36 millimeters, is 2 to 3 millimeters for xenon and sulfur hexafluoride, 3 to 4 millimeters for krypton, 4 to 5 millimeters of dry argon, and for box-type glazing, which is over 15 cm thick, the distance between the various partitions in the package will be in the range of 4 to 6 millimeters for xenon and sulfur hexafluoride, 6 to 8 millimeters for krypton and 12-16 millimeters of dry argon and dry air.

[0021] The two-compartment glazing is mounted in a

position inclined at 30-60 degrees, preferably 45 degrees, while the bottom pane should come into contact with the lower temperature zone and the upper pane with a zone of higher temperatures.

[0022] The glazing of thickness exceeding 15 centimeters is made as a hermetic insulation glass with a frame made of rigid polymer foam with stainless steel corrugated foil insertion (inox), and fitted with an external volume and pressure changes compensation system in the form of a bellow, preferably of stainless steel, connected to the space between insulating glass panes with a wire.

[0023] The frame carrier of the screen is in a form of a single, textured nanofibers or bands (*roving*) of textured nanofibers, 20-100 nanometers in diameter, transparent in visible light, preferably coated with an antireflective layer of *moth-eye* type or dielectric.

[0024] The conductive layer of nanofibers is in a form of an openwork conductive nanostructure of metal (preferably Ag or Au), metallized with dielectric core or of oxide (ITO, doped ZnO), possibly with carbon nanofibers (nanotube), optionally metallized, with a mesh pattern of 300- 1000 nanometers in size, optionally, ring, square or hexagonal (*chicken wire*), with conductive nanofibers or nanowires, preferably covered with an antireflective layer of *moth-eye* type or dielectric.

[0025] The covering and densificating veil is made of nanofibers is of 5-25 nanometers in diameter, preferably porous and transparent in visible light.

[0026] The covering and densificating veil is provided with an additional layer of gluing and sealing nanomembrane or inorganic polymer with a thickness of 5-10 nanometers that is transparent and invisible as a result of destructive interference.

[0027] The structure according the invention is completely transparent thermal insulation, i.e. not diffusing, not refracting and not reflecting visible radiation, and also, not distorting the view through the glazing. Such type of insulation can find its usage especially in building industry in structures of which task is to let the day light through to the room and also to observe the building's surroundings: windows, greenhouses, venues, production halls, elevations etc. Such insulations can also find their usage in other industries and the production of science-research devices in different kinds of sight-glasses, inspection openings, ovens, cryogenic devices etc.

Brief description of the drawings

[0028] The solution according to the invention is presented in the embodiments on the drawings in which individual figures show:

Figure 1 - glazing with internal package of tulle nanofibrous screens that are parallel to the glass panes - an illustrative cross-section view of the insulation glass chamber,

Figure 2 - glazing with internal package of tulle nanofibrous screens that are parallel to the glass

panes; insulation glass system is installed in inclined position,

Figure 3 A - a cross-section through the glazing with a package of tulle screens, B - three-layer structure of tulle, C, D, E - selected geometric and material variants of tulle layers of nanofibers or conductive nanowires (a mirror for infrared): C - connected nanorings, D - square meshes, E - hexagonal mesh, F-retaining frame, a sample implementation of a variant with square mesh arrangement.

G,H,I - illustrative, sample geometric and material variants of systems that build the layer of elastic and stretched frame of the screen: G - band of spiral-sinusoidal carbon nanotubes, H - elastic bands of natural spider thread, an equivalent of *stretch* yarn (*Spandex*® or *Lycra*®), I - magnification of a single, spirally twisted, helycoidal carbon nanotube, J - an illustrative nanofibrous veil structure of low surface density, covering and sealing the entire tulle screen.

Figure 4 - A - construction of compound glazing of bold hermetic insulating glass type with external compensation, B - detail of cross-section of a rigid hermetic frame of insulating glass chamber with stainless steel corrugated foil insertion, submerged in a rigid polymer foam, C - installation with a bellow of stainless steel and a valve to compensate for changes in the volume of gas in the insulating glass chamber under the influence of changes in temperature and atmospheric pressure,

Figure 5 - thick insulating glass, with a package of stretched screens of tulle with thickness equal to the thickness of the wall,

Figure 6 - insulating glass, with a package of screens of increased thickness, extreme option - embedding the insulating glass into double glazed façade,

Figure 7 - glazing inclined at an angle of 45 degrees, with embedding the inclined insulating glass into double glazed façade.

[0029] The numbers indicate:

- 1 - outer glass panes,
- 2 - low-emissive coating,
- 3 - a package of tulle nanofibrous membranes;

Embodiments of the invention

[0030] Transparent and invisible partitions of an openwork design, made of nanofibrous, single or multilayer tulle, placed on the present patent application (unlike the stretched, solid polyester membrane packages Heat-Mirror® of company Southwall Technologies) are oriented parallel to the panes and stretched over rigid but thermally insulating frames, placed as a package in the window frame. Although in theory, vertical layout is not as effective for blocking convection as inclined one, it eliminates most of the problems connected with mounting the membranes to the glass, so that the connections are

invisible. It requires, however, application of optically efficient, stretched, invisible to the unaided eye, tulle screens of nanofibers in order to maintain the quality of the image visible through the glazing.

[0031] Optimal in terms of thermal insulation and technologically and economically rational, the distance between the vertical screens is dependent on the type of gas, which we use to fill the space between the panes. For a vertically-oriented package, it will range from 4 millimeters (for xenon and sulfur hexafluoride) to 16 millimeters (for dry argon), and specifically for box-like glazing, over 15 cm thick, the space between the different partitions in the package will be in the range of 4 to 6 millimeters for xenon and sulfur hexafluoride, 6 to 8 millimeters for krypton and 12-16 mm for dry argon and dry air. It is beneficial in terms of thermal resistance to keep the value of the dimensionless Reynolds number below 1700 for the mobile layer of gas in the convection cells, developing in the vertical glazing chambers (see discussion in the text of U.S. Patent 4808457 "*Heavy gas-filled multilayer insulation panels*", for a similar solution, both geometrically and thermally, but concerning an opaque structure, applied by Whirlpool Corporation).

[0032] Thermal resistance of such glazing will be proportional to its total thickness, since after the radical reduction of convection and radiation, the primary mechanism of heat transfer will remain the conduction in the gas layer, and so, it is advantageous to use as thick glasses as possible (Fig. 5, 6). The structure of insulating glass filled with a system of vertical nonfibrous tulle screens may even have the total thickness exceeding 80 cm, suitable for buildings with a system of double glazed façades (figure 6), or can take the form of inclined glass, preferably at 45 degrees, and built into such a façade (Figure 7), or can function as an independent, inclined glazing.

[0033] Proper orientation of the inclined glass depends on the temperature distribution, the bottom pane should come into contact with the lower temperature zone and the upper pane with a zone of higher temperatures, because then the thermal resistance of the glazing is significantly higher than for vertical glazing of the same thickness. As mentioned above, for such hermetic insulating glass of substantial thickness, it is necessary to introduce an external volume compensation system (Figure 4). For packages of screens of large size and small mutual distances, as in the proposed structure, the problem may be their tendency to adhere to one another under the influence of Van der Waals forces, therefore, it will be beneficial to keep them in the distance and parallel to each other by additional, stressed fasteners made of nanofibers, placed perpendicularly to the package of screens and attached to the outer panes (figure 3).

[0034] A similar effect can be achieved through electrostatic repulsion, by giving the layers of conductive tulle of nanowires that form a package inside the glass, a like, same electrostatic charge, e.g. by connecting them to a source of constant voltage. Screens may not be identical over entire cross-section of the insulating glass. Module,

types and sequence of these types of vertical screens in the package may vary depending on the type of gas, thickness of the entire glazing and optical properties of screens used. Outer glass panes do not come into contact with the tulle screens, so on the inner side they can be entirely covered with low-emission coatings of extreme parameters.

10 Claims

1. Structure of thermal insulation of glazing with two-compartment insulation glass, mounted in a vertical position, consisting of two outer transparent panes of glass, between which there is a transparent gas medium and invisible transparent elements parallel to the panes, **characterized in that** the transparent partitions take the form of pre-stressed tulle screens of nanofibers with an openwork design, consisting of at least two of the following three layers of tulle: (i) a frame carrier of mechanically strong, flexible or textured nanofibers, (ii) a conductive layer of nanofibers or nanowires stretched over a frame carrier, and (iii) a covering and densifying veil made of nanofibers, 5-25 nanometers in diameter, and the distance between the screens depends on the type of gas used, and in the case of standard glazing thickness of 16 to 36 millimeters, is 2 to 3 millimeters for xenon and sulfur hexafluoride, 3 to 4 millimeters for krypton, 4 to 5 millimeters of dry argon, and for box-type glazing, which is over 15 cm thick, the distance between the various partitions in the package will be in the range of 4 to 6 millimeters for xenon and sulfur hexafluoride, 6 to 8 millimeters for krypton and 12-16 millimeters of dry argon and dry air.
2. Structure as claimed in claim 1, **characterized in that** the two-compartment glazing is mounted in a position inclined at 30-60 degrees, preferably 45 degrees, while the bottom pane should come into contact with the lower temperature zone and the upper pane with a zone of higher temperatures.
3. Structure as claimed in claim 1, **characterized in that** the glazing of thickness exceeding 15 centimeters is made as a hermetic insulation glass with a frame made of rigid polymer foam with stainless steel corrugated foil insertion, and fitted with an external volume and pressure changes compensation system in the form of a bellows, preferably of stainless steel, connected to the space between insulating glass panes with a wire.
4. Structure as claimed in claim 1, **characterized in that** the frame carrier of the screen is in a form of a single, textured nanofibers or bands of textured nanofibers, 20-100 nanometers in diameter, transparent in visible light, preferably coated with an antire-

flective layer of *moth-eye* type or dielectric.

5. Structure as claimed in claim 1, **characterized in that** the conductive layer of nanofibers is in a form of an openwork conductive nanostructure of metal, preferably Ag or Au, metallized with dielectric core or of oxide, preferably ITO, doped ZnO, possibly with carbon nanofibers, optionally metallized, with a mesh pattern of 300-1000 nanometers in size, optionally, ring, square or hexagonal, with conductive nanofibers or nanowires, preferably covered with an antireflective layer of *moth-eye* type or dielectric.
6. Structure as claimed in claim 1, **characterized in that** the covering and densificating veil is made of nanofibers is of 5-25 nanometers in diameter, preferably porous and transparent in visible light.
7. Structure as claimed in claim 1, **characterized in that** the covering and densificating veil is provided with an additional layer of gluing and sealing nanomembrane or inorganic polymer with a thickness of 5-10 nanometers that is transparent and invisible as a result of destructive interference.

Patentansprüche

1. Wärmedämmungsstruktur mit Gas, für aus zwei Kammern bestehenden Verbundverglasungen, die vertikal montiert werden und sich aus zwei außenliegenden transparenten Glastafeln zusammensetzen, zwischen denen sich ein durchsichtiges gasförmiges Medium und transparente, durchsichtige, zu der Glasfläche parallel angebrachte Elemente befinden, **dadurch gekennzeichnet, dass** die durchsichtigen Trennelemente die Form von angespannten tüllartigen Schirmen aus Nanofasern mit spitzenartiger Konstruktion aufweisen und aus mindestens zwei von den nachfolgenden drei Tüllschichten bestehen: (i) einem Traggerüst aus mechanisch widerstandsfähigen, elastischen oder texturierten Nanofasern, (ii) einer auf dem Traggerüst ausgespannten Schicht aus leitenden Nanofasern oder Nanodrähten, sowie (iii) einem überdeckenden und verdickenden Schleier, der aus Nanofasern mit einem Durchmesser von 5-25 Nanometern gebaut wird, wobei die Abstandsbreite zwischen den Schirmen gasartabhängig ist und bei der Verglasung, deren Standarddicke 16 bis 36 Millimetern aufweist, 2 bis 3 Millimeter für Xenon und Schwefelhexafluorid, 3 bis 4 Millimeter für Krypton, 4 bis 5 Millimeter für trockenes Argon beträgt, und die Abstandsbreite zwischen den einzelnen Trennungen im Paket für Kastenverglasungen, die über 15 cm hinaus dick sind, in den Bereichen 4 bis 6 Millimeter für Xenon und Schwefelhexafluorid, 6 bis 8 Millimeter für Krypton und 12 bis 16 Millimeter für trockenes Argon und trockene Luft liegen.

2. Die Struktur nach Anspruch 1 einer thermischen Gasisolierung für aus zwei Kammern bestehenden Verbundverglasungen, **dadurch gekennzeichnet, dass** sie in geneigter Position unter dem Winkel von 30-60 Grad, vorzugsweise 45 Grad, montiert werden, wobei die untere Glastafel mit der Zone niedrigerer Temperaturen, und die obere Glastafel mit der Zone höherer Temperaturen in Berührung gebracht werden soll.
3. Die Struktur nach Anspruch 1, **dadurch gekennzeichnet, dass** die Verglasung mit einer Dicke von über 15 Zentimeter hinaus als eine hermetische Verbundverglasung mit Glasrahmen aus steifem Polymerkunststoff mit einer Einlage, die aus gewellter nichtrostender Stahlfolie ausgefertigt und mit einem System für die externe Kompensation von Volumen- und Druckveränderungen in Form eines kleinen Balges aus vorzugsweise nichtrostendem Stahl, der durch eine Leitung mit der Kammer der Verbundverglasung verbunden ist, versehen wird.
4. Die Struktur nach Anspruch 1, **dadurch gekennzeichnet, dass** das Traggerüst des Schirmes die Form von vereinzelt texturierten Nanofasern oder eines Streifens von texturierten Nanofasern mit einem Durchmesser von 20-100 Nanometern, die im sichtbaren Licht transparent sind und vorzugsweise mit einer Antireflexbeschichtung vom Typ *moth-eye* oder einer dielektrischen Antireflexbeschichtung überzogen werden, aufweist.
5. Die Struktur nach Anspruch 1, **dadurch gekennzeichnet, dass** die Schicht der leitenden Nanofasern die Form einer spitzenartigen leitenden Nanostruktur aufweist, die metallisch, vorzugsweise Ag oder Au, metallisiert mit dielektrischem Kern oder oxidiert, bevorzugt ITO mit ZnO dotiert, gegebenenfalls aus Kohlennanofasern, optional metallisiert, mit einem Muster aus anliegenden Maschen mit einer Größe von 300-1000 Nanometer, deren Form optional: ring-, quadrat- oder hexagonalartig ist, mit leitenden Nanofasern oder Nanodrähten, die mit einer Antireflexbeschichtung vom Typ *moth-eye* oder einer dielektrischen Antireflexbeschichtung überzogen werden.
6. Die Struktur nach Anspruch 1, **dadurch gekennzeichnet, dass** der überdeckende und verdickende Schleier, der aus Nanofasern mit einem Durchmesser von 5-25 Nanometern gebaut wird, vorzugsweise porös und in sichtbarem Licht transparent ist.
7. Die Struktur nach Anspruch 1, **dadurch gekennzeichnet, dass** der überdeckende und verdickende Schleier mit einer zusätzlichen zuklebenden und verdichtenden transparenten Schicht aus der Polymer-, oder nichtorganischen Nanomembran mit ei-

ner Dicke von 5 -10 Nanometer, die infolge der destruktiven Interferenz transparent ist, versehen wird.

nomètres, transparentes à la lumière visible, avantageusement recouverte d'une couche antireflet du type *moth-eye* ou diélectrique.

Revendications

1. La structure d'isolation thermique à gaz du double vitrage à deux compartiments, avec les vitres montées dans une position verticale, est constituée de deux panneaux externes transparents en verre entre lesquels sont prévus un milieu gazeux transparent et des éléments transparents invisibles placés parallèlement, **caractérisée en ce que** les cloisons transparentes sont sous la forme d'écrans de tulle précontraint de nanofibres à motif ajouré, constitués d'au moins deux des trois couches de tulle suivantes: (i) un support de cadre fait de nanofibres résistantes mécaniquement, flexibles ou texturées, (ii) une couche conductrice de nanofibres ou nanofils étirés sur un support de cadre et (iii) un voile de protection et de densification fait de nanofibres d'un diamètre de 5 à 25 nanomètres, étant précisé que la distance entre les écrans dépend du type de gaz et, pour le vitrage d'une épaisseur standard de 16 à 36 millimètres, cette distance est comprise entre 2 et 3 millimètres pour le xénon et l'hexafluorure de soufre, entre 3 et 4 millimètres pour le krypton, entre 4 et 5 millimètres pour l'argon sec, et pour un vitrage du type de caisson de plus de 15 cm d'épaisseur, la distance entre les écrans de l'ensemble est comprise entre 4 et 6 millimètres pour le xénon et l'hexafluorure de soufre, entre 6 et 8 millimètres pour le krypton et entre 12 et 16 millimètres pour l'argon sec et l'air sec.
2. La structure selon la revendication 1 d'isolation thermique à gaz du double vitrage à deux compartiments avec les vitres montrées dans une position inclinée sous l'angle de 30 à 60 degrés, avantageusement de 45 degrés, la vitre inférieure doit être en contact avec la zone de températures plus basses et la vitre supérieure avec la zone de températures plus hautes.
3. La structure selon la revendication 1, **caractérisée en ce que** le vitrage d'une épaisseur supérieur à 15 centimètres est fait comme un vitrage hermétique avec le support de cadre en mousse de polymère rigide et une cloison de film ondulé en acier inox et muni d'un dispositif de compensation externe de changement du volume et de pression sous la forme d'un soufflet avantageusement en acier inox, relié par une conduite au compartiment du double vitrage.
4. La structure selon la revendication 1, **caractérisée en ce que** le support de cadre de l'écran a la forme de simples nanofibres texturées ou de bandes de nanofibres texturées, d'un diamètre de 20-100 na-
5. La structure selon la revendication 1, **caractérisée en ce que** la couche conductrice de nanofibres a la forme d'une nanostructure conductrice ajourée, métallique, le plus avantageusement Ag ou Au, métallisée avec le noyau diélectrique ou d'oxyde, le plus avantageusement ITO dopé au ZnO, éventuellement en nanofibres de carbone, optionnellement métallisées, à motif du maillage aux mailles en contact de dimensions de 300 à 1000 nanomètres, optionnellement: en forme d'anneaux, carrées ou hexagonales, aux nanofibres ou nanofils conducteurs avantageusement recouverts d'une couche antireflet du type *moth-eye* ou diélectrique.
6. La structure selon la revendication 1, **caractérisée en ce que** le voile de protection et de densification est construit en nanofibres d'un diamètre de 5 à 25 nanomètres, avantageusement poreuses et transparentes à la lumière visible.
7. La structure selon la revendication 1, **caractérisée en ce que** voile voile de protection et de densification est muni d'une couche supplémentaire d'encollage et d'étanchéité transparente, invisible à la suite d'une interférence destructive de nanomembrane de polymère ou inorganique d'une épaisseur de 5 à 10 nanomètres.

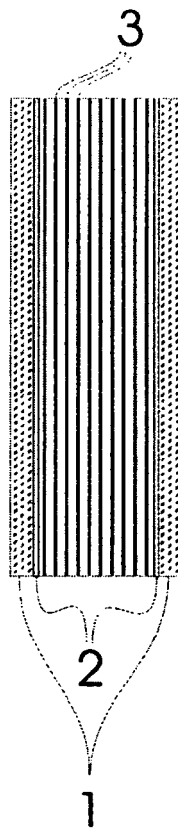


Fig. 1

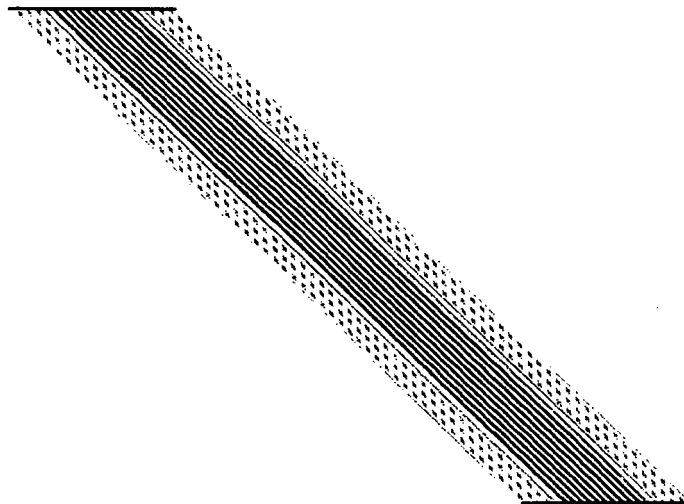


Fig. 2

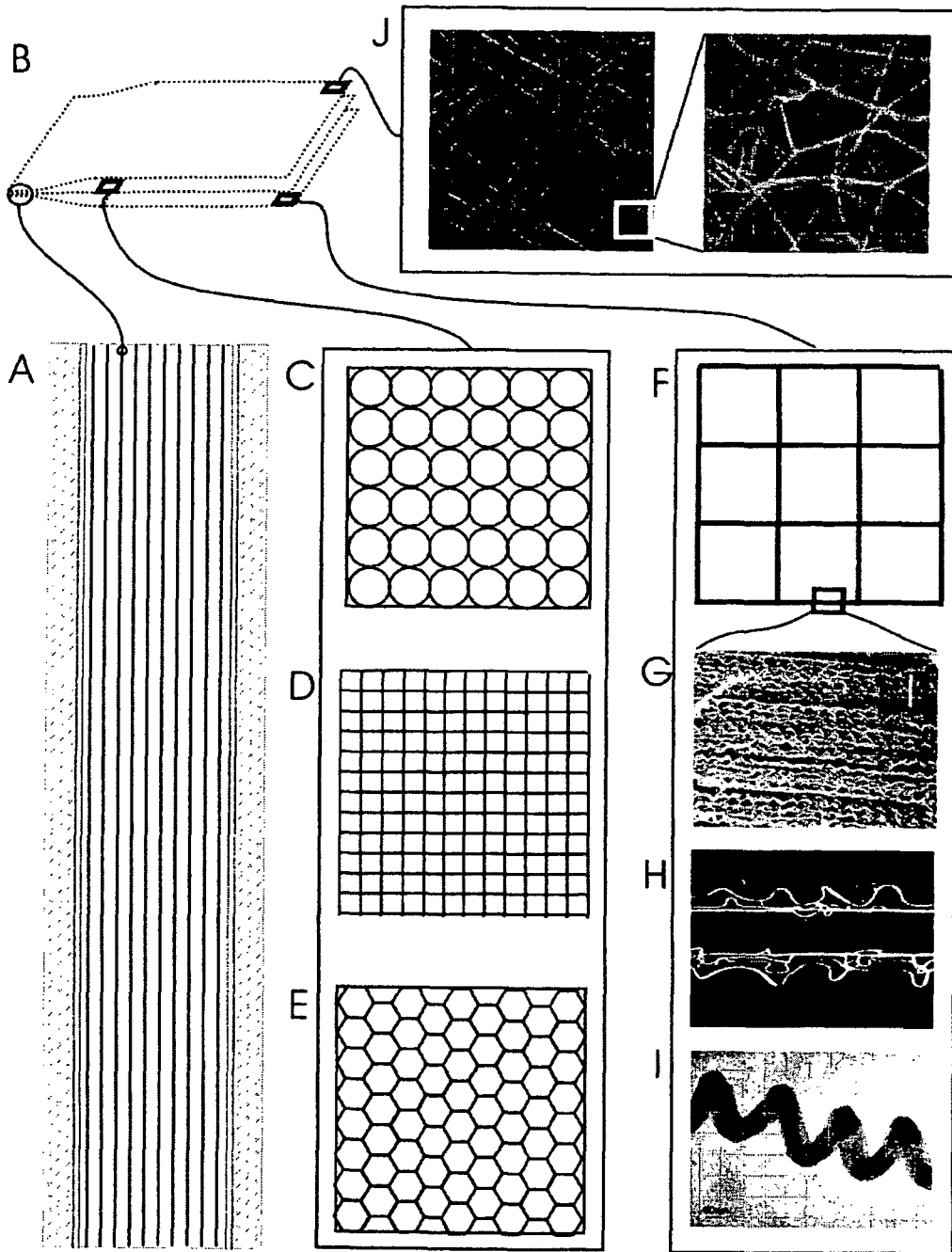


Fig. 3

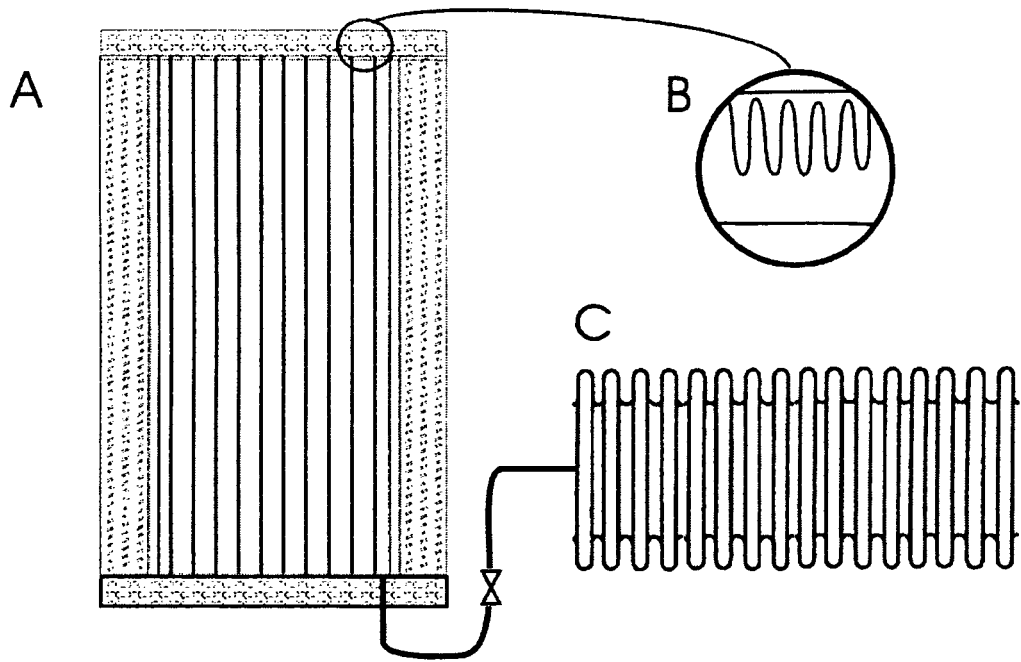


Fig. 4

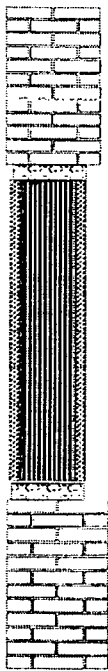


Fig. 5

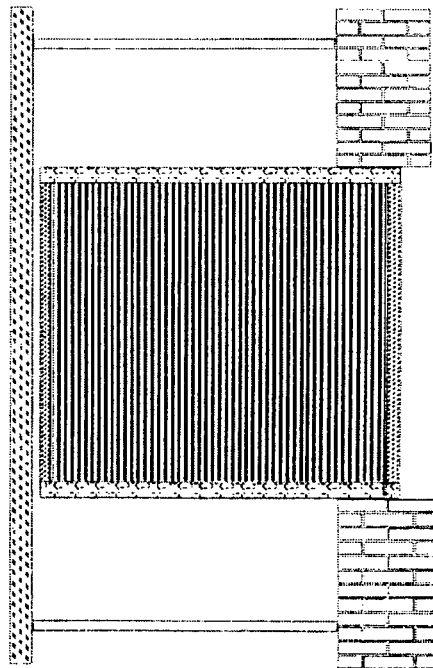


Fig. 6

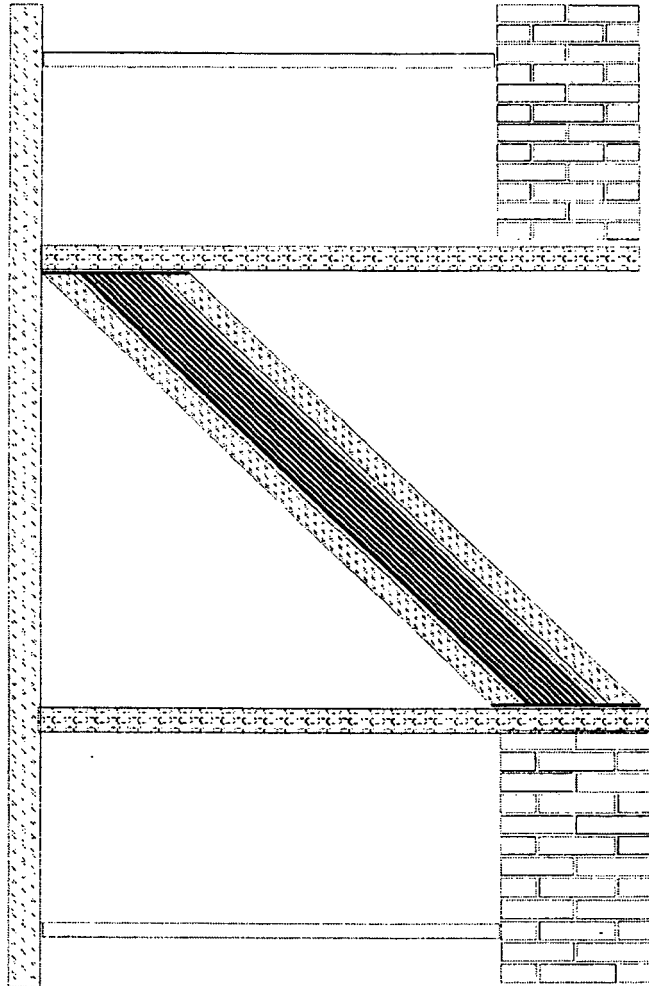


Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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