

PANE COMPRISING A TITANIUM CARBIDE COATING

[0001] The invention relates to a pane with a coating, its production and use.

5 [0002] Panes with coatings with low light transmission with a functional layer with TiN stacks are known from WO 2018/129135 A1, TiN/NiCr(N) stacks from WO 2018/129125 A1 and TiN/ITO stacks from US 2018/0237336 A1. Nb- and NbN-functional layers are known from WO 2009/112759 A2, WO 01/21540 A1 and WO 2021/069616 A1.

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[0003] Furthermore, tools are known from EP 0 693 574 B2 and JP H11-114704 A in which TiC is used to improve the mechanical stability of the tools. Furthermore, CN 105970177 A discloses a solar-selectively absorbing high-temperature coating based on TiC for use in the technical field of solar energy utilization. Accordingly, these disclosures relate to clearly different technical fields than the field of coated panes.

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[0004] In addition, the use of TiC stacks in coated substrates is known from EP 3 515 871 A1 and EP 0 718 250 B2. In these documents, the TiC layer is used as a barrier layer against the diffusion of alkali ions and oxygen, while an IR-reflecting layer based on silver is used.

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[0005] US 2002/045073 A1 describes methods for obtaining photoactive coatings and/or anatase crystalline phases of titanium oxides and articles produced therefrom. The subject matter comprises a substrate and a coating, wherein a functional coating may be disposed between the coating and the substrate. The functional coating is intended to modify one or more physical properties of the substrate. This means that the functional coating, if present, is arranged directly on the substrate.

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[0006] S. R. Reineck et al., Colloque international sur les plasmas et la pulvérisation cathodique, Société Française du Vide, Vol. colloque 4,

September 13, 1982, pp. 385-395, describes high-rate sputtering for the production of architectural glass coatings. A glass substrate with a titanium carbide coating is disclosed. However, no lower and upper highly refractive dielectric layer or layer sequence and no thickness of the titanium carbide coating are described.

[0007] C. G. Granqvist, Solar Energy Materials and Solar Cells, vol. 91, no. 17, 2007, pp. 1529-1598, discloses transparent conductors as solar energy materials.

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[0008] While TiN offers good thermal performance in terms of low emissivity combined with solar control properties, the TiN-containing coating undergoes a drastic color change during thermal annealing, which precludes the application of the same coating for thermally annealed and non-thermally annealed products and thus reduces the overall market volume. In comparison, Nb coatings offer little color change after thermal annealing and low emissivity, but poor solar control properties. Conversely, solar control properties and a low color change after thermal annealing can be achieved using NbN, but low emissivity is not achieved with this material.

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[0009] The object of the present invention is to provide a cost-effective and sustainable solar control coating for panes which has high chemical and mechanical resistance and which shows negligible color shift after thermal annealing. A further object of the invention is to provide an economical and environmentally friendly method for producing a sustainable solar control coating for panes. Finally, it is an object of the present invention to provide a use for the solar control coating according to the invention for panes.

[0010] The object of the present invention is achieved by a pane according to claim 1, a method according to claim 12 and a use according to claim 14. Preferred embodiments can be seen in the dependent claims.

[0011] The pane is provided to separate the interior from the external environment in a window opening. The pane according to the invention comprises at least one glass pane and a coating. The glass pane has two surfaces (main surfaces), namely an outer surface and an interior-side surface, and a peripheral edge surface between the two main surfaces. Outer surface means that main surface which, in the installed position, faces the external environment. Interior-side surface means that main surface which, in the installed position, faces the interior. The coating is arranged on said outer surface or the interior-side surface of the glass pane. The coating is preferably arranged on the interior-side surface of the glass pane, as this provides the coating with particular protection against damage caused by mechanical and/or chemical influences from the environment.

[0012] According to the invention, the coating comprises, starting from the glass pane, in the following order, at least:

- a lower (optically) highly refractive dielectric layer or layer sequence,
- an IR-reflecting layer based on titanium carbide (TiC), and
- an upper (optically) highly refractive dielectric layer or layer sequence.

[0013] The great advantage of the present invention is that the pane according to the invention, in addition to its infrared (IR) reflecting properties, has a high chemical and mechanical resistance and shows little color change after possible thermal annealing. The IR-reflecting properties are provided in particular by the IR-reflecting layer based on titanium carbide and relate to the near infrared range, so that the coating can be used as a solar control coating and (partially) reflects the IR components of solar radiation. The IR-reflecting properties also affect heat radiation in the mid-IR range, so that it also acts as an emissivity-reducing coating (low-E coating) and reduces the radiation of heat from the pane into the interior. Furthermore, it is not susceptible to corrosion, so that it can be used on an exposed surface, which is necessary for emissivity-reducing coatings (interior-side exposed surface) and is

unavoidable in the case of monolithic panes because only exposed surfaces are available.

5 [0014] According to the invention, an “exposed surface” is defined as an external or open surface which forms an interface with the surrounding atmosphere and is accessible and touchable by persons.

10 [0015] Furthermore, with the coating according to the invention, a light transmission of the pane of 50% or less can be achieved, which is advantageous, for example, for use as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building. Furthermore, due to the chemical resistance of titanium carbide, at most only a slight color change occurs due to thermal annealing. Moreover, because titanium is an abundant element, titanium carbide can be considered a sustainable material and cost-
15 efficient production is also facilitated. By using the upper highly refractive dielectric layer or layer sequence, the oxidation of the IR-reflecting layer based on titanium carbide during a possible temperature treatment, such as thermal annealing, can be further reduced or prevented.

20 [0016] The coating is preferably arranged over the entire area of said surface so that the entire surface is covered by the coating without exception. However, it is also possible that some regions of the surface are not provided with the coating, for example a peripheral edge region or a local uncoated region which acts as a data transmission window to improve the permeability for
25 electromagnetic radiation (antenna signals). Such a data transmission window may be necessary or helpful to ensure the permeability for electromagnetic radiation (e.g., antenna signals), which can be attenuated or blocked by the electrically conductive layer based on TiC. Preferably, at least 80% of the surface is covered by the coating, particularly preferably at least 90%.

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[0017] In one embodiment of the invention, the pane is designed as a laminated pane. A laminated pane comprises at least an outer pane and an

inner pane which are connected to each other via a thermoplastic intermediate layer. In the sense of the invention, inner pane means the pane of the laminated pane facing the interior. Outer pane means the pane facing the external environment. The glass pane according to the invention having the coating can represent the inner pane or the outer pane of the laminated pane. The coating can be on the outer surface or the interior-side surface of the glass pane, which is used as an inner pane or as an outer pane. If the glass pane is used as the outer pane of the laminated pane, the coating is preferably located on the interior-side surface of the glass pane, as this protects the coating from deterioration by mechanical and/or chemical influences from the environment and also allows lower reflectivities to be achieved. Insofar as the glass pane represents the inner pane of a laminated pane, the coating on both the outer surface and the interior-side surface of the glass pane is protected from these environmental influences. In one embodiment of the invention, the coating is located on the outer surface of the glass pane which is used as the inner pane of a laminated pane, so that lower reflectivities can be achieved. According to a further embodiment, the coating is arranged on the interior-side surface of the glass pane when the glass pane is used as the inner pane of a laminated pane, because it thus represents the surface of the laminated pane exposed to the interior and can therefore additionally exert an emissivity-reducing effect. Laminated panes can be used, for example, in the automotive sector as so-called laminated safety glass (VSG) or in the building sector as insulating glazing. The pane can, for example, be a rear window or roof window of a motor vehicle or rail vehicle or a pane for a building.

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[0018] In an alternative embodiment of the invention, the pane according to the invention is a monolithic pane which is designed as a single glass pane. Apart from the glass pane with the coating, there is no other pane. In the case of a single glass pane, the coating is preferably arranged on the interior-side surface of the glass pane, because the coating is thus protected from impairment by mechanical and/or chemical influences from the environment. The pane can be used in particular as a so-called single-pane safety glass

(ESG), wherein the glass pane is thermally tempered. The monolithic pane can be, for example, a rear window or roof window of a motor vehicle or rail vehicle or a pane for a building.

5 [0019] The IR-reflecting layer based on titanium carbide has a layer thickness of 2 nm to 50 nm, preferably from 3 nm to 45 nm, and in particular from 5 nm to 40 nm. This achieves good IR-reflective properties and a light transmission TL of the pane of 25% or more and 50% or less. Titanium carbide (TiC) is also known as TiC_x where x is from 0.8 to 1.2, preferably from 0.9 to 1.1, more
10 preferably about 1.0. Preferably, the titanium carbide is deposited substantially stoichiometrically, which corresponds to an atomic ratio of titanium to carbon of approximately 1:1. Titanium carbide exhibits electrical conductivity, which is also the reason for its IR-reflecting effect. The specific electrical resistance of thin films is usually higher than the tabulated values for the solid body (*bulk*
15 values). The specific resistance of the IR-reflecting layer based on titanium carbide according to the invention is preferably less than $300\ \mu\Omega\ \text{cm}$, more preferably less than $250\ \mu\Omega\ \text{cm}$. The specific resistance depends crucially on the proportion of carbon in the IR-reflecting layer; layer parameters, such as density and crystallinity, also have an effect. The specific resistance is
20 expressed in the refractive index of the IR-reflecting layer. Strictly speaking, specific resistance refers to the specific electrical resistance, which is often also referred to as resistivity. Its inverse is the electrical conductivity. The specific resistance can be determined using a commercially available resistance meter.

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[0020] The refractive index (real part of the complex refractive index) of the IR-reflecting layer based on titanium carbide is preferably in the range from 2.3 to 3.4 in a wavelength range from 400 nm to 780 nm or from 2.9 to 6.0 in a wavelength range from 780 nm to 2500 nm, particularly preferably from 2.9 to
30 3.3 in a wavelength range from 400 nm to 780 nm or from 3.3 to 6.0 in a wavelength range from 780 nm to 2500 nm. The extinction coefficient (imaginary part of the complex refractive index) of the IR-reflecting layer based

on titanium carbide is preferably in the range from 2.0 to 3.7 in a wavelength range from 400 nm to 780 nm or from 3.5 to 6.5 in a wavelength range from 780 nm to 2500 nm, particularly preferably from 2.0 to 3.5 in a wavelength range from 400 nm to 780 nm or from 3.7 to 6.5 in a wavelength range from 780 nm to 2500 nm. According to one embodiment, the refractive index (real part of the complex refractive index) of the IR-reflecting layer based on titanium carbide is in the range of 2.4 to 3.0 at a wavelength of 550 nm, more preferably in the range of 2.8 to 3.0 at a wavelength of 550 nm. According to a further embodiment, the extinction coefficient (imaginary part of the complex refractive index) of the IR-reflecting layer based on titanium carbide is in the range of 2.7 to 2.9 at a wavelength of 550 nm, more preferably in the range of 2.7 to 2.8 at a wavelength of 550 nm.

[0021] If a layer of the coating according to the invention is formed based on a material, the layer consists predominantly of this material, in particular substantially of this material, in addition to any impurities or doping. The aforementioned dielectric materials (oxides, nitrides) can be deposited stoichiometrically, substoichiometrically, or hyperstoichiometrically. Therefore, stoichiometric coefficients are not used when specifying the molecular formulas. The molecular formulas are for abbreviation purposes only; they do not contain any information about stoichiometry.

[0022] Doping (e.g., aluminum, zirconium, titanium or boron) can be used to provide dielectric materials with a certain electrical conductivity. A person skilled in the art will nevertheless identify them as dielectric layers in terms of their function, as is customary in the field of thin layers. The material of the dielectric layers preferably has an electrical conductivity (reciprocal of the specific resistance) of less than 10^{-4} S/m.

[0023] Unless otherwise stated, the thickness or layer thickness of a layer in the sense of the present invention always means the geometric thickness. If

reference is made instead to the optical thickness, which is the product of the geometric thickness and the refractive index, this is explicitly stated in each case.

[0024] Unless noted otherwise, the indicated values for refractive indices are
5 measured at a wavelength of 550 nm. The refractive index can be determined,
for example, by ellipsometry. Ellipsometers are commercially available - for
example, from the Sentech company. If the absorption is very strong and an
accurate measurement with ellipsometry is not possible, the refractive index
10 can be determined using optical models from simulations. A simulation
can be carried out, for example, using software commonly used in the field,
such as CODE.

[0025] According to the invention, the pane comprises an upper highly
refractive dielectric layer or layer sequence. According to one embodiment, the
15 IR-reflecting layer based on titanium carbide and the upper highly refractive
dielectric layer or layer sequence are in direct contact with each other.

[0026] "In direct contact" in the sense of the invention means that there is no
further layer between the layers that are in direct contact with each other.
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[0027] The upper highly refractive dielectric layer or layer sequence preferably
has a refractive index of more than 1.9, for example between 1.9 and 2.5. It
can be formed as a single layer (in this case there is an upper highly refractive
dielectric layer) or as a stack of a plurality of layers (in this case there is an
25 upper highly refractive dielectric layer sequence). In the case of a layer
sequence, all layers preferably have a refractive index of more than 1.9.

[0028] The upper highly refractive dielectric layer or layer sequence preferably
has an optical thickness of from 10 nm to 120 nm, and particularly preferably
30 from 20 nm to 100 nm.

[0029] In an advantageous embodiment, the upper highly refractive dielectric layer or layer sequence contains a layer based on a nitride or is formed therefrom. This means that if an upper dielectric layer is present, it is formed on the basis of a nitride, and if an upper dielectric layer sequence is present, it contains at least one layer based on a nitride. The nitride is preferably silicon nitride (SiN) or a silicon-metal mixed nitride, for example silicon zirconium nitride (SiZrN), silicon hafnium nitride (SiHfN), silicon titanium nitride (SiTiN) or silicon aluminum nitride (SiAlN). These have suitable refractive indices (SiN: 2.0; SiZrN: 2.2), are comparatively simple and inexpensive to produce and are commonly used for thin-film coatings on glass panes. In a further advantageous embodiment, the upper highly refractive dielectric layer or layer sequence contains a layer based on an oxide or is formed therefrom, in particular titanium oxide (TiO, refractive index 2.3). As a result, the (average) refractive index of the upper highly refractive layer(s) can be further increased, which is advantageous, for example, for an anti-reflective effect insofar as the pane according to one embodiment further comprises a low refractive dielectric layer or layer sequence, as described further below.

[0030] In a particularly advantageous embodiment, that layer of the upper highly refractive layer or layer sequence which is in direct contact with the IR-reflecting layer based on TiC is formed on the basis of a nitride, in particular on the basis of SiN or SiZrN. This prevents the IR-reflecting layer from being oxidized during deposition or subsequent heat treatment, as could occur if it comes into contact with an oxide layer. This can be achieved by having an upper highly refractive dielectric layer which is based on the nitride, or by having an upper highly refractive dielectric layer sequence whose lowermost layer (i.e., closest to the IR-reflecting layer) is based on the nitride.

[0031] In one embodiment, a single upper highly refractive dielectric layer is present based on a nitride, in particular based on silicon nitride (SiN) having a layer thickness of 10 nm to 60 nm, particularly preferably from 20 nm to 50 nm, for example from 30 nm to 45 nm, or based on silicon zirconium nitride (SiZrN)

having a layer thickness of 10 nm to 50 nm, particularly preferably from 15 nm to 45 nm. For other silicon-metal mixed nitrides, substantially the same layer thicknesses can be used as for SiZrN.

5 [0032] In a further embodiment, an upper highly refractive dielectric layer sequence is present. This includes “from bottom to top” (i.e., in the direction starting from the IR-reflecting layer based on titanium carbide) in the following order preferably:

- a first layer based on a nitride, in particular silicon nitride (SiN), or silicon-
10 metal mixed nitride, in particular silicon zirconium nitride (SiZrN), and
- a second layer based on an oxide, in particular titanium oxide (TiO).

[0033] The first layer is preferably in direct contact with the IR-reflecting layer and prevents its oxidation. The second layer increases the average refractive
15 index of the layer sequence. The second layer based on TiO preferably has a layer thickness of from 5 nm to 25 nm, particularly preferably from 10 nm to 20 nm. The first layer preferably has a layer thickness of 10 nm to 30 nm, particularly preferably of 15 nm to 25 nm, if it is based on SiN. The first layer preferably has a layer thickness of 10 nm to 25 nm, particularly preferably of
20 15 nm to 20 nm, if it is based on SiZrN.

[0034] According to the invention, the coating further comprises a lower highly refractive dielectric layer or layer sequence formed between the glass pane and the IR-reflecting layer. By using the lower highly refractive dielectric layer
25 or layer sequence, components of the glass pane can be prevented from penetrating into the IR-reflecting layer based on titanium carbide during possible temperature treatment. According to a preferred embodiment, the lower highly refractive dielectric layer or layer sequence and the IR-reflecting layer are in direct contact with each other.

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[0035] The lower highly refractive dielectric layer or layer sequence preferably has a refractive index of more than 1.9, for example between 1.9 and 2.5. It can also

be formed as a single layer (in this case there is a lower highly refractive dielectric layer) or as a stack of a plurality of layers (in this case there is a lower highly refractive dielectric layer sequence). In the case of a layer sequence, all layers preferably have a refractive index of more than 1.9.

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[0036] The lower highly refractive dielectric layer or layer sequence preferably has an optical thickness of from 10 nm to 220 nm, and particularly preferably from 20 nm to 200 nm.

10 [0037] The materials of the lower and upper highly refractive dielectric layers or layer sequence can be selected independently of each other. In an advantageous embodiment, the lower highly refractive dielectric layer or layer sequence contains a layer based on a nitride or is formed therefrom. The nitride is preferably silicon nitride (SiN) or a silicon-metal mixed nitride, for
15 example silicon zirconium nitride (SiZrN), silicon hafnium nitride (SiHfN), silicon titanium nitride (SiTiN) or silicon aluminum nitride (SiAlN). In a further advantageous embodiment, the lower highly refractive dielectric layer or layer sequence contains a layer based on an oxide or is formed therefrom, in particular titanium oxide (TiO).

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[0038] In a particularly advantageous embodiment, that layer of the lower highly refractive layer or layer sequence which is in direct contact with the IR-reflecting layer based on TiC is formed on the basis of a nitride, in particular on the basis of SiN or SiZrN. This prevents the IR-reflecting layer from being
25 oxidized during subsequent heat treatment, as could occur if it comes into contact with an oxide layer. This can be achieved by having a lower highly refractive dielectric layer formed on the basis of the nitride, or by having a lower highly refractive dielectric layer sequence whose uppermost layer (i.e., closest to the IR-reflecting layer) is formed on the basis of the nitride.

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[0039] In a particularly advantageous embodiment, a single lower highly refractive dielectric layer based on a nitride is present, in particular based on

silicon nitride (SiN) having a layer thickness of 10 nm to 110 nm, particularly preferably from 20 nm to 105 nm, in particular from 30 nm to 100 nm, or based on silicon zirconium nitride (SiZrN) having a layer thickness of 15 nm to 55 nm, particularly preferably from 20 nm to 45 nm.

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[0040] In a further embodiment, a lower highly refractive dielectric layer sequence is present, which, starting from the glass pane, comprises, in the following order:

- a first layer based on an oxide, in particular titanium oxide (TiO) and
- 10 - a second layer based on a nitride, in particular silicon nitride (SiN), or silicon-metal mixed nitride, in particular silicon zirconium nitride (SiZrN).

[0041] The second layer is preferably in direct contact with the IR-reflecting layer and prevents the oxidation thereof. The first layer increases the average
15 refractive index of the layer sequence. The first layer based on TiO preferably has a layer thickness of from 5 nm to 25 nm, particularly preferably from 10 nm to 20 nm or from 10 nm to 18 nm. The second layer preferably has a layer thickness of 10 nm to 40 nm, particularly preferably of 15 nm to 35 nm, in particular of 25 nm to 35 nm or of 30 nm to 35 nm, if it is based on SiN. The
20 second layer preferably has a layer thickness of 10 nm to 35 nm, particularly preferably of 15 nm to 30 nm, if it is based on SiZrN.

[0042] According to one embodiment, the coating further comprises a low refractive dielectric layer or layer sequence having a refractive index of less than
25 1.6 which is arranged on the upper highly refractive dielectric layer. With the help of this low refractive dielectric layer or layer sequence, the pane can have an anti-reflective effect in addition to the IR-reflecting property.

[0043] The low refractive dielectric layer or layer sequence has a refractive
30 index of less than 1.6, for example between 1.2 and 1.6, preferably less than 1.5. It can be formed as a single layer (in this case a low refractive dielectric layer) or as a stack of a plurality of layers (in this case a low refractive dielectric

layer sequence). In the case of a layer sequence, all layers have a refractive index of less than 1.6.

5 [0044] The low refractive dielectric layer or layer sequence preferably has an optical thickness of from 40 nm to 130 nm, and particularly preferably from 55 nm to 115 nm. Particularly good anti-reflective properties are thus achieved.

10 [0045] In an advantageous embodiment, the low refractive dielectric layer or layer sequence contains a layer based on an oxide or is formed therefrom. The oxide is preferably silicon oxide (SiO₂). This has a suitable refractive index (1.45), can be produced by thin-film technology, but also wet-chemically, and is commonly used for coatings on glass panes.

15 [0046] In a preferred embodiment, a single low refractive dielectric layer is present, in particular based on SiO₂, having a layer thickness of 30 nm to 90 nm, particularly preferably of 40 nm to 80 nm.

20 [0047] In one embodiment of the invention, the low refractive dielectric layer (in particular SiO₂ layer) is a thin film which can be produced, for example, by vapor deposition. Instead of a single low refractive layer, there can also be a low refractive dielectric layer sequence consisting of a plurality of individual layers.

25 [0048] The coating according to the invention has been described above as containing or comprising certain layers or, according to some embodiments, may contain or comprise certain layers. This means that in addition to the layers mentioned, further layers can be present, for example between the individual layers or layer sequences or as part of one or more layer sequences. According to a preferred embodiment, the coating consists only of the lower
30 highly refractive layer(s), the IR-reflecting layer and the upper highly refractive layer(s), wherein no further layers are present in between, above or below. It is further preferred that the individual layers (sequences) consist only of the

layers explicitly mentioned above and do not contain any further layers. According to a preferred embodiment, the pane according to the invention does not comprise a silver layer. The layers mentioned are sufficient to produce a good IR shielding effect. Additional layers would increase the cost and effort of production. However, according to one embodiment, the coating may further comprise the low refractive layer(s) described above in order to obtain an anti-reflective effect in addition to the IR-reflective property.

[0049] According to an advantageous embodiment, the glass pane contains or consists of flat glass, preferably soda lime glass, borosilicate glass or quartz glass. The glass can be made of clear glass or tinted or colored glass. A clear glass is a glass pane that has an integrated light transmission of at least 90% in accordance with ISO 9050. Tinted or colored glass panes have lower integrated light transmission. The same specifications also apply to the inner pane and the outer pane if the pane is a laminated pane. The thickness of the glass pane can be freely selected to suit the requirements of the specific application. The thickness of the glass pane or the inner pane or the outer pane is usually from 0.5 mm to 5 mm.

[0050] According to one embodiment, the pane is curved in one or more spatial directions, as is usual, for example, for motor vehicle panes, wherein the typical radii of curvature are in a range of from approximately 10 cm to approximately 40 m. The interior-side surface of the pane is generally curved concavely. According to a further embodiment, the pane is flat, for example if it is intended as a pane for buses, trains or tractors or for buildings.

[0051] The pane according to the invention preferably has an interior-side emissivity of less than 65%, particularly preferably less than 60%, most preferably less than 50%. Here, interior-side emissivity is the measure that indicates how much heat radiation the pane emits into an interior, for example of a building or of a vehicle, in the installed position compared to an ideal heat emitter (a black body). Within the meaning of the invention, emissivity is

understood to mean the normal emissivity at 283 K according to the standard EN 12898.

[0052] The pane according to the invention preferably has a light transmission of 50% or less, more preferably of 48% or less. According to a particularly preferred embodiment, the pane has a light transmission of 25% or more and 50% or less. A pane with such light transmission is particularly advantageous in areas with very strong sunlight, as it allows a pleasant darkening of the incoming light through the pane. Light transmission refers to the integrated light transmission in accordance with ISO 9050, measured with a light source of illuminant D65.

[0053] According to one embodiment, the pane according to the invention has the smallest possible color difference ΔE . The color difference ΔE is a measure of a color change, for example due to a temperature treatment, and is measured in accordance with EN ISO 11664-4. The lower the color level, the less it is perceived by the human eye. After thermal annealing, the pane preferably has a color difference ΔE of less than 5, more preferably less than 4, even more preferably less than 3. According to a particularly preferred embodiment, $\Delta E(R_c)$, which corresponds to the color difference measured from the coating side, is less than 5, more preferably less than 4, even more preferably less than 3. In a particularly preferred embodiment, $\Delta E(R_g)$, which corresponds to the color difference measured from the glass pane side, is less than 5, more preferably less than 4, even more preferably less than 3, most preferably less than 2. A color difference of less than 2 is virtually imperceptible to the human eye. For example, if the pane is used as a pane for a building that has undergone thermal annealing, the observer outside the building will not see any color difference between such an annealed pane compared to a non-annealed pane if the $\Delta E(R_g)$ of the annealed pane is less than 2.

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[0054] The coating according to the invention has electrical conductivity due to the TiC-based layer, so that it can also be used as a heat coating. For this

purpose, it is connected to so-called busbars which extend along two opposite side edges of the pane and are connected to the poles of a voltage source so that a current can flow through the coating and heat the pane. Due to the surface resistance, particularly advantageous heating effects are achieved
5 when the voltage source has a voltage of 42 volts to 48 volts or even 300 V to 400 V. Such voltages are available in particular in electric vehicles.

[0055] The invention further comprises a method for producing a pane, wherein
10 (a) a glass pane is provided with an outer surface and an interior-side surface,
(b) a coating is applied to the outer surface or the interior-side surface of the glass pane by depositing the layers in the following order:
- a lower highly refractive dielectric layer or layer sequence,
- an IR-reflecting layer based on titanium carbide, and
- an upper highly refractive dielectric layer or layer sequence.

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[0056] The upper highly refractive dielectric layer or layer sequence is preferably deposited by vapor deposition, for example by chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition (PECVD) and atomic layer deposition (ALD). Physical vapor deposition (PVD), for
20 example evaporation deposition, is particularly preferred, cathode sputtering ("sputtering") and in particular magnetic field-assisted cathode sputtering ("magnetron sputtering") are very particularly preferred.

[0057] According to the invention, the coating further comprises a lower highly
25 refractive dielectric layer or layer sequence deposited between the glass pane and the IR-reflecting layer. The lower highly refractive dielectric layer or layer sequence can be produced using the same methods as the upper highly refractive dielectric layer or layer sequence, with magnetron sputtering being particularly preferred here as well.

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[0058] The IR-reflecting layer based on TiC can also be deposited using the methods mentioned, with magnetron sputtering being particularly preferred

here as well. In a particularly advantageous embodiment, the IR-reflecting layer is deposited by reactive magnetron sputtering. It has been shown that this allows the production of IR-reflecting layers with particularly advantageous mechanical resistance, light transmission, reflective color and low specific resistance at a high deposition rate. These advantageous properties can be attributed to the fact that by using reactive magnetron sputtering, excellent layer homogeneity (i.e., consistent composition, crystallinity, layer thickness, and density) can be achieved with good crystallinity and density.

[0059] Reactive magnetron sputtering is a special variant of magnetron sputtering, which in turn is a variant of sputtering. During sputtering, a target (cathode) is bombarded with ions, whereupon material is dissolved from the target and then deposited on the surface to be coated. While in simple sputtering only an electric field is applied, in magnetron sputtering an additional magnetic field is arranged behind the cathode plate. Due to the overlay of electric field and magnetic field, the charge carriers no longer move parallel to the electric field lines, but circulate on a helical line above the target surface. This lengthens their path and increases the number of collisions per electron. The effectively higher ionization capacity of the electrons leads to an increase in the sputtering rate. This means that significantly higher coating rates can be achieved at the same process pressure. In addition, denser layers can be created. Reactive magnetron sputtering is a method based thereon, wherein one or more reactive gases are added to an inert working gas (such as Ar). The gases react with the sputtered layer atoms on the target, in the vacuum chamber or on the surface to be coated and form new materials. The resulting reaction products then deposit on the surface to be coated. According to a preferred embodiment, the reactive gas is at least one of methane, acetylene and nitrogen, more preferably at least one of methane and acetylene, and most preferably methane or acetylene is used, because by using only one reactive gas the properties of the reaction product (such as stoichiometry, crystallinity and layer thickness) can be more easily controlled. When using reactive magnetron sputtering, a titanium target is preferred. The target and the

sputtered layer can be doped with additional materials, such as nitrogen, boron or aluminum, which can affect the mechanical, electrical, chemical and optical properties of the layer and/or increase the deposition rate. According to a particularly preferred embodiment, the reactive magnetron sputtering is
5 reactive DC (*direct current*) magnetron sputtering or reactive ACMF (*alternating current mid-frequency*) magnetron sputtering, which allows good monitoring of the sputtering and is also cost effective.

[0060] According to another embodiment, the IR-reflecting layer based on TiC
10 is produced by simple magnetron sputtering using a titanium carbide target and an inert working gas (e.g., Ar).

[0061] According to one embodiment, the coating further comprises a low refractive dielectric layer or layer sequence having a refractive index of less
15 than 1.6, which layer or layer sequence is deposited on the upper highly refractive dielectric layer.

[0062] In one embodiment of the invention, the low refractive dielectric layer is also deposited by the aforementioned methods of vapor deposition, with
20 magnetic-field-assisted cathode sputtering being particularly preferred here as well.

[0063] The IR-reflecting layer based on TiC, the upper highly refractive dielectric layer, the lower highly refractive dielectric layer and the low refractive
25 dielectric layer correspond to the layers described above for the pane according to the invention.

[0064] After the coating has been applied, the pane is preferably subjected to a heat treatment, which improves the crystallinity of the layers and regularly
30 improves the light transmission and optical properties of the pane. The temperature treatment can, for example, be carried out at a temperature of at least 500 °C. The temperature treatment can also be carried out as part of a

bending and/or prestressing method. The temperature treatment described above is also referred to according to the invention as “thermal annealing” or “annealing”.

5 [0065] According to one embodiment, after the coating has been applied, the pane can be subjected to a bending process in order to bring it into a cylindrical or spherically curved shape, as is customary for panes for use in vehicles, in particular for panes for use in passenger cars or trucks. For bending, the pane is softened by heating so that it can become plastically pliable, and is then
10 shaped by methods known per se, for example by gravity bending, press bending and/or suction bending. Typical temperatures for glass-bending processes are, for example, 500°C to 700°C.

[0066] If the pane is to be designed as a laminated pane, the coated (and
15 possibly curved) glass pane is connected to the outer pane or inner pane via a thermoplastic intermediate layer. Lamination methods known per se, for example autoclave methods, vacuum bag methods, vacuum ring methods, calender methods, vacuum laminators or combinations thereof, are used here. The glass pane and the outer pane or inner pane are usually connected via
20 the intermediate layer under the influence of heat, vacuum and/or pressure. The thermoplastic intermediate layer is preferably formed from at least one thermoplastic film, preferably a PVB film, EVA film or PU film. The typical thicknesses for such films are within the range from 0.2 mm to 2 mm, in particular from 0.3 mm to 1 mm.

25 [0067] The invention also encompasses the use of a pane according to the invention as a window pane of a means of transport on land, on water or in the air, preferably of a motor vehicle or rail vehicle, particularly preferably as a rear window or roof pane, or as a pane for a building, preferably as a window pane,
30 facade pane or door pane.

[0068] Various specific applications of the pane according to the invention are conceivable:

- Thus, the coating can serve to provide a pane with a low light transmittance TL of 50% or less and low emissivity, which can be particularly advantageous when used as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building, preferably as a window pane, facade pane or door pane.

- Because the coating can be used for both thermally annealed and not thermally annealed products, because thermal annealing causes at most only a slight color change of the pane, the corresponding manufacturing methods are efficient, so that the production costs for the corresponding products are low. In particular, a pane according to the invention, which has been subjected to thermal annealing, and a pane according to the invention, which has not been subjected to thermal annealing, can be used in close proximity to each other without creating a visually disadvantageous impression for the observer because the pane according to the invention experiences at most a slight color change during thermal annealing and thus is almost indistinguishable from the pane according to the invention which has not been subjected to thermal annealing.

- Due to the at most slight color change during thermal annealing, the pane according to the invention can be used in a variety of ways as an annealed pane without any undesirable coloring of the pane occurring, which can be advantageous in particular when used as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building, preferably as a window pane, facade pane or door pane.

[0069] In the following, the invention is explained in more detail with the aid of drawings and examples of embodiments. The drawings are schematic representations and are not true to scale. The drawings do not limit the invention in any way.

[0070] In the drawings:

Fig. 1 shows a cross section through an embodiment of the pane 1 according to the invention,

- Fig. 2 shows a cross section through a further embodiment of the pane 1 according to the invention,
- Fig. 3 shows a cross section through a further embodiment of the pane 1 according to the invention,
- 5 Fig. 4 shows a cross section through a further embodiment of the pane 1 according to the invention,
- Fig. 5 shows a cross section through a further embodiment of the pane 1 according to the invention,
- Fig. 6 shows a cross section through a general coating 20 on a glass pane 2,
- 10 Fig. 7 shows a cross section through a further general coating 20 on a glass pane 2,
- Fig. 8 shows a cross section through an embodiment of the coating 20 according to the invention on a glass pane 2,
- Fig. 9 shows a cross section through a further embodiment of the coating 20 according to the invention on a glass pane 2,
- 15 Fig. 10 shows a flowchart of an embodiment of the method according to the invention,
- Fig. 11 shows a spectrum of the light transmission TL in relation to the wavelength of the pane 1 according to the invention as per Example 1,
- 20 Fig. 12 shows a spectrum of the light reflection RL_c in relation to the wavelength of the pane 1 according to the invention as per Example 1,
- Fig. 13 shows a spectrum of the light transmission TL in relation to the wavelength of the pane 1 according to the invention as per Example 2,
- Fig. 14 shows a spectrum of the light reflection RL_{out} in relation to the wavelength of the pane 1 according to the invention as per Example 2,
- 25 Fig. 15 shows a spectrum of the light transmission TL in relation to the wavelength of the pane 1 according to the invention as per Example 3,
- Fig. 16 shows a spectrum of the light reflection RL_{out} in relation to the wavelength of the pane 1 according to the invention as per Example 3,
- 30 Fig. 17 shows a spectrum of the light transmission TL in relation to the wavelength of the pane 1 according to the invention as per Example 4, and

Fig. 18 shows a spectrum of the light reflection R_{Lout} in relation to the wavelength of the pane 1 according to the invention as per Example 4.

[0071] Fig. 1 shows an embodiment of a pane 1 according to the invention.

5 The pane 1 is intended, for example, as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building. It is a monolithic pane (single glass pane) and comprises a single glass pane 2 made of, for example, thermally annealed soda lime glass having a thickness of 1.9 mm. The outer pane 2 has an outer surface I, which in the installed position faces the external
10 environment, and an interior-side surface II, which in the installed position faces the interior. The interior-side surface II is completely provided with a coating 20 according to the invention.

[0072] Fig. 2 shows a further embodiment of a pane 1 according to the
15 invention. The pane 1 is intended, for example, as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building. It is a monolithic pane (single glass pane) and comprises a single glass pane 2 made of, for example, thermally annealed soda lime glass having a thickness of 1.9 mm. The outer pane 2 has an outer surface I, which in the installed position
20 faces the external environment, and an interior-side surface II, which in the installed position faces the interior. The outer surface I is completely provided with a coating 20 according to the invention.

[0073] The coating 20 according to the invention has IR-reflective properties.
25 It therefore acts as a solar control coating. This increases the thermal comfort in the interior, as it heats up less. In addition to its infrared (IR)-reflecting properties, the coating 20 according to the invention is also chemically and mechanically resistant due to the use of TiC in the IR-reflecting layer and shows at most a slight color change after a possible thermal annealing.

30

[0074] Both surfaces I, II of such a single glass pane are exposed, i.e., they have contact with the atmosphere. They could not be coated with conventional,

corrosion-prone (e.g., silver-based) IR-reflective coatings. Because the coating
20 according to the invention with IR-reflecting effect is not susceptible to
corrosion, such a coating is possible without any problems.

5 [0075] Fig. 3 shows a further embodiment of a pane 1 according to the
invention. The pane 1 is formed as a laminated pane, wherein a glass pane 2
functions as an outer pane and is connected to an inner pane 5 via a
thermoplastic intermediate layer 4. In the installed position, the glass pane 2
faces the external environment. In the installed position, the inner pane 5 faces
10 the interior. The glass pane 2 has an outer surface I and an interior-side
surface II. The inner pane 5 likewise has an outer surface III and an interior-
side surface IV. The glass pane 2 and the inner pane 5 consist, for example,
of soda lime glass having a thickness of 4 mm. The thermoplastic intermediate
layer 4 is formed, for example, from a film based on polyvinyl butyral (PVB)
15 having a thickness of 0.38 mm. The pane 1 is intended, for example, as a rear
window or roof window of a motor vehicle or rail vehicle or as a pane for a
building. The interior-side surface II of the glass pane 2 is fully provided with a
coating 20 according to the invention.

20 [0076] Fig. 4 shows a further embodiment of a pane 1 according to the
invention. The pane 1 is formed as a laminated pane, wherein a glass pane 2
functions as an inner pane and is connected to an outer pane 3 via a
thermoplastic intermediate layer 4. In the installed position, the outer pane 3
faces the external environment. In the installed position, the glass pane 2 faces
25 the interior. The outer pane 3 has an outer surface I and an interior-side surface
II. The glass pane 2 likewise has an outer surface III and an interior-side
surface IV. The glass pane 2 and the outer pane 3 consist, for example, of
soda lime glass having a thickness of 4 mm. The thermoplastic intermediate
layer 4 is formed, for example, from a film based on polyvinyl butyral (PVB)
30 having a thickness of 0.38 mm. The pane 1 is intended, for example, as a rear
window or roof window of a motor vehicle or rail vehicle or as a pane for a

building. The outer surface III of the glass pane 2 is fully provided with a coating 20 according to the invention.

[0077] Fig. 5 shows a further embodiment of a pane 1 according to the invention. The pane 1 is formed as a laminated pane, wherein a glass pane 2 functions as an inner pane and is connected to an outer pane 3 via a thermoplastic intermediate layer 4. In the installed position, the outer pane 3 faces the external environment. In the installed position, the glass pane 2 faces the interior. The outer pane 3 has an outer surface I and an interior-side surface II. The glass pane 2 likewise has an outer surface III and an interior-side surface IV. The glass pane 2 and the outer pane 3 consist, for example, of soda lime glass having a thickness of 4 mm. The thermoplastic intermediate layer 4 is formed, for example, from a film based on polyvinyl butyral (PVB) having a thickness of 0.38 mm. The pane 1 is intended, for example, as a rear window or roof window of a motor vehicle or rail vehicle or as a pane for a building. The interior-side surface IV of the glass pane 2 is fully provided with a coating 20 according to the invention.

[0078] Fig. 6 shows a general coating 20 on a glass pane 2. The coating 20 is arranged on the interior-side surface II or IV or on the exterior surface I or III of the glass pane 2. The coating 20 consists of an IR-reflecting layer 22 based on titanium carbide and an upper highly refractive dielectric layer 23, which are arranged in this order on the glass pane 2, starting from its surface I, II, III or IV. The IR-reflecting effect is provided by the IR-reflecting layer 22 based on titanium carbide. The upper highly refractive dielectric layer 23 reduces or prevents the oxidation of the IR-reflecting layer 22 during a possible temperature treatment.

[0079] Fig. 7 shows a further general coating 20 on a glass pane 2. It differs from the pane 1 of Fig. 6 in that instead of a single upper highly refractive dielectric layer 23, there is an upper highly refractive dielectric layer sequence 23a, 23b. The layer sequence consists of a first highly refractive dielectric layer

23a and a second highly refractive dielectric layer 23b, which are arranged in this order on the IR-reflecting layer 22. The first layer 23a is a nitride layer and is in direct contact with the IR-reflecting layer 22. The second layer 23b is an oxide layer with a particularly high refractive index. The first layer 23a prevents
5 contact between the IR-reflecting layer 22 and the oxide second layer 23b, so that undesired oxidation of the IR-reflecting layer 22 can be prevented during deposition of the layers or during a subsequent thermal treatment.

[0080] Fig. 8 shows an embodiment of the coating 20 according to the
10 invention on a glass pane 2. It differs from the pane 1 of Fig. 6 in that the coating 20 further comprises a lower highly refractive dielectric layer 21 formed between the glass pane 2 and the IR-reflecting layer 22. The lower highly refractive dielectric layer 21 can prevent components of the glass pane 2 from penetrating the IR-reflecting layer 22 based on titanium carbide during a
15 possible temperature treatment.

[0081] Fig. 9 shows a further embodiment of the coating 20 according to the invention on the glass pane 2. It differs from the embodiment of Fig. 8 in that the coating 20 further comprises a low refractive dielectric layer 24 with a
20 refractive index of less than 1.6 which is arranged on the upper highly refractive dielectric layer 23. This coating 20 allows the pane to have an anti-reflective effect in addition to its IR-reflecting properties.

[0082] Fig. 10 shows an exemplary embodiment of the method according to
25 the invention for producing a pane 1 with coating 20 using a flow chart.

Examples

Example 1

30

[0083] A pane 1 according to the invention was produced. It was designed as a single glass pane and comprised a glass pane 2 (Planiclear® from Saint-

Gobain Glass, soda lime glass, light transmission TL of 91%) having a thickness of 1.9 mm, on the surface of which a coating 20 according to the invention was applied. Starting with the glass pane 2, the layer sequence having the listed layer thicknesses and materials was as follows:

- 5 - lower highly refractive dielectric layer 21: SiN (30 nm, refractive index 2.0),
- IR-reflecting layer 22 based on titanium carbide: TiC (30 nm), and
- upper highly refractive dielectric layer 23: SiN (30 nm, refractive index 2.0).

[0084] The lower highly refractive dielectric layer 21 and the upper highly refractive dielectric layer 23 were each deposited by magnetron sputtering. The IR-reflecting layer 22 was deposited by reactive magnetron sputtering using a titanium target and acetylene as the reactive gas. Properties of the pane 1 according to the invention are shown in Tables 1 and 2. The coated pane 1 was further subjected to a heat treatment at a temperature of 640 °C for a period of 8 min ("thermal annealing"). Properties of the annealed pane 1 according to the invention are also shown in Tables 1 and 2.

Comparative example

[0085] A pane was also produced according to the comparative example. It was designed as a single glass pane and comprised a glass pane (Planiclear® from Saint-Gobain Glass, soda lime glass, light transmission TL of 91%) having a thickness of 1.9 mm, on the surface of which a coating was applied. Starting with the glass pane, the layer sequence with the listed layer thicknesses and materials was as follows:

- lower highly refractive dielectric layer: SiN (30 nm, refractive index 2.0),
- IR-reflecting layer 22 based on titanium nitride: TiN (15 nm), and
- upper highly refractive dielectric layer: SiN (30 nm, refractive index 2.0).

[0086] The lower highly refractive dielectric layer and the upper highly refractive dielectric layer were each deposited by magnetron sputtering. The IR-reflecting layer was deposited by magnetron sputtering using a titanium

nitride target. Properties of the pane according to the comparative example are also shown in Tables 1 and 2. The coated pane according to the comparative example was further subjected to a heat treatment at a temperature of 640°C for a period of 8 min (“thermal annealing”). Properties of the annealed pane according to comparative example are also shown in Tables 1 and 2, wherein it should be noted that for the comparative example RLg, a*Rg, b*Rg, ρ and ε were not measured.

[0087] In Tables 1 and 2,

- 10 - TL is the integrated light transmission in accordance with ISO 9050 (illuminant D65);
 - a*T and b*T are the values of the transmission color in the L*a*b* color space, measured with an angle of incidence of 8° and an angle of observation of 2° (illuminant D65);
- 15 - RLc is the integrated light reflection, measured from the coating side with an angle of incidence of 8° and an observation angle of 2° (illuminant D65);
 - a*Rc and b*Rc are the values of the reflection color from the coating side in the L*a*b* color space, measured with an angle of incidence of 8° and an angle of observation of 2° (illuminant D65);
- 20 - RLg is the integrated light reflection, measured from the glass side with an angle of incidence of 8° and an observation angle of 2° (illuminant D65);
 - a*Rg and b*Rg are the values of the reflection color from the glass side in the L*a*b* color space, measured with an angle of incidence of 8° and an angle of observation of 2° (illuminant D65);
- 25 - ρ is the specific resistance, measured with NAGY resistance meter ZPM00052;
 - ε the normal interior-side emissivity at 283 K according to EN 12898;
 - $\Delta E(T)$ is the color difference, related to the transmission, measured in accordance with EN ISO 11664-4;
- 30 - $\Delta E(Rc)$ is the color difference, measured from the coating side in accordance with EN ISO 11664-4; and

- $\Delta E(R_g)$ is the color difference, measured from the glass side in accordance with EN ISO 11664-4.

Table 1

5

IR-reflecting layer	Temperature treatment	TL [%]	a*T	b*T	RLc [%]	a*Rc	b*Rc
TiC	No (rt)	25.0	-1.8	0	22.5	2.1	22.2
TiC	Yes (8 min at 640 °C)	26.7	-1.1	1.9	20.3	0.6	19.7
TiN	No (rt)	50.9	-2.5	-4.6	13.5	1.0	5.9
TiN	Yes (8 min at 640 °C)	54.9	-2.8	-2.9	11.4	2.2	-0.9

“rt” means “room temperature”

Table 2

IR-reflecting layer	Temperature treatment	RLg [%]	a*Rg	b*Rg	ρ [$\mu\Omega$ cm]	ϵ [%]	$\Delta E(T)$	$\Delta E(R_c)$	$\Delta E(R_g)$
TiC	No (rt)	25.8	-1.9	5.7	240	49	-	-	-
TiC	Yes (8 min at 640 °C)	25.4	-2.7	4.5	225	46	2.0	2.9	1.4
TiN	No (rt)	-	-	-	-	-	-	-	-
TiN	Yes (8 min at 640 °C)	-	-	-	-	-	1.7	6.9	-

10 “rt” means “room temperature”

[0088] The pane 1 according to the invention as per Example 1 has an attractive transmission color a*T and b*T and reflection color a*Rc, b*Rc, a*Rg and b*Rg and a low specific resistance ρ . In addition, it exhibits solar control properties and a low emissivity ϵ . In addition, the pane 1 according to the invention as per Example 1 showed only a small color difference ΔE due to the thermal treatment. In contrast, a significant color change was measurable for the comparative example using TiN. This is particularly evident in the $\Delta E(R_c)$ value, which was only 2.9 for the pane 1 according to the invention as per Example 1,

while the comparative example had a significantly higher value of 6.9. The higher the value of ΔE , $\Delta E(R_c)$ and $\Delta E(R_g)$, the stronger the color change.

[0089] Fig. 11 and 12 show the light transmission and the light reflection, respectively, of the pane 1 according to the invention as per Example 1, which was subjected to the temperature treatment. The experimental measurements are shown in black. In addition, a simulation of the heat-treated pane 1 according to the invention was carried out as per Example 1 with the layer sequence listed above. The simulated data (shown in gray in Fig. 11 and 12) show good agreement with the experimental data.

Examples 2 to 4

[0090] Further temperature-treated panes 1 according to the invention were simulated. They were designed as laminated panes and comprised a glass pane 2 and a further glass pane as inner pane (glass pane and inner pane: Planiclear® from Saint-Gobain Glass, soda lime glass, light transmission TL of 91%) having a thickness of 4.0 mm each, with the glass pane 2 acting as the outer pane and the coating being arranged on the interior-side surface (II) of the glass pane 2 as the outer pane. The arrangement of the panes and the coating 20 for the laminated panes was as follows:

Example 2:

- inner pane 5: glass (4.0 mm)
- thermoplastic intermediate layer 4: PVB (0.38 mm)
- upper highly refractive dielectric layer 23: TiO 23b (15 nm), SiN 23a (23 nm), wherein SiN 23a has direct contact with the IR-reflecting layer 22
- IR-reflecting layer 22 based on titanium carbide: TiC (28.2 nm)
- lower highly refractive dielectric layer 21: SiN (49.8 nm), and
- the glass pane 2 as outer pane: glass (4.0 mm).

Example 3:

- inner pane 5: glass (4.0 mm)
- thermoplastic intermediate layer 4: PVB (0.38 mm)
- 5 - upper highly refractive dielectric layer 23: TiO₂ 23b (5.8 nm), SiN₂ 23a (37.1 nm), wherein SiN₂ 23a has direct contact with the IR-reflecting layer 22
- IR-reflecting layer 22 based on titanium carbide: TiC (23.5 nm)
- lower highly refractive dielectric layer 21: TiO₂ (0.3 nm), and
- the glass pane 2 as outer pane: glass (4.0 mm).

10

Example 4:

- inner pane 5: glass (4.0 mm)
- thermoplastic intermediate layer 4: PVB (0.38 mm)
- 15 - upper highly refractive dielectric layer 23: SiN₂ (24.8 nm)
- IR-reflecting layer 22 based on titanium carbide: TiC (11.1 nm)
- lower highly refractive dielectric layer 21: SiN₂ (5.6 nm), TiO₂ (5.2 nm), wherein SiN₂ has direct contact with the IR-reflecting layer 22, and
- the glass pane 2 as outer pane: glass (4.0 mm).

20

[0091] Properties of the panes 1 according to the invention of Examples 2 to 4 are shown in Table 3.

[0092] The properties TL, a*T, b*T and ϵ listed in Table 3 correspond to the
25 properties given above for Tables 1 and 2, respectively, wherein these were simulated and not measured.

[0093] In addition, in Table 3

- R_{Lin} is the integrated light reflection, simulated by the inner pane of the
30 laminated glass with an incidence angle of 8° and an observation angle of 2° (illuminant D65);

- a^*R_{in} and b^*R_{in} are the simulated values of the reflection color from the inner pane of the laminated pane in the $L^*a^*b^*$ color space, simulated with an angle of incidence of 8° and an angle of observation of 2° (illuminant D65);
- RL_{out} is the integrated light reflection, simulated from the outer pane of the laminated pane with an incidence angle of 8° and an observation angle of 2° (illuminant D65);
- a^*R_{out} and b^*R_{out} are the simulated values of the reflection color from the outer pane of the laminated pane in the $L^*a^*b^*$ color space, simulated with an angle of incidence of 8° and an angle of observation of 2° (illuminant D65); and
- g is the *Solar Control* value, which corresponds to the percentage of solar energy that passes through the glass into a room. This factor takes into account the direct transmission of the glass and the phenomenon of energy reflectivity of the glass wall toward the interior (glass heats up by absorbing solar rays), measured in accordance with ISO 9050 AM 1.5.

15

[0094] The pane 1 according to the invention as per Example 2 has a light transmission TL of 29%, a similar internal and external reflection (RL_{in} and RL_{out} respectively) as well as neutral transmission colors a^*T and b^*T and reflection colors a^*R_{in} , b^*R_{in} , a^*R_{out} and b^*R_{out} at a low g value. In addition,

20 the pane 1 according to the invention as per Example 3 shows a light transmission TL of 30% and a high external reflection RL_{out} , while it has neutral transmission colors a^*T and b^*T and reflection colors a^*R_{in} , b^*R_{in} , a^*R_{out} and b^*R_{out} and a low g value. The pane 1 according to the invention as per Example 4 has a light transmission TL of 46% with similar internal and

25 external reflection (RL_{in} and RL_{out} , respectively), neutral reflection color a^*R_{in} , b^*R_{in} , a^*R_{out} and b^*R_{out} and transmission color a^*T and b^*T and a low g value.

[0095] Fig. 13 to 18 show the light transmission and the light reflection of the

30 panes 1 according to the invention as per Examples 2 to 4.

Table 3

Coating	TL [%]	a*T	b*T	RLin [%]	a*Rin	b*Rin	RLout [%]	a*Rout	b*Rout	ϵ [%]	g
Example 2	29	-3.7	10.4	14.4	3.8	3.0	16.2	1.6	-2.0	47	34
Example 3	30	-1.8	7.1	8.8	2.3	0	30.5	-2.8	-1.0	50	35
Example 4	46	-1.0	4.3	12.8	-2.0	-2.5	17.0	-2.2	-5.6	60	49

List of reference signs:

- | | | | |
|----|-------|--|--|
| | (1) | Pane | |
| | (2) | Glass pane | |
| 5 | (3) | Outer pane | |
| | (4) | Thermoplastic intermediate layer | |
| | (5) | Inner pane | |
| | (20) | Coating | |
| 10 | (21) | Lower highly refractive dielectric layer | |
| | (22) | IR-reflecting layer based on titanium carbide | |
| | (23) | Upper highly refractive dielectric layer | |
| | (23a) | First layer of an upper dielectric layer sequence | |
| | (23b) | Second layer of an upper dielectric layer sequence | |
| 15 | (24) | Low refractive dielectric layer | |
| | (I) | Outer surface of the glass pane 2 in the case of a single glass pane /
outer surface of the glass pane 2 or the outer pane 3 in the case of a
laminated pane | |
| 20 | (II) | Interior-side surface of the glass pane 2 in the case of a single glass
pane / interior-side surface of the glass pane 2 or the outer pane 3 in
the case of a laminated pane | |
| | (III) | Outer surface of the glass pane 2 or the inner pane 5 in the case of a
laminated pane | |
| 25 | (IV) | Interior-side surface of the glass pane 2 or the inner pane 5 in the case
of a laminated pane | |

Claims

1. A pane (1), comprising
 - at least one glass pane (2) having an outer surface (I, III) and an interior-side surface (II, IV), and
 - a coating (20) on the outer surface (I, III) or the interior-side surface (II, IV) of the glass pane (2),
wherein the coating (20) comprises at least, starting from the surface (I, II, III, IV) of the glass pane (2), in the following order:
 - a lower highly refractive dielectric layer (21) or layer sequence,
 - an IR-reflecting layer (22) based on titanium carbide, and
 - an upper highly refractive dielectric layer (23) or layer sequence (23a, 23b),
wherein the IR-reflecting layer (22) has a layer thickness of 2 nm to 50 nm.
2. The pane (1) according to claim 1, wherein the highly refractive dielectric layer (21, 23) or layer sequence (23a, 23b) contains a layer based on silicon nitride (SiN), silicon-metal mixed nitride or titanium oxide (TiO).
3. The pane (1) according to claim 1 or 2, wherein the refractive index of the highly refractive dielectric layer (21, 23) or layer sequence (23a, 23b) is greater than 1.9.
4. The pane (1) according to any one of claims 1 to 3, wherein the upper highly refractive dielectric layer (23) or layer sequence (23a, 23b) has an optical thickness of from 10 nm to 120 nm, preferably from 20 nm to 100 nm.
5. The pane (1) according to any one of claims 1 to 4, wherein the pane (1) has a light transmission TL of 50% or less.

6. The pane (1) according to any one of claims 1 to 5, wherein the glass pane (2) contains or consists of flat glass, preferably soda lime glass, borosilicate glass or quartz glass.
- 5 7. The pane (1) according to any one of claims 1 to 6, wherein the pane (1) comprises no silver layer.
8. The pane (1) according to any one of claims 1 to 7, which is designed as a laminated pane, wherein the glass pane (2) is connected to an outer pane
10 (3) via a thermoplastic intermediate layer (4).
9. The pane (1) according to any one of claims 1 to 7, which is designed as a laminated pane, wherein the glass pane (2) is connected to an inner pane (5) via a thermoplastic intermediate layer (4).
15
10. The pane (1) according to any one of claims 1 to 7, which is designed as a single glass pane.
11. The pane (1) according to any one of claims 1 to 10, wherein the pane
20 (1) has a light transmission TL of 25% or more.
12. A method for producing a pane (1), wherein
 - (a) a glass pane (2) is provided with an outer surface (I, III) and an interior-side surface (II, IV),
 - 25 (b) a coating (20) is applied to the outer surface (I, III) or the interior-side surface (II, IV) of the glass pane (2) by depositing the layers in the following order:
 - a lower highly refractive dielectric layer (21) or layer sequence,
 - an IR-reflecting layer (22) based on titanium carbide, and
 - 30 - an upper highly refractive dielectric layer (23) or layer sequence (23a, 23b),wherein the IR-reflecting layer (22) has a layer thickness of 2 nm to 50 nm.

13. The method according to claim 12, wherein the IR-reflecting layer (22) is deposited by reactive magnetron sputtering.

- 5 14. A use of a pane (1) according to any one of claims 1 to 11 as a window pane of a means of transport on land, on water or in the air, preferably of a motor vehicle or rail vehicle, particularly preferably as a rear window or roof pane, or as a pane for a building, preferably as a window pane, facade pane or door pane.