

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(10) **DK/EP 2801846 T3**

(12) Oversættelse af
europæisk patentskrift

-
- (51) Int.Cl.: **G 02 B 1/111 (2015.01)** **G 02 B 1/113 (2015.01)** **G 02 B 1/12 (2006.01)**
G 02 B 1/14 (2015.01) **G 02 C 7/02 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2019-10-21**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-07-24**
- (86) Europæisk ansøgning nr.: **14163993.0**
- (86) Europæisk indleveringsdag: **2014-04-09**
- (87) Den europæiske ansøgnings publiceringsdag: **2014-11-12**
- (30) Prioritet: **2013-05-06 DE 102013208310**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Carl Zeiss Vision International GmbH, Turnstrasse 27, 73430 Aalen, Tyskland**
- (72) Opfinder: **Hugenberg, Norbert, Fuchsweg 34, 73434 Aalen, Tyskland**
HAIDL, Markus, Hegelstrasse 49/6, 73431 Aalen, Tyskland
VON BLANCKENHAGEN, Bernhard, Schlossstrasse 6/2, 73433 Aalen, Tyskland
Holz, Lothar, Tilsiterstrasse 23, 73432 Unterkochen, Tyskland
Kraus, Stefan, Waiblingerstrasse 55, 73434 Aalen, Tyskland
MACIONCZYK, Frank, Weingartenstrasse 77, 73447 Oberkochen, Tyskland
Krause, Michael, Ammonitenweg 35, 89081 Ulm, Tyskland
Green, Erwin, Kapfenburgstrasse 24, 73432 Aalen, Tyskland
WINTER, Karl-Heinz, Galgenweg 16, 73457 Essingen, Tyskland
Faul, Silvia, Wehrleshalde 22, 73434 Aalen, Tyskland
Peng, Bin, Im Heimatwinkel 1, 73434 Aalen, Tyskland
Pütz, Dr., Jörg, Fahrbachstrasse 290, 73431 Aalen, Tyskland
Kiefer, Patrick, Mittlere Waldparkstrasse 2, 75239 Eisingen, Tyskland
Krieger, Michael, Milanweg 107, 73434 Aalen, Tyskland
NEUFFER, Andreas, Teckstrasse 20, 71679 Asperg, Tyskland
Stroisch, Marc, Schleiermacherstrasse 35, 73431 Aalen, Tyskland
Glöge, Thomas, Georg-von-der-Vring-Strasse 11, 73614 Schorndorf, Tyskland
Kollo, Anja, Eichklingenstrasse 21, 73453 Abtsgmünd, Tyskland
Hanssen, Adalbert, Elsterweg 4, 73434 Aalen, Tyskland
- (74) Fuldmægtig i Danmark: **RWS Group, Europa House, Chiltern Park, Chiltern Hill, Chalfont St Peter, Bucks SL9 9FG, Storbritannien**
- (54) Benævnelse: **Optisk element med en belægning med høj diffusivitet**
- (56) Fremdragne publikationer:
EP-A1- 2 437 084
EP-A2- 0 698 798
US-A1- 2011 058 142

Fortsættes ...

Description

The invention relates to an optical element, in particular a spectacle lens or a spectacle lens blank, comprising a substrate body produced from a transparent plastic, and comprising a coating having a plurality of layers, said coating comprising a hard lacquer layer adjoining the substrate body and an antireflection coating arranged on the hard lacquer layer and having a mono- or multilayer construction.

An optical element of this type is known in the form of an optical lens embodied as a spectacle lens e.g. from EP 2 437 084 A1.

For optical lenses, in particular for spectacle lenses, plastic that is transparent in the visible spectral range is increasingly being used nowadays as material instead of silicate glass. Compared with silicate glass, plastic affords the advantages of a lower weight, a higher breaking strength, colorability and the possibility of providing rimless frames. One known disadvantage of optical lenses composed of plastic, however, is that their surface area is highly susceptible to mechanical stresses and can easily be damaged by scratching.

In order to minimize this susceptibility to mechanical stresses and scratching in the case of optical lenses composed of plastic, a coating comprising a hard lacquer layer, which is intended to protect the optical lens against mechanical effects, is applied to the plastic.

Furthermore, it is known to provide optical elements with an antireflection coating. Disturbing specular reflections can thus be avoided in the case of spectacle lenses. Antireflection coatings generally contain at least one layer composed of an inorganic, oxidic material that is optically transparent. An antireflection coating can contain in particular a sequence of layers composed of optically

transparent, inorganic, oxidic material in which layers having a first refractive index and layers having a second refractive index, which second refractive index is higher than the first refractive index, are successively alternated.

5

Furthermore, it is known to embody an optical element with an antireflection coating which also protects against scratching. EP 0 698 798 A2 proposes for this purpose, for example, an antireflection coating containing a layer of borosilicate glass, which layer is vapor-deposited onto a precoated substrate body by means of a PVD (Physical Vapor Deposition) method.

10

In a coating on a substrate body composed of plastic, defects can arise which are initiated by the incorporation of water vapor or water molecules into the substrate body if the latter comes into contact with moisture, i.e. water or water vapor, but also with customary cleaning media such as e.g. alcohol or acetone.

20

US 2011/058142 A1 describes a spectacle lens coating comprising a hard lacquer layer which consists of two partial layers of hard lacquer lying one above the other. Here the lower partial layer is treated by means of a corona discharge or is produced with a fluorosurfactant as a flow control additive.

25

In general, a coating has an at least passage-impeding, often even blocking effect for these substances with which in particular a spectacle lens comes into contact repeatedly over the course of its lifetime.

30

US 2011/305827 A1 discloses a spectacle lens coating comprising a layer having a pore structure. Said layer having a pore structure has an antisoiling effect. It is applied as a cover layer on a layer on the surface of the substrate body.

35

If these substances penetrate into an optical element e.g. on

account of damage to the coating, that can have the consequence that, in the case of the optical element, the substrate body or else a layer applied thereto, such as a hard lacquer layer, for example, swells. Generally, in the case of the optical element, that then leads to local alterations of an optically active surface. On account of an individual scratch location, the optical element can thus easily be damaged in this way in a region extending over one square millimeter or else a number of square millimeters. In this region, an optically active surface of the optical element can also rise, often by 0.1 μm even by up to 1 μm .

It is true that the substances that penetrated into such a layer composed of hard lacquer and/or a plastic body diffuse out again over time when the optical element is no longer exposed to the relevant substances. These diffusion processes lead to local volume changes, however, which in part are irreversible. They cause surface deformations, in particular, which e.g. not only bring about point and line patterns (warpage) on a coating, but also, in the case of spectacle lenses, can cause striations discernible to the naked eye under ambient lighting and furthermore also layer defects on account of mechanical stresses.

Therefore, it is an object of the invention to provide an optical element comprising a permanent and at the same time scratch-resistant coating on a substrate body composed of plastic, and to specify a method for producing such an optical element.

This object is achieved by means of an optical element comprising the features of Claim 1 and a method comprising the features of Claim 10. Advantageous embodiments of the invention are specified in the dependent claims.

The inventors have recognized that, in the case of an optical element, the occurrence of defects in a coating applied on a substrate body composed of plastic can be prevented by

ensuring that the coating has in particular a permeability to water vapor or water molecules which enables the incorporation and extraction of water molecules in the plastic body on a timescale which exceeds the timescale for the incorporation and extraction of water molecules at the locations at which a coating is damaged, i.e. the timescale for the incorporation and extraction of water molecules when the plastic body is uncoated, by not more than approximately five-fold, i.e. by not more than approximately half an order of magnitude.

An optical element according to the invention can be embodied as a lens, in particular as a spectacle lens. It has a substrate body composed of plastic that is transparent in the visible spectral range. An optical element according to the invention has a coating having a plurality of layers, said coating comprising a hard lacquer layer adjoining the substrate body.

The coating on the substrate body has a diffusivity D_F which ensures the absorption of water molecules passing through the coating in the substrate body and the release of water molecules from the substrate body through the coating from an air atmosphere arranged on that side of the coating which faces away from the substrate body with a moisture flow density j_D which, proceeding from the equilibrium state of the quantity of the water molecules incorporated in the substrate body in an air atmosphere at 23°C and 50% relative air humidity, brings about the setting of the equilibrium state of the quantity of the water molecules incorporated in the substrate body in an air atmosphere at 40°C and 95% relative air humidity within a time interval which is longer by not more than a time period having the length $\Delta t = 10h$, preferably by not more than a time period having the length $\Delta t = 9h$ or $\Delta t = 8h$ or $\Delta t = 7h$ or $\Delta t = 6h$ or $\Delta t = 5h$ or $\Delta t = 4h$ or $\Delta t = 3h$ or $\Delta t = 2h$, particularly preferably by not more than a time period having the length $\Delta t = 1h$, than the time interval required for setting this equilibrium state under corresponding conditions in the case of an uncoated substrate

body identical to the substrate body.

The diffusivity D_F of a coating is understood here to mean the permeability of the coating in particular to water molecules and water vapor, i.e. the capability of the coating to permit in particular the diffusion of water vapor and water molecules through the coating.

The diffusivity D_F of a coating links the moisture flow density j_D for the moisture flow penetrating through the coating with the density C_{FS} of water molecules incorporated in the substrate body via diffusion and the density C_{FG} of water molecules in the gas atmosphere on that side of the coating which faces away from the substrate body, as follows:

$$j_D = D_F (C_{FG} - \alpha C_{FS}),$$

wherein α is a constant.

Within the meaning of the invention, the quantity of the water molecules incorporated in the substrate body is in an equilibrium state if the number of water molecules incorporated into the substrate body changes by not more than 1% within 24 h.

The quantity of the water molecules incorporated into a substrate body can be measured gravimetrically, for example, or else, as described for instance in the publication by U. Schulz et al., Near-infrared spectroscopy for monitoring water permeability of optical coatings on plastics, Applied Optics, 862 26 (1997), can be determined by measuring an absorption spectrum for the substrate body in the infrared spectral range.

The relative air humidity is understood here to mean the ratio of the actually contained mass of water vapor in the air to the maximum possible mass of water vapor in the air. The relative air humidity is the ratio between the absolute air

humidity and the maximum air humidity of air at a specific temperature T , i.e. the ratio of the water vapor mass m_W contained in an air volume V to the maximum possible water vapor mass in the air volume V at the temperature T , if the
5 water vapor partial pressure in the air is equal to the saturation vapor pressure of water.

The plastic of the substrate body can be e.g. a polyurethane, a polythiourethane, PMMA, a polycarbonate, a polyacrylate or a
10 polydiethylene glycol bis(allyl carbonate) (CR 39). Furthermore, the plastic can also be a material from the MR product series from Mitsui Chemicals, e.g. the material MR-10[®], MR-7[®], MR-8[®] or MR-174[®], or the material Trivex.

15 The hard lacquer layer in the optical element according to the invention is transparent preferably in the visible spectral range. It has as far as possible a refractive index which corresponds to the refractive index of the plastic of the substrate body or which is close to said refractive index, in
20 order to ensure a good optical transmissivity and to avoid undesired color interferences. The hard lacquer layer is applied on the substrate body e.g. by means of a dipping method, a spraying method or a spin-coating method. In principle, however, it is possible also to apply the hard
25 lacquer layer to the substrate body by some other known method.

The hard lacquer layer is produced from a sol-gel hard lacquer composition, e.g. a sol-gel hard lacquer composition based on
30 an acrylic polymer, an epoxy polymer, a urethane polymer, a melamine polymer, or else an inorganic material, in particular a quartz-based inorganic material, such as e.g. siloxane. The material for the sol-gel hard lacquer composition can also be an organically modified ceramic in which, instead of an oxygen
35 atom, a metal atom, for instance titanium, is incorporated into a polysiloxane matrix. In accordance with one particularly preferred embodiment, the sol-gel hard lacquer composition is an inorganic-organic silicone resin.

An optical element according to the invention preferably has a coating having a scratch resistance corresponding to a Bayer number Z_B where $Z_B \geq 8$, preferably $Z_B \geq 10$, in particular $Z_B \geq 14$, that is determined in an extended Bayer test and characterizes the scratch resistance of a coating.

An extended Bayer test for characterizing the scratch resistance of a coating of an optical element is understood here to mean the scratch resistance test - described below - from Colts Laboratories for spectacle lenses, this test being correspondingly applied to such a coating: during this test, a specific quantity of sharp-edged particles are led over the surface of the spectacle lens and the spectacle lens is subsequently evaluated optically. During the Bayer test from Colts Laboratories, for this purpose an abrasive material is led over test lenses and reference lenses in the form of uncoated spectacle lenses composed of the plastic CR39 (poly(allyl diglycol carbonate)) having an optical power of 0 diopters, said lenses being fixed to a bottom of a small trough, by means of lateral movement of the trough. The test lenses are subsequently evaluated by measurement of the quantity of scattered light generated by the scratching. The result of the test is a number indicating how much more durable the test lens is compared with the reference lens composed of the uncoated material CR39, i.e. poly(allyl diglycol carbonate).

An optical element according to the invention can have in particular a coating applied to the plastic body and containing at least one antireflection coating having at least one layer which is preferably densified by means of ion bombardment, preferably by means of ion bombardment at an ion current density $I \geq 30 \mu\text{A}/\text{cm}^2$ at the location of the partial layer during the duration of a vapor deposition process for producing the partial layer.

In the case of an optical element according to the invention,

therefore, the antireflection coating applied to the hard lacquer layer can have a single- or multilayered construction. Preferably, a two-, three-, four-, five- or six-layered construction is chosen for an antireflection coating. In the case of antireflection coatings having a two- or multilayered construction, an advantageous layer sequence is one in which a layer having a high refractive index adjoins a layer having a low refractive index. In other words, for such a multilayered construction it is expedient for layers having a low refractive index and layers having a high refractive index to alternate alternately. In addition, it is possible to provide further layers, for example adhesive layers (e.g. having a thickness in a range of approximately 5 nm to 5 μ m), which need not have an optical function, but which can be advantageous for the resistance, adhesion properties, climate resistance, etc. By way of example, it is also possible to replace the above antireflection coating by a reflective coating comprising one or more reflective layers and, if appropriate, antireflection layers or to provide both an antireflection coating and a reflective coating.

Examples of suitable materials for such an antireflection and/or reflective coating are e.g. silicon or boron, but also oxides, fluorides, silicides, borides, carbides, nitrides and sulfides of metals and nonmetals. For the coating process, these substances can be used individually or else as a mixture of two or more of said materials.

In particular, the materials SiO, SiO₂, ZrO₂, Al₂O₃, TiO, TiO₂, Ti₂O₃, Ti₃O₄, CrO_x (where x = 1-3), such as e.g. Cr₂O₃, Y₂O₃, Yb₂O₃, MgO, Nb₂O₅, Ta₂O₅, CeO₂ and HfO₂ etc., or corresponding mixed oxides, the materials MgF₂, AlF₃, BaF₂, CaF₂, Na₃AlF₆ and Na₅Al₃F₁₄, and the materials Cr, W, Ta and Ag, are suitable for producing an antireflection coating.

35

A suitable antireflection and/or reflective coating can be applied by customary methods, preference being given to producing the individual layers by means of vapor deposition,

sputtering and/or by means of CVD methods, in particular by means of plasma-enhanced CVD methods. It is particularly preferred to apply an antireflection coating by means of deposition from a vapor phase such that a densified layer
5 having a high abrasion resistance is formed.

The layer thickness d_A of an antireflection coating having a single- or multilayered construction is not subject to any particular restriction, in principle. However, this is
10 preferably set to a thickness d_A where $d_A \leq 2000$ nm, preferably $d_A \leq 1500$ nm, particularly preferably $d_A \leq 500$ nm. However, the minimum layer thickness d_{Am} of the antireflection coating is as far as possible approximately $d_{Am} \geq 100$ nm.

By way of example, such an antireflection coating can be constructed from alternating high and respectively low refractive index layers composed of TiO_2 and SiO_2 , comprising for example $\lambda/8-TiO_2$, $\lambda/8-SiO_2$, $\lambda/2-TiO_2$ and $\lambda/4-SiO_2$, wherein the layer thickness indicated here is preferably related to
20 the wavelength $\lambda = 550$ nm. Such an antireflection coating having a multilayer construction can be produced in particular by means of known PVD methods (Physical Vapor Deposition).

In order that the relevant coating for the optical element has
25 a high scratch resistance, it is advantageous if said coating contains at least one quartz layer substantially consisting of SiO_2 or a layer consisting of a mixture of SiO_2 and Al_2O_3 , with a layer thickness $d \geq 100$ nm.

The inventors have recognized that the constitution of the surface of the hard lacquer layer, in particular the interfacial energy σ_s of said surface, plays a crucial part for the diffusivity D_F of a coating comprising further layers applied to the hard lacquer layer, such as e.g. partial layers
35 for an antireflection coating applied to the hard lacquer layer.

The interfacial energy σ_s of the surface of a substrate is a

measure of the energy expenditure required to alter said surface. It is determined by the intermolecular forces at the surface, which can be decomposed into a dispersive component attributed to the intermolecular van der Waals forces, and a polar component caused by permanent dipole moments of molecules in the hard lacquer layer.

The interfacial energy σ_s of a surface, as described e.g. in the publication Kui-Xiang Ma et al., Investigation of surface energy for organic light emitting polymers and indium tin oxide, Thin Solid Films, 140 371 (2000), can therefore be decomposed into a dispersive component $\sigma_s^{\text{dispersive}}$ caused by the permanent dipoles of the molecules and a polar component σ_s^{polar} caused by the van der Waals forces.

The inventors have discovered that if the contribution of the polar component σ_s^{polar} to the interfacial energy $\sigma_s = \sigma_s^{\text{dispersive}} + \sigma_s^{\text{polar}}$ of the hard lacquer layer is as high as possible, the diffusivity of a coating comprising one or more partial layers of an antireflection coating applied on the hard lacquer layer can be decisively increased.

According to the invention, that is achieved, in particular, by treating the hard lacquer layer on the substrate with a corona discharge.

When the hard lacquer layer on the substrate is treated with a corona discharge, the substrate with the hard lacquer layer applied thereon is brought between two electrodes in a gas atmosphere at atmospheric pressure, to which electrodes an AC voltage in the kV range is applied. In this case, the design of the electrodes is chosen such that a dielectric barrier discharge is present, in the case of which only electrons whose average free path length is small are accelerated. Here, surface modifications can be induced here not only by the corona discharge itself, but also chemically by the ozone that arises in this case.

The increase in the polar component of the interfacial energy can also be achieved according to the invention by treating the hard lacquer layer on the substrate with a low-pressure air plasma.

5

An optical element in the form of a spectacle lens or spectacle lens blank is placed into a plasma chamber for this purpose in a holding ring, e.g. in the holding ring of a washing frame. A low-pressure plasma discharge is maintained
10 in said chamber by means of microwaves. The plasma thus generated is preferably a non-thermal plasma, i.e. the electrodes have a high temperature in the plasma, whereas the temperature of the ions in the low-pressure plasma is low. The low-pressure plasma is preferably operated in the pressure
15 range $P \approx 10$ Pa. The plastic surfaces of the relevant spectacle lens are charged by being arranged in the plasma, such that the positive ions in the plasma are accelerated and interact with the surface of the hard lacquer. It is advantageous to provide in the plasma chamber a microwave
20 shield, which makes it possible to arrange electrically conductive assemblies directly at the plasma chamber. Such a plasma chamber can be operated in particular with a gas atmosphere comprising pure oxygen, argon, a mixture of oxygen and nitrogen or a mixture of oxygen and argon.

25

Furthermore, one concept of the invention involves treating the hard lacquer layer with a glow discharge in order thus to increase the polar component of the interfacial energy.

30

For this purpose, the substrate with a hard lacquer layer applied thereon is arranged in a vacuum chamber with a low-pressure gas atmosphere, the pressure of which is in the pressure range of between 0.1 Pa and 1 Pa. The vacuum chamber contains a glow electrode for generating a glow discharge
35 which interacts with the surface of the hard lacquer layer. The gas atmosphere in the vacuum chamber preferably consists of oxygen, argon, air or corresponding mixtures of these gases.

One concept of the invention also consists in increasing the contribution of the polar component σ_s^{polar} to the interfacial energy $\sigma_s = \sigma_s^{\text{dispersive}} + \sigma_s^{\text{polar}}$ of the hard lacquer layer by
5 producing the hard lacquer layer from a sol-gel hard lacquer composition containing a fluorosurfactant as flow control additive.

One concept of the invention further also consists in
10 increasing the diffusivity of the coating applied to the substrate in the direction perpendicular to the surface, by introducing in the coating a multiplicity of preferably microscopic and/or mesoscopic pores, i.e. pores whose
15 diameters are small compared with the wavelength of visible light, but which are very much larger than the dimensions of atoms or molecules of the order of magnitude of one or more angstroms (Å). These microscopic and/or mesoscopic pores can have the form of holes, in particular, and extend at least as far as the hard lacquer layer proceeding from the surface of
20 the coating on the side facing away from the substrate body.

In order that these structures do not have a diffractively disturbing effect, they preferably do not form regular patterns having period lengths of the order of magnitude of
25 the light wavelength, but rather microscopic and/or mesoscopic pores which are distributed irregularly on the relevant optical element.

In principle, the structures can also be arranged in a
30 translationally symmetrical manner in at least one section of the coating. However, this translational symmetry is permitted to exist only on a length range whose order of magnitude is outside the wavelengths of visible light. In other words, the spatial frequency k of the arrangement of the microscopic
35 and/or mesoscopic pores must satisfy the following relationship: $k \gg 1/400 \text{ nm}$ or $k \ll 1/800 \text{ nm}$.

In the context of the invention, these relevant structures in

the form of holes are distributed statistically over the surface e.g. in a manner similar to a shot charge. These holes then act as microscopic and/or mesoscopic diffusion channels. The latter are so densely situated that the swelling processes
5 no longer give rise to macroscopic local corrugations which appear in an optically disturbing manner or as a consequence of which the antireflection layers are locally deformed so much that their adhesion to the underlying layers is impaired.

10 In this case, the diameter D_L of the holes preferably satisfies the following relationship: $D_L \leq 5 \mu\text{m}$, preferably $D_L \leq 1 \mu\text{m}$, particularly preferably $D_L \leq 0.2 \mu\text{m}$.

According to the invention, the mesoscopic pores are produced
15 e.g. by exposure of the coating to a preferably high-energy particle beam, in particular by exposure to a particle beam containing noble gas atoms and/or carbon atoms and/or gold atoms. As an alternative thereto, it is also possible to produce the mesoscopic pores by exposure of the coating to
20 pulsed laser light.

One concept of the invention also consists in adding foreign substances in the form of foreign molecules or nanoparticles on at least one inner layer of the coating, in particular on
25 the hard lacquer layer, and/or on or in the substrate body and/or providing foreign structures on at least one inner layer of the coating, in particular on the hard lacquer layer.

The mesoscopic pores can be produced e.g. by exposure of the
30 coating to a preferably high-energy particle beam, in particular by exposure to a particle beam containing noble gas atoms and/or carbon atoms and/or gold atoms, in order thus to obtain a high value for the diffusivity of the coating on the substrate body.

35

The invention is explained in greater detail below on the basis of the exemplary embodiments illustrated schematically in the drawing.

In the figures:

figure 1 shows a partial section of an optical element comprising a coating having a hard lacquer layer and an antireflection coating arranged thereon;

figure 2 shows a graph for elucidating the diffusivity of the coating;

figure 3 shows an installation for treating the hard lacquer layer of an optical element with a corona discharge;

figure 4 shows a low-pressure plasma installation for generating a plasma for treating the hard lacquer layer of an optical element;

figure 5 shows an installation for generating a plasma for treating the hard lacquer layer with a glow discharge;

figure 6 shows the dependence of the diffusivity of the coating on the polar component of the interfacial energy of the surface of the hard lacquer layer;

figure 7 shows an installation for applying foreign structures to the hard lacquer layer of an optical element;

figure 8 shows a partial section of a further optical element comprising a hard lacquer layer and partial layers of an antireflection coating that are arranged thereon and pervaded by holes;

figure 9 shows an installation for producing the holes in the partial layers of an antireflection coating by means of particle bombardment; and

figure 10 shows an installation for producing the holes in the partial layers of an antireflection coating by means of

laser light.

The optical element 10 shown in a partial section, which is not true to scale, in figure 1 has a substrate body 12 composed of plastic, e.g. the plastic CR39. A hard lacquer layer 14 is situated on the substrate body 12 and adjoins the substrate body 12. The hard lacquer layer 14 is applied with a sol-gel hard lacquer composition that is preferably spun onto the substrate body 12 by means of spin coating or applied by means of dip coating.

On the hard lacquer layer 14 there is a coating 15 embodied as a layer stack and having an antireflection coating, which comprises a plurality of partial layers, and a topcoat. This layer stack comprises a layer 16 composed of aluminum oxide (Al_2O_3) having a thickness of 57 nm, this layer being applied to the hard lacquer layer 14. A 25 nm thick layer 18 composed of quartz (SiO_2) is situated on the layer 16. A further layer 20 composed of aluminum oxide, the thickness of which is 44 nm, lies above the layer 18. The layer 20 is followed by a 61 nm thick further layer 22 composed of quartz. The latter is coated with a 60 nm thick layer 23 composed of aluminum oxide. A first high refractive index layer 24, which is highly refractive with respect to visible light and consists of titanium oxide and is 8.5 nm thick, is applied on the layer 23. On the layer 24 there is then applied a layer 26 composed of aluminum oxide having a thickness of 45 nm, which is coated by a second high refractive index layer 28 composed of titanium oxide having a thickness of 22 nm. Finally, a layer 30 composed of quartz having a thickness of 106 nm is applied on the layer 28 composed of titanium oxide.

The layer stack of the antireflection coating is produced in an electron beam evaporation installation. Such an installation has a vacuum chamber, in which the substrate body 12 of the optical element with the hard lacquer layer 14 applied thereon is arranged. By means of an electron beam, the material of the individual layers is sequentially evaporated

in the vacuum chamber, such that it deposits sequentially on the substrate body. The electron beam evaporation installation preferably contains an ion source, which enables the layers vapor-deposited onto the substrate body 12 to be densified
5 during the vapor deposition.

A layer 32 is situated as a topcoat on the layer 30 of the coating 15. The layer 32 consists of a superhydrophobic material which ensures that the optical element 10 can easily
10 be cleaned.

The material of the layer 32 is preferably a material from the class of the perfluorinated alkanes, which are then clinically coupled via a silane-functional group to the OH groups of the
15 layer 30 constructed from quartz. Said OH groups on the surface are also designated as so-called silanol groups by those skilled in the art.

A layer based on such perfluorinated molecules is abrasion-
20 resistant on account of the chemical coupling described above, i.e. the functionality is not eroded even in the use situation of the spectacle lens, that is to say even after e.g. 2 years of daily cleaning by the wearer of the spectacles. On account of the chemical properties of such a topcoat, drops of water
25 thereon form a large contact angle ($> 90^\circ$) with the surface. Macroscopic drops of water then bead away from said surface.

The coating 15 produced in the manner described above is highly scratch-resistant. Specifically, it has a Bayer number
30 Z_B - determined by the Bayer test explained above - for which:
 $Z_B \geq 10$.

The coating 15 on the substrate body 12 nevertheless has a diffusivity D_F which ensures the absorption of water molecules
35 passing through the coating 15 in the substrate body 12 and the release of water molecules from the substrate body 12 through the coating 15 from an air atmosphere arranged on that side of the coating 15 which faces away from the substrate

body 12 with a moisture flow density j_D which, proceeding from the equilibrium state of the quantity of the water molecules incorporated in the substrate body 12 in an air atmosphere at 23°C and 50% relative air humidity, brings about the setting
5 of the equilibrium state of the quantity of the water molecules incorporated in the substrate body 12 in an air atmosphere at 40°C and 95% relative air humidity within a time interval which is longer by not more than a time period having the length $\Delta t = 5h$ than the time interval required for setting
10 this equilibrium state under corresponding conditions in the case of an uncoated substrate body identical to the substrate body 12.

Figure 2 elucidates in the graph 33 the diffusivity of the
15 coating 15 on the substrate body 12 of an optical element 10. With the curve 34, figure 2 shows the rise in the density c_{FS} for the water molecules incorporated into the substrate body 12 as a function of time t , if the optical element 10, from a dry environment in which the air humidity is low, is arranged
20 in an environment having a high air humidity. After approximately 24 h, the density c_{FS} for the water molecules incorporated into the substrate body 12 is saturated, i.e. this density is then invariant with respect to time.

25 By contrast, the curve 35 shows the rise in the density c_{FS} of the water molecules incorporated into an uncoated substrate body 12, which for the rest is identical to the substrate body 12 on which the curve 35 is based. As is evident from a comparison of the curves 35 and 34, although the setting of
30 the equilibrium state for the density c_{FS} of in the through the coating 15 is slowed down in the case of the optical element 10, the diffusivity D_F of the coating is so high that it extends the length of the time interval required for setting the relevant equilibrium state by not more than 5 times the
35 length of the time interval that is required in order that the corresponding equilibrium state is established in the case of a substrate body which is identical to the substrate body 12 but is uncoated.

This diffusivity D_F of the coating is ensured in the case of the optical element 10 by virtue of the fact that the polar component σ_s^{polar} of the interfacial energy $\sigma_s = \sigma_s^{\text{dispersive}} + \sigma_s^{\text{polar}}$ of the hard lacquer layer 14 is increased by said hard lacquer layer being treated with a corona discharge in an installation for generating such a corona discharge.

Figure 3 shows such an installation 40. The installation 40 has a first, grounded planar electrode 42 and a further planar electrode 44, to which a high voltage $U \geq 1 \text{ kV}$ can be applied. Between the two electrodes 42, 44, the installation 40 has a receiving region for arranging a substrate body 12, on which a corresponding hard lacquer layer 14 is applied. The application of high voltage to the electrode 44 generates a shower 46 of flashes which impinges on the hard lacquer layer 14 and which, together with the ozone produced by means of the shower 46 of flashes, has the effect that the polar component of the interfacial energy σ_s of the surface 48 of the hard lacquer layer 14 which faces away from the substrate body 12 is increased.

In order to ensure the desired diffusivity D_F of the coating 14 in the case of the optical element 10 shown in figure 1, alternatively or additionally it is also possible to treat the hard lacquer layer 14 by means of a plasma generated in a low-pressure plasma installation.

Figure 4 shows a low-pressure plasma installation 50 suitable for this. The low-pressure plasma installation 50 has a vacuum chamber 52 with a receiving region for arranging a substrate body 12 for an optical element 10 with a hard lacquer layer 14 applied thereon. The vacuum chamber 52 has a connection 54 for a vacuum pump. The vacuum chamber 52 has a gas inlet 56, through which in particular oxygen, argon, a mixture of oxygen and nitrogen or of oxygen and argon can be introduced into the vacuum chamber 52. The low-pressure plasma installation 50 contains a microwave generator 58, by means of which the

vacuum chamber 52 can be exposed to microwaves in order, at a pressure P in the vacuum chamber 52 of $P \approx 10$ Pa, to ignite a plasma that is used for treating the hard lacquer layer 14 on the substrate body 12.

5

Alternatively or additionally it is also possible to treat the hard lacquer layer 14 on a substrate body 12 by means of a plasma generated by means of a glow discharge in a vacuum chamber, in order to ensure the desired diffusivity D_F of the coating 14 in the case of the optical element 10 shown in figure 1.

Figure 5 shows such an installation 60. In the installation 60 there is a vacuum chamber 62 having electrically conductive walls and a receiving region for arranging a substrate body 12 with a hard lacquer layer 14. The vacuum chamber 62 has a connection 64 for a vacuum pump and has a gas inlet 66. In the installation 60 there is a glow electrode 68, to which a high voltage $U \geq 1$ kV can be applied, in order to ignite a plasma for treating the surface 48 of the hard lacquer layer 14 in a gas atmosphere which consists of oxygen, argon, air or corresponding mixtures and the pressure P of which is in a pressure range of between 0.1 Pa and 1 Pa.

In order to ensure the desired diffusivity D_F of the coating 15 in the case of the optical element 10 shown in figure 1, it is also possible, however, for the hard lacquer layer 14 to be produced from a sol-gel hard lacquer composition containing a fluorosurfactant as a flow control additive.

30

The table below compares the interfacial energy overall and also the dispersive component and the polar component of the interfacial energy of a hard lacquer layer - applied to a substrate body composed of the material MR-8[®] in the form of a liquid sol-gel hard lacquer composition comprising the silicone-based flow control additive SF1188A from Momentive, a flow control additive based on a copolymer comprising a polydimethylsiloxane and a polyoxyalkylene, and a

35

corresponding sol-gel hard lacquer composition comprising the flow control additive FC-4430 from 3M, which is constructed on the basis of a fluorinated polymeric ester, i.e. contains fluorosurfactant:

5

Sample No.	Flow control additive	σ_s [mJ/Nm]	$\sigma_s^{\text{dispersive}}$ [mJ/Nm]	σ_s^{polar} [mJ/Nm]
1	FC4430	23.89	21.93	1.96
2	FC4430	23.13	21.10	2.03
3	SF1188	24.42	23.43	0.99
4	SF1188	24.68	23.49	1.19

The dispersive and polar components are measured here by means of the so-called OWRK method using the test liquids diiodomethane and ethylene glycol, said method being described
 10 e.g. in the dissertation by Carsten Weiß, Friedrich-Alexander University Erlangen-Nuremberg (2002), published on 08.07.2004, on page 54 and page 55.

The table shows that use of a flow control additive containing
 15 fluorosurfactant has the effect that the polar component of the interfacial energy of the hard lacquer layer applied to a substrate body is less than in the case of a silicone-based flow control additive.

Figure 6 elucidates with the graph 70 the diffusivity D_F of the
 20 coating 15 on the substrate body 12 of an optical element 10. The hard lacquer layer 14 of the substrate body 12 is produced here from a sol-gel hard lacquer composition containing a fluorosurfactant as flow control additive. With the curve 72,
 25 figure 6 shows the rise in the density c_{FS} for the water molecules incorporated into the substrate body 12 as a function of time t , if the optical element 10, from a dry environment in which the air humidity is low, is arranged in an environment having a high air humidity. After approximately
 30 150 h, here the density c_{FS} for the water molecules incorporated into the substrate body 12 is saturated, i.e. the quantity of the water molecules incorporated in the substrate

body is then approximately invariant with respect to time.

By contrast, the curve 74 shows the rise in the density c_{FS} of the water molecules incorporated into the substrate body of an optical element corresponding to the optical element 10 shown in figure 1, said substrate body having, however, a hard lacquer layer which corresponds to the hard lacquer layer 14 and the construction and thickness of which corresponds to the hard lacquer layer 14 in the case of the optical element 10, but which is produced from a sol-gel hard lacquer composition comprising a silicone-based flow control additive. As is apparent from the curve 64, the substrate body in the case of this optical element is not even close to being saturated, even after more than 200 h.

In order to obtain a high diffusivity D_F for the coating 15 in the case of the optical element 10 shown in figure 1, it is additionally possible to add on the hard lacquer layer 14, or else other inner layers of the antireflection coating, foreign substances, in particular foreign molecules and/or foreign structures, e.g. nanoparticles, for instance nanoparticles composed of SiO_2 or else nanoparticles consisting of polymers.

Figure 7 shows an installation 80 for correspondingly applying foreign structures to such a hard lacquer layer or to further layers of an optical element.

The installation 80 has a vacuum chamber 82 having electrically conductive walls, in which a substrate body 12 coated with a hard lacquer layer 14, e.g. a spectacle lens blank, can be arranged. The vacuum chamber 82 has an opening 84 for connection to a valve arrangement and vacuum pump, which make it possible to generate in the vacuum chamber 82 an exactly defined composition for a gas atmosphere which has a predefinable pressure. There are ring-shaped glow electrodes 86, 88 in the vacuum chamber 82. The glow electrodes 86, 88 are produced from a nanoparticle material. The glow electrodes 86, 88 are connected to a device for providing a high voltage

via bushings 90, 92 in the wall of the vacuum chamber 82. As a result of a high voltage being applied to the glow electrodes 86, 88, in the vacuum chamber 82 it is possible to ignite a glow discharge in the case of which the nanoparticle material of the glow electrodes is sputtered onto the hard lacquer layer 14 at a pressure of e.g. 10^{-4} mbar, such that they are added there.

It should be noted that the installation 80 is also suitable, in principle, for applying partial layers for an antireflection coating to the hard lacquer layer 14 with nanoparticles added thereon. For this purpose, an electron beam evaporator 93 is arranged in the installation 80, by means of which electron beam evaporator the different materials for layers in an antireflection coating can then be vapor-deposited onto the substrate body 12. In order to densify the layers vapor-deposited onto the substrate body 12, an ion source 94 is also preferably integrated into the installation 80. Said ion source is designed in such a way that it enables an ion bombardment of the substrate body 12 during the vapor deposition of coatings with an ion energy E_I which can be set in an expedient manner and is preferably in a range of $1 \text{ eV} \leq E_I \leq 100 \text{ eV}$.

It should be noted that the glow electrodes 86, 88 in the vacuum chamber 82 must be sufficiently close to the substrate body 12, in order that the corresponding nanoparticles can deposit uniformly on said substrate body and in this case are nevertheless scattered individually thereon, such that they are not visible.

Corresponding nanoparticle coverings are known e.g. as disturbing effects of glow lamps that have long been used in vapor-deposited layers. Here, however, there is a desire to produce them with a much lower density than is the case for a glow lamp that has long been used. Furthermore, it is endeavored, of course, to be able to produce these nanoparticle coverings appropriately rapidly.

Unlike in the case of a glow lamp, therefore, here an electrode material is chosen which sputters relatively well at the glow discharge voltage and the residual gas pressure to be set. Furthermore, the electrode material is chosen here such that the layers deposited thereabove in the case of the relevant optical element 10 are influenced by said electrode material locally particularly effectively with impurities. The choice of suitable materials for the nanoparticles, the gas type for the residual gas to be ionized, the pressure to be set and the voltage for the glow discharge are dependent here on the desired construction of the layers, in particular on the desired construction of that layer which is vapor-deposited directly onto the nanoparticles.

As an alternative to applying impurity particles to a hard lacquer layer 14, it is also possible, prior to the vapor deposition of a layer in a corresponding vacuum installation, to deposit foreign substances or foreign structures (e.g. molecules or nanoparticles), as impurities or seeds for impurities on the surface and then later to carry out vapor deposition over them. This can e.g. also be effected by introducing finely dispersed substances beforehand into the material, e.g. the basic material of the substrate body 12, for instance into a spectacle lens, or else into the hard lacquer layer, if it is endeavored to modify the properties of the layer, which substances, provided that they lie at the surface, locally influence the chemical bonding force of the layer to be applied, such that, at the locations at which the particles composed of the basic material lie at the surface, impurities are brought about in the vapor-deposited layer.

Furthermore, for substances which are already finely dispersed in a hard lacquer layer or a basic material, in a defined process step it is possible to initiate a chemical reaction which ensures that superficially finely dispersed isolated locations arise at which a layer vapor-deposited at such a location has a gap.

By means of impurity particles applied externally in this way or an externally induced chemical reaction, it is possible, in particular in a vapor-deposited antireflection coating, thus to produce impurities which can significantly increase the diffusivity D_F of a coating 15 of an optical element 10.

It should also be noted that the diffusivity D_F of a coating 15 of an optical element 10 can also be obtained by means of a targeted modification of the surface chemistry and energy. Such a modification of an interface in the case of an optical element 10 can furthermore e.g. also be produced with coatings which are produced using wet-chemical or physical methods. Furthermore, such interfaces can also be modified by means of printing, for instance by means of nanoimprints, or else by bombardment with high-energy particles.

It should be stated in this connection that nanoparticles can be deposited on a layer applied to a substrate body 12, in principle, also by means of the electron beam evaporator 93 in the installation 80.

Moreover, it should be noted that it is also possible, in principle, to incorporate into a coating in a targeted manner impurities in the form of foreign substances which increase the diffusivity D_F of the coating.

Figure 8 shows a further optical element 10', as a partial section, said optical element comprising a substrate body 12 composed of plastic, e.g. composed of the plastic CR39. Insofar as the construction of the optical element 10' corresponds to the construction of the optical element 10 from figure 1, this is identified in figure 8 by means of the numbers used in figure 1 as reference signs.

Unlike the optical element 10 from figure 1, the optical element 10' contains a multiplicity of holes 100. The holes 100 extend from the surface 48 of the coating 15 to the hard

lacquer layer 14. However, the hard lacquer layer 14 is not pervaded by the holes 100. The holes 100 act as microscopic and/or mesoscopic pores in the coating 15 which increase the diffusivity D_F thereof. In this case, the diameter D_L of the
5 holes satisfies the following relationship: $D_L \leq 5 \mu\text{m}$.

The holes 100 in the coating 15 of the optical element 10' are produced e.g. by means of a focused electron or ion beam in a vacuum chamber.

10 Figure 9 shows an installation 110 for producing the above-explained microscopic and/or mesoscopic pores in the coating 15. The installation 110 has a vacuum chamber 112, in which an electron and/or ion source 114 is arranged. The electron
15 and/or ion source 114 is assigned an acceleration unit 116 and a deflection unit 118. The electron and/or ion source 114 serves for exposing the coating 15 of an optical element 10' arranged in the vacuum chamber 112 to a particle beam of electrons and/or ions.

20 With the particle beam, the electrons or ions are shot in a statistically distributed manner onto the surface of the optical element 10' to be treated, such that the entire surface 48 is strewn with diffusive holes.

25 That need not take place with a single particle rather it can also occur sequentially by the deflection positions being left unchanged in each case for long enough. In order to produce a plurality of holes simultaneously, e.g. an electron- or ion-
30 optically diffractive structure can also be arranged in front of the deflection unit.

The acceleration unit 116 ensures that the electrons or ions have sufficiently high energy in order that they perforate a
35 coating 15 to be modified with regard to its diffusion properties, such that the layers which otherwise act as a diffusion barrier therein become more permeable.

In principle, the perforation of layers in the coating 15 and the application of different layers can also be combined in one installation 110. This measure affords the advantage that corresponding holes can be produced with a lower energy of the electrons and/or ions.

In this case, the deflection unit 118 controls the particle beam provided by the electron and/or ion source 114 preferably by means of a random number generator. What can thus be achieved is that the holes 100 produced in the coating 15 of an optical element 10' in the installation 110 are distributed approximately statistically over the area, such that the microscopic and/or mesoscopic structures of the holes do not generate discernible diffraction phenomena under visible light.

Another way of simultaneously producing a multiplicity of holes by means of ion bombardment consists in providing in front of the actual ion source a plate having a multiplicity of statistically distributed holes, which acts as a perforated diaphragm. This perforated diaphragm is then imaged ion-optically onto the surface of the relevant optical element. In this case, the optical element is exposed to the corresponding particle beam until the holes produced in the coating or a layer of the coating are deep enough to achieve the desired diffusion-influencing effect. By moving the plate or the optical element it is possible to displace the locations at which the optical element is exposed to a particle beam.

It should be noted that the electrons or ions must have a sufficiently high kinetic energy above the destruction threshold of the surface to be processed. In the case of bombardment with ions, the choice of the type of ions can also influence the effect.

It should also be noted that in principle a regular pattern of "holes" or disturbances can also be produced in a coating 15 of an optical element 10 by means of a focused electron or ion

beam. Such patterns could arise e.g. by virtue of the focused electron or ion beam itself being an interference figure and therefore comprising a regularity: this has the advantage over the explanation given above that with one "focal process" a multiplicity of holes can be produced all at once by the relevant individual interference figures being positioned alongside one another step by step in order thus to cover the entire optical element, i.e. the spectacle lens, for example. For the case where the extent of the imaged interference figures or the focusing conditions does/do not permit the entire optical element to be covered all at once, care must be taken to ensure that the interference figure projected onto the optical element has a period length either small enough or large enough that a discernible diffraction no longer occurs: period lengths of the order of magnitude of the light wavelength should therefore be avoided in the case of the projected patterns.

Figure 10 shows a further installation 120 for producing the above-explained microscopic and/or mesoscopic pores in the coating 15 of an optical element 10'.

The installation 120 contains a laser 122 for generating pulsed laser light, for the pulse duration t_p of which the following preferably holds true: $t_p \leq 15$ ns. The laser beam is directed through an optical unit 124 onto a highly reflective target 126, which acts as an amplitude object or preferably as a pure phase object and generates a speckle pattern on the optical element 10'.

The installation 120 comprises a vacuum chamber 127 having an optical window 128, which acts as a lens. Through the window 128 the laser light from the laser 122 is directed onto the optical element 10' arranged in the vacuum chamber 126. In this case, the wavelength of the laser light is chosen such that the latter is absorbed in the coating 15 of the optical element 10' and in the process generates corresponding holes 100 in the coating 15.

Further modifications and developments of the invention arise as a result of combination of different features of the exemplary embodiments described above. It should also be noted
5 that an optical element according to the invention can be embodied in particular as a lens, as a spectacle lens, or else as a spectacle lens blank or a spectacle lens semifinished product.

10 To summarize, in particular the following preferred features of the invention should be emphasized. An optical element 10, 10', e.g. a spectacle lens or spectacle lens blank, has a substrate body 12, which is produced from a plastic that is transparent preferably in the visible spectral range, and a
15 coating 15 having a plurality of layers 14, 16, 18, said coating 15 comprising a hard lacquer layer 14 adjoining the substrate body 12. The coating 15 has a diffusivity D_F which ensures the absorption of water molecules passing through the coating 15 in the substrate body 12 and the release of water
20 molecules from the substrate body 12 through the coating 15 from an air atmosphere arranged on that side of the coating 15 which faces away from the substrate body 12 with a moisture flow density j_D which, proceeding from the equilibrium state of the quantity of the water molecules incorporated in the
25 substrate body 12 in an air atmosphere at 23°C and 50% relative air humidity, brings about the setting of the equilibrium state of the quantity of the water molecules incorporated in the substrate body 12 in an air atmosphere at 40°C and 95% relative air humidity within a time interval
30 which is longer by not more than a time period having the length $\Delta t = 10h$, preferably by not more than a time period having the length $\Delta t = 9h$ or $\Delta t = 8h$ or $\Delta t = 7h$ or $\Delta t = 6h$ or $\Delta t = 5h$ or $\Delta t = 4h$ or $\Delta t = 3h$ or $\Delta t = 2h$, particularly preferably by not more than a time period having the length
35 $\Delta t = 1h$, than the time interval required for setting this equilibrium state under corresponding conditions in the case of an uncoated substrate body identical to the substrate body 12.

List of reference signs:

	10, 10'	Optical element
	12	Substrate body
5	14	Hard lacquer layer
	15	Coating
	16, 18, 20, 22, 23, 24,	
	26, 28, 30, 32	Layers
	34, 35, 72	Curves
10	40, 60, 80, 110, 120	Installation
	42, 44	Electrodes
	46	Shower of flashes
	48	Surface
	50	Low-pressure plasma installation
15	52, 62, 82, 112	Vacuum chamber
	54, 64	Connection
	56	Gas inlet
	58	Microwave generator
	66	Gas inlet
20	68, 86, 88	Glow electrode
	70	Graph
	84	Opening
	90, 92	Bushings
	93	Electron beam evaporator
25	100	Holes
	114	Electron and/or ion source
	115	Coating
	116	Acceleration unit
	118	Deflection unit
30	122	Laser
	124	Optical unit
	126	Target
	128	Window

Patentkrav

1. Optisk element (10, 10'), især brilleglas eller
brilleglas-råemne, med et substratlegeme (12), der er
5 fremstillet af et transparent kunststof, og med en belægning
(15), der har flere lag (14, 16, 18), og som omfatter et til
substratlegemet (12) tilstødende hårdlaklag (14) og en på
hårdlaklaget (14) anbragt antirefleksbelægning med en et-
eller flerlags opbygning, kendetegnet ved, at belægningen (15)
10 har en diffusivitet D_F , der garanterer optagelsen af gennem
belægningen (15) gennemtrængende vandmolekyler i
substratlegemet (12) og frigivelsen af vandmolekyler fra
substratlegemet (12) gennem belægningen (15) fra en på den fra
substratlegemet (12) bortvendte side af belægningen (15)
15 anbragt luftatmosfære med en fugtighedsstrømtæthed j_D , der
udgående fra en ligevægtstilstand for mængden af de
vandmolekyler, der er indlejret i substratlegemet (12) i en
luftatmosfære ved 23 °C og 50 % relativ luftfugtighed, hvilken
ligevægtstilstand er defineret ved, at tallet for de i
20 substratlegemet indlejrede vandmolekyler i løbet af 24 h ikke
ændres med mere end 1 % og bevirker indstillingen af
ligevægtstilstanden for mængden af de vandmolekyler, der er
indlejret i substratlegemet (12) i en luftatmosfære ved 40 °C
og 95 % relativ luftfugtighed inden for et tidsinterval, som
25 med ikke mere end et tidsrum med længden $\Delta t = 10h$, foretrukket
med ikke mere end et tidsrum med længden $\Delta t = 9h$ eller $\Delta t = 8h$
eller $\Delta t = 7h$ eller $\Delta t = 6h$ eller $\Delta t = 5h$ eller $\Delta t = 4h$ eller
 $\Delta t = 3h$ eller $\Delta t = 2h$, særligt foretrukket med ikke mere end et
tidsrum med længden $\Delta t = 1h$, er længere end det tidsinterval,
30 der er nødvendigt til indstillingen af denne ligevægtstilstand
under tilsvarende betingelser ved et med substratlegemet (12)
identisk ubelagt substratlegeme, hvorved der i belægningen er
udformet et multiplum af fortrinsvis mikroskopiske og/eller
mesoskopiske porer især i form af huller (100), som udgående
35 fra belægningens (15) overflade (48) på den fra
substratlegemet (12) bortvendte side strækker sig i det
mindste frem til hårdlaklaget (14)

2. Optisk element ifølge krav 1, kendetegnet ved, at belægningen (15) har en ridsefasthed, der svarer til et i en udvidet Bayer-test, der karakteriserer en ridsefasthed af belægningen (15), bestemt Bayer-tal Z_B med $Z_B \geq 8$, fortrinsvis $Z_B \geq 10$, især $Z_B \geq 14$.
3. Optisk element ifølge krav 1 eller 2, kendetegnet ved, at belægningen (15) indeholder i det mindste en antirefleksbelægning med i det mindste et i et vakuumkammer pådampet dellag, som ved hjælp af ionbeskydning er fortættet, fortrinsvis ved hjælp af ionbeskydning ved ionstrømtæthed $I \geq 30 \mu\text{A}/\text{cm}^2$ på dellagets sted under varigheden af en pådampfingsproces til genereringen af dellaget.
4. Optisk element ifølge et af kravene 1 til 3, kendetegnet ved, at belægningen (15) har i det mindste et i det væsentlige af SiO_2 bestående kvartslag (30) eller et af en blanding af SiO_2 og Al_2O_3 bestående lag med en lagtykkelse $d \geq 100 \text{ nm}$.
5. Optisk element ifølge et af kravene 1 til 4, kendetegnet ved, at hullernes (100) diameter D_L opfylder det følgende forhold: $D_L \leq 5 \mu\text{m}$, fortrinsvis $D_L \leq 1 \mu\text{m}$, særligt foretrukket $D_L \leq 0,2 \mu\text{m}$.
6. Optisk element ifølge et af kravene 1 til 5, kendetegnet ved, at de mikroskopiske og/eller mesoskopiske porer er anbragt uregelmæssigt i belægningen (15).
7. Optisk element ifølge et af kravene 1 til 6, kendetegnet ved, at de mikroskopiske og/eller mesoskopiske porer i i det mindste et afsnit af belægningen (15) er anbragt translationssymmetrisk, hvor der for rumfrekvensen k for anbringelsen af de mikroskopiske og/eller mesoskopiske porer gælder: $k \gg 1 / 400 \text{ nm}$ eller $k \ll 1 / 800 \text{ nm}$.
8. Optisk element ifølge et af kravene 1 til 7, kendetegnet ved, at de mesoskopiske porer er fremstillet ved påvirkning af belægningen (15) eller af lag (30) i belægningen med en

fortrinsvis højenergetisk partikelstråle, især ved påvirkning med en partikelstråle, der indeholder ædelgasatomer og/eller carbonatomer og/eller guldatomer, og/eller at de mesoskopiske porer er fremstillet ved påvirkning af belægningen (15) eller af lag (30) i belægningen (15) med pulset laserlys.

9. Optisk element ifølge et af kravene 1 til 8, kendetegnet ved, at der på i det mindste et indvendigt liggende lag af belægningen (15), især på hårdlaklaget (14), og/eller på og/eller i substratlegemet (12) er aflejret fremmedstoffer i form af fremmedmolekyler eller nanopartikler, og/eller at der på i det mindste et indvendigt liggende lag af belægningen (15), især på hårdlaklaget (14), er anbragt fremmede strukturer.

10. Fremgangsmåde til fremstilling af et optisk element (10,10') ifølge krav 1, omfattende trinene - tilvejebringelse af et substratlegeme (12), der er fremstillet af et transparent kunststof, - påføring af en belægning (15), der har flere lag, på substratlegemet (12), hvorved - belægningen (15) har et til substratlegemet (12) tilstødende hårdlaklag (14), som genereres ved påføringen af en sol-gel-hårdlaksammensætning på substratlegemet (12), og hvorved - belægningen (15) har i det mindste en på hårdlaklaget (14) anbragt antirefleksbelægning med en et- eller flerlags opbygning, kendetegnet ved, at - hårdlaklaget (14) før påføringen af antirefleksbelægningen behandles med en corona-udladning og/eller med et lavtryks-luftplasma og/eller med en glimudladning, og - der i belægningen (15) udformes et multiplum af fortrinsvis mikroskopiske og/eller mesoskopiske porer især i form af huller (100), som udgående fra belægningens (15) overflade (48) på den fra substratlegemet (12) bortvendte side strækker sig i det mindste frem til hårdlaklaget (14).

11. Fremgangsmåde ifølge krav 10, kendetegnet ved, at - der på hårdlaklaget (14) før påføringen af det i det mindste ene optiske lag (16, 18, 20) aflejres fremmedstoffer, især

fremmedmolekyler og/eller fremmede strukturer, især nanopartikler, og/eller

5 at der på i det mindste et indvendigt liggende lag (16, 18, 20) af belægningen (15), især på hårdlaklaget (14), ved hjælp af laserlys og/eller ved partikelbeskydning og/eller ved hjælp af printning, især ved hjælp af nanoimprints, anbringes fremmede strukturer.

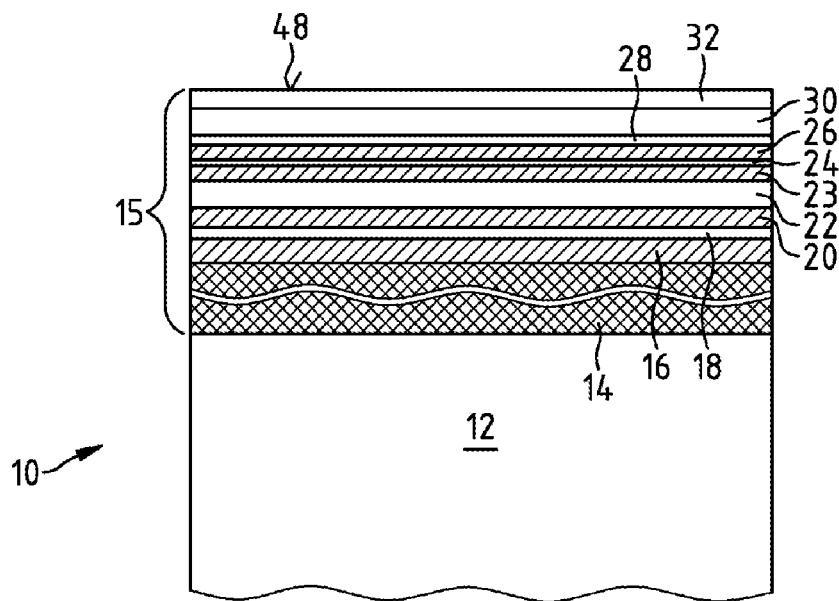


Fig.1

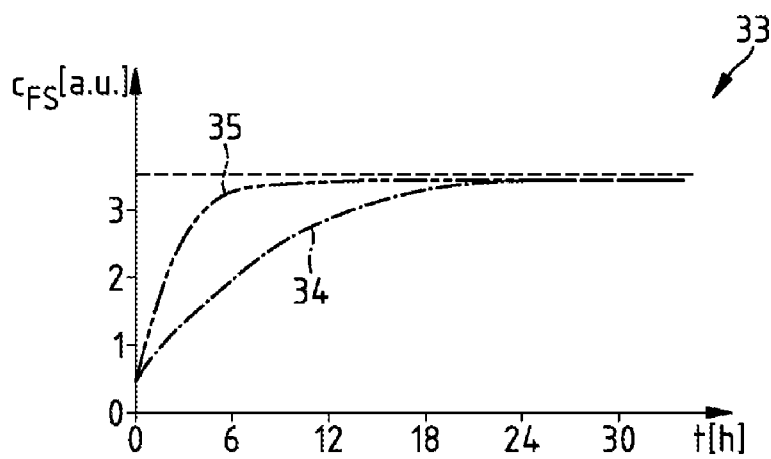


Fig.2

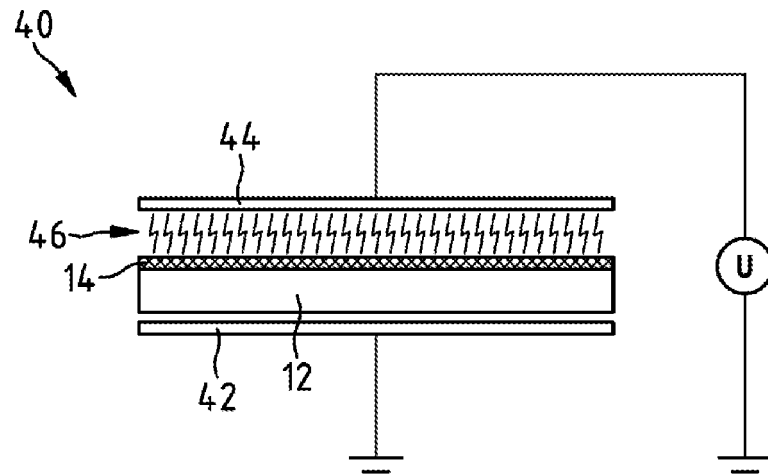


Fig.3

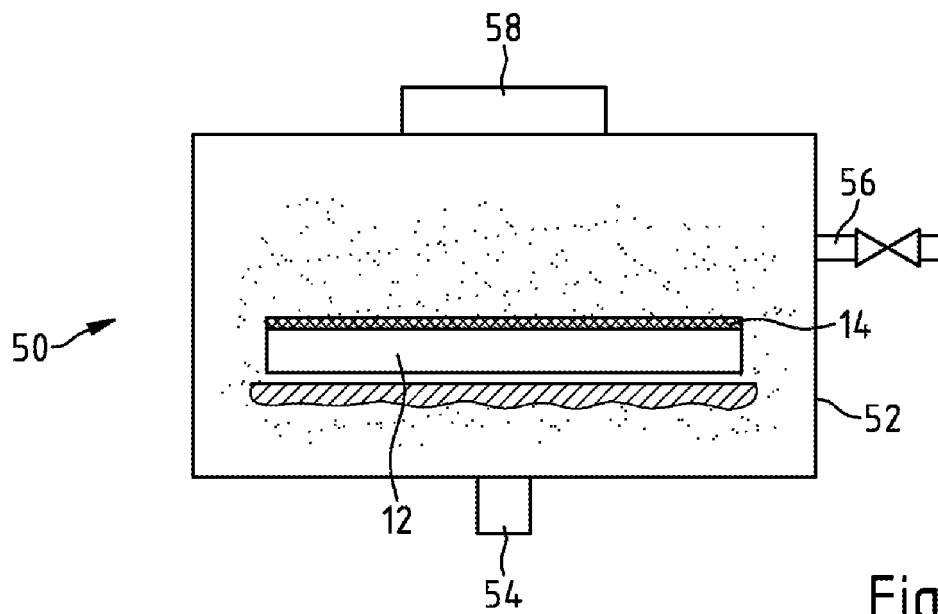


Fig.4

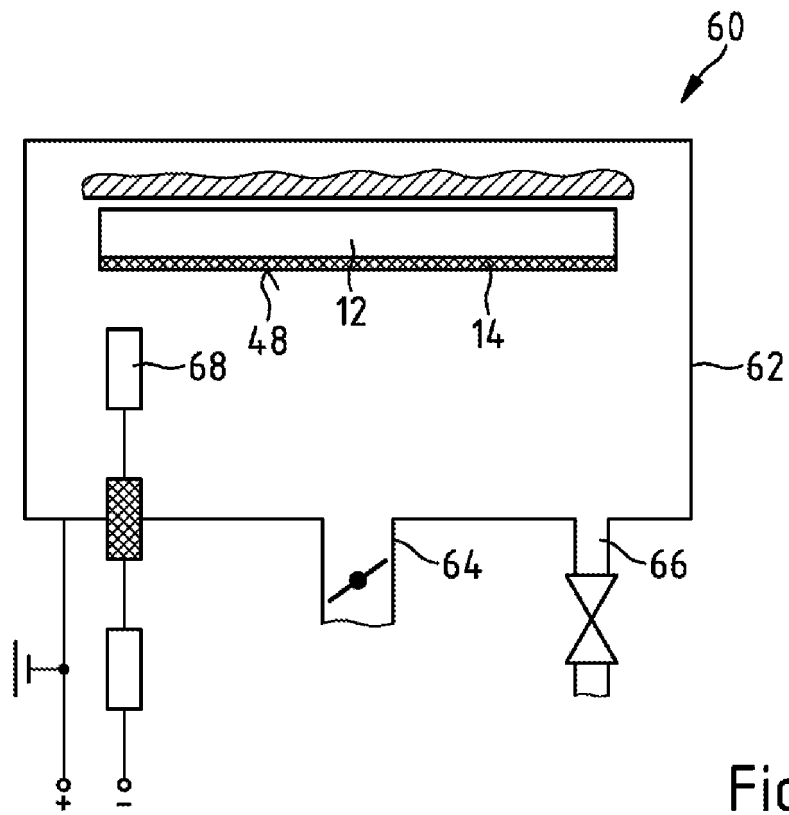


Fig.5

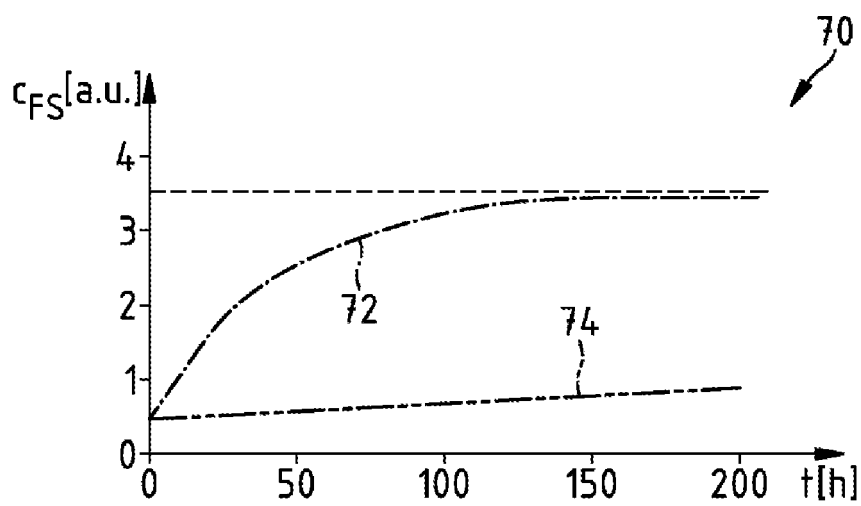


Fig.6

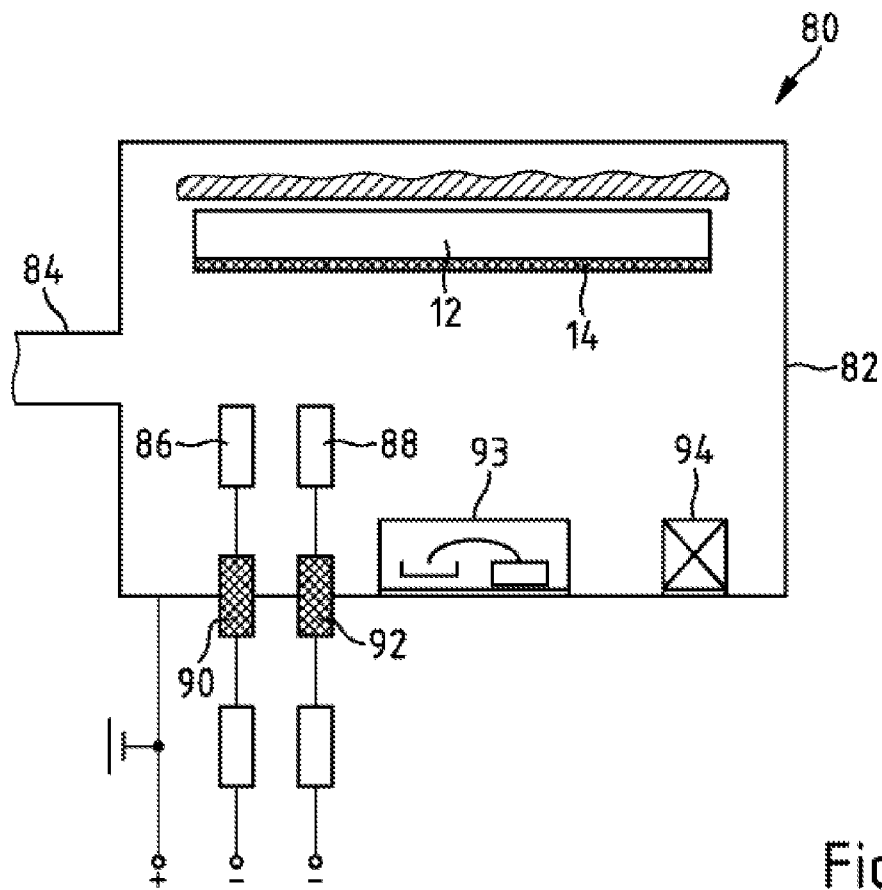


Fig.7

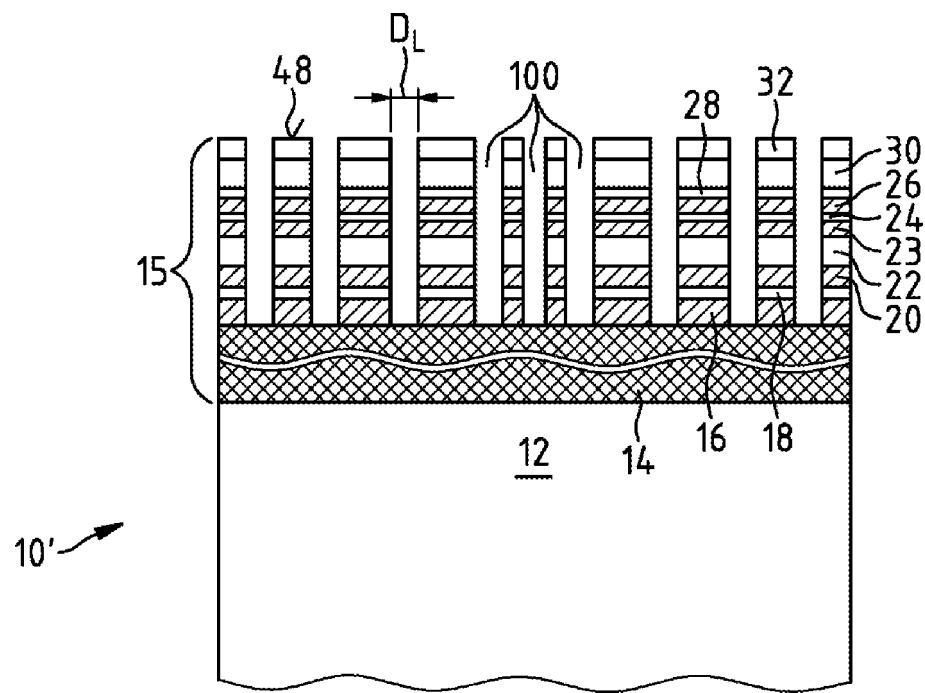


Fig.8

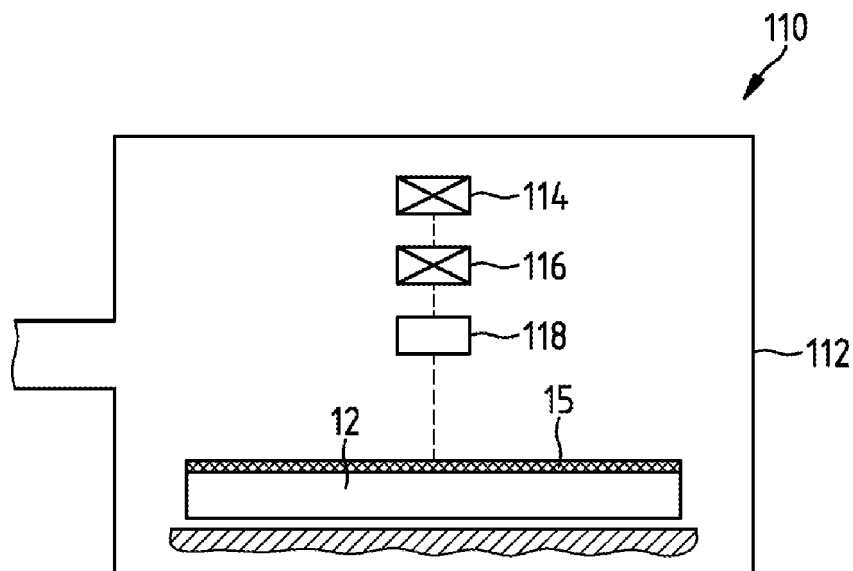


Fig.9

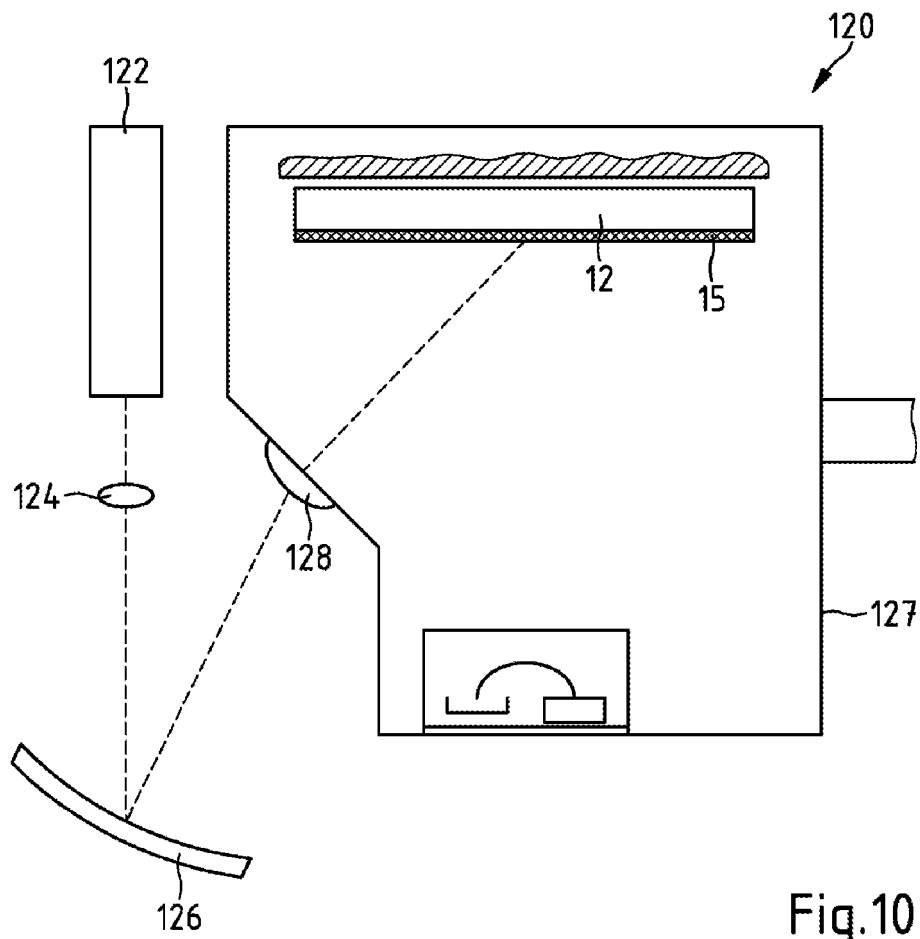


Fig.10