

Bonding agent for the bonding of components, method for the bonding of components made of material with high silicic acid content, and component assembly obtained according to said method

The present invention relates to a method for bonding components made of
5 material with a high silicic acid content by means of a substance-to-substance bonding by means of a SiO₂-containing bonding mass that is formed between the connecting surfaces of the components and has a chemical composition that is generic with regard to the material with a high silicic acid content.

Moreover, the invention relates to a component assembly comprising at least two
10 components made of material with a high silicic acid content, which are bonded to each other by means of a SiO₂-containing bonding mass, whereby the SiO₂-containing bonding mass is amorphous and has a chemical composition that is generic with regard to the material with high silicic acid content.

Moreover, the invention relates to an SiO₂-containing bonding agent for bonding
15 components by means of substance-to-substance bonding.

Herein, the term, "material with a high silicic acid content", shall be defined to denote a doped or non-doped quartz glass with a SiO₂ fraction of at least 85%. This material shall hereinafter also be termed "quartz glass" for short. Quartz glass is characterized by a low thermal expansion coefficient, optical transparence over
20 a wide range of wavelengths, and high chemical and thermal inertness.

Components made of quartz glass are being used for a multitude of applications, such as for example in the manufacture of lamps as cladding tubes, bulbs, covering plates or reflector carriers for lamps and radiators in the ultraviolet, infrared, and visible part of the spectrum, in chemical apparatus engineering or
25 semiconductor manufacture in the form of reactors and apparatus made of quartz glass for the treatment of semiconductor components, carrier trays, jars, crucibles, protective shields or simple quartz glass components such as tubes, rods, plates, flanges, rings or blocks. In order to generate certain properties, the quartz glass is doped with other substances such as titanium, aluminum, boron, germanium.

Frequently, there is a need to connect glass elements to each other, for example for the manufacture of components of complex shape from simpler pre-formed parts. Commonly, this connection is provided by welding the components to each other. For example, EP 1 042 241 A1 describes a method for the butt-like welding of quartz glass tubes. Welding comprises melting the surfaces to be connected and pressing the softened surfaces against each other which can easily lead to undesired plastic deformation at the welding zone. Though it is possible to remove deformations of this kind by extensive after-treatment, some dimensional imperfections usually remain.

With regard to the manufacture of precision parts that are assembled from several quartz glass components, bonding techniques have therefore been proposed which include adhesive procedures using organic adhesive masses, but are resistant to low temperatures only, or diffusion welding procedures using activating intermediary layers.

A procedure of the latter type is described for example in DE 29 23 011 A1. In order to achieve a vacuum-tight connection of quartz glass elements, this reference proposes to vapor-deposit an aluminum layer with a thickness of 0.001 mm on the connecting surfaces, previously polished to be even, followed by pressing the connecting surfaces against each other at a pressure of 7 Nmm^{-2} , and then heat this composite in a vacuum to a temperature of approximately 630°C .

This bonding technique requires very costly treatment of the surface; the composite is incapable of resisting temperatures that are significantly higher than the melting temperature of aluminum.

In addition, melting bonds utilizing melt-in materials adapted to the respective thermal expansion coefficient are generally known. For example, product brochure no. 9016 "Technische Gläser/Technical Glasses" of Schott Glaswerke (printing note: 9016 d XII/81) names a number of glass solders for different bonding materials with medium expansion coefficients in the range between $4 \times 10^{-6} / ^\circ\text{C}$ and $11 \times 10^{-6} / ^\circ\text{C}$ (the expansion coefficient of quartz glass is approx. $0.5 \times 10^{-6} / ^\circ\text{C}$).

A bonding method utilizing melt-in materials of this type is known from DD 289 513 A5. To afford a dimensionally-stable and vacuum-tight connection of precision parts made of quartz glass, this reference proposes to use a glass solder based on lead-zinc borate. The glass solder consists of lead oxide, zinc oxide, boron
5 oxide, and silica oxide at the following weight fractions: 76% PbO, 11% ZnO, 9% B₂O₃, and 2% SiO₂. A glass solder powder containing particles with a particle size between 1 µm and 70 µm is used to prepare an acetone-soluble paste, which is then applied to one of the connecting surfaces. The parts to be connected (tube and plate) are fixed in position with regard to each other and the connecting
10 surfaces are pressed together firmly. This composite is then placed in a soldering furnace and subjected to a temperature treatment with a maximal temperature of 450 °C for a period of 3.5 hours. In the process, the glass solder melts and is converted to a crystalline phase with a higher melting temperature.

The substance-to-substance bond thus afforded is characterized by a low vacuum
15 leakage rate - up to a temperature of 500 °C. However, this bonded connection does not meet the particularly stringent requirements with regard to temperature resistance and thermal fatigue resistance of many applications of quartz glass in heat technology. In addition, the known bonded connection also fails to meet requirements with regard to purity and absence of contamination as exist for
20 example in applications of semiconductor manufacture, optics, but also in the areas of chemistry, medicine, research, and analytical technology.

This disadvantage is circumvented in the bonding method of the type specified above, that is described in JP 63-069734 A. As a bonding agent for bonding an optical fiber to a quartz glass substrate, this document proposes a polymerizable
25 sol made up of metal alkoxides with a composition that is similar to that of fiber and substrate. After the polymerization reaction, the gel thus obtained is heated or vitrified for further solidification of the bond by means of laser or heater such that an SiO₂-containing bonding mass whose chemical composition is generic with regard to the material with a high silicic acid content is generated between the
30 connecting surfaces of the components.

A similar method is described in printed specification DE 23 42 852 B2. For bonding optical precision parts made of silicate glasses, this document proposes a SiO₂-bonding layer that is generated by hydrolysis of vaporized SiCl₄ vapors by means of water vapor. The thickness of the SiO₂ bonding layer is in the range of
5 100 to 200 nm; its solidification is effected by heating in a furnace at a temperature between 150 °C and 250 °C.

The two latter methods require expensive starting substances and a number of difficult and costly procedural steps to carry out the method such that these methods never became established in practical application for cost and
10 productivity reasons.

It is therefore the object of the present invention to provide a method facilitating the cost-efficient manufacture of a mechanically- and thermally-stable component assembly made of material with a high silicic acid content and to provide a SiO₂-containing bonding agent that is suitable for said method.

15 It is another object of the invention to provide a component assembly composed from at least two bonded components made of material with a high silicic acid content, which component assembly is characterized by a high degree of reliability, temperature resistance, and thermal fatigue resistance, and which can also be used in applications that are sensitive to contamination.

(20 With regard to the method, the object is met by the invention on the basis of the method described above in that the provision of the SiO₂-containing bonding mass comprises the following procedural steps:

- (a) provision of an aqueous slurry containing amorphous SiO₂ particles;
- (b) formation of a slurry mass between the connecting surfaces which are fixed
25 in position with regard to each other;
- (c) drying of the slurry mass; and
- (d) solidification of the slurry mass by heating with formation of the SiO₂-containing bonding mass.

In the method according to the invention, the bonding of the components is based on a SiO₂-containing bonding mass between the connecting surfaces, said bonding mass being generated using an aqueous slurry containing amorphous SiO₂ particles. The castable or paste-like slurry in the form of a slurry mass is
5 situated between the connecting surfaces that are fixed with respect to each other, and subsequently solidified by drying and heating.

In the process, there necessarily takes place some shrinkage of the slurry mass. Consequently, a particular challenge of the method according to the invention is to prevent tearing of the slurry mass upon drying and solidification. This is achieved
10 by starting with a slurry that contains amorphous SiO₂ particles. These are subject to mutual interactions which stabilize the slurry mass even in its paste-like and dry state and promote the sintering activity which facilitates solidification of the dried slurry mass at comparably low temperature with formation of a dense, crack-free SiO₂-containing bonding mass. Another contribution is made by the polar nature of
15 the aqueous slurry medium and the amorphous structure of the SiO₂ particles which have a high intrinsic sintering activity.

The homogenized slurry is then applied in the form of a "slurry mass" to one connecting surface or both connecting surfaces, whereby the connecting surfaces are subsequently fixed in position with respect to each other or on each other. It is
20 also possible to provide a slurry mass between connecting surfaces which are previously fixed in position with respect to each other.

The slurry mass is dried in a separate procedural step prior to the solidification of the slurry mass, for example at room temperature, by heating or freeze-drying, or the drying according to procedural step (c) and the solidification according to
25 procedural step (d) form a common temperature treatment process.

In order to solidify and condense the dried slurry mass, the slurry mass is heated to a temperature that leads to a sintering or melting of the amorphous SiO₂ particles and formation of a crack-free SiO₂-containing bonding mass that consists of partly opaque and partly transparent or completely transparent glass with a high
30 silicic acid content.

In the process, it is important to prevent or at least minimize crystallization within the SiO₂-containing bonding mass since this would weaken the bond. In this context, it is also important that the SiO₂ particles used for forming the slurry are amorphous. They consist of synthetically manufactured SiO₂ or are manufactured
5 on the basis of purified naturally occurring raw material.

Another technical challenge is the manufacture of a stable SiO₂-containing bonding mass providing a stable and reliable connection between the components even upon temperature changes. In this regard, a special focus is on the thermal expansion coefficient SiO₂-containing bonding mass and its temperature
10 dependence compared to the thermal expansion coefficient or coefficients of the components to be connected.

In this regard, the "generic nature" of the SiO₂-containing bonding mass with regard to the material with a high silicic acid content plays an important role. Herein this shall mean that the SiO₂ content of the bonding mass differs from that
15 of the highly silicic acid-containing components to be bonded by maximally 10 wt-%, preferably by maximally 3 wt-%.

The use of "generic material" for the formation of the bonding mass has the following effects:

- on the one hand, it facilitates the approximation, to the extent possible, of the
20 thermal expansion coefficients of the quartz glass of the components and of the bonding mass, and, associated with this, particularly good adhesion of the solidified SiO₂-containing bonding mass to the connecting surfaces and, particularly, a high thermal fatigue resistance of this assembly;
- and, on the other hand, contamination of the quartz glass of the connected
25 components or their operative environment by foreign substances present in the generic material is thus prevented or reduced;

Roughness and unevenness of the connecting surfaces do not necessarily have disadvantageous effects in the method according to the invention. Rather, a certain degree of surface roughness improves the adhesion of the slurry mass and
30 SiO₂-containing bonding mass. In addition, it is easy to apply the slurry mass

between the connecting surfaces thick enough such that costly processing of these surfaces in an earlier step can be prevented.

In a first preferred variant of the method, the particle sizes of the amorphous SiO_2 particles were in the range of up to $500\text{ }\mu\text{m}$, preferably up to $100\text{ }\mu\text{m}$, whereby
5 amorphous SiO_2 particles with particle sizes in the range between $1\text{ }\mu\text{m}$ and $50\text{ }\mu\text{m}$ account for the majority of the volume.

Amorphous SiO_2 particles in this size range and of this size distribution show advantageous sintering behavior and comparably little shrinking upon drying. The coarser particles contribute to a high solids content of the slurry, which leads to
10 lower relative shrinkage of the slurry mass. As a result of the interactions illustrated above, which may even lead to the formation of molecular SiO_2 bonds, the finer particles act similar to a binding agent promoting the sintering and vitrification behavior. Experience indicates that, with a slurry of this type, a slurry mass with high greenbody density can be generated and dried and solidified
15 without cracks forming.

Preferably, the SiO_2 content of the amorphous SiO_2 particles is at least 99.9 wt-%.

The solid fraction of the slurry made using such particles consists of at least 99.9% of SiO_2 . Binding agents or similar additives are not considered. As such, this is a generic starting material for a component assembly made of non-doped quartz
20 glass. This starting material is not associated with any risk of contamination or crystallization.

A contribution to the interactions effecting high sintering activity is made if the amorphous SiO_2 particles are generated by wet comminution of amorphous SiO_2 starting grains.

25 In the process, the desired particle size distribution is set by means of the aqueous slurry homogenization process, whereby the amorphous SiO_2 particles are reduced in size during the homogenization from comparably coarse grains with diameters for example in the range between $200\text{ }\mu\text{m}$ and $5,000\text{ }\mu\text{m}$ depending on their degree of solidification. During wet comminution, amorphous SiO_2 particles of

any size are produced in the slurry, including those which form with each other the bonds described above already in the slurry, whereby the polar nature of the water plays an important role. This improves the stability of the slurry mass.

Advantageously, the solids content of the slurry during the generation of the slurry mass between the connecting surfaces is at least 65 wt-%, preferably at least 80 wt-%, particularly preferably at least 83 wt-%.

(10 A high solids content during the application or introduction of the slurry mass reduces the shrinkage during drying and solidification, and thereby reduces the formation of strains in the SiO₂-containing bonding mass and, in addition, the dimensional stability and dimensional accuracy of the assembly. Setting a high solids content in the slurry is favored by the polar nature of the aqueous medium. However, there may be arguments in favor of a low viscosity slurry depending on which procedure for the application of the slurry is selected.

15 For the application of the slurry, the known procedure are basically suitable, such as spraying, electrostatically-supported spraying, flooding, centrifugation, laying on (painting), troweling. Especially in application procedures that are well-suited for even coverage of large areas by means of immersion or spraying, comparably low slurry viscosities are advantageous.

(20 Aside from amorphous, dense SiO₂ particles, the slurry can also contain other amorphous SiO₂ starting material.

For example, it has proven favorable for at least part of the amorphous SiO₂ particles to be provided in the form of porous granulate particles made of agglomerates of nano-scale, amorphous, synthetically-produced SiO₂ primary particles with a mean primary particle size of less than 100 nm.

25 The porous granulate consists of agglomerates of nano-scale, amorphous, synthetically-produced SiO₂ primary particles with a mean primary particle size of less than 100 nm. Primary particles of this type are obtained by flame hydrolysis or oxidation of silicon compounds. Upon granulation, agglomeration of the fine-particulate SiO₂ primary particles leads to the formation of the coarser granulate particles. As a result, some compaction and solidification is initiated as early as in
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the slurry mass which later favors the sintering and vitrification; the compaction and solidification is based on a certain degree of solubility and mobility of individual primary particles in the slurry, which contributes to the formation of so-called "sintering necks" between adjacent amorphous SiO_2 particles in the slurry mass. When the SiO_2 -enriched liquid phase in the area of these "necks" is dried, these necks solidify and lead to a firm connection between the individual amorphous SiO_2 particles, and to compaction and solidification of the slurry mass, which simplifies the subsequent sintering. The porosity of the granulates and the associated large specific surface effect high sintering activity.

It has been particularly favorable to set the pH value of the slurry to a value in the range between 3 and 5.5.

The acidic pH value improves the cross-linking reactions of the amorphous SiO_2 particles with each other and simplifies the thermal solidification of the slurry mass.

During wet comminution, the gradual dissolution of the amorphous SiO_2 particles of the slurry - up to the solubility limit - lowers the pH value automatically. However, especially for acceleration of the process, a procedure is preferred, in which the pH value of the slurry is set by adding an acid or a base.

It has proven favorable to provide for an exposure time between the formation of the slurry mass between the connecting surfaces being fixed in position with respect to each other, and the drying of the slurry mass.

This improves the adhesion of the slurry mass on the connecting surfaces and strengthens the bonds between the amorphous SiO_2 particles. Presumably, this effect is due to cross-linking reactions which proceed, and are aided by the moisture that is present, during the exposure time between amorphous SiO_2 particles of the still moist slurry mass and the SiO_2 of the connecting surfaces of the components. The duration of the exposure time depends on the quantity of slurry mass and is on the order of a few minutes to several hours.

In a preferred variant of the method, the solidification of the slurry mass comprises a sintering with formation of an at least partly opaque bonding mass.

Compared to vitrification to the extent of complete transparency, sintering requires comparably lower sintering temperatures and/or shorter sintering times. This favors the preservation of the dimensional accuracy of the component assembly to be produced, reduces the energy requirements, and prevents detrimental thermal effects on the components to be connected and crystallization in the area of the bonding mass.

Experience has shown that even just sintering (and not only complete vitrification) is sufficient to achieve sufficient mechanical resistance of the SiO₂-containing bonding mass for most applications.

(10 The degree of compaction depends on the sintering temperature and sintering time. The higher the temperature, the shorter the sintering time can be, and vice versa. A common and preferred temperature treatment for sintering of the slurry mass comprises heating at a temperature in the range between 800 °C and 1450 °C, preferably at a temperature below 1300 °C.

15 In the simplest case, the sintering is performed in a sintering furnace, in which the components to be connected are placed. The homogeneous heating of the entire component assembly in a sintering furnace reduces the formation of strain and prevents deformation of the assembly.

(20 In a preferred variant of the method, the solidification of the slurry mass comprises vitrification with formation of an at least partly transparent solidified SiO₂-containing bonding mass.

Complete vitrification of the SiO₂-containing bonding mass (in contrast to sintering) is preferred when particularly stringent requirements regarding the tightness, mechanical strength, absence of particles, and chemical inertness must be met by the assembly, when optical transparency is required in this area for technical reasons, or for solely aesthetic reasons. In this case, the SiO₂-containing bonding mass contains no or few pores and possesses high density at a level similar to that of the silicic acid-containing components.

However, usually it is sufficient to vitrify areas of the SiO₂-containing bonding mass that are close to the surface. Provided these vitrified areas connect the connecting

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surfaces to each other, they contribute to increased mechanical strength and also to the tightness of the assembly even if the SiO₂-containing bonding mass otherwise is pore-containing and opaque.

Helium leakage tests show that vacuum-tightness levels up to 10⁻⁹ bar can be
5 implemented without difficulty in component assemblies that are shaped like hollow bodies and manufactured by means of the latter variant of the method according to the invention.

Vitrification is preferably performed through the use of a heat source whose maximal heating effect can be limited locally to the slurry mass.

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10 Hereby, the effect of the high temperature required for vitrification can be limited locally to the slurry mass to be vitrified, and therefore plastic deformations can be prevented or reduced. It is preferable to use burners or infrared lasers (for example CO₂ lasers) for this purpose.

If a preceding sintering step is used, it is advantageous to utilize the residual heat
15 and vitrify the component assembly while it is still hot. This contributes to the saving of energy and reduces the formation of strains.

In another preferred variant of the method solving the object mentioned above with regard to the thermal expansion coefficient of the SiO₂-containing bonding mass, a
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20 slurry containing one or more of the following doping agents is used: Al₂O₃, TiO₂, Y₂O₃, AlN, Si₃N₄, ZrO₂, BN, HfO₂, Si, Yb₂O₃ and/or SiC.

The addition of one or more of the doping agents specified above allows the thermal expansion coefficient of the SiO₂-containing bonding mass to be adapted to that or those of the components to be connected. Preferably, the doping agent
25 doping is performed such that the formation of a crystalline phase in the SiO₂-containing bonding mass is prevented. This is achieved, for example, by melting the doping agent jointly with the SiO₂ fraction of the bonding mass to form a glass and subsequent comminution of the glass such that doped amorphous particles are obtained.

For the reasons stated above, in the case that at least one of the components with a high silicic acid content to be connected contains a doping agent of this type, it is preferred to use a procedure in which the aqueous slurry also contains particles of this material as doping agent.

- 5 With regard to the bonding of components made of quartz glass, a SiO₂-containing bonding mass that is generic with regard to this material can be used, in which the SiO₂ content of the bonding mass differs from those of the components by max. 10 wt-%, preferably by max. 3 wt-%.

(10 With regard to the component assembly, the object specified above is met starting from the assembly mentioned above in that the SiO₂-containing bonding mass is manufactured from amorphous, sintered or vitrified SiO₂ particles with particle sizes in the range of up to 500 µm, whereby SiO₂ particles with particle sizes in the range between 1 µm and 50 µm account for the largest volume fraction of the bonding mass.

- 15 The SiO₂-containing bonding mass is amorphous and has a chemical composition that is generic with respect to the material with a high silicic acid content of the components to be connected. Please refer to the statements made above with regard to the definition of the term, "generic".

(20 This bonding mass is preferably generated by means of the method according to the invention described above utilizing a slurry containing amorphous SiO₂ particles. Consequently, in contrast to the assembly of the type specified in the introduction, the SiO₂-containing bonding mass consists of sintered or vitrified SiO₂ particles with particle sizes in the range of up to 500 µm, whereby amorphous SiO₂ particles with particle sizes in the range between 1 µm and 50 µm account for the
25 largest volume fraction.

The cristobalite fraction of the SiO₂-containing bonding mass is max. 1 wt-%, since, if it were otherwise, the formation of crystals would weaken the bonded connection.

A bonding mass consisting of generic material particles of this type imparts particularly good adhesion and high thermal fatigue resistance properties on the component assembly according to the invention, which is suitable also for contamination-sensitive applications, and which also meets stringent dimensional accuracy requirements. The component assembly according to the invention possesses one or multiple bonding sites. The application options are multifarious. Examples include wafer carriers, which must meet stringent requirements with regard to their dimensional accuracy, thermal stability, and absence of contamination, or structural elements made of quartz glass assembled from simple elements, such as frames for telescopes, reflectors or the like, which are characterized by their low weight or by a low thermal expansion coefficient. It is advantageous for containers, such as reactor shells for performing chemical and physical processes or tanks for the reception of liquids, gases, and solids, to consist of the component assembly according to the invention. Aside from these and the above-mentioned utilization options in lamp manufacture, semiconductor manufacture or laboratory equipment, the use of component assemblies according to the invention also lends itself in the area of fiber optics, for example for connecting parts of a preform for optical fibers to each other or bond mounting elements made of quartz glass to such a preform, for the manufacture of optical waveguide components, such as plugs, couplers, branch-offs, connectors.

It has proven favorable for the specific density of the SiO_2 -containing bonding mass to be at least 2.0 g/cm^3 , preferably at least 2.1 g/cm^3 .

The bonding site of a component assembly of this type is characterized by particularly high mechanical firmness, chemical inertness, gas-tightness, and absence of particles.

In a particularly preferred embodiment of the component assembly according to the invention, the SiO_2 -containing bonding mass comprises an SiO_2 fraction of at least 99.9 wt-%.

In this regard, this concerns a bonding mass made of a generic material for a component assembly made of non-doped quartz glass such that notable

differences in the expansion coefficient and its temperature dependence and contamination and crystallization problems are prevented.

In a first preferred refinement of the component assembly according to the invention, the SiO₂-containing bonding mass is partly or completely transparent.

- 5 A component of this type is preferred when particularly stringent requirements with regard to the tightness, firmness, absence of particles, and chemical inertness of the assembly exist or when optical transparency is required in this area for technical reasons or desired for aesthetic reasons. In this case, the SiO₂-
(10 containing bonding mass contains no or few pores and possesses high density at a similar level as that of the components having an high silicic acid-content.

Usually, it is sufficient for only the areas of the SiO₂-containing bonding mass that are close to the surface to be completely vitrified and transparent. These connect the connecting surfaces of the components to each other and thus contribute to the mechanical firmness, tightness, and absence of particles from the assembly.

- 15 For adapting its thermal expansion coefficient to the components of the component assembly, it has proven useful for the SiO₂-containing bonding mass to contain doping agents in the form of Al₂O₃, TiO₂, Y₂O₃, AlN, Si₃N₄, ZrO₂, BN, HfO₂, Si, Yb₂O₃ and/or SiC, preferably as amorphous particles.

- (20 The thermal expansion coefficient of the SiO₂-containing bonding mass is adapted to that or those of the components to be connected by means of adding one or more of the doping agents specified above.

- Preferably, the doping is performed such that the formation of a crystalline phase in the bonding mass is prevented. This is achieved, for example, by melting the doping agent jointly with the SiO₂ fraction of the bonding mass to form a glass and
25 subsequent comminution of the glass to form doped amorphous SiO₂ particles.

In the case that at least one of the components to be connected consists of a material with a high silicic acid content that contains one or more of the doping agents, Al₂O₃, TiO₂, Y₂O₃, AlN, Si₃N₄, ZrO₂, B₂O₃, HfO₂ or Yb₂O₃, the SiO₂-

containing bonding mass preferably comprises the same doping agent or same doping agents.

Adding to the bonding mass a doping agent that corresponds to the doping of the component allows the thermal expansion coefficient to be adapted particularly
5 easily to that or those of the components to be connected.

A particularly preferred embodiment of the component assembly according to the invention provides an opaque SiO_2 -containing bonding mass that is situated in the gap between two quartz glass tubes that are arranged such as to be coaxial with respect to each other.

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10 Herein, the opaque SiO_2 -containing bonding mass serves, on the one hand, for fixation in position of the quartz glass tubes with respect to each other and imparts on the assembly of tubes the properties of an opaque cylinder with regard to the translucence and shielding of heat radiation, even if one of the quartz glass tubes is or both quartz glass tubes are transparent. This is advantageous especially in
15 the case of quartz glass tubes with a large volume, which can only be obtained by heat forming of standard-sized tubes and lose all or a large part of their translucence in the process.

The present invention is manifested in particular in the use of a SiO_2 -containing bonding means in order to connect components made of material with a high silicic
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20 acid content by substance-to-substance bonding. This is characterized according to the invention in that comprises amorphous SiO_2 particles with particle sizes in the range of up to $500\text{ }\mu\text{m}$, whereby amorphous SiO_2 particles with particle sizes in the range between $1\text{ }\mu\text{m}$ and $50\text{ }\mu\text{m}$ account for the largest volume fraction.

The SiO_2 -containing bonding means according to the invention is provided as a
25 powder-like, paste-like or liquid mass prior to its intended use. The powder-like, paste-like or liquid mass is used to generate the amorphous SiO_2 particles by drying and solidification according to the method illustrated above, whereby the amorphous SiO_2 particles act mutually stabilizing by means of interactions and facilitate solidification of the bonding mass at comparably low temperature with
30 formation of a dense and crack-free SiO_2 -containing bonding mass.

The amorphous structure of the SiO_2 particles effects high sintering activity, which is even enhanced if the amorphous SiO_2 particles have particle sizes in the range of up to 100 μm .

A frequently encountered task is to connect components made of different materials, e.g. of glass and of ceramic. Since the expansion coefficients are usually quite different, the thermal fatigue resistance is low. However, it has been found that a stabile bonding connection can be attained through the use of the bonding means according to the invention even in the case of components to be connected that are made from different materials, as long as it is ensured that the temperature of use of the component assembly is low, i.e. below 300 °C. It is a helpful contribution to adapt the expansion coefficient of the SiO_2 bonding mass by means of doping.

Composite components are manufactured from ceramics and quartz glass for example in lamp manufacturing. A known embodiment comprises a lamp tube made of quartz glass the ends of which are sealed off on both sides by means of end caps made of aluminum oxide. End caps of this type have thus far been attached to both ends of a lamp tube by means of an organic adhesive leading to depositions forming on the lamp tube due to the vaporization of ingredients of the adhesive. Such deposits are prevented by manufacturing the assembly using the bonding means according to the invention. The absence of contamination and particles as well as sufficient tightness are achieved by the SiO_2 -containing bonding mass having sufficient density, whereby a compaction of areas close to the surface by means of a laser is preferred in order to prevent thermal stress from affecting the surrounding areas, such as heat-sensitive electrical components arranged in the area of the aluminum oxide end caps.

Composite components are generally known. Herein, an embodiment of a component assembly made of ceramic and quartz glass for use in semiconductor manufacturing having the form of a quartz glass wafer holder is proposed whose surface is fully or partly coated by a ceramic layering element.

In the semiconductor industry, equipment and apparatus that is particularly exposed to chemical stress is made of ceramic materials such as aluminum oxide

or silicon carbide which both are characterized by high etch resistance with respect to most of the process media used in the manufacturing of semiconductors. Therefore, according to the invention, a relatively cheap basic component made of quartz glass is manufactured for the wafer holder, and its
5 surface is connected to a ceramic layering element by applying the bonding means according to the invention and by generating the SiO₂-containing bonding mass described above. The comparatively cheaper basic body made of quartz glass that is provided with a thin, compact ceramic layer that shows the same etch resistance as a massive ceramic body. A sufficiently stabile bond between the
10 basic component and the ceramic layering element is attained provided an operating temperature of 300 °C is not exceeded, whereby it is possible to meet this prerequisite in the use of the holder for single wafer application.

Ceramic layering elements that are suitable for this purpose are commercially available in the form of ceramic foils.

15 In the following, the invention is illustrated in more detail by means of exemplary embodiments and one drawing. The following is shown in schematic representation in the figures:

Figure 1 shows an embodiment of the component assembly according to the invention in the form of quartz glass tubes which are connected to
20 each other by their longitudinal sides;

Figure 2a shows the assembly of two quartz glass plates in accordance with the method according to the invention;

Figure 2b shows the component assembly obtained by means of the procedural step shown in Figure 2a, in the form of two quartz glass plates which
25 are placed on top of each other by their flat sides;

Figure 3 shows another embodiment of the component assembly according to the invention in the form of a dome-shaped reactor shell assembled from individual parts;

Figure 4 shows a procedural step for the assembly of several individual parts to form a wafer carrier by means of the method according to the invention;

Figure 5a shows an embodiment of the component assembly according to the invention in the form of quartz glass plates connected to each other in a butt-like fashion;

Figure 5b shows another embodiment of quartz glass plates connected to each other in a butt-like fashion;

Figure 6 shows a top view of a component assembly composed from plate- and tube-shaped individual elements, in the form of a lightweight reflector carrier;

Figure 7 shows a side view of a laboratory device with a conical ground joint assembled from individual elements,

Figure 8 shows a side view of a section of a component assembly according to the invention in the form of quartz glass tubes, which are arranged coaxial with respect to each other and are fixed in position on a quartz glass ring,

Figure 9 shows another embodiment of the component assembly according to the invention, in which a holder made of quartz glass is connected to a preform for optical fibers,

Figure 10 shows a radial cross-section of another embodiment of the component assembly according to the invention in the form of an opaque tube,

Figure 11 shows an embodiment of a component assembly in the form of an UV discharge lamp, and

Figure 12 shows an embodiment of a component assembly in the form of a single wafer holder.

1. Preparation of the slurry

A homogeneous stabilized basic slurry is prepared. To prepare a batch of 10 kg of basic slurry, 1.8 kg of deionized water whose conductivity is less than 3 μ S and 8.2 kg of an amorphous quartz glass grains made of natural raw material with

grain sizes in the range between 250 μm and 650 μm and an SiO_2 content of 99.99 % are mixed in a quartz glass-lined rotary drum grinder with a volume of approximately 20 liters.

This mixture is then comminuted by means of quartz glass grinding beads on a roller bracket at 23 rpm for a period of 3 days until a homogenous stabilized base slurry with a solids content of 78 % wt-% is obtained. During the comminution process, the dissolving SiO_2 reduces the pH to a value of approximately 4.

The amorphous SiO_2 particles in the base slurry obtained after wet comminution of the quartz glass grains have a particle size distribution that is characterized by a D_{50} value of approximately 5 μm and a D_{90} value of approximately 23 μm .

Additional amorphous SiO_2 grains with a mean grain size of approximately 5 μm is then added to the basic slurry thus obtained until the solids content is 87 wt-%. The mixture is then homogenized in a rotary drum grinder for 12 hours at 25 rpm. The slurry thus obtained has a solids content of 87 % wt-% and a density of almost 2.0 g/cm^3 .

The basic slurry is used in this state for the manufacture of an adhesive connection as shall be described in more detail in the following.

2. Preparation of an adhesive connection using the slurry

Figure 1 shows in a schematic representation a so-called "twin tube" made of quartz glass. This twin tube consists of a cladding tube 1 whose cross-section is figure 8-shaped and which is subdivided into two sub-spaces 3, 4 by a central fin 2. The sub-spaces 3, 4 serve to receive one heating spiral each, whereby the electrical connections are guided out of the cladding tube 1 through crimps on its ends (not shown in Figure 1). The main direction of the light radiation of the twin tube 9 is downwards in the embodiment shown as indicated in a symbolic fashion by the direction arrow 5. On the upper side 6 of the twin tube 9 facing away from the main direction of the light radiation 5, it is intended to bond a quartz glass cooling tube 8 whose longitudinal axis extends parallel to the longitudinal axis of the twin tube 9.

For this purpose, the surfaces of the cooling tube 8 and twin tube 9 are cleaned with alcohol and then cleaned with 30% hydrofluoric acid in order to remove other surface contaminations, in particular due to alkaline and alkaline earth compounds.

5 Subsequently, the slurry mass described above is introduced into the trough between the two tube-halves of the twin tube 9 and then the cooling tube 8 is pressed onto this such that it is introduced into the trough, whereby a small quantity of slurry mass is squeezed out in upward direction and thus forms a slurry build-up 10 along the contact surface. The bonding mass 7 between the contact
10 surfaces is a few tenths of a millimeter thick.

This arrangement is allowed to rest for approximately 6 hours in an air atmosphere, during which the slurry layer 7 dries slowly. Complete drying is achieved through the use of an IR radiator in an air atmosphere. After drying, the bonding mass 7 is free of cracks and approximately 0.4 mm thick in the area of the
15 contact surfaces, and somewhat thicker in the area of the trough and slurry build-up 10.

The dried bonding mass 7 is then vitrified in a sintering furnace in an air atmosphere. The heating profile for vitrification comprises a heating ramp during which the bonding mass 7 is heated from room temperature to a heating
20 temperature of 1,300 °C over the course of two hours. The bonding mass 7 is then kept at this heating temperature for two hours. After this treatment, the bonding mass 7 is completely sintered, optically opaque, and has a mean specific density of approximately 2.12 g/cm³.

The assembly thus prepared is then removed from the sintering furnace while it is
25 still hot and the area around the sintered slurry build-up 10 is vitrified by means of a oxyhydrogen gas burner. For this purpose, the oxyhydrogen gas burner is moved along the free surface of the sintered slurry build-up 10 to heat the build-up until it is completely transparent. The remaining area of the sintered bonding mass 7 - between the cooling tube 8 and the twin tube 9 - remains opaque such that the
30 mean specific density does not change significantly.

Subsequently, the still hot assembly of twin tube 9 and cooling tube 8 is placed in the sintering furnace, which is still heated to a temperature of 1,100 °C, and slowly allowed to cool therein. The first cooling ramp has a cooling rate of 5 °C/min and ends at a furnace temperature of 1,050 °C, the second cooling ramp has a cooling rate of 10 °C/min and ends at a furnace temperature of 950 °C. The further cooling proceeds uncontrolled inside the closed furnace. The relatively slow cooling anneals the component assembly such that existing mechanical strains are reduced or removed and the formation of strain due to cooling is prevented.

The assembly consisting of twin tube 9 and quartz glass cooling tube 8 is mechanically stable and characterized by its high thermal fatigue resistance even at operating temperatures above 1,000 °C.

Figure 2b shows in a schematic representation a composite body 20 comprising a lower quartz glass plate 22 and an upper quartz glass plate 21 which are connected to each other by means of an opaque SiO₂-containing intermediary layer 23 with a thickness of 1 mm. The plates are each 2 mm thick and square in shape with edges 200 mm in length.

The opaque intermediary layer 23 serves for example as a transmission barrier for heat radiation. Quartz glass components - such as flanges - in high temperature applications are often made completely or partly of opaque quartz glass to block heat radiation. For the purpose of cleaning, the components usually are etched with hydrofluoric acid-containing chemicals. However, opaque quartz glass has a low etching resistance such that the serviceable life of such opaque quartz glass components ends after relatively few cleaning cycles. For this reason, transparent quartz glass is melted onto the opaque surface areas of the components. This is a hot process which tends to cause deformation of the component such that a costly after-treatment is required.

The composite body 20 according to the invention as shown schematically in Figure 2b represents such an opaque component of this type that is covered by transparent quartz glass on its both sides. It is suited to replace components of this type which are costly to produce until now, whereby the transparent layers 21, 22 can easily be applied also in thick layers.

In order to prepare the composite body 20, the plates 21, 22 are first degreased and cleaned as described by means of Example 1. Subsequently, the slurry described above is applied by spraying to the upper side of the lower quartz glass plate 22 and the lower side of the upper quartz glass plate 21 in the form of one
5 slurry layer 24, 25 each which each is approximately 0.8 mm thick, whereby the low viscosity slurry is sprayed on using a spraying nozzle. The spraying process is terminated as soon as about even coverage is achieved, as is shown in **Figure 2a** in a schematic fashion.

Immediately thereafter, the upper plate 21 is placed on the lower plate 22,
10 whereby fixation of the two plates 21, 22 with respect to each other is achieved. This arrangement is allowed to rest for approximately 6 hours in an air atmosphere, during which the slurry layer 24, 25 dries slowly. Complete drying is achieved through the use of an IR radiator in an air atmosphere. The dried slurry layer 24, 25 is free of cracks and maximally approximately 1.4 mm thick.

15 After drying of the slurry layer, the composite body 20 is sintered in a sintering furnace in an air atmosphere. The heating profile for sintering comprises a heating ramp during which the slurry layer is heated from room temperature to a heating temperature of 1,250 °C over the course of one hour. The composite body 20 is then kept at this heating temperature for two hours. The slurry layer thus gives rise
20 to a sintered, but still opaque intermediary layer 23, which firmly connects the two quartz glass plates 21, 22 and consists of generic material with regard to the quartz glass plates 21, 22, and has a mean specific density of approximately 2.10 g/cm³.

The composite body 20 thus prepared is then allowed to cool slowly in the
25 sintering furnace as described above by means of Example 1.

The plate-shaped composite body 20 thus prepared is opaque and 5 mm thick. It consists of three layers 21, 22, 23, of which the middle layer 23 is approximately 1 mm thick and accounts for the opacity and is covered on both sides by layers 21, 22 made of dense and tight, transparent quartz glass with a thickness of 2 mm
30 each, which is characterized by its high etching resistance. In addition, the composite body 20 is thermally stable, characterized by high thermal fatigue

resistance even at operating temperatures above 1,000 °C, and generates absolutely no problems related to particles.

The method described above is also well-suited for the manufacture of a composite body that consists completely of transparent quartz glass. For this purpose, it is only necessary to completely vitrify the intermediary layer 23 rather than to sinter it. For this purpose, the composite body is vitrified in a vitrification furnace in an air atmosphere after drying of the slurry layer. The heating profile for vitrification comprises a heating ramp during which the slurry layer is heated from room temperature to a heating temperature of 1,400 °C over the course of four hours. The composite body is then kept at this heating temperature for two hours. The slurry layer thus gives rise to a sintered, transparent intermediary layer of generic material, which firmly connects two quartz glass plates and has a mean specific density of approximately 2.2 g/cm³. In this fashion, it is not only possible to increase the thickness of quartz glass plates, but also to build-up quartz glass blocks.

Further embodiments of the composite component according to the invention are shown schematically in Figures 3 to 10, whereby the bonding technique using an SiO₂ slurry, as described in more detail in Figures 1 and 2, is used in each case to connect the components to each other.

Figure 3 shows a dome-shaped reactor shell 30 as is used for etching or performing CVD processes in the manufacture of semiconductors. The bell jar 30 consists of a tube-shaped side part 31 made of transparent quartz glass, whose upper side is sealed in a gas-tight fashion by a dome-shaped covering element 32 which is also made of transparent quartz glass, and on whose lower side a flange 33 made of opaque quartz glass is provided. The covering element 32 and the flange 33 are fixed to the side part 31 by means of bonding connections using the slurry described above followed by vitrification by means of a burner. The bonding connection between the side part 31 and the covering element 32 is provided in the form of a butt seam weld 34. The connection between flange 33 and the side part 31 comprises an area 36 for sealing the annular gap between flange 33 and side part 31, which area 36 is completely vitrified in the area of the front side for a

depth of approx. 100 μm and otherwise is opaque, and a fillet weld 35 for mechanical stabilization. The seam connections each consist of pure SiO_2 and therefore of a material that is generic with regard to the reactor shell components, and have a mean specific density of approximately 2.20 g/cm^3 .

- 5 Quartz glass containers of any shape and size can be assembled in a similar fashion from simple plate-, ring- and circle-shaped individual elements. Pertinent examples include cuvettes made of quartz glass or tanks for the reception of etching agents.

(10 **Figure 4** shows in a schematic fashion a procedural step for assembling a wafer carrier from several individual parts by means of the method according to the invention. The wafer carrier consists of side flanges 42 made of transparent quartz glass arranged opposite each other (one of the side flanges is shown in Figure 4), which are connected by means of fins 41. The fins 41, which serve to bear wafers and are provided with transverse slits 43 for this purpose, are connected to the
15 side flanges 42 by means of the method according to the invention using a SiO_2 -containing bonding mass. For this purpose, the side flanges are provided with circular bore holes 44, into which bonding mass 45 in the form of the slurry described above is filled prior to inserting the fins 41. The bonding sites thus generated are then dried and subsequently vitrified to transparency by a burner
20 flame such that the bonding sites thus obtained consist of a material that is generic with regard to the wafer carrier, and have a mean specific density of approximately 2.20 g/cm^3 .

(**Figure 5a** shows a section of a transparent quartz glass plate 50 with a thickness of 30 mm which is assembled from individual parts 51, 52. The individual parts 51,
25 52 are connected to each other by means of butt seams 53 made of transparent quartz glass. The butt seams 53 are generated by fixing in a butt-like fashion the quartz glass plates 51, 52 with respect to each other such that a gap of approximately 1.5 mm remains, and then filling the gap with an SiO_2 slurry. The slurry is allowed to dry for 5 hours in an air atmosphere (as described by means of
30 Figure 1) and is then vitrified by means of an oxyhydrogen burner flame. The upper side of the assembly thus obtained is subsequently ground and polished to

be even such that an optically homogeneous quartz glass plate 50 is obtained.

The seam connections each consist of pure SiO_2 and therefore of a material that is generic with regard to the individual parts 50, 51, and have a mean specific density of approximately 2.20 g/cm^3 .

- 5 In this fashion, it is possible to produce quartz glass plates with large surface areas without resorting to hot forming processes.

Figure 5b shows an alternative bonding technique for the manufacture of quartz glass plates with large surface areas by placing against each other in a butt-like fashion and fixing smaller plate elements 54, 55. In the process, the plate

- (10 elements 54, 55 are each provided with beveled edges 56. The bevels are fixed in position with respect to each other, as shown in Figure 5b, and SiO_2 slurry is filled into the gap. After drying and vitrification of the slurry, as shown above by means of Figure 5a, a transparent quartz glass plate is obtained which is particularly resistant to bending stress due to the size and arrangement of the bonding sites.

- 15 **Figure 6** shows in a schematic fashion a component assembly composed from plate- and tube-shaped individual elements, in the form of a lightweight reflector carrier 60. Reflector carriers of this type are used in telescopes, for example. Aside from their lightweight design, a particular focus is placed on the dimensional stability upon changes of the temperature. Due to its low thermal expansion
- (20 coefficient, quartz glass is well-suited to provide the reflector carrier. The low weight is achieved by assembling the reflector carrier from simple, lightweight machined parts made of quartz glass. However, welding the machined parts made of quartz glass together causes deformation of the reflector carrier. If the machined parts made of quartz glass are glued to each other according to state-
- 25 of-the-art techniques, the non-adapted difference in the thermal expansion coefficients of adhesive and quartz glass leads to deformations during operation.

- The method according to the invention is the first to provide a gluing technique for the manufacture of lightweight reflector carriers made of machined parts made of quartz glass, whereby the carriers are not associated with a risk of deformation
- 30 upon variations in the temperature since the adhesive is generic with regard to the quartz glass of the machined parts.

Figure 6 shows in a schematic fashion a telescope reflector carrier 60 made of plate elements 61 to 64, which are connected to each other by means of fins 65 and a ring element 66. The connection is afforded by fillet welds 67 (of which only a small number is shown in schematic fashion) between the respective machined parts. The method according to the invention described above is used to generate the fillet welds. The fillet welds 67 are sintered at as low a temperature as possible in order to avoid deformation. They are opaque, each consist of pure SiO_2 and therefore of a material that is generic with regard to the plate elements 61 to 64, and have a mean specific density of approximately 2.10 g/cm^3 .

10 In the embodiment of the component assembly according to the invention in accordance with **Figure 7**, which is provided in the form of a laboratory device 70, a ground joint part 71 with a conical ground joint is prepared first, and then connected to a bushing-shaped shaft 72 by bonding using a SiO_2 -containing bonding mass, which is provided in the form of a circumferential fillet weld 73.

15 The circumferential fillet weld 73 consist of pure SiO_2 and therefore of a material that is generic with regard to the ground joint part 71 and the shaft 72, and has a mean specific density of approximately 2.20 g/cm^3 .

In identical or similar fashion, other laboratory devices made of quartz glass can be assembled from simple individual elements.

20 **Figure 8** shows a side view of a section of a component assembly 80 according to the invention in the form of quartz glass tubes 81, 82 which are arranged coaxial with respect to each other and are fixed on a quartz glass ring 83.

The quartz glass tubes 81, 82 are connected to each other by means of a SiO_2 -containing bonding mass 84 according to the invention, and are simultaneously
25 fixed in an annular groove of the quartz glass ring 83.

The fixing mass is opaque and consists of pure SiO_2 . Hence, it is generic with regard to the quartz glass tubes 81 and 82, and has a mean specific density of approximately 2.10 g/cm^3 .

In identical or similar fashion, arrangements of coaxial quartz glass tubes, for example for the manufacture of chemical apparatus or for the manufacture of flame hydrolysis burners made of quartz glass, are manufactured, whereby it is also possible to dispense with the quartz glass ring 83.

5 **Figure 9** shows in a schematic fashion a preform 90 for the manufacture of optical fibers, zones of which are softened in a furnace 91 and thereby elongated to a strand 92. For the bracket of the preform, a holding cylinder 93 made of quartz glass is provided which is connected in a butt-like fashion to the upper front-face end of the preform 90. The bonding procedure according to the invention is used
10 to generate this connection, whereby an all-around fillet weld is provided on the inside of the holding cylinder 93, and on the outer jacket, an all-around outer build-up made 95 made of partly opaque, partly transparent quartz glass is provided, which overlaps the abutment site. Fillet weld 94 and outer build-up 95 are generated by sintering and vitrification of a SiO_2 slurry layer by means of a burner
15 flame, whereby only the outer areas of the slurry layer become completely vitrified. Thus, the assembly is exposed to relatively little temperature strain as compared to attachment of the holding cylinder by melting and there is little impact on the preform 90. Fillet weld 94 and outer build-up 95 each consist of pure SiO_2 and therefore of a material that is generic with regard to the preform 90, and have a
20 mean specific density of approximately 2.15 g/cm^3 .

(In this context, another example for the component assembly according to the invention is the joining of bodies shaped like half cups, for example tube halves generated by cutting in longitudinal direction.

Figure 10 shows a radial cross-section of an opaque quartz glass tube 100
25 comprising an internal tube 101 and an external tube 102, which both consist of transparent quartz glass. The internal tube 101 has an internal diameter of 50 mm and an external diameter of 54 mm. The external tube 102 has an internal diameter of 60 mm and an external diameter of 65 mm. The gap remaining between the quartz glass tubes 101, 102 with a gap width of 3 mm is filled with an
30 opaque SiO_2 -containing bonding mass 103 according to the present invention and serves the purpose, on the one hand, to connect the quartz glass tubes 101, 102

to each other and, on the other hand, to impart opacity on the tube assembly 100, which serves to shield heat radiation.

The SiO₂-containing bonding mass 103 consist of pure SiO₂ and therefore of a material that is generic with regard to the quartz glass tubes 101, 102, and has a
5 mean specific density of approximately 2.10 g/cm³.

In the embodiments of the component assembly according to the invention illustrated above, the individual components consist of non-doped quartz glass. Hence, the SiO₂-containing bonding mass used to effect the corresponding bonded connection ideally also consists of non-doped quartz glass in these cases.

(10 In the presence of one or multiple doping agents in the quartz glass of the components with an effect on the thermal expansion coefficient of quartz glass, the SiO₂-containing bonding mass is selected such that its thermal expansion coefficient and the temperature dependence thereof are similar to those of the component, and, in the case of components doped differently, preferably are
15 between the corresponding expansion coefficients.

The application of the slurry between or onto the connecting surfaces of the components is subject to the influence of the flow properties of the slurry. The application of homogeneous layers to large surface areas is facilitated by a so-called dilatancy effect (Kelvin effect), whereas otherwise the so-called intrinsic
(20 viscosity or thixotropy is desired rather. The slurry property called intrinsic viscosity (thixotropy) is evident in that the viscosity of the slurry is reduced in dependence on the shearing rate (for example during stirring). This is related to diminished interactions between the amorphous SiO₂ particles due to the action of shear forces. After the elimination of the shear forces - when the slurry mass in contact
25 with the connecting surfaces of the components is at rest - these interactions intensify again and lead to the formation of physical or chemical bonds between the amorphous SiO₂ particles of the slurry mass. The intrinsic viscosity of the slurry can be increased by adding coarser SiO₂ particles.

Figure 11 shows a schematic depiction of an UV discharge lamp 111 as is used in
30 the area of tanning devices or for the disinfection of surfaces or liquids. The discharge lamp 111 essentially consists of a tube-shaped transparent discharge

vessel 112 made of quartz glass, whose front ends are sealed by caps 116 made of aluminum oxide. The electrical connections 113 for the electrodes, which are arranged inside the discharge vessel 112, are guided through one of the caps 116.

5 The aluminum oxide caps 116 are glued on using the bonding means according to the invention. For this purpose, the surfaces of discharge vessel 112 and caps 116 to be glued together are cleaned with alcohol. Subsequently, the slurry mass described above is applied to the front-side ends of the discharge vessel 112 and then the caps 116 are pressed on, whereby a small amount of the slurry mass is squeezed from the gap between the jacket surface of the discharge vessel 112
10 and the cap 116 and thus forms a circumferential slurry rim 115.

The assembly thus generated is exposed to air for approx. 6 hours, whereby the slurry layer also slowly dries. The assembly is dried completely exposed to air. The bonding mass is free of cracks after drying. Subsequently, the dried bonding mass is vitrified exposed to air. In the process, it is made sure that the heat-
15 sensitive electrical parts inside the cap 116 and the discharge vessel 112 are not heated to temperatures in excess of 200 °C. This is achieved through the use of a CO₂ laser acting only locally and for short periods of time on the slurry rim 115, by moving the laser along the free surface of the slurry rim 115 and heating it until it is largely transparent and attains a mean specific density of approx. 2.15 g/cm³. The
20 remaining bonding mass between the caps 116 and the discharge vessel 112 remains opaque such that the mean specific density does not change significantly as compared to that of the dried bonding mass.

The assembly of discharge vessel 112 and aluminum oxide caps 116 is mechanically stabile, gas-tight, and characterized by the absence of particles.
25 However, the operating temperature is restricted to temperatures below 200 °C.

Figure 12 shows a schematic depiction of a single wafer holder 120 made of quartz glass for the processing of 8inch wafers. The holder 120 essentially forms a ring with an external diameter of 256 mm and an internal diameter of 196 mm that is provided with a circumferential recess for taking up the wafer.

It consists of a composite body made from a quartz glass plate 122 and a common commercially available ceramic foil 124 made of Al_2O_3 that is manufactured by means of deep-drawing. The quartz glass plate is 12 mm thick and the Al_2O_3 foil 124 is approx. 1 mm thick. These components 122, 124 are connected to each other by means of an opaque SiO_2 -containing intermediate layer 0.4 mm in thickness that is manufactured on the basis of the bonding means according to the invention as follows:

The quartz glass plate 122 is first de-greased and then cleaned in HF-containing etch solution. Subsequently, the bonding means according to the invention provided in the form of the slurry described above is applied to the top side of the quartz glass plate 122 in the form of a slurry layer 123 with a thickness of 0.8 mm by means of spraying, whereby the easily flowing slurry is sprayed on by means of a spraying nozzle. The spraying process is completed once approximately even coating is achieved.

Immediately thereafter, the Al_2O_3 foil 124 is then placed on, which effects the fixation of the components 122, 124 with respect to each other. This arrangement is exposed to air for approx. 6 hours, whereby the slurry layer 123 also slowly dries. Complete drying is achieved in a sintering furnace exposed to air at a temperature of approx. 200 °C. The dried slurry layer 123 is free of cracks.

Because it is covered by the Al_2O_3 foil, the wafer holder thus manufactured is characterized by very high etch resistance, including with respect to fluorine-containing process media, and generates no problems with particles. Its temperature fatigue resistance is sufficient, provided the temperatures of its use are below 200 °C, which is easy to provide in applications of the holder 120 for single wafer processing.

CLAIMS

1. A method for bonding components made of quartz glass using a substance to substance bond by forming an SiO.sub.2-containing bonding mass between connecting surfaces of the components, said method comprising the following steps: (a) providing an aqueous slurry with a solid fraction of amorphous SiO.sub.2 particles, said solid fraction having an SiO.sub.2 content of at least 99.9 wt-%, the amorphous SiO.sub.2 particles having particle sizes in a range of up to 500 .mu.m, and the amorphous SiO.sub.2 particles that have particle sizes in a range of between 1 .mu.m and 50 .mu.m constituting a majority by volume of the solid fraction, said aqueous slurry being derived by wet comminution of amorphous SiO.sub.2 starting grains; (b) forming a slurry mass between the connecting surfaces which are fixed in position with regard to each other; (c) drying of the slurry mass; and (d) solidifying the slurry mass by sintering and vitrifying the sintered slurry mass so as to form the SiO.sub.2-containing bonding mass, the components to be bonded each having an SiO.sub.2 content, and the bonding mass having an SiO.sub.2 content differing from the SiO.sub.2 content of the components to be bonded by at most 3 wt-%; wherein the sintering is performed at a first heating temperature in a sintering furnace in which the components to be connected are placed and homogeneously heated; and wherein the vitrification is performed at a second heating temperature higher than the first heating temperature using an additional directional heat source whose maximal heating effect is limited locally to the slurry mass.
2. The method according to claim 1, wherein the solidification comprises sintering of the slurry mass so as to form an at least partly opaque solidified bonding mass.
3. The method according to claim 2, wherein the sintering comprises a temperature treatment of the slurry mass at a temperature between 800.degree. C. and 1,450.degree. C.
4. The method according to claim 2, wherein the sintering comprises a temperature treatment of the slurry mass at a temperature below 1,450.degree. C.
5. The method according to claim 1, wherein the solidification comprises vitrification of the slurry mass so as to form an at least partly transparent, solidified SiO.sub.2-containing bonding mass.

6. The method according to claim 1, wherein the particle sizes of the amorphous SiO.sub.2 particles are in the range of up to 100 .mu.M.
7. The method according to claim 1, wherein the solids content of the slurry during the generation of the slurry mass between the connecting surfaces is at least 65 wt-%.
8. The method according to claim 1, wherein at least part of the amorphous SiO.sub.2 particles is present in the form of porous granulate particles made of agglomerates of nano-scale, amorphous, synthetically-produced SiO.sub.2 primary particles with a mean primary particle size of less than 100 nm.
9. The method according to claim 1, wherein an exposure time is provided between the formation of the slurry mass between the connecting surfaces being fixed in position with respect to each other, and the drying of the slurry mass.
10. The method according to claim 1, wherein the solids content of the slurry during the generation of the slurry mass between the connecting surfaces is at least 80 wt-%.
11. The method according to claim 1, wherein the solids content of the slurry during the generation of the slurry mass between the connecting surfaces is at least 85 wt-%.
12. The method according to claim 1 wherein said components are a tube-shaped side part and a dome-shaped covering element of a bell jar, and the SiO.sub.2-containing bonding mass forms a weld between said tube-shaped side part and said dome-shaped covering element.
13. The method according to claim 12, wherein a further slurry mass is formed from the aqueous slurry between connecting surfaces of the side part and a flange of the bell jar, and vitrification of the slurry masses is provided by a burner.
14. The method according to claim 13, wherein the second SiO.sub.2-containing bonding mass forms a fillet weld between the flange and the side part.
15. The method according to claim 14, wherein the tube shaped side part and the dome-shaped element are of transparent quartz glass.

16. The method according to claim 15, wherein the flange is of opaque quartz glass.
17. The method according to claim 12, wherein the weld is a butt seam weld.
18. The method according to claim 1, wherein, in said wet comminution, SiO_2 dissolves to a degree at which the slurry has a pH value in a range between 3 and 5.5.
19. The method according to claim 1, wherein the vitrification is performed by burners or infrared lasers.
20. The method according to claim 1, wherein the vitrification uses residual heat from the sintering.