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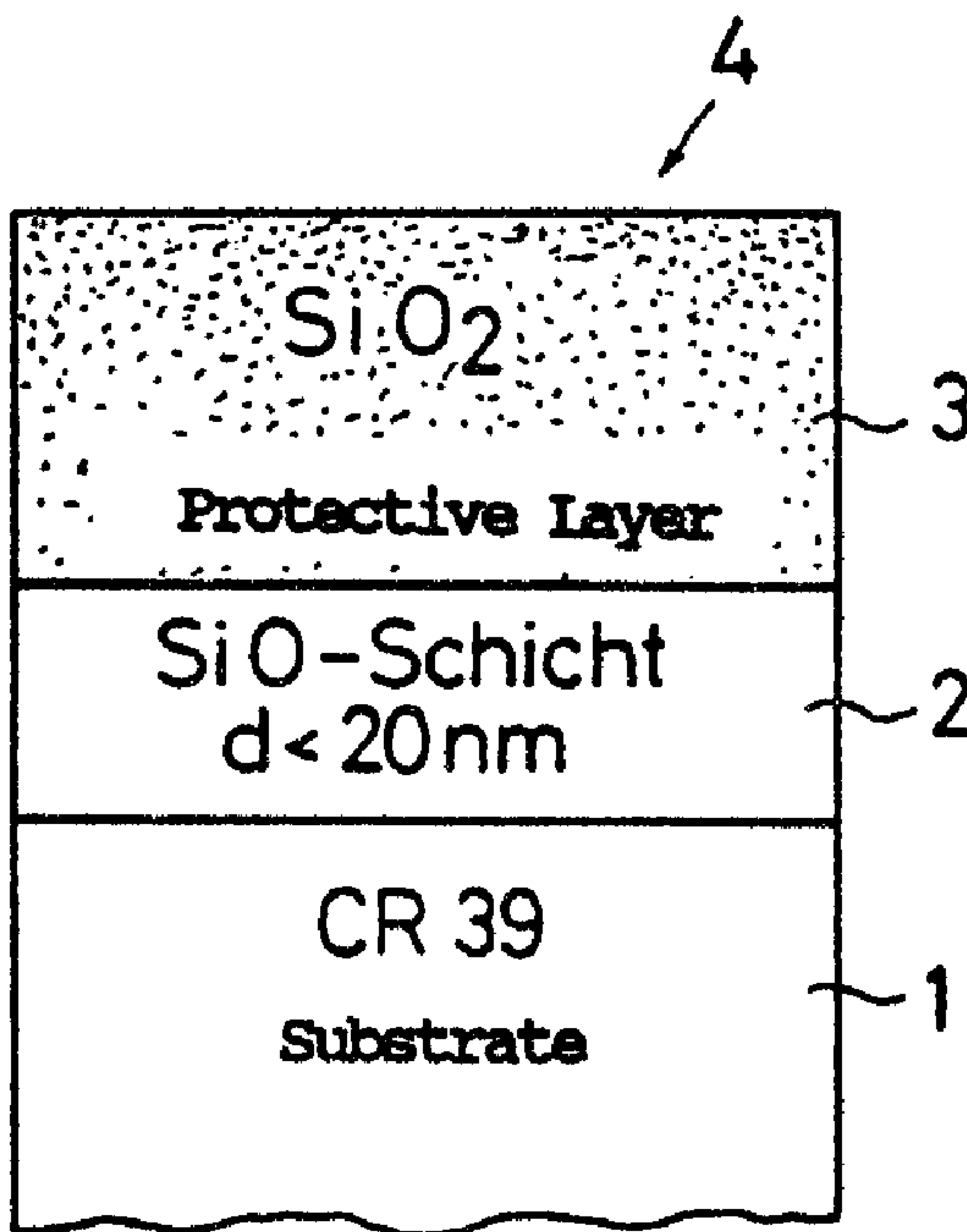
(54) Titre : METHODE ET DISPOSISTIF DESTINES A LA PRODUCTION D'UN REVETEMENT ANTI-REFLETS POUR LENTILLES

(54) Title: PROCESS AND DEVICE FOR THE PRODUCTION OF A REFLECTION-REDUCING COATING ON LENSES



(57) Abrégé/Abstract:
The invention relates to a scratch-resistant coating for optical materials comprising synthetics as wall as to a process for the production of this coating. In order for the synthetic material, for example a CR39 lens, to be protected against scratches, first a very thin adhesion layer of SiO is applied, which is subsequently provided with a thick SiO_2 layer. Both layers are deposited in a vacuum chamber which comprises a vaporizer and a plasma source.

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Abstract

Title: PROCESS AND DEVICE FOR THE PRODUCTION OF A REFLECTION-REDUCING COATING ON LENSES

The invention relates to a scratch-resistant coating for optical materials comprising synthetics as well as to a process for the production of this coating. In order for the synthetic material, for example a CR39 lens, to be protected against scratches, first a very thin adhesion layer of SiO is applied, which is subsequently provided with a thick SiO_2 layer. Both layers are deposited in a vacuum chamber which comprises a vaporizer and a plasma source.

PROCESS AND DEVICE FOR THE PRODUCTION OF A REFLECTION-REDUCING COATING ON LENSES

The invention relates to a process and a device according to the preamble of Patent Claims 1 and 10.

With lenses the problem very often arises of applying a protective coating which is light-permeable and yet reflection-reducing. This applies for camera lenses as well as also for lenses of eye glasses. In the case of inept or careless handling by the user, eyeglasses can be subjected to extreme stress which cases scratching not only of synthetic glasses but also of silicate glasses. For surface damages as a rule sharp objects are responsible which are drawn across the surface under pressure. That can be, for example, sand with its sharp edges in a polishing cloth or the case of the glasses but also rough tissue.

Because they combine the property of low weight and greater resistance to breakage with the possibility of individual coloring, synthetic glasses are used increasingly more often. However, they have the serious disadvantage that their surfaces which are considerably softer compared to silicate glasses are very susceptible to mechanical damage.

As a synthetic material for lenses duroplastics are used widely which comprise macromolecules chemically closely enmeshed with one another. They are most often very brittle at room temperatures. In addition, they are temperature stable, not weldable, insoluble, and only weakly swellable. One duroplastic preferred in lens systems used for eyeglasses is CR 39 which is a diallyldiethylene glycolcarbonate. Only very recently, apart from these synthetic materials used nearly exclusively in lens systems for glasses, other synthetic materials such as polymethylmethacrylate (PMMA), polystyrene (PS), and polycarbonate (PC) have been employed.

If, for example, a CR 29 synthetic is to be provided with an appropriate protective covering, the problems of detachment of the protective layer from the lens body, the difference in heat expansion of protective layer and lens body as well as in many cases the low temperature stability of the protective coating must be solved.

With silicate coatings the substrate is heated to a high temperature of approximately 300°C whereby sufficient energy is available for the coating molecules applied in a

vapor deposition process in order to generate defect-free dense layers. In contrast, when producing a synthetic layer, the vapor deposition as a rule must be carried out at low temperature.

In order to make available the energy required in this case, the grown layers are bombarded with ions of an inert gas. Additional ionization of the vapor particles and the reactive gas reinforces the densification process in the layer condensation.

Apart from these so-called ion-assisted deposition processes (IAD), the so-called plasma polymerization is also known in which during the layer formation the properties of the layer can be changed continuously so that, on the one hand, they are adapted to the synthetic surface from the aspect of the chemical structure and, on the other, form on the boundary to the air a glass-like structure which has a very high mechanical resistance.

A process for the production of transparent protective coatings comprising silicon compounds is already known which is used in the coating of synthetic substrates (DE-A—3 624 467 = EP-A-0 254 205). In this process a chemical vapor deposition takes place under the effect of a plasma (= plasma chemical vapor deposition) onto a polymerizable monomeric organic compound from the group of the siloxans and silazans wherein to the polymerization process oxygen is supplied in excess. The plasma is therein generated by means of high frequency between two electrodes of which the one has the function of a cathode and is connected with the substrates. Before the coating proper the substrates are exposed in an atmosphere comprising a noble gas to an ion bombardment by glow discharge in the presence of the organic compounds.

In another known process of plasma-enhanced coating of a substrate with a polymerizable silicon-comprising monomer the monomers are restricted to silans, silazans or disilazans and the plasma coating is carried out until a particular Taber wear index is attained (EP-A-O 52 870).

A device is also known (DE-C-3 931 713) with which optical lenses can be coated on both sides in a plasma-enhanced process. This device comprises two electrodes between which are disposed holding elements for the work pieces to be coated. The holding elements therein are at a defined electrical potential.

A similar process is known (EP-A-O 403 985) for the pretreatment of transparent synthetic substrates intended for vacuum coating. It has been found that through plasma

bombardment of the substrate surface this surface is changed in such a way that the subsequence layer can be applied with a high degree of adhesive strength.

In a further device for the coating of substrates a vacuum chamber is provided with a substrate carrier disposed in it and having a plasma generator, a magnet and an electron emitter wherein, in addition, in the vacuum chamber a device for the generation of atoms, molecules or clusters of the materials for the generation of the layer on the substrates is disposed, which is located immediately next to the plasma generator and opposite the substrates (EP-90123712.3, K.Matl, W. Klug, A. Zöller: Ion assisted deposition with a new plasma source, Paper presented at the Sec. PSE Conf., Garmisch-Partenkirchen 1990). One advantage of this device reside therein that, in contrast to earlier devices of the ion-assisted deposition (IAD), it can act upon substrate holders having a diameter of approximately 1m with high plasma density.

Moreover, antireflection coatings are know which are applied onto synthetic lenses and comprise for example two layers of which the first layer is a SiO_2 layer and the second layer a SiO layer (De-OS 27 39 044, Figure 1A).

Further, antireflection coatings are known comprising four or more descrete layers wherein for example, beginning at the substrate, the layer sequence is as follows: SiO, SiO_2, CeO_2, SiO_2, CeO_2 (DE-OS 38 18 341).

DE-A-39 09 654 describes a reflection-reducing system on substrates of plastic resin comprising a first layer of SiO and a second layer of SiO_2. Herein the second layer merely serves for improving the breaking strength and, therefore, has a thickness of only 10 nm to 60 nm.

A mar resistant coating formed on a substrate of plastics is also known wherein the coating has a thickness of 1 μm to 10 μm (US-A-3 811 753). However, the combination of mar-resistance and adhesive strength cannot be achieved with this coating.

Further, it is known to apply a coating of 4 μm on lenses made of polymer which consists of vaporized glass, more specifically borosilicate glass (DE-A-25 38 982). Glass is made of SiO_2 to only 80 per cent. Further, the thickness of the base coating of SiO and SiO_2 on which the glass is vaporized is not indicated.

With a further known reflection-reducing system consisting of two or three separate coatings first a homogenous layer of SiO or an inhomogeneous coating of SiO and a substance of a higher refractive index are applied to an object (DE-A-22 10 505). However, the degree of oxidation of the first SiO layer is not indicated. Further, only the refractive index is inhomogeneous, but not the hardness of the layer.

It is also known to utilize SiO having an optical thickness of $\lambda/4$ and $\lambda/2$ for reflection reducing of polycarbonate and other synthetic substrate materials (US-A-3 356 522; US-1-4 497 539). No distinction is made between coatings having good adhesive strength and abrasion-resistance properties.

With another known antireflection coating system for lenses of a synthetic polymer a first coating is made of a compound of SiO and SiO_2 having an index of refraction of 1,8 and an optical thickness of $\lambda/4$ (=approximately 70 nm) and further coatings of TiO_2, CeO2, $A1_2O_3$ and SiO_2 having a refractive index of $\lambda/4$ or $\lambda/2$, respectively (DE-C-27 38 044).

Lastly, a process for the production of synthetic objects with hard coatings is also known, in which a layer based on silicon is disposed on a foundation material and onto this layer a SiO_2 film is applied (EP-A-O 266 225). The SiO_2 layer is herein applied by means of a vacuum vapor deposition process preferably in an ion-plating process.

The invention is based on the task of creating a scratch-resistant coating of eyeglasses, lenses and the like comprising a relatively soft synthetic material.

In one aspect the present invention provides an optical lens comprising a transparent plastic material substrate and a first layer of SiO which is disposed directly on the substrate and which has a thickness of one atomic layer to 50 nm, and a second layer of SiO_2 on the first

layer. The second layer has a thickness of at least 500 nm and comprises at least two regions having different hardness, the region having the lower hardness being adjacent to the first layer.

In another aspect, the present invention provides a method for the production of a layer with nonhomogeneous hardnesses on a transparent plastic material substrate in a plasma coating installation. The method comprises the steps of:

First arranging one or more transparent plastic-material substrates in a substrate holder.
SiO is then evaporated in an evaporator with simultaneous irradiation of the substrate with a plasma from a plasma source to form a layer of SiO having a thickness of one atomic layer to 50 nm.
SiO_2 is then evaporated in an evaporator with simultaneous irradiation of the substrate with a plasma from a plasma source in which process either the plasma power and/or the gas pressure and/or the coating rate is altered so that a layer of SiO_2 having a thickness of at least 500 nm and having nonhomogeneous hardness is formed on the SiO layer.

In yet another aspect, the present invention provides for an apparatus for performing the above method. The apparatus includes a chamber in which plasma can be generated, a substrate holder for holding one or more transparent plastic-material substrates, a plasma source opposite the substrate holder, an evaporator next to the plasma source containing SiO, an evaporator next to the plasma source containing SiO_2 granules, at least one ring magnet above the substrate holder, means for controlling the plasma power of the plasma sources, means for controlling the gas pressure, and means for controlling the coating rate of the evaporator containing SiO_2 granules.

The advantage achieved with the invention resides in particular therein that the tensions between the relatively soft synthetic substrate and the hard coating are decreased.

The SiO layer is selected to be of minimum thickness because SiO, for the application according to the invention, has optically undesirable properties and is therefore used primarily for the purpose of ensuring adhesion. With increasing layer thickness of SiO the reflection increases. This leads to an increase of the oscillations of the reflections curve (r = f(•)) brought about by the succeeding thick SiO_2 layer. Moreover, SiO is not absorption-free. A thin SiO layer therefore keeps the undesirable reflections and absorption within reasonable limits and yet fulfils the requirements made of the adhesive strength. The SiO_2 protective layer, in contrast, must be relatively thick, i.e. > 500 nm since otherwise the requirements made of the scratch-resistant are not met. Thinner SiO_2 layers at the given stress break down even if they are very hard. Moreover, they cause undesirable oscillations of the reflection curve. In the case of thicker SiO_2 layers the oscillations are also present, however, the wavelength interval of the minima and maxima becomes smaller with increasing layer thickness so that on visual inspection no disturbing interference effects can be observed.

Embodiment examples of the invention are depicted in the drawing and will be described in greater detail in the following. Therein show:

Fig. 1 a two-layer configuration on a synthetic lens substrate;

Fig. 2 a three-layer configuration on a synthetic lens substrate;

Fig. 3 a seven-layer configuration on a synthetic lens substrate;

Fig. 4 a schematic representation of a plasma IAD process for the generation of thin layers.

In Figure 1 is depicted a lens substrate 1 of a synthetic material, for thickness CR 39, which is provided with a very thin SiO layer 2 having a thickness of one atom up to 20 nm. This layer 2 serves essentially for the purpose of effecting a better adhesion of a protective coating 3 with a

thickness of at least 500 nm of SiO_2.

As has been found a SiO_2 layer applied directly adheres only poorly on synthetic materials. In so-called boiling tests coated substrates are cyclically immersed for a defined time in a boiling salt solution comprising for example 5% NaCl in water. They are subsequently plunged into cold water. A layer of SiO_2 applied directly on a synthetic material becomes very rapidly detached in such boiling tests, for example after 5 to 10 minutes. In contrast, if a SiO layer 2 is disposed between the SiO_2 layer 3 and the substrate of synthetic material which is coated under simultaneous plasma and ion bombardment with a resistance vaporizer boat or an electron beam gun, the adhesion of the SiO_2 layer 3 increases considerably. Even after a boiling test lasting 40 minutes no impairments on layers 2 and 3 could be detected.

With the thick SiO_2 layer 3 the wear properties are significantly improved relative to the synthetic substrate 1. CR 39, for example, has a hardness of approximately 180 to 200 N/mm^2. Dense quartz, in contrast, has a hardness of 4500 N/mm^2. The hardness of the protective layer 3 can be adjusted in a very broad range via the plasma and coating parameters. Through special plasma coatings hardness values of approximately 1000 N/mm^2 up to nearly 4500 N/mm^2 have so far been achieved.

The wear resistance increases basically with the hardness and the layer thickness wherein at a layer thickness beginning at approximately 3 to 8 μm a saturation effect in the wear resistance occurs as a function of the hardness. In the production of very hard and consequently brittle layers, strong tensions between layer and substrate are generated. For example CR 39 has a coefficient of thermal expansion of approximately $1 * 10^{-4}/K$ while, in contrast, the coefficient of thermal expansion of quartz is almost negligible. Accordingly, a 70 mm CR 39 lens expands by approximately 0.4 mm at a temperature difference of 80°C. The expansion of quartz, in contrast, is nearly 0. The tensions caused thereby make great demands made on the adhesion of the layer. It is therefore useful to break down at least a part of the tensions in the layer itself. This is achieved via a hardness gradient i.e. the hardness increases from the interior on the substrate in the outward direction. For the production of the SiO_2 layer it is suggested to use as the starting material SiO_2 instead of a suboxide. SiO_2 can be vaporized with very low vaporizer power. The temperature stress placed on

the substrates can thereby be kept to a minimum during the production of the thick protective layer.

By inserting a layer 5 between the SiO and the SiO_2 layer the oscillations in the reflection curve can be decreased considerably. This layer 5 has preferably an index of refraction smaller than the index of refraction of the substrate 1 and greater than the index of refraction of the protective layer 3. If CR 39 is used as the substrate and if the protective layer 3 comprises SiO_2, the index of refraction of layer 5 is between 1.45 and 1.52. The thickness of layer 5 herein is approximately 80 to 120 nm which at a wavelength of light of 550 nm corresponds to a quarter wavelength. Through this measure the oscillations due to the thickness of the layer 3 are attenuated.

Figure 3 depicts a variant in which as intermediate layer 6 a SiO_x layer is used wherein x is a value between 1 and 2. On the SiO_2 layer 3 is disposed a combination of four further layers 7 to 10 which serve exclusively for the purpose of reducing the reflection. These layers comprise alternately Ta_2O_5 and SiO_2 wherein the uppermost layer is SiO_2.

The production of the layers takes place in the manner described in the following and in conjunction with Figure 4.

In a standard vacuum installation 20 the layers are deposited by means of an electron beam vaporizer 21 (see above Matl, Klug, Zöller). A plasma source 22 is herein disposed in the center and on the bottom 23 of the installation 20 and directed onto an electrically insulating substrate holder 24. In the plasma source 22 is disposed a cylindrical electron-emitting LaB_6 cathode 25 encompassed by a cylindrical anode 26 having a diameter of approximately 50 mm. A glow discharge plasma is generated wherein a noble gas, primarily argon, is introduced via a line 28.

A cylindrical magnet coil 29 encloses the anode 26 and brings about that the possibility for movement of the electrons generated by the plasma is considerably increased in the axial direction and considerably decreased in the radial direction. The electrons move in spiral form about the magnetic field lines whereby the plasma reaches the coating chamber 20. On the top 30 of the coating chamber 20 and above the substrate holder 24 is provided an annular magnet coil 31 with an inner diameter greater than the diameter of the substrate holder. The magnetic field of this ring magnet 31

and the magnetic field of the cylinder coil 29 are superimposed and form a guidance field for the electrons on their way from the cathode 25 heated indirectly by a heater 27 and fed, in turn, by the energy supply 32, as well as for the entire plasma between the plasma source 22 and the substrate holder 24. In front of the dome-form substrate holder 24 is generated a dome-form plasma boundary layer. Because the potential of the substrate holder 24 relative to the plasma is negative, the ions are accelerated out of the plasma boundary layer and bombard a growing film which is thereby densified. A significant advantage of the production process in comparison to the conventional IAD processes with one ion source resides therein that the ions starting out of a plasma boundary layer forming parallel to the entire inner face of the substrate holder are accelerated over a short distance. In the case of an ion source where the acceleration takes place from the bottom of the chamber the conditions are different. In the device according to Figure 4 the ions from the plasma boundary layer are not influenced by collisions and energy losses. Moreover, the plasma extends over the entire area between the plasma source 22 and the substrate holder 24 so that the ion source basically covers the same area as the substrate holder 24. With a conventional ion source with grid extraction an extraction grid area is required corresponding nearly to the beamed-upon area on the substrate.

A reactive gas, for example O_2, N_2 is introduced into the chamber 20 via a line 34. Due to the plasma in the chamber 20 it is ionized and activated. The vaporized material 35 of the electron beam gun 21 must also pass through the plasma from the substrate holder 24 so that it becomes ionized and activated.

The plasma source 22 is electrically insulated from the chamber 20. Apart from the supplied discharge voltage one therefore in addition also obtains a potential difference between the source 22 and the chamber 20. The source 22 assumes a variable positive potential relative to the chamber 20 while the substrate holder 24 is nearly at the same potential as the chamber 20. The ion energy is determined by the potential difference between the anode tube 26 fed from a dc current source 36 with a positive potential, and the substrate holder 24. The variable potential of source 22 is a function of the discharge voltage, the partial pressures of the gases

and the strength of the magnetic field. Through the positive floating potential of the electric field an electric field is generated which reflects the electrons between source 22 and substrate holder 24. If they do not impinge on the anode tube 26 they are reflected on the cathode potential and can again come out of the source. Consequently, oscillating electron paths with an effective ionization and excitation of gas atoms and molecules are obtained. Due to the repulsion effect generated by the electric fields in the vicinity of the anode the plasma in front of the substrate holder 24 is dominated by ions. This can be recognized by the potential of the substrate holder 24 which is approximately between 3 and 5 volts relative to the chamber wall 20. The discharge parameters are up to 80 volts discharge voltage, 70 A discharge current, and 5 kW plasma power. The pressures are 1×10^{-4} to 8×10^{-4} mbars with a ratio of O_2: Ar of up to 4 : 1. The described operation of the plasma source makes it possible to separate the plasma generation process from the vaporization process.

All vaporizable starting materials, for example oxides and fluorides, can be vaporized in the vaporizer 21 since no coupling between plasma source and vaporizer source exists.

For the vapor deposition of a scratch-resistant SiO_2 layer, SiO_2 granulate is used which is vaporized with electron beam generator 40 in the electron beam vaporizer 21. For this granulate a relatively low vaporizer power is required. In order to keep low the vaporizer power even in the case of highly refractive material for example Ta_2O_5 a multicup crucible with cups of minimum size is preferably used of which only one cup 41 is depicted. After pumping the chamber 20 down to a pressure of $< 2 \times 10^{-5}$ mbars the vapor deposition of the layer system is carried out.

The SiO adhesion layer is deposited at a rate of approximately 0.1 nm/s. The plasma source 22 is added simultaneously with the opening of a vaporizer diaphragm not shown. The source 22 is herein operated with pure argon at a partial pressure of approximately 2.5×10^{-4} mbars. The discharge current is approximately 30 A at a discharge voltage of approximately 30 V. After obtaining the desired layer thickness the plasma source 22 is switched off simultaneously with the closing of the vaporizer diaphragm.

Subsequently, the vapor deposition of the thick SiO_2 protective layer takes place. Herein the plasma source 22 is also operated with argon.

The hardness of the SiO_2 layer is a function of the plasma discharge power i.e. current and voltage, the gas pressure, and the coating rate. The hardness gradient of the layer is adjusted with these parameters. Especially low hardness values are achieved with low plasma power (< 1 kW) at relatively high pressure (approximately 6×10^{-4} mbars), and a high coating rate (approximately 5 x 10 nm/s). The greatest hardness values were achieved in experiments carried out with a plasma power of approximately 5 kW, at a pressure of 1.5×10^{-4} mbars and at a rate of 0.1 nm/s. After the desired layer thickness has been achieved, the plasma source 22 is switched off with the closing of the vaporizer diaphragm.

Subsequently, the vapor deposition of the first highly refractive layer Ta_2O_5 takes place. In principle, other highly refractive materials can also be used such as for example titanium oxide, zirconium oxide, etc. In the highly refractive layers the plasma source 22 is also operated with argon at a pressure of approximately 2×10^{-4} mbars. In addition, oxygen is introduced into the chamber 20 through line 34 with a partial pressure of approximately 4×10^{-4} mbars. An oxygen inlet directly into the plasma source, analogously to inlet 28, is also possible. During the vapor deposition of the tantalum pentoxide layer the plasma source is operated with a discharge power of approximately 5 kW. The coating rate is approximately 0.2 nm/s. The next layer SiO_2 is deposited in principle like the SiO_2 protective layer and specifically at a pressure of 2×10^{-4} mbars, a plasma power of approximately 4 kW, and a coating rate of approximately 0.5 nm/s.

The vapor deposition of the succeeding highly refractive layer takes place with the same parameters as the first highly refractive layer. The last SiO_2 layer is deposited like the preceding SiO_2 layer.

The optimum production parameters of the $\lambda/4$ SiO_x intermediate layer for the attenuation of the oscillations of the spectral curve disposed between the SiO layer and the protective layer, are a function of the hardness and, consequently, the index of refraction of the protective layer. The following parameters are suitable: pressure approximately 2×10^{-4} mbars, plasma power approximately 4 kW, rate approximately 0.1 nm/s.

It is understood that for the generation of atoms, molecules or clusters of the materials, for example SiO or SiO_2, which are to be applied onto a synthetic lens or the like, instead of an electron beam vaporizer also a

thermal vaporizer or a sputtering cathode can be used. It is only essential that the plasma is generated in a device separated from the electron beam gun, etc. Thereby that the plasma is generated in the plasma source 22 and the small particles to be applied in a vaporizer source 21, the uniformity of the coating is especially high. Moreover, the coating parameters can be adjusted largely independently of one another, which is of great significance for the production of layers with toughness gradients.

The substrate holder 24 whose lower edge is denoted by 33, can be rotated by means of a shaft 42. It can be provided on its underside with numerous lenses or the like to be coated. Moreover, the substrate holder 24 can have a vaporizer protection not shown which in the deposition of insulating materials prevents the coating of a portion of the surface of the substrate holder with these insulating materials and consequently makes possible the draining of electrical charges via the substrate carrier. Further details of the device according to Figure 4 can be found in German Patent Application P 40 20 158.9 and are therefore not described in further detail.

When with an arrangement according to Fig. 4 the plasma power is put down in kW as a function of time this results in a straight line substantially linearly rising from 0,5 to 5,5 kW, whereas simultaneously the pressure falls almost linearly from $6 * 10^{-4}$ mbar to $1 * 10^{-4}$ mbar. At the same time the rate decreases from 5,5 nm/s to almost 0 nm/s.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An optical lens comprising a transparent plastic material substrate and a first layer of SiO which is disposed directly on the substrate and which has a thickness of one atomic layer to 50 nm, and a second layer of SiO_2 on the first layer, characterized in that the second layer has a thickness of at least 500 nm and comprises at least two regions having different hardness, the region having the lower hardness being adjacent to the first layer.

2. The optical lens according to Claim 1, characterized in that the second layer has a thickness of 3000 to 10,000 nm.

3. The optical lens according to Claim 1, characterized in that the hardness of the second layer increases continuously from the first layer up to that surface of the second layer which faces away from the first layer.

4. The optical lens according to claim 1, characterized in that the hardness of the second layer increases from 500 N/mm^2 to 4500 N/mm^2.

5. The optical lens according to claim 1, characterized in that there is provided between the first layer and the second layer a third layer of a material whose refractive index is less than the refractive index of the substrate and greater than the refractive index of the protective layer.

6. The optical lens according to claim 5, characterized in that the third layer is composed of SiO where $1 < x \leq 2$.

7. The optical lens according to claim 1, characterized in that a multilayer coating system is provided on the second layer.

8. The optical lens according to claim 7, characterized in that the coating system has four layers of which two layers are composed of Ta_2O_5 with two layers of SiO_2.

9. The optical lens according to claim 1, characterized in that the first layer has a thickness of 5 nm.

10. The optical lens according to claim 7, characterized in that the coating system has up to six layers of which up to three layers are composed of Ta_2O_5 and up to three layers of SiO_2.

11. A method for the production of a layer with nonhomogeneous hardnesses on a transparent plastic material substrate according to claim 1 in a plasma coating installation, which method comprises the following steps:

arrangement of one or more transparent plastic-material substrates in a substrate holder;
evaporation of SiO in an evaporator with simultaneous irradiation of the substrate with a plasma from a plasma source to form a layer of SiO having a thickness of one atomic layer to 50 nm;
evaporation of SiO_2 in an evaporator with simultaneous irradiation of the substrate with a plasma from a plasma source in which process one or more of plasma power, gas pressure and coating rate is altered so that a layer of SiO_2 having a thickness of at least 500 nm and

having nonhomogeneous hardness is formed on the SiO layer.

12. The method according to claim 11, characterized in that plasma discharge current increases with time.

13. The method according to claim 11, characterized in that the gas pressure decreases with time.

14. The method according to claim 11, characterized in that the evaporation rate decreases with time.

15. The method according to any one of claims 12 to 14 characterized in the that process is altered for about 15 minutes.

16. The method according to claim 12,characterized in that the plasma discharge current increases from about 10 A to 100 A within a time interval of 5 to 20 minutes.

17. The method according to claim 13, characterized in that the gas pressure decreases from approximately 8 x 10^{-4} mbar to 1 x 10^{-4} mbar within a time interval of 5 to 30 minutes.

18. The method according to claim 14, characterized in that the power of the evaporator decreases within a time interval of 5 to 30 minutes so that the coating rate drops from 10 nm/s to 0.1 nm/s.

19. The method according to claim 11, characterized by the following steps:

a) a plasma discharge current which flows between a cathode and an anode increases from 10 A to 100 A within a time interval of about 5 minutes to 30 minutes;

b) simultaneously with the increase in the plasma discharge current, the pressure of the gas or gas mixture contained in vacuum chamber decreases from 8 x 10^{-4} mbar to 1 x 10^{-4} mbar;

c) simultaneously with the increase in the plasma discharge current, power of the evaporator decreases.

20. An apparatus for performing the method according to claim 11, comprising;

a chamber in which plasma can be generated;
a substrate holder for holding one or more transparent plastic-material substrates;
a plasma source opposite the substrate holder;
an evaporator next to the plasma source containing SiO;
an evaporator next to the plasma source containing SiO_2 granules;
at least one ring magnet above the substrate holder;
means for controlling plasma power of the plasma source;
means for controlling gas pressure; and
means for controlling coating rate of the evaporator containing SiO_2 granules.

21. The apparatus according to claim 20, characterized in that the plasma source has a cylindrical anode in which an electron emitter is situated and in that said cylindrical anode is surrounded by a cylindrical coil, a gas inlet being introduced into the interior of the cylindrical anode.

22. The apparatus according to claims 20 and 21, characterized in that the plasma source is electrically isolated from the vacuum chamber.

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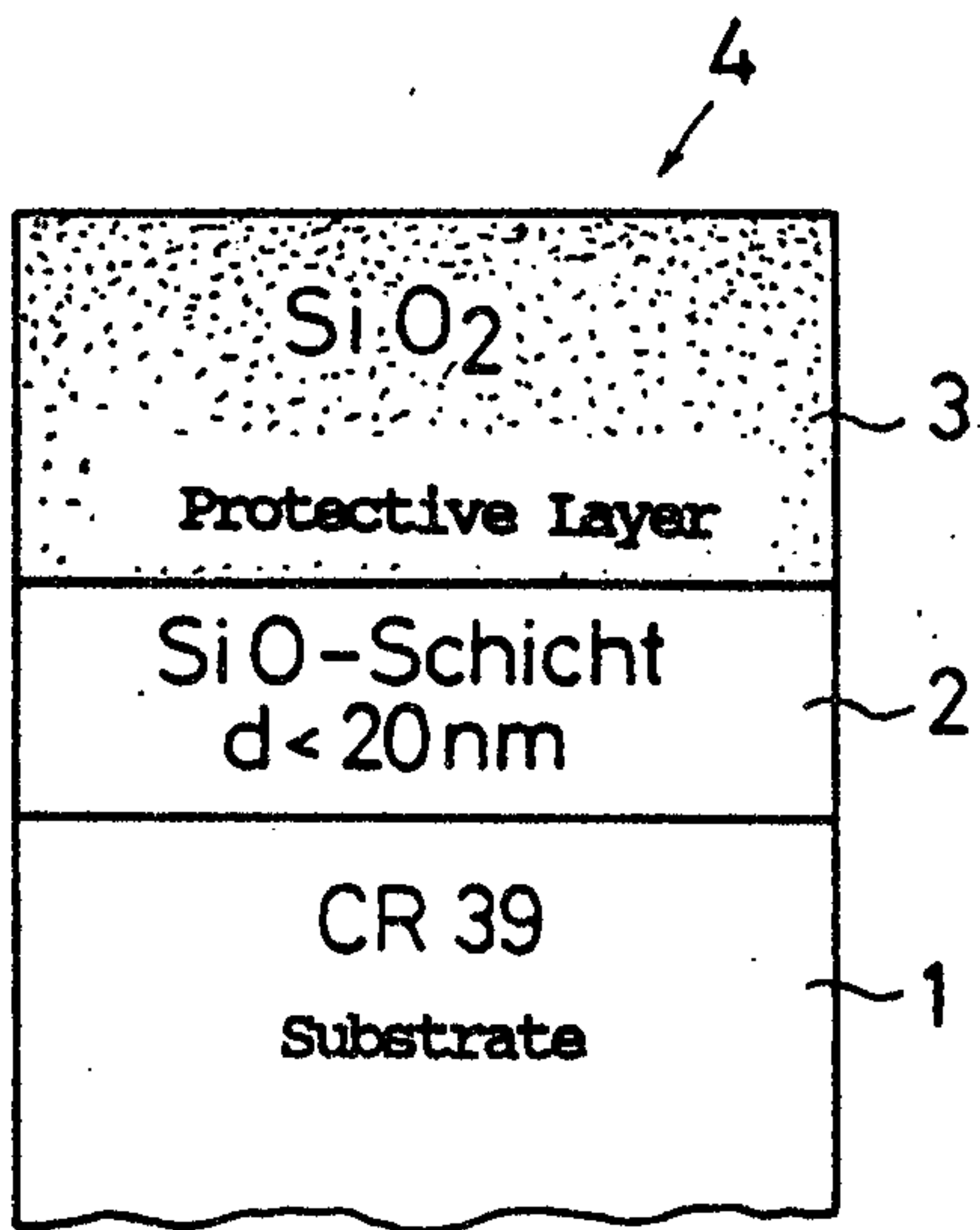

FIG.1

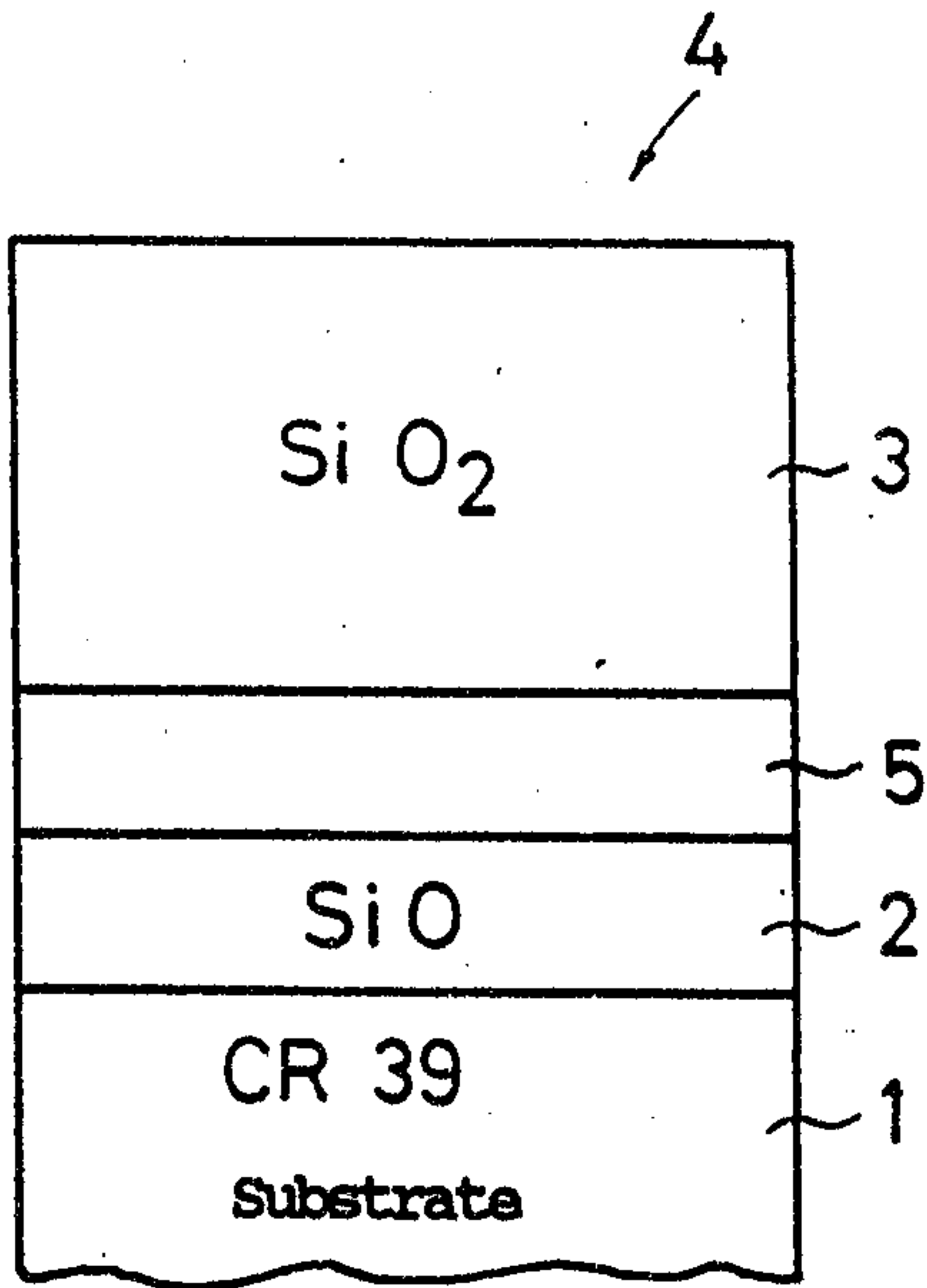

FIG.2

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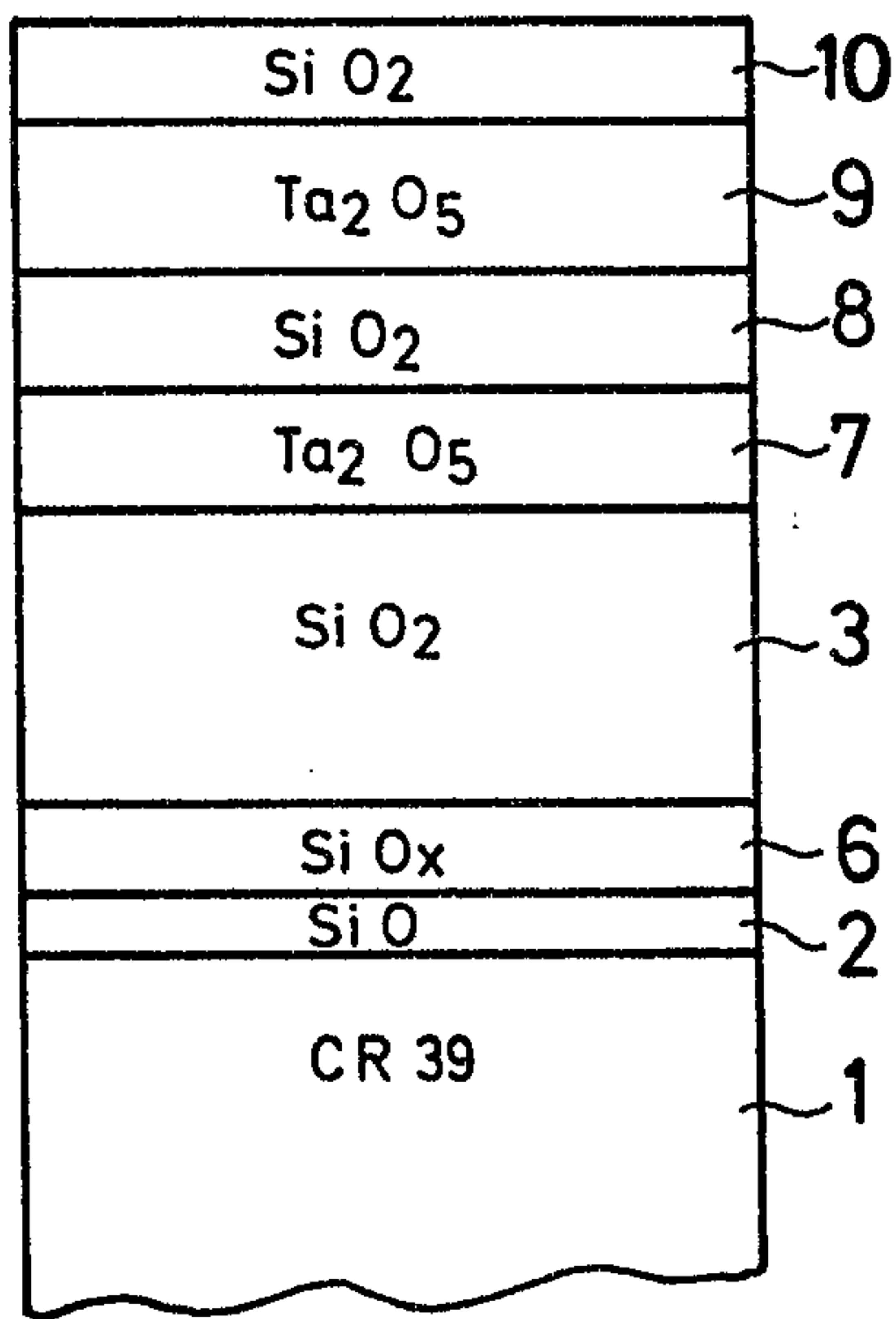

FIG. 3

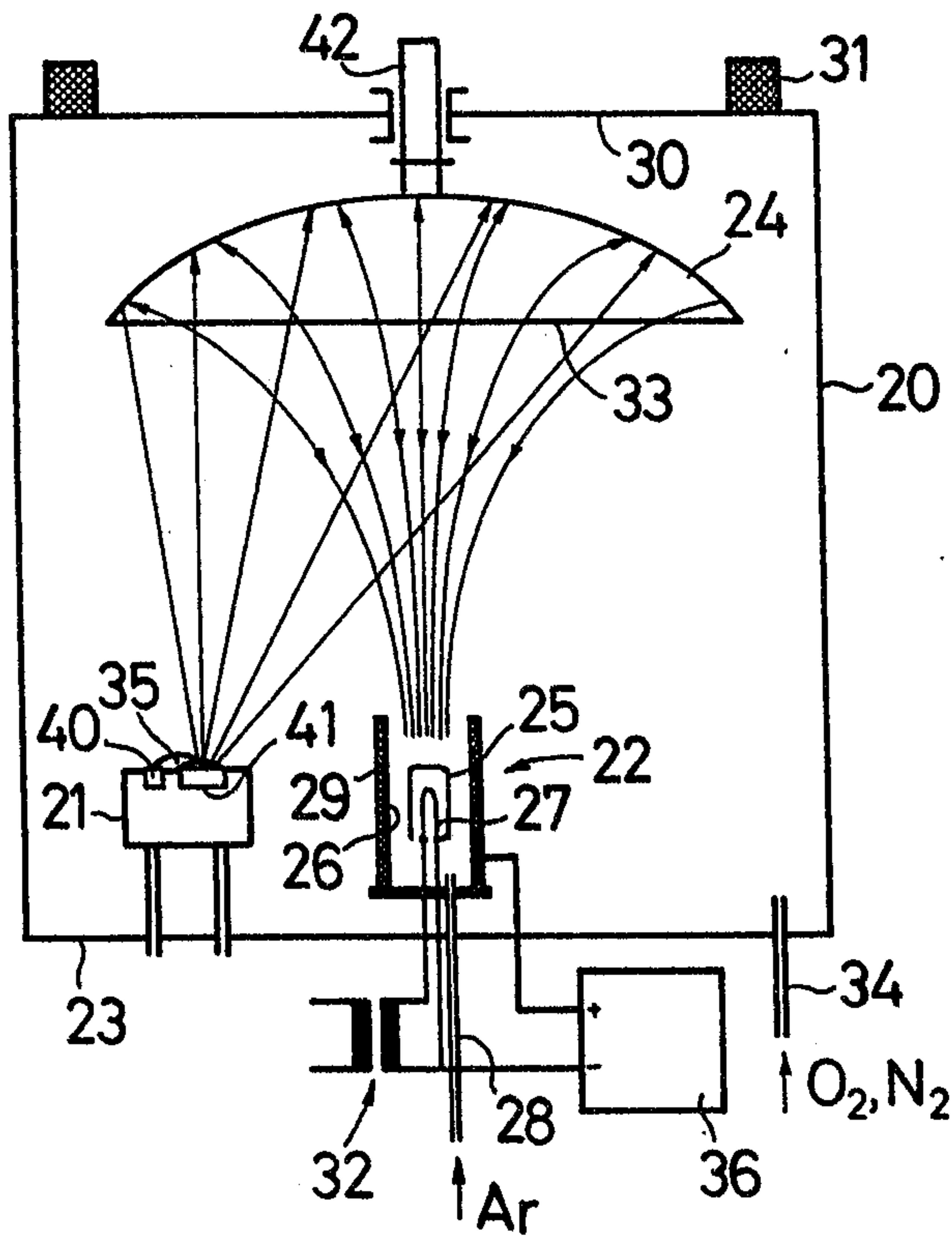

FIG. 4

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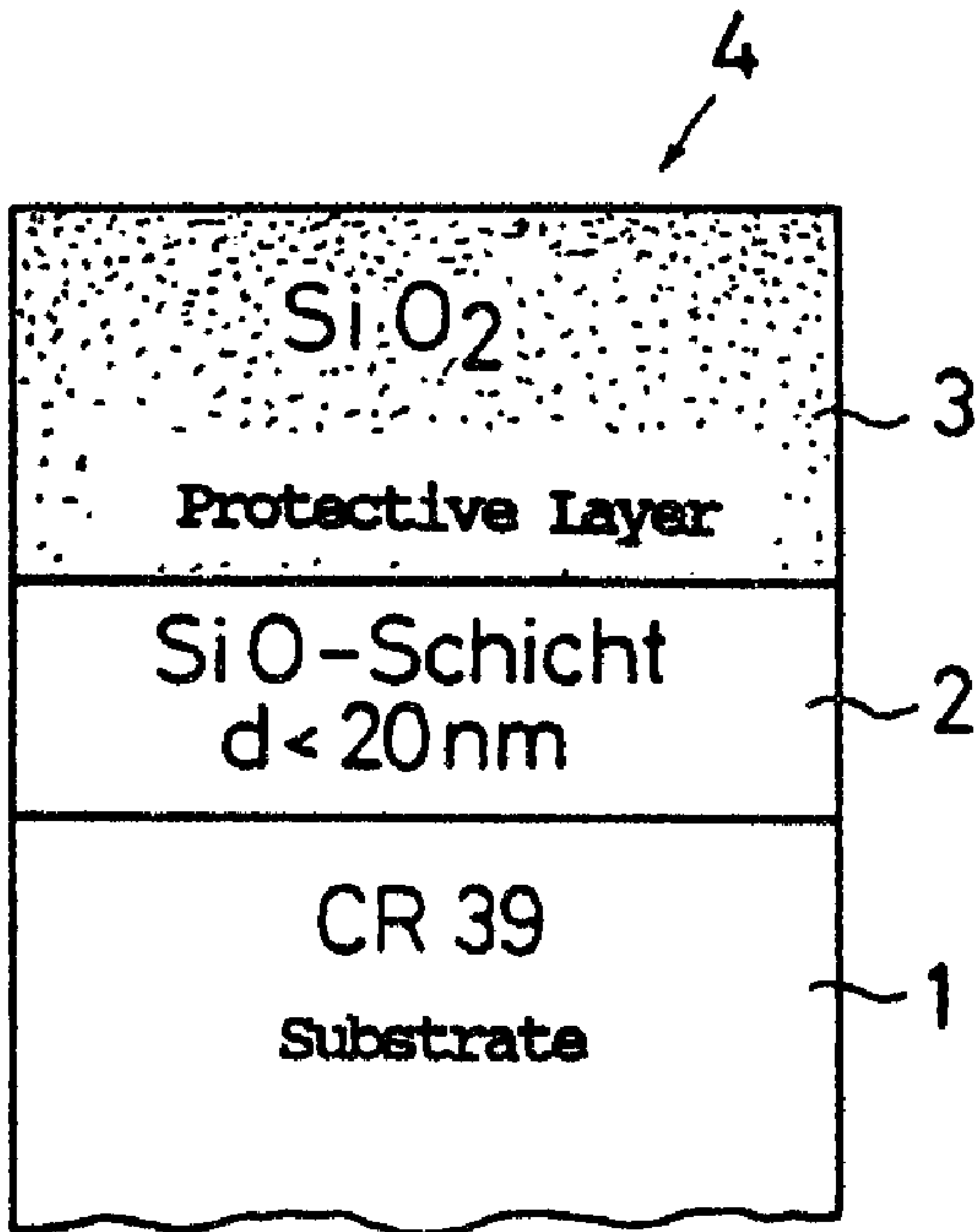
4
SiO_2
Protective Layer
3
SiO-Schicht
d<20nm
2
CR 39
Substrate
1