HU000027255T2

(19) **HU**

(11) Lajstromszám: **E 027 255**

(13) **T2**

MAGYARORSZÁG
Szellemi Tulajdon Nemzeti Hivatala

EURÓPAI SZABADALOM
SZÖVEGÉNEK FORDÍTÁSA

(21) Magyar ügyszám: **E 12 770152**
(22) A bejelentés napja: **2012. 10. 11.**

(96) Az európai bejelentés bejelentési száma:
EP 20120770152
(97) Az európai bejelentés közzétételi adatai:
EP 2765976 A2 **2013. 04. 18.**
(97) Az európai szabadalom megadásának meghirdetési adatai:
EP 2765976 B1 **2016. 02. 24.**

(51) Int. Cl.: ***A61K 6/02*** *(2006.01)*
C03C 30/76 *(2006.01)*
C03C 30/83 *(2006.01)*
C03C 30/97 *(2006.01)*
C03C 4/00 *(2006.01)*
C03C 10/00 *(2006.01)*

(86) A nemzetközi (PCT) bejelentési szám:
PCT/EP 12/070222
(87) A nemzetközi közzétételi szám:
WO 13053866

(30) Elsőbbségi adatok:
11185338 **2011. 10. 14.** **EP**

(72) Feltaláló(k):
RITZBERGER, Christian, CH-9472 Grabs (CH)
APEL, Elke, CH-9479 Oberschan (CH)
HÖLAND, Wolfram, CH-9494 Schaan (LI)
RHEINBERGER, Volker, CH-9490 Vaduz (LI)

(73) Jogosult(ak):
Ivoclar Vivadent AG, 9494 Schaan (LI)

(74) Képviselő:
SBGK Szabadalmi Ügyvivői Iroda, Budapest

(54) **Négy vegyértékű fémoxidot tartalmazó lítium-szilikát üvegkerámia és lítium-szilikát üveg**

Lithium silicate glass ceramic and glass with tetravalent metal oxide

The invention relates to lithium silicate glass ceramic and glass which contain tetravalent metal oxide selected from ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 and mixtures thereof and are particularly suitable for use in dentistry, preferably for the preparation of dental restorations.

Lithium silicate glass ceramics are characterized as a rule by very good mechanical properties, which is why they have been used for a long time in the dental field and there primarily for the preparation of dental crowns and small bridges. The known lithium silicate glass ceramics usually contain as main components SiO_2, Li_2O, Na_2O or K_2O, and nucleating agents such as P_2O_5 as well as additional components such as e.g. La_2O_3.

DE 24 51 121 describes lithium disilicate glass ceramics which contain K_2O. They are prepared from corresponding nuclei-

containing starting glasses which are heated to temperatures of from 850 to 870°C for the crystallization of lithium disilicate. The purpose for which the glass ceramics are used is not disclosed.

EP 827 941 describes sinterable lithium disilicate glass ceramics for dental purposes, which also contain K_2O or Na_2O in addition to La_2O_3. The lithium disilicate crystal phase is produced at a temperature of 850°C.

Lithium disilicate glass ceramics which likewise contain La_2O_3 as well as K_2O are known from EP 916 625. A heat treatment is carried out at 870°C for the formation of lithium disilicate.

EP 1 505 041 describes lithium silicate glass ceramics containing K_2O, which, when lithium metasilicate is present as main crystal phase, can be very satisfactorily machined e.g. by means of CAD/CAM processes, in order to then be converted by further heat treatment at temperatures of from 830 to 850°C into high-strength lithium disilicate glass ceramics.

EP 1 688 398 describes similar K_2O-containing lithium silicate glass ceramics which are moreover substantially free from ZnO. A heat treatment at 830 to 880°C is applied to them to produce lithium disilicate.

US 5,507,981 describes processes for producing dental restorations and glass ceramics that can be used in these processes. These are in particular lithium disilicate glass ceramics with a low level of Li_2O which contain as a rule either Na_2O or K_2O.

US 6,455,451 relates to lithium disilicate glass ceramics which also contain K_2O in addition to Li_2O. However, the production of the desired lithium disilicate crystal phase requires high temperatures of from 800 to 1000°C.

WO 2008/106958 discloses lithium disilicate glass ceramics for veneering zirconium oxide ceramics. The glass ceramics contain

Na_2O and are produced by heat treatment of nuclei-containing glasses at 800 to 940°C.

WO 2009/126317 describes GeO_2-containing lithium metasilicate glass ceramics which contain K_2O and small quantities of SiO_2. The glass ceramics are processed to form dental products primarily using machining.

WO 2011/076422 relates to lithium disilicate glass ceramics which also contain K_2O in addition to high levels of ZrO_2 or HfO_2. The crystallization of lithium disilicate takes place at high temperatures of from 800 to 1040°C.

Common to the known lithium disilicate glass ceramics is that they require heat treatments at more than 800°C in order to effect the precipitation of lithium disilicate as main crystal phase. A large quantity of energy is therefore also necessary for their production. Further, with the known glass ceramics the alkali metal oxides, such as in particular K_2O or Na_2O, as well as La_2O_3, are as a rule present as essential components which are clearly required for the production of glass ceramics with the sought properties and in particular the formation of the sought lithium disilicate main crystal phase.

There is therefore a need for lithium silicate glass ceramics during the preparation of which the crystallization of lithium disilicate can be effected at lower temperatures. Further, they should also be able to be prepared without the alkali metal oxides, such as K_2O or Na_2O, as well as La_2O_3, previously regarded as necessary, and be suitable in particular for the preparation of dental restorations primarily in view of their optical and mechanical properties.

This object is achieved by the lithium silicate glass ceramic according to any one of claims 1 to 12 or 15. Also a subject of the invention are the starting glass according to claim 13 or 15, the lithium silicate glass with nuclei according to claim 14 or 15, the process for the preparation of the glass ceramic and the lithium silicate glass with nuclei according

to claim 16 or 17 as well as the use according to claims 18 or 19.

The lithium silicate glass ceramic according to the invention is characterized in that it comprises

tetravalent metal oxide selected from ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 and mixtures thereof,
at least 12.1 wt.-% Li_2O,
less than 0.1 wt.-% La_2O_3,
less than 1.0 wt.-% K_2O
less than 2.0 wt.-% Na_2O.
67.0 to 79.0 wt.-% SiO_2 and
0 to 6.0 wt.-% Al_2O_3.

It is preferred that the glass ceramic comprises the tetravalent metal oxide or mixtures thereof in an amount of from 0.1 to 15, in particular 2.0 to 15.0, particularly preferred 2.0 to 11.0 and even more preferred 2.0 to 8.0 wt.-%.

It is particularly surprising that the formation of the glass ceramic according to the invention with lithium disilicate as main crystal phase is also achieved in the absence of various components regarded as necessary for conventional glass ceramics, such as alkali metal oxides, in particular K_2O, Na_2O and La_2O_3, even at very low and thus advantageous crystallization temperatures of in particular from 640 to 740°C. The glass ceramic also has a combination of optical and mechanical properties as well as processing properties that are very advantageous for the use as dental material.

The glass ceramic according to the invention accordingly preferably comprises less than 0.5 and in particular less than 0.1 wt.-% K_2O. It is particularly preferably substantially free from K_2O.

A glass ceramic is also preferred which comprises less than 1.0, in particular less than 0.5 and preferably less than 0.1 wt.-% Na_2O and particularly preferred is substantially free from Na_2O.

Moreover, a glass ceramic which is substantially free from La_2O_3 is preferred.

A glass ceramic, excluding lithium silicate glass ceramic which comprises at least 6.1 wt.-% ZrO_2, is also preferred.

Further, a glass ceramic, excluding lithium silicate glass ceramic which comprises at least 8.5 wt.-% transition metal oxide selected from the group consisting of oxides of yttrium, oxides of transition metals with an atomic number from 41 to 79 and mixtures of these oxides, is also preferred.

The glass ceramic according to the invention comprises 67.0 to 79.0 wt.-% SiO_2.

It is also preferred that the glass ceramic comprises 12.5 to 20.0 and in particular 15.0 to 17.0 wt.-% Li_2O.

It is further preferred that the molar ratio between SiO_2 and Li_2O is from 1.7 to 3.1, in particular 1.75 to 3.0. It is very surprising that the production of lithium disilicate is achieved within this broad range. Specifically at ratios of less than 2.0 conventional materials usually form lithium metasilicate instead of lithium disilicate.

In a further preferred embodiment the molar ratio between SiO_2 and Li_2O is at least 2.2, in particular 2.3 to 2.5, and preferably about 2.4, as a glass ceramic with particularly high strength is thus obtained.

The glass ceramic according to the invention can also comprise a nucleating agent. P_2O_5 is particularly preferably used for this. The glass ceramic preferably comprises 0 to 10.0, in particular 0.5 to 9.0 and preferably 2.5 to 7.5 wt.-% P_2O_5.

However, metals in amounts of in particular from 0.005 to 0.5 wt.-%, such as in particular Ag, Au, Pt and Pd, can also be used as nucleating agents.

In a further preferred embodiment, the glass ceramic comprises at least one and preferably all of the following components:

Component	wt.-%
SiO_2	67.0 to 79.0
Li_2O	12.5 to 20.0
tetravalent metal oxide or mixtures	2.0 to 15.0
P_2O_5	0 to 7.0, in particular 0.5 to 7.0
Al_2O_3	0 to 6.0, in particular 0.5 to 3.5.

The glass ceramic according to the invention can moreover also comprise additional components which are selected in particular from oxides of divalent elements, oxides of trivalent elements, further oxides of pentavalent elements, oxides of hexavalent elements, melt accelerators, colourants and fluorescent agents.

Suitable oxides of divalent elements are in particular MgO, CaO, SrO, BaO and ZnO and preferably CaO.

Suitable oxides of trivalent elements are in particular Al_2O_3, Y_2O_3 and Bi_2O_3 and mixtures thereof, and preferably Al_2O_3, already mentioned above as a component.

The term "further oxides of pentavalent elements" refers to oxides of pentavalent elements with the exception of P_2O_5. Examples of suitable further oxides of pentavalent elements are Ta_2O_5 and Nb_2O_5.

Examples of suitable oxides of hexavalent elements are WO_3 and MoO_3.

A glass ceramic which comprises at least one oxide of divalent elements, at least one oxide of trivalent elements, at least one further oxide of pentavalent elements and/or at least one oxide of hexavalent elements is preferred.

Examples of melt accelerators are fluorides.

Examples of colourants and fluorescent agents are oxides of d- and f-elements, such as the oxides of Ti, V, Sc, Mn, Fe, Co, Ta, W, Ce, Pr, Nd, Tb, Er, Dy, Gd, Eu and Yb. Metal colloids, e.g. of Ag, Au and Pd, can also be used as colourants and in addition can also act as nucleating agents. These metal colloids can be formed e.g. by reduction of corresponding oxides, chlorides or nitrates during the melting and crystallization processes. The metal colloids can be present in the glass ceramic in an amount of from 0.005 to 0.5 wt.-%.

The term "main crystal phase" used below refers to the crystal phase which has the highest proportion by volume compared with other crystal phases.

The glass ceramic according to the invention has lithium metasilicate as main crystal phase in one embodiment. In particular the glass ceramic comprises more than 5 vol.-%, preferably more than 10 vol.-% and particularly preferred more than 15 vol.-% lithium metasilicate crystals, relative to the total glass ceramic.

In a further particularly preferred embodiment, the glass ceramic has lithium disilicate as main crystal phase. In particular the glass ceramic comprises more than 10 vol.-%, preferably more than 20 vol.-% and particularly preferred more than 30 vol.-% lithium disilicate crystals, relative to the total glass ceramic.

The lithium disilicate glass ceramic according to the invention is characterized by particularly good mechanical properties and can be produced e.g. by heat treatment of the lithium metasilicate glass ceramic according to the invention.

However, it can be formed in particular by heat treatment of a corresponding starting glass or of a corresponding lithium silicate glass with nuclei.

It has surprisingly been shown that the lithium disilicate glass ceramic according to the invention has very good mechanical and optical properties and processing properties even in the absence of components regarded as essential for conventional glass ceramics. The combination of its properties even allows it to be used as dental material and in particular material for the preparation of dental restorations.

The lithium disilicate glass ceramic according to the invention has in particular a fracture toughness, measured as K_{IC} value, of at least 1.8 $MPa \cdot m^{0.5}$ and in particular more than about 2.0 $MPa \cdot m^{0.5}$. This value was determined using the Vickers method and calculated using Nilhara's equation.

The invention also relates to a lithium silicate glass with nuclei that are suitable for forming lithium metasilicate and/or lithium disilicate crystals, wherein the glass comprises the components of the above-described glass ceramics according to the invention. Thus this glass is characterized in that it comprises

tetravalent metal oxide selected from ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 and mixtures thereof,
at least 12.1 wt.-% Li_2O,
less than 0.1 wt.-% La_2O_3,
less than 1.0 wt.-% K_2O
less than 2.0 wt.-% Na_2O
67.0 to 79.0 wt.-% SiO_2 and
0 to 6.0 wt.-% Al_2O_3.

In respect of preferred embodiments of this glass reference is made to the preferred embodiments described above of the glass ceramics according to the invention.

The glass with nuclei according to the invention can be produced by heat treatment of a correspondingly composed starting glass according to the invention. The lithium metasilicate glass ceramic according to the invention can then be formed by a further heat treatment, and in turn be converted into the lithium disilicate glass ceramic according to the invention by further heat treatment, or the lithium disilicate glass ceramic according to the invention can also preferably be formed directly from the glass with nuclei. The starting glass, the glass with nuclei and the lithium metasilicate glass ceramic can consequently be regarded as precursors to the production of the high-strength lithium disilicate glass ceramic.

The glass ceramics according to the invention and the glasses according to the invention are present in particular in the form of powders, granular material or blanks, e.g. monolithic blanks, such as platelets, cuboids or cylinders, or powder green compacts, in unsintered, partly sintered or densely-sintered form. They can easily be further processed in these forms. They can, however, also be present in the form of dental restorations, such as inlays, onlays, crowns, veneers, facets or abutments.

The invention also relates to a process for the preparation of the glass ceramic according to the invention and the glass with nuclei according to the invention, wherein a correspondingly composed starting glass, the glass with nuclei according to the invention or the lithium metasilicate glass ceramic according to the invention is subjected to at least one heat treatment in the range of from 450 to 950°C, in particular 450 to 750 and preferably 480 to 740°C.

The starting glass according to the invention is therefore characterized in that it comprises

tetravalent metal oxide selected from ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 and mixtures thereof,

at least 12.1 wt.-% Li_2O,

less than 0.1 wt.-% La_2O_3,
less than 1.0 wt.-% K_2O
less than 2.0 wt.-% Na_2O
67.0 to 79.0 wt.-% SiO_2 and
0 to 6.0 wt.-% Al_2O_3.

In addition, it preferably also comprises suitable amounts of SiO_2 and Li_2O, in order to allow the formation of a lithium silicate glass ceramic, and in particular a lithium disilicate glass ceramic. Further, the starting glass can also comprise still further components, such as are given above for the lithium silicate glass ceramic according to the invention. All those embodiments are preferred for the starting glass which are also given as preferred for the glass ceramic.

With the process according to the invention, the glass with nuclei is prepared by means of a heat treatment of the starting glass at a temperature of from 480 to 520°C. The lithium disilicate glass ceramic according to the invention is then preferably produced from the glass with nuclei through further heat treatment at 640 to 740°C.

Thus, much lower temperatures are used according to the invention for the crystallization of lithium disilicate than with the conventional lithium disilicate glass ceramics. The energy thus saved represents a clear advantage. Surprisingly, this low crystallization temperature is also possible in the absence of components, such as K_2O and Na_2O as well as La_2O_3, regarded as essential for conventional glass ceramics.

To prepare the starting glass, the procedure is in particular that a mixture of suitable starting materials, such as carbonates, oxides, phosphates and fluorides, is melted at temperatures of in particular from 1300 to 1600°C for 2 to 10 h. To achieve a particularly high homogeneity, the obtained glass melt is poured into water in order to form a granular glass material, and the obtained granular material is then melted again.

The melt can then be poured into moulds to produce blanks of the starting glass, so-called solid glass blanks or monolithic blanks.

It is also possible to put the melt into water again in order to prepare a granular material. This granular material can then be pressed, after grinding and optionally addition of further components, such as colourants and fluorescent agents, to form a blank, a so-called powder green compact.

Finally, the starting glass can also be processed to form a powder after granulation.

The starting glass, e.g. in the form of a solid glass blank, a powder green compact or in the form of a powder, is then subjected to at least one heat treatment in the range of from 450 to 950°C. This means that a first heat treatment is initially carried out at a temperature in the range of from 480 to 520°C to prepare a glass according to the invention with nuclei which are suitable for forming lithium metasilicate and/or lithium disilicate crystals. This first heat treatment is carried out for a period of from 10 min to 120 min and in particular 10 min to 30 min. The glass with nuclei can then preferably be subjected to at least one further temperature treatment at a higher temperature and in particular more than 570°C to effect crystallization of lithium metasilicate or lithium disilicate. This further heat treatment is preferably carried out for a period of from 10 min to 120 min, in particular 10 min to 60 min and particularly preferably 10 min to 30 min. To crystallize lithium disilicate, the further heat treatment is carried out at 640 to 740°C.

Therefore, in an embodiment of the process

(a) the starting glass is subjected to a heat treatment at a temperature of from 480 to 520°C in order to form the glass with nuclei, and

(b) the glass with nuclei is subjected to a heat treatment at a temperature of from 640 to 740°C in order to form the glass ceramic with lithium disilicate as main crystal phase.

The duration of the heat treatments carried out in (a) and (b) is preferably as given above.

The at least one heat treatment carried out in the process according to the invention can also take place during a hot pressing or sintering-on of the glass according to the invention or the glass ceramic according to the invention.

Dental restorations, such as bridges, inlays, onlays, crowns, veneers, facets or abutments, can be prepared from the glass ceramics according to the invention and the glasses according to the invention. The invention therefore also relates to their use for the preparation of dental restorations. It is preferred that the glass ceramic or the glass is shaped into the desired dental restoration by pressing or machining.

The pressing is usually carried out at increased pressure and increased temperature. It is preferred that the pressing is carried out at a temperature of from 700 to 1200°C. It is further preferred to carry out the pressing at a pressure of from 2 to 10 bar. During pressing, the desired shape change is achieved by viscous flow of the material used. The starting glass according to the invention and in particular the glass with nuclei according to the invention, the lithium metasilicate glass ceramic according to the invention and the lithium disilicate glass ceramic according to the invention can be used for the pressing. The glasses and glass ceramics according to the invention can be used in particular in the form of blanks, e.g. solid blanks or powder green compacts, e.g. in unsintered, partly sintered or densely-sintered form.

The machining is usually carried out by material removing processes and in particular by milling and/or grinding. It is

particularly preferred that the machining is carried out as part of a CAD/CAM process. The starting glass according to the invention, the glass with nuclei according to the invention, the lithium metasilicate glass ceramic according to the invention and the lithium disilicate glass ceramic according to the invention can be used for the machining. The glasses and glass ceramics according to the invention can be used in particular in the form of blanks, e.g. solid blanks or powder green compacts, e.g. in unsintered, partly sintered or densely-sintered form. The lithium metasilicate glass ceramic according to the invention and lithium disilicate glass ceramic according to the invention are preferably used for the machining. The lithium disilicate glass ceramic can also be used in a not yet fully crystallized form which was produced by heat treatment at a lower temperature. This has the advantage that an easier machining, and thus the use of simpler equipment for the machining, is possible. After the machining of such a partly crystallized material, the latter is usually subjected to a heat treatment at a higher temperature and in particular 640 to 740°C in order to effect further crystallization of lithium disilicate.

In general, after the preparation of the dental restoration shaped as desired by pressing or machining, the latter can also in particular be heat-treated in order to convert the precursors used, such as starting glass, glass with nuclei or lithium metasilicate glass ceramic, into lithium disilicate glass ceramic or to increase the crystallization of lithium disilicate or to reduce the porosity, e.g. of a porous powder green compact used.

However, the glass ceramic according to the invention and the glass according to the invention are also suitable as coating material of e.g. ceramics and glass ceramics. The invention is therefore also directed to the use of the glass according to the invention or the glass ceramic according to the invention for coating of in particular ceramics and glass ceramics.

The invention also relates to a process for coating ceramics and glass ceramics, wherein the glass ceramic according to the invention or the glass according to the invention is applied to the ceramic or glass ceramic and is subjected to increased temperature.

This can take place in particular by sintering-on and preferably by pressing-on. With sintering-on, the glass ceramic or the glass is applied to the material to be coated, such as ceramic or glass ceramic, in the usual way, e.g. as powder, and then sintered at increased temperature. With the preferred pressing-on, the glass ceramic according to the invention or the glass according to the invention is pressed on, e.g. in the form of powder green compacts or monolithic blanks, at an increased temperature of e.g. from 700 to 1200°C, and applying pressure, e.g. 2 to 10 bar. The methods described in EP 231 773 and the press furnace disclosed there can be used in particular for this. A suitable furnace is e.g. the Programat EP 5000 from Ivoclar Vivadent AG, Liechtenstein.

It is preferred that, after conclusion of the coating process, the glass ceramic according to the invention is present with lithium disilicate as main crystal phase, as it has particularly good properties.

Because of the above-described properties of the glass ceramic according to the invention and the glass according to the invention as its precursor, these are suitable in particular for use in dentistry. A subject of the invention is therefore also the use of the glass ceramic according to the invention or the glass according to the invention as a dental material and in particular for the preparation of dental restorations or as a coating material for dental restorations, such as crowns, bridges and abutments.

Finally, the glasses and glass ceramics according to the invention can also be mixed together with other glasses and glass ceramics in order to produce dental materials with properties adjusted as desired. Compositions and in particular

dental materials which comprise the glass according to the invention or the glass ceramic according to the invention in combination with at least one other glass and/or one other glass ceramic therefore represent a further subject of the invention. The glass according to the invention or the glass ceramic according to the invention can therefore be used in particular as main component of an inorganic-inorganic composite or in combination with a plurality of other glasses and/or glass ceramics, wherein the composites or combinations can be used in particular as dental materials. The combinations or composites can particularly preferably be present in the form of sintered blanks. Examples of other glasses and glass ceramics for the preparation of inorganic-inorganic composites and of combinations are disclosed in DE 43 14 817, DE 44 23 793, DE 44 23 794, DE 44 28 839, DE 196 47 739, DE 197 25 553, DE 197 25 555, DE 100 31 431 and DE 10 2007 011 337. These glasses and glass ceramics belong to the group of silicates, borates, phosphates or aluminosilicates. Preferred glasses and glass ceramics are of SiO_2-Al_2O_3-K_2O type (with cubic or tetragonal leucite crystals), SiO_2-B_2O_3-Na_2O type, alkali-silicate type, alkali-zinc-silicate type, silicophosphate type, SiO_2-ZrO_2 type and/or lithium-aluminosilicate type (with spodumene crystals). By mixing such glasses or glass ceramics with the glasses and/or glass ceramics according to the invention, for example the coefficient of thermal expansion can be adjusted as desired in a broad range of from 6 to 20 • 10^{-6} K^{-1}.

The invention is explained in more detail below by means of examples.

Examples

Examples 1 to 13 - Composition and crystal phases

A total of 13 glasses and glass ceramics according to the invention with the composition given in Table I were prepared by melting corresponding starting glasses followed by heat treatment for controlled nucleation and crystallization.

For this, the starting glasses weighing from 100 to 200 g were first melted from customary raw materials at 1400 to 1500°C, wherein the melting was very easily possible without formation of bubbles or streaks. By pouring the starting glasses into water, glass frits were prepared which were then melted a second time at 1450 to 1550°C for 1 to 3 h for homogenization.

In the case of Examples 1 to 6 and 8 to 13, the obtained glass melts were then poured into preheated moulds in order to produce glass monoliths.

In the case of Example 7, the obtained glass melt was cooled to 1400°C and converted to a fine-particle granular material by pouring into water. The granular material was dried and ground to a powder with a particle size of < 90 µm. This powder was moistened with some water and pressed to form a powder green compact at a pressing pressure of 20 MPa.

The glass monoliths (Examples 1-6 and 8-13) as well as the powder green compact (Example 7) were then converted by thermal treatment to glasses and glass ceramics according to the invention. The thermal treatments used for controlled nucleation and controlled crystallization are also given in Table I. The following meanings apply

T_N and t_N	temperature and time used for nucleation
T_C and t_C	temperature and time used for crystallization of lithium disilicate or lithium metasilicate
LS	lithium metasilicate

It can be seen that a first heat treatment in the range of from 480 to 520°C resulted in the formation of lithium silicate glasses with nuclei and these glasses crystallized due to a further heat treatment already at 640 to 740°C to glass ceramics with lithium disilicate or lithium metasilicate as main crystal phase, as was established by X-ray diffraction tests.

The produced lithium silicate glass ceramics were able to be very satisfactorily machined into the form of various dental restorations, in a CAD/CAM process or by hot pressing, which restorations were also provided with a veneer if required.

They were also able to be applied by hot pressing as coatings onto in particular dental restorations, e.g. in order to veneer the latter as desired.

Example 14 - Processing via powder green compacts

The glass ceramics according to Examples 1 and 10 were ground to powders with an average particle size of < 90 µm.

In a first variant, the obtained powders were pressed with or without pressing auxiliaries to powder green compacts and the latter were partly or densely sintered at temperatures of from 800 to 1100°C and then further processed by machining or by hot pressing to form dental restorations.

In a second variant, the obtained powders were pressed with or without pressing auxiliaries to powder green compacts and the

latter were then further processed by machining or by hot pressing to form dental restorations. In particular, the dental restorations obtained after the machining were then densely sintered at temperatures of from 900 to 1100°C.

With both variants, in particular crowns, caps, partial crowns and inlays as well as coatings on dental ceramics and dental glass ceramics were prepared.

Example 15 - Hot pressing of glass with nuclei

A glass with the composition according to Example 7 was prepared by mixing corresponding raw materials in the form of oxides and carbonates for 30 min in a Turbula mixer and then melting the mixture at 1450°C for 120 min in a platinum crucible. The melt was poured into water in order to obtain a fine-particle granular glass material. This granular glass material was melted again at 1530°C for 150 min in order to obtain a glass melt with particularly high homogeneity. The temperature was reduced to 1500°C for 30 min and cylindrical glass blanks with a diameter of 12.5 mm were then poured into pre-heated, separable steel moulds or graphite moulds. The obtained glass cylinders were then nucleated at 500°C and stress-relieved.

The nucleated glass cylinders were then processed by hot pressing at a pressing temperature of 970°C and a pressing time of 6 min using an EP600 press furnace, Ivoclar Vivadent AG, to form dental restorations, such as inlays, onlays, veneers, partial crowns, crowns, laminating materials and laminates. In each case, lithium disilicate was detected as main crystal phase.

Table I

Example	1	2	3	4	5	6	7
Composition	wt.-%	wt.-%	wt.-%	wt.-%	wt.-%	wt.-%	wt.-%
SiO_2	73.8	69.4	76.4	73.7	73.8	78.4	78.1
Li_2O	15.3	19.7	12.7	15.3	15.3	16.3	16.3
P_2O_5	3.4	3.4	3.4	7.0	0.5	3.3	-
Al_2O_3	-	-	-	-	-	-	-
ZrO_2	3.5	3.5	3.5	2.0	5.2	-	-
TiO_2	4.0	4.0	4.0	2.0	5.2	-	5.6
CeO_2	-	-	-	-	-	2.0	-
GeO_2	-	-	-	-	-	-	-
SnO_2	-	-	-	-	-	-	-
Rb_2O							
Cs_2O	-	-	-	-	-	-	-
CaO	-	-	-	-	-	-	-
Ag_2O	-	-	-	-	-	-	-
Pd	-	-	-	-	-	-	-
Au	-	-	-	-	-	-	-
SiO_2/Li_2O molar ratio	2.39	1.75	3.00	2.39	2.39	2.39	2.39
Optical properties (after pouring)	opaque glass	transparent	transparent	transparent	transparent	transparent	transparent
T_g/°C	489	482	495	479	503	483	483
T_N/°C	510	500	510	500	520	500	500
t_N/min.	10	10	10	10	10	10	10
T_C/°C	680	700	700	740	680	650	680
t_C/min.	20	20	20	20	20	20	40
Main crystal phase $_{RT\text{-}XRD}$	lithium disilicate	lithium disilicate	lithium disilicate	lithium disilicate	lithium disilicate	lithium disilicate	lithium metasilicate
Other crystal phases	Li_2SiO_3, cristobalite	Li_2SiO_3, Li_3PO_4	Li_3PO_4	Li_2SiO_3, Li_3PO_4	LS	-	-

Example	8	9	10	11	12	13
Composition	wt.-%	wt.-%	wt.-%	wt.-%	wt.-%	wt.-%
SiO_2	75.75	75.75	72.8	78.4	70.2	73.9
Li_2O	15.8	15.8	15.1	16.3	14.5	15.3
P_2O_5	-	-	3.6	3.3	3.2	3.3
Al_2O_3	3.0	3.0	-	-	2.9	-
ZrO_2	5.4	5.4	2.5	-	5.0	-
TiO_2	-	-	-	-	-	3.0
CeO_2	-	-	-	-	-	
GeO_2	-	-	-	-	-	
SnO_2	-	-	-	2.0	-	
Rb_2O	-	-	2.0	-	4.3	-
Cs_2O	-	-	-	-	-	4.5
CaO	-	-	3.8	-	-	-
Ag_2O	-	-	0.2	-	-	-
Pd	0.05	-	-	-	-	-
Au	-	0.05	-	-	-	-
SiO_2/Li_2O molar ratio	2.39	2.39	2.40	2.40	2.40	2.40
Optical properties (after pouring)	transparent	opaque glass	transparent	opaque glass	transparent	transparent
T_g/°C	489	486	462	472	485	479
T_N/°C	510	510	490	490	500	500
t_N/min.	10	10	10	10	10	10
T_C/°C	620	620	700	640	700	700
t_C/min.	30	30	20	20	20	20
Main crystal phase	lithium metasilicate	lithium metasilicate	lithium disilicate	lithium disilicate	lithium disilicate	lithium disilicate
Other crystal phases	-	-	Li_3PO_4	Li_3PO_4	Li_3PO_4	Li_3PO_4

Négy vegyértékű fémoxidot tartalmazó lítium-szilikát üvegkerámia és lítium-szilikát üveg

SZABADALMI IGÉNYPONTOK

1. Lítium-szilikát üvegkerámia, mely tartalmaz

négy vegyértékű fémoxidot, a ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 és ezek keverékei közül kiválasztva,

67,0-79,0 tömeg% SiO_2-t,

legalább 12,1 tömeg% Li_2O-t,

0-6,0 tömeg% Al_2O_3-at,

kevesebb, mint 0,1 tömeg% La_2O_3-at,

kevesebb, mint 1,0 tömeg% K_2O-t, és

kevesebb, mint 2,0 tömeg% Na_2O-t.

2. Az 1. igénypont szerinti üvegkerámia, ahol olyan lítium-szilikát üvegkerámia ki van zárva, amely legalább 6,1 tömeg% ZrO_2-t tartalmaz és/vagy az olyan üvegkerámia ki van zárva, amely legalább 8,5 tömeg% átmenetifém-oxidot tartalmaz, az ittriumoxidok, 41-79 atomszámú átmenetifém-oxidok és ezeknek az oxidoknak a keverékei csoportból kiválasztva.

3. Az 1. vagy 2. igénypont szerinti üvegkerámia, mely kevesebb, mint 0,5 tömeg%, különösen kevesebb, mint 0,1 tömeg%, K_2O-t tartalmaz, és előnyösen lényegében K_2O-tól mentes.

4. Az 1-3. igénypontok bármelyike szerinti üvegkerámia, mely kevesebb, mint 1,0 tömeg%, különösen kevesebb, mint 0,5 tömeg%, előnyösen levesebb, mint 0,1 tömeg% Na_2O-t tartalmaz, és előnyösen lényegében Na_2O-tól mentes.

5. Az 1-4. igénypontok bármelyike szerinti üvegkerámia, mely lényegében La_2O_3-tól mentes.

6. Az 1-5. igénypontok bármelyike szerinti üvegkerámia, mely a négy vegyértékű fémoxidot vagy annak keverékeit 0,1-15, különösen 2,0-15,0, és előnyösen 2,0-8,0 tömeg% mennyiségben tartalmazza.

7. Az 1-6. igénypontok bármelyike szerinti üvegkerámia, mely fő kristályos fázisként lítium-metaszilikátot tartalmaz, és különösen több mint 5 térfogat%, előnyösen több mint 10

térfogat% és különösen előnyösen több mint 15 térfogat% lítium-metaszilikát kristályt tartalmaz.

8. Az 1-6. igénypontok bármelyike szerinti üvegkerámia, mely fő kristályos fázisként lítium-diszilikátot tartalmaz, és különösen több mint 10 térfogat%, előnyösen több mint 20 térfogat% és különösen előnyösen több mint 30 térfogat% lítium-diszilikát kristályt tartalmaz.

9. Az 1-8. igénypontok bármelyike szerinti üvegkerámia, mely 12,5-20,0, és különösen 15,0-17,0 tömeg% Li_2O-t tartalmaz, és/vagy SiO_2-t és Li_2O-t tartalmaz, 1,7-3,1, különösen 1,75-3,0 mól arányban, vagy legalább 2,2 mól arányban, különösen 2,3-2,5 mól arányban, és előnyösen körülbelül 2,4 mól arányban.

10. Az 1-9. igénypontok bármelyike szerinti üvegkerámia, mely 0-10,0, különösen 0,5-9,0 és előnyösen 2,5-7,5 tömeg% P_2O_5-öt tartalmaz.

11. Az 1-10. igénypontok bármelyike szerinti üvegkerámia, amely legalább egy, és előnyösen valamennyi alábbi komponenst tartalmazza:

Komponens	tömeg%
SiO_2	67,0-79,0
Li_2O	12,5-20,0
négy vegyértékű fémoxid keverék	2,0-15,0
P_2O_5	0-7,0, különösen 0,5-7,0
Al_2O_3	0-6,0, különösen 0,5-3,5.

12. Az 1-11. igénypontok bármelyike szerinti lítium-szilikát üvegkerámia, mely fő kristályos fázisként lítium-diszilikátot tartalmaz, és törési szilárdsága K_{IC} értékként mérve legalább 1,9 $MPa \cdot m^{0,5}$, és különösen több mint 2,3 $MPa \cdot m^{0,5}$.

13. Kiindulási üveg, mely tartalmazza az 1-6. vagy 9-11. igénypontok bármelyike szerinti üvegkerámia komponenseit.

14. Lítium-szilikát üveg, mely lítium-metaszilikát és/vagy lítium-diszilikát kristályok képzésére alkalmas magot tartalmaz, ahol az üveg tartalmazza az 1-6. vagy 9-11. igénypontok bármelyike szerinti üvegkerámia komponenseit.

15. Az 1-12. igénypontok bármelyike szerinti üvegkerámia vagy a 13. vagy 14. igénypont szerinti üveg, ahol az üveg és az üvegkerámia por, granulátum, kitöltetlen héj-anyag vagy fogpótlás formájában van.

16. Eljárás az 1-12. vagy 15. igénypontok bármelyike szerinti üvegkerámia vagy a 14. vagy 15. igénypont szerinti üveg előállítására, ahol a 13. vagy 15. igénypont szerinti

kiindulási üveget, a 14. vagy 15. igénypont szerinti magot tartalmazó üveget, vagy a 7., 9-11. vagy 15. igénypont szerinti, fő kristályos fázisként lítium-metaszilikátot tartalmazó üvegkerámiát legalább egy hőkezelésnek vetjük alá 450-950 °C, különösen 450-750 és előnyösen 480-740 °C hőmérsékleten.

17. Eljárás lítium-szilikát üvegkerámia előállítására, mely

négy vegyértékű fémoxidot, a ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 és ezek keverékei közül kiválasztva,

legalább 12,1 tömeg% Li_2O-t,

kevesebb, mint 0,1 tömeg% La_2O_3-at,

kevesebb, mint 1,0 tömeg% K_2O-t, és

kevesebb, mint 2,0 tömeg% Na_2O-t tartalmaz,

ahol az eljárás során

(a) egy kiindulási üveget, mely tartalmazza az üvegkerámia komponenseit, hőkezelésnek vetünk alá, 480-520 °C hőmérsékleten, 10 perc – 120 perc időtartamon át, lítium-diszilikát kristályok képzésére alkalmas magot tartalmazó üveg előállítására, és

(b) a magokat tartalmazó üveget 460-740°C-os hőkezelésnek vetjük alá, fő kristályos fázisként lítium-diszilikátot tartalmazó üvegkerámia előállítására.

18. Lítium-szilikát üvegkerámia, kiindulási üveg vagy lítium-metaszilikát és/vagy lítium-diszilikát kristályok képzésére alkalmas magot tartalmazó üveg alkalmazása, ahol az üvegkerámia vagy az üveg

négy vegyértékű fémoxidot, a ZrO_2, TiO_2, CeO_2, GeO_2, SnO_2 és ezek keverékei csoportból kiválasztva,

67,0-79,0 tömeg% SiO_2-t,

legalább 12,1 tömeg% Li_2O-t,

kevesebb, mint 0,1 tömeg% La_2O_3-at,

kevesebb, mint 1,0 tömeg% K_2O-t, és

kevesebb, mint 2,0 tömeg% Na_2O-t

tartalmaz,

fogászati anyagként és különösen fogpótlások bevonására és fogpótlások készítésére.

19. A 18. igénypont szerinti, fogpótlások készítésére való alkalmazás, ahol az üvegkerámia vagy az üveg préseléssel vagy mechanikai megmunkálással a kívánt fogpótlássá, különösen híddá, töméssé (inlay), betétté (onlay), bevonattá, részleges koronává, koronává, lappá vagy rögzítő elemmé van formázva.

A meghatalmazott

Derzsi [illegible]
[illegible]
[illegible] Szab[illegible] Ügyvivői Iroda
H-1062 [illegible] út 113.
Telefo[illegible] Fax: 461-1099
Email: [illegible]