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Title of the Invention

A Glass-ceramic Substrate for a Magnetic Disk and a Method for Manufacturing the Same ✓

Background of the Invention

This invention relates to a magnetic disk substrate used for a hard magnetic disk recording device and, more particularly, to a magnetic disk substrate made of a glass-ceramic having an improved surface characteristic capable of preventing sticking of a magnetic head to a magnetic disk in a CSS (contact start and stop) type magnetic disk, a magnetic disk formed by subjecting the magnetic disk substrate to a film-forming process and a method for manufacturing the magnetic disk substrate.

There is an increasing tendency for utilizing a personal computer for multiple media purposes and this tendency necessitates a hard magnetic disk device of a larger recording capacity. For this purpose, the bit number and track density of a magnetic disk must be increased and the size of a bit cell must be reduced for increasing a surface recording density. As for a magnetic head, it must be operated in closer proximity to the disk surface in conformity with the reduction of the bit cell and, accordingly, it has become important to develop a technique for preventing sticking of a magnetic head to a magnetic disk surface and accompanying head crash and damage to a magnetic film.

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In a CSS type magnetic disk device, the magnetic head repeats an operation according to which the magnetic head is in contact with the magnetic disk before starting of operation of the device and is lifted from the magnetic disk when the operation of the device is started. If the surface of contact of the magnetic head with the magnetic disk is a mirror surface, sticking of the magnetic head to the magnetic disk occurs with the result that rotation of the magnetic disk is not started smoothly due to increase in friction and damage to the disk surface occurs. Thus, the magnetic disk is required to satisfy two conflicting demands of realizing lowering of the magnetic head and prevention of sticking of the magnetic head. Characteristics required generally for a magnetic disk substrate are as follows:

(1) In a CSS type magnetic disk, sticking tends to occur between the head and the magnetic disk due to increase in contact resistance caused by a high speed rotation of the magnetic disk, if the magnetic disk has a smooth surface with surface roughness (Ra) below 50 Å in a landing zone of the disk, i. e., an area in the disk where the magnetic head starts and stops its operation. On the other hand, if the magnetic disk has a roght surface with surface roughness (Ra) above 300 Å in the landing zone, there is a danger of occurrence of crash of the magnetic head. It is necessary, therefore, to

control projections or depressions on the surface in the landing zone to a surface roughness of 50 Å to 300 Å and also to control an interval of such projections or depressions in the landing zone to 10 μm to 200 μm.

(2) Since the amount of lifting of the head tends to decrease to the order of 0.025 μm or below owing to improvement in recording density of the magnetic disk, a data zone on the surface of the magnetic disk should have a surface roughness (Ra) of 3 Å - 9 Å which enables the head to maintain this amount of lifting.

(3) The magnetic disk substrate should not have crystal anisotropy, a foreign matter or other defects and should have a dense, fine and homogeneous texture.

(4) The material of the magnetic disk should have sufficient mechanical strength and hardness for standing a high speed rotation and contact with the head.

(5) The material of the magnetic disk must not contain Na_2O and F ingredients in principle because Na_2O and F ingredients cause dispersion of sodium ion during the film forming process with resulting deterioration in characteristics of the film.

(6) The material of the magnetic disk must have chemical durability against rinsing and etching with various chemicals.

Aluminum alloy has been conventionally used as a material of magnetic disk substrate. The aluminum alloy substrate, however, tends to produce a substrate surface

having projections or spot-like projections and depressions during the polishing process due to defects inherent in the material. As a result, the aluminum alloy substrate is not sufficient in flatness. Further, since an aluminum alloy is a soft material, deformation tends to take place so that it cannot cope with the recent requirement for making the magnetic disk thinner and the requirement for high density recording because the disk tends to be deformed by contact with the head with resulting damage to the recorded contents.

As a material for overcoming this problem of the aluminum alloy substrate, known in the art are glass substrates for magnetic disks made of a chemically tempered glass such as a sodium lime glass (SiO_2 - CaO - Na_2O) and alumino-silicate glass (SiO_2 - Al_2O_3 - Na_2O). This glass substrate, however, has the following disadvantages:

(1) Polishing is made after chemical tempering and so the tempered layer tends to cause instability in thinning the disk substrate.

(2) For improving the CSS characteristics, the substrate must be subjected to mechanical or chemical processing called texturing. Since a mechanical processing or a thermal processing such as by laser beam cause a cracking or other defetcs due to distortion in the chemically tempered layer, texturing must be conducted

by a chemical etching or a grain growth processing but this prevents mass production of the product at a competitive cost.

(3) Since the Na_2O ingredient is included as an essential ingredient in the glass, the film forming characteristic of the glass is deteriorated with the result that a surface coating processing becomes necessary for preventing eluting of the Na_2O ingredient. This prevents mass production of the product at a competitive cost.

Aside from the aluminum alloy substrate and chemically tempered glass substrate, known in the art are some substrate made of glass-ceramics. For example, Japanese Patent Application Laid-open No. 6-329440 discloses a glass-ceramic of a SiO_2 - Li_2O - MgO - P_2O_5 system which includes lithium disilicate ($li_2O \cdot 2SiO_2$) and alpha-quartz (alpha-SiO_2) as predominant crystal phases. This glass-ceramic is an excellent material in that, by controlling the grain size of globular grains of alpha-quartz, the conventional mechanical texturing or chemcial texturing becomes unnecessary and surface roughness (Ra) of a polished surface can be controlled within a range from 15 Å to 30 Å. This glass-ceramic cannot cope with the above described target surface roghness (Ra) of 3 Å to 9 Å and also cannot sufficiently cope with the above described tendency to lowering of the amont of lifting of a magnetic head necessitated by

rapid increase in the recording capacity. Besides, in this glass-ceramic, no discussion about the landing zone to be described later in this specification is made at all.

Japanese Patent Application Laid-open No. 7-169048 discloses a photo-sensitive glass-ceramic of a SiO_2 - Li_2O system including Au and Ag as photo-sensitive metals characterized in that a data zone and a landing zone are formed on the surface of a magnetic disk substrate. A predominant crystal phase of this glass-ceramic is lithium silicate ($Li_2O \cdot SiO_2$) and/or lithium disilicate ($Li_2O \cdot 2SiO_2$). In case lithium silicate ($Li_2O \cdot SiO_2$) is used, the glass-ceramic has a poor chemical durability so that it has a serious practical problem. Further, in forming of the landing zone, a part of the substrate (i.e., landing zone) is crystallized and is subjected to chemcial etching by using 6% solution of HF. However, forming of the substrate with an uncrystallized part and a crystallized part makes the substrate instable mechanically as well chemically. As for chemical etching by HF solution, it is difficult to control concentration of the HF solution because of evaporation and other reasons so that this method is not suitable for a large scale production of products.

Several methods are known for forming a landing

zone and a data zone on the surface of a magnetic disk substrate. For example, Japanese Patent Application Laid-open No. 6-290452 discloses a method for forming a landing zone on a carbon substrate by a pulsed laser having a wavelength of 523 nm. In this case, however, there are the following problems:

(1) A carbon substrate is formed by pressing at a high pressure and burning at a high temperature of about 2600 °C with resulting difficulty in a large scale production at a low cost.

(2) A carbon substrate has a high surface hardness and, therefore, processing of end portions and precision polishing of the surface are difficult with resulting difficulty in a large scale production at a low cost.

(3) The forming of the landing zone utilizes oxidization and evaporation of carbon by the pulse laser. Since carbon is a material which causes a very strong thermal oxidization reaction, the formed landing zone becomes instable and thus it poses a serious problem in reproduceability.

Japanese Patent Application Laid-open No. 7-65359 and United States Patent No. 5062021 disclose a method for forming a landing zone on an aluminum alloy by a pulsed laser. The aluminum alloy has the above described problems. Besides, the surface of the substrate after irradiation of laser beam tends to have a defect due to oxidization of a molten portion and

remaining of splash of molten metal on the surface.

It is, therefore, an object of the present invention to provide a glass-ceramic substrate for a magnetic disk which has eliminated the above described disadvantages of the prior art magnetic disk substrates and is capable of stably lifting a magnetic head in a landing zone where the magnetic head performs the CSS operation and is also capable of reducing the amount of lifting of the magnetic head in a data zone for realizing a high recording density of the data zone.

It is another object of the invention to provide a magnetic disk formed by subjecting the magnetic disk substrate to a film forming process.

It is another object of the invention to provide a method for manufacturing the glass-ceramic substrate for a magnetic disk.

Summary of the Invention

Accumulated studies and experiments made by the inventors of the present invention for achieving the above described objects of the invention have resulted in the finding, which has led to the present invention, that a glass-ceramic obtained by subjecting to heat treatment, within a specific temperature range, a base glass of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 system or a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 - ZrO_2 system or a glass of either of these

systems further containing at least two of NiO, CoO, MnO_2, V_2O_5, CuO and Cr_2O_3 as a coloring agent has a crystal phase of either lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate ($Li_2O \cdot 2SiO_2$) and alpha-quartz (alpha-SiO_2) or a mixed crystal of lithium disilicate ($Li_2O \cdot 2SiO_2$) and alpha-cristobalite (alpha-SiO_2) with fine globular crystal grains, has an excellent flatness after polishing and is extremely advantageous for forming of a landing zone and a data zone on the surface of the magnetic disk substrate because it has an excellent processability when it is subjected to processing by a laser (a CO_2 laser or a laser diode pumped solid-state laser).

For achieving the object of the invention, there is provided a glass-ceramic substrate for a magnetic disk having a data zone and a landing zone, said landing zone having a multiplicity of projections or depressions formed by irradiation of laser beam.

According to the invention, a laser used is a CO_2 laser or a laser diode pumped solid-state laser.

According to the invention, said laser diode pumped solid-state laser is an Nd-YAG laser, an Nd-YVO_4 laser or an Nd-YLF laser.

In one aspect of the invention, a wavelength of said laser diode pumped solid-state laser is within a range of 0.2 μm - 0.6 μm or within a range of 1.05 μm - 1.40 μm.

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In another aspect of the invention, surface roughness (Ra) of a polished surface of the landing zone is within a range from 3 Å to 9 Å and height of the projections or depressions formed by the laser beam in the landing zone is within a range from 50 Å to 300 Å and surface roughness (Ra) of the projections and depressions is within a range from 10 Å to 50 Å.

In another aspect of the invention, interval of the projections or depressions is within a range from 10 μm to 200 μm.

In another aspect of the invention, a glass-ceramic used is a glass-ceramic of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 system or of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 - ZrO_2 system.

In another aspect of the invention, a glass-ceramic substrate for a magnetic disk is formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%

Sb_2O_3	0 - 1%
As_2O_3	0 - 1%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2), and said laser being a CO_2 laser.

In another aspect of the invention, a glass-ceramic substrate includes, in addition to the above described ingredients, 0.5 - 5% of ZrO_2.

In another aspect of the invention, a glass-ceramic substrate for a magnetic disk includes at least two ingredients of NiO, CoO, MnO_2, V_2O_5, CuO, Cr_2O_3 as a coloring agent.

In another aspect of the invention, a glass-ceramic substrate for a magnetic disk is formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%

Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
$V_2O_5 + CuO + Cr_2O_3 + MnO_2$ + CoO + NiO	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-critobalite (alpha-SiO_2), and said laser being a laser diode pumped solid-state laser.

In another aspect of the invention, a glass-ceramic substrate includes, in addition to the above described ingredients, 0.5 - 5% of ZrO_2.

In another aspect of the invention, in the glass-ceramic substrate, percent transmission by a laser diode pumped solid-state laser of a wavelength of 1.06 μm at a thickness of 0.635 mm is 80% to 40%.

In another aspect of the invention, a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and

alpha-quartz (alpha-SiO_2), crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.1 μm to 0.5 μm, and crystal grains of alpha-quartz have a globular grain structure made of aggregated particles and have a diameter within a range from 0.3 μm to 1.0 μm.

In another aspect of the invention, a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2), crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.1 μm to 0.5 μm, and crystal grains of alpha-cristobalite have a globular grain structure made of aggregated particles and have a diameter within a range from 0.2 μm to 1.0 μm.

In another aspect of the invention, a glass-ceramic substrate for a magnetic disk is formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
ZrO_2	0.5 - 5%

Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
NiO	0.5 - 3%
CoO	0.5 - 3%
MnO_2	0 - 0.5%
V_2O_5	0 - 0.5%
CuO	0 - 1%
Cr_2O_3	0 - 1.5%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-critobalite (alpha-SiO_2), and said laser being a laser diode pumped solid-state laser.

In another aspect of the invention, in the glass-ceramic, percent transmission by a laser diode pumped solid-state laser of a wavelength of 0.2 μm - 0.6 μm or 1.05 μm - 1.40 μm at a thickness of 0.635 mm is 0% to 40%.

In another aspect of the invention, a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) or a mixed crystal of lithium disilicate and alpha-cristobalite (alpah-SiO_2), crystal grains of lithium disilicate have a globular

grain structure and have a diameter within a range from 0.05 μm to 0.3 μm, crystal grains of alpha-cristobalite have a globular grain structure and have a diameter within a range from 0.10 μm to 0.50 μm and crystal grains of alpha-quartz have a globular grain structure made of aggregated particles and have a diameter within a range from 0.10μm to 1.00 μm.

In another aspect of the invention, there is provided a method for manufacturing a glass-ceramic substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%;

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a CO_2 laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

In another aspect of the invention, the method for manufacturing a glass-ceramic uses a base glass which includes 0.5 - 5% of ZrO_2 in addition to the above described ingredients and uses a crystallizing temperature within a range from 680 °C to 780 °C.

In another aspect of the invention, a method for manufacturing a magnetic disk substrate for a magnetic disk having a data zone and a landing zone comprises steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%

ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
$V_2O_5 + CuO + Cr_2O_3 + MnO_2$ + $CoO + NiO$	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a laser diode pumpled solid-state laser, said projections or depressions having a height within a

range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

In another aspect of the invention, the method for manufacturing a glass-ceramic substrate uses a base glass which includes 0.5 - 5% of ZrO_2 in addition to the above described ingredients and uses a crystallizing temperature within a range from 680 °C to 780 °C.

In another aspect of the invention, there is provided a method for manufacturing a glass-ceramic substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
ZrO_2	0.5 - 5%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
NiO	0.5 - 3%
CoO	0.5 - 3%

MnO_2	0 - 0.5%
V_2O_5	0 - 0.5%
CuO	0 - 1%
Cr_2O_3	0 - 1.5%

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a laser diode pumpled solid-state laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

In still another aspect of the invention, there is provided a magnetic disk having a film of a magnetic media formed on said glass-ceramic substrate.

The composition of the glass-ceramic substrate of the invention is expressed on the basis of composition of oxides as in its base glass. The above described content ranges of the respective ingredients have been selected for the reasons stated below.

The SiO_2 ingredient is an important ingredient which produces lithium disilicate ($Li_2O \cdot 2SiO_2$), alpha-quartz (alpha-SiO_2) and/or alpha-cristobalite (alpha-SiO_2) crystal as a predominant crystal phase when the base glass is subjected to heat treatment. If the amount of this ingredient is below 70%, the crystal produced in the glass-ceramic is instable and its texture tends to become too rough. If the amount of this ingredient exceeds 80%, difficulty arises in melting and forming the base glass.

The Li_2O ingredient is also an important ingredient which produces lithium disilicate ($Li_2O \cdot 2SiO_2$) cystal as a predominant crystal phase by heat treating the base glass. If the amount of this ingredient is below 9%, growth of this crystal becomes difficult and melting of the base glass becomes also difficult. If the amount of this ingredient exceeds 12%, the grown crystal of the glass-ceramic becomes instable and its texture tends to become too rough and, besides, chemical durability and hardness of the glass-ceramic are deteriorated.

The K_2O ingredient improves melting property of the base glass and prevents crystal grains from becoming too

rough. If the amount of this ingredient is below 2%, the above effects cannot be obtained whereas, if the amount of this ingredient exceeds 5%, the grown crystal becomes too rough, there occurs change in the crystal phase and chemical durability is deteriorated.

The MgO and ZnO ingredients are important ingredients which have been found in the present invention to cause a globular crsytal grain of lithium disilicate ($Li_2O \cdot 2SiO_2$), alpha-quartz (alpha-SiO_2) and alpha-cristobalite (alpha-SiO_2) as a predominant crystal phase. If the amount of MgO is below 0.5%, that of ZnO is below 0.2% and the total amount of MgO and ZnO is below 1.2%, these effects cannot be obtained whereas, if the amount of MgO exceeds 5%, that of ZnO exceeds 3% and the total amount of MgO and ZnO exceeds 5%, the desired crystals cannot grow.

The P_2O_5 ingredient is an essential ingredient as a nucleating agent for the glass-ceramic. If the amount of this ingredient is below 1.5%, sufficient forming of a nucleus cannot be attained and a resulting crystal will become too rough whereas, if the amount of this ingredient exceeds 3%, devitrification occurs with resulting difficulty in mass production.

The Al_2O_3 ingredient improves chemical durability and hardness of the glass-ceramic. If the amount of this ingredient is below 2%, these effects cannot be

obtained whereas, if the amount of this ingredient exceeds 5%, melting property is deteriorated and devitrification occurs and the grown crystal changes to beta-spodumene ($Li_2O \cdot Al_2O_3 \cdot 4SiO_2$).

In a case where the glass-ceramic substrate of the present invention is made of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 - ZrO_2 system, the ZrO_2 ingredient is a very important ingredient which has been found in the present invention to function as a nucleating agent in the same manner as the P_2O_5 ingredient and moreover significantly contribute to growth of fine crystal grains and improve the mechanical strength and chemcial durability of the glass-ceramic. If the amount of this ingredient is below 0.5%, these advantageous results cannot be attained whereas, if the amount of this ingredient exceeds 5%, difficulty arises in melting of the base glass and an unmelted portion such as $ZrSiO_4$ is produced.

The As_2O_3 and/or Sb_2O_3 ingredients may be added as refining agents in melting of the base glass. It will suffice if each ingredient up to 1% is added.

In a case where forming of projections or depressions in the landing zone is made by irradiation of laser beam by a laser diode pumped solid-state laser, addition of a coloring agent has been found to be indispensable for attaining a sufficient absorption of laser beam. In a case where forming of projections or

depressions is made by a CO_2 laser, addition of a coloring agent is unnecessary but it is possible to irradiate a CO_2 laser beam on a system including a coloring agent.

In the present invention, at least two different coloring agents must be used from among NiO, CoO, MnO_2, V_2O_5, CuO and Cr_2O_3. The glass-ceramic of the invention which includes a coloring agent can be classified into a V_2O_5 - CuO - MnO_2 system and a NiO - CoO system depending upon the coloring agents used as essential ingredients.

In the coloring agent system of V_2O_5 - CuO - MnO_2, the V_2O_5, CuO and MnO_2 ingredients are essential ingredients as the coloring agents for improving the laser absorption effect without adversely affecting the crystal microstructure of the glass when laser beam is irradiated by a laser diode pumped solid-state laser for forming of projections and depressions in the landing zone. If the amount the respective coloring agents is below 0.02%, this advantageous result cannot be obtained whereas, if the amount of the respective coloring agents exceeds 0.8%, crystals grown tend to become too rough. The total amount of V_2O_5 + CuO + MnO_2 should preferably be within a range from 0.08% to 2.5%. In the laser processing by a laser diode pumped solid-state laser, percent transmission available at the laser wavelength

(1.06 μm) of the V_2O_5 - CuO - MnO_2 system colored glass-ceramic is 80% to 40% at a plate thickness of 0.635 mm. In this coloring agent system, Cr_2O_3, CoO and/or NiO ingredients may be optionally added because these ingredients have an effect similar to the V_2O_5, CuO and MnO_2 ingredients. If the amount of each of these optional coloring agents exceeds 0.8%, grown crystal grains tend to become too rough.

It has been found that a particularly preferable percent transmission for sufficiently heating the glass-ceramic by a laser diode pumped solid-state laser without excessively increasing the laser output at the laser wavelength used for this purpose (i.e., 0.2 μm - 0.6 μm or 1.05 μm - 1.40 μm) is 0% to 40% at a plate thickness of 0.635 mm. By determining the percent transmission at a value within this range, laser irradiation time can be held to the minimum and therefore an excessive stress is not produced in the surface portion of the substrate whereby forming of projections or depressions can be achieved in a stable manner while ensuring a large scale production of the substrate.

This preferable percent transmission of 0% to 40% can be realized by using the NiO - CoO system as the coloring agents.

In the NiO - CoO system, the NiO, CoO, V_2O_5, MnO_2, CuO and Cr_2O_3 ingredients are used as coloring agents

for improving the laser absorption effect without adversely affecting the microstructure of the crystal phase of the glass in forming of projections or depressions in the landing zone by a laser diode pumped solid-state laser. The NiO and CoO ingredients, particularly the CoO ingredient, are important ingredients which absorb laser light at the wavelength of 0.2 μm - 0.6 μm and 1.05 μm - 1.40 μm and thereby reduces the percent transmission of the glass-ceramic substrate. it has, however, been found that there is limitation in absorption by the CoO ingredient alone in any of these wavelength ranges with the result that the percent transmission cannot be sufficiently reduced and that, by coexistence of the NiO ingredient with the CoO ingredient, the percent transmission is reduced significantly in all of the wavelength ranges and the percent transmission of 0% - 40% can thereby be achieved. Therefore, both the NiO and CoO ingredients are indispensable ingredients for achieving the desired range of percent transmission. If the amount of the respective ingredients is below 0.5%, the desired effect cannot be attained whereas if the amount of the respective ingredients exceeds 3%, the grown crystal grains tend to become too rough.

The MnO_2, V_2O_5, CuO and Cr_2O_3 ingredients may also be added because they are also effective for

complementing reduction of the percent transmission by the NiO and CoO ingredients. If the amount of the MnO_2 ingredient exceeds 0.5%, that of the CuO ingredient 1% and that of the Cr_2O_3 ingredient 1.5% respectively, grown crystal grains tend to become too rough and percent transmission is adversely affected. If the amount of the V_2O_5 ingredient exceeds 1.5%, grown crystal grains tend to become too rough and coloring of the glass-ceramic is adversely afftected by the reduction effect peculiar to V_2O_5 in the heat treatment for crystallization.

For manufacturing the glass-ceramic substrate for a magnetic disk, the base glass having the above described composition is subjected to heat forming and/or cold forming, is heat treated for producing a crystal nucleus under a temperature within a range from 450 ℃ to 550 ℃ for about one to twelve hours and is further heat treated for crystallization under a temperature within a range from 680 ℃ to 780 ℃ for about one to twelve hours.

The glass-ceramic which has been crystallized under the above described conditions is either lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) or a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2). The crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.1 μm to 0.5 μm in the system

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which has no coloring agent or has the coloring agent system of V_2O_5 - CuO - MnO_2 and a dimater within a range from 0.05 μm - 0.30 μm in the system which has the coloring agent system of NiO - CoO. The crystal grains of alpha-quartz have a globular grain structure made of aggregated particles and have a diameter within a range from 0.30 μm to 1.0 μm. The crystal grains of alpha-cristobalite have a globular grain structure and have a diameter within a range from 0.20 μm to 1.0 μm in the system which has no coloring agnet or has the coloring agent system of V_2O_5 - CuO - MnO_2 and a diamter within a range from 0.10 μm to 0.50 μm in the system which has the coloring agent system of NiO - CoO.

Owing to the specific composition and the specific crystal phase and grain diamter described above, the glass-ceramic substrate according to the invention has the melting point within a range from 950 °C to 1150 °C and other conditions which are most suited to stable forming of projections or depressions by irradiation of laser beam as described later.

The glass-ceramic obtained by the above described heat treatment is subjected to conventional lapping and polishing processes and thereupon a glass-ceramic substrate for a magnetic disk having a surface roughness (Ra) within a range from 3 Å to 9 Å is provided.

The glass-ceramic substrate is then subjected to

the process of forming of projections or depressions in the landing zone by a CO_2 laser or a laser diode pumped solid-state laser.

The laser wavelength of the laser diode pumped solid-state laser used in forming projections or depressions in the landing zone is limited to either 0.3 μm - 0.6 μm or 1.05 μm - 1.40 μm. By irradiation of laser beam of this wavelength, projections or depressions having height within a range from 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å are formed in the landing zone at an interval within a range from 10 μm to 200 μm. Thus, a glass-ceramic substrate for a magnetic disk as shown in Fig. 1 which has a landing zone formed with projections or depressions having height within a range from 50 Å to 300 Å and a data zone which has an excellent smooth surface can be provided. In Fig. 1, a glass-ceramic substrate 1 has a landing zone 3 provided outside of a central opening 5 and a data zone 2 provided outside of the landing zone 3. Reference character 4 designates a portion called "ring" formed inside of the landing zone 3. Fig. 2 shows a shape of projections or depressions formed in the landing zone. Fig. 3 shows a shape of projections formed in the landing zone. Fig. 4 shows interval of projections or depressions formed in the landing zone. Fig. 5 shows height of projections or depressions formed in the landing zone.

Lasers generally used for surface change such as cutting, welding and microprocessing of a material are classified to an Ar laser, a CO_2 laser, an excimer laser and a laser diode pumped solid-state laser. It has been found that, in the laser processing for the glass-ceramic of the invention, suitable lasers are limited to the laser diode pumped solid-state laser and CO_2 laser because the Ar laser and excimer laser produce an unsuitable shape of projections or depressions and also cause a surface defect due to splashing of molten material.

For forming projections or depressions in the landing zone by the laser diode pumped solid-state laser or the CO_2 laser, a polished glass-ceramic substrate is rotated in a state clamped by a spindle and pulsed laser beam is irradiated vertically on the surface of the landing zone at a predetermined interval.

In irradiating the pulsed laser, a spot diameter within a range from 2 μm to 50 μm is used in the case of the laser diode pumped solid-state laser and a spot diamter within a range from 15 μm to 50 μm is used in the case of the CO_2 laser. Laser irradiation conditions such as laser output and pulse width are controlled in accordance with the composition of the glass-ceramic under processing.

Principal conditions which affect forming of

projections or depressions on the substrate surface by irradiation of laser beam are (1) laser output, (2) length of laser pulse and (3) laser spot diameter, i.e., the area of irradiation on the substrate surface. As for material of the substrate, melting point of the glass and that of the grown crystal affect forming of projections or depressions. Particularly, as for the material of the substrate for which the laser diode pumped solid-state laser is used, the absorption characteristics at the laser wavelength used (0.2 μm - 0.6 μm or 1.05 μm - 1.40 μm), that is, low percent transmission at the laser wavelength used, is the most important factor and other factors which affect forming of projections or depressions are melting points of the glass and grown crystal by laser irradiation (heat-up). For example, a substrate made of an ordinary glass in which no crystal is grown does not selectively absorb the used wavelength of a laser diode pumped solid-state laser and therefore the surface of the substrate is not heated up with the result that no projections or depressions can be formed. Even if this ordinary glass is improved to a glass which can absorb the used wavelength of the laser diode pumped solid-state laser, the melting point of this glass is lower than the melting point of a glass-ceramic as shown in the following Table 1 and, as a result, a melted portion of the glass becomes instable when it is subjected to

irradiation of laser beam so that it is difficult to control forming of projections or depressions. Besides, a microcrack which is produced by thermal strain between a portion which is irradiated with laser beam and a portion which is not irradiated significantly reduces strength of the substrate. In the case of a glass-ceramic substrate, the type of a crystal grown significantly affects the melting point of the glass-ceramic. The glass-ceramic substrate according to the invention has a higher melting point than the substrate made of a glass and hence projections or depressions can be formed in a stable manner by irradiation of laser beam. In contrast, conventional glass-ceramics such as those of $MgO - Al_2O_3 - SiO_2$, $ZnO - Al_2O_3 - SiO_2$ and $Li_2O - Al_2O_3 - SiO_2$ systems do not selectively absorb the used wavelength of the laser diode pumped solid-state laser and therefore it is not possible to heat up the substrate surface thereby to form projections and depressions. Even if these conventional glass-ceramics are changed to materials which absorb the used laser wavelength, it will be necessary to perform the laser processing with a high output since the melting points of these materials are higher than the glass-ceramic of the present invention as shown in the following Table 1. As a result, in these glass-ceramics, microcracks due to strain will be generated and forming of projections or

depressions of a desired shape will become extremely difficult.

Table 1

	Melting point
Al_2O_3 - SiO_2 glass	800 °C - 900 °C
MgO - Al_2O_3 - SiO_2 glass ceramic	1300 °C - 1400 °C
ZnO - Al_2O_3 - SiO_2 glass-ceramic	1250 °C - 1350 °C
Li_2O - Al_2O_3 - SiO_2 glass-ceramic	1300 °C - 1400 °C
Glass-ceramic of the present invention	950 °C - 1150 °C

The glass-ceramic substrate formed with projections or depressions in the landing zone by the laser processing is then subjected to a film forming process which is known per se and thereby is formed into a high recording density magnetic disk. More specifically, the glass-ceramic substrate is heated in vacuum and then is coated, by a sputtering process, with an intermediate layer of cromium, a magnetic layer of cobalt alloy and a protective layer of carbon and then is coated again with a lubricating material layer on the surface of the protective layer to provide a magnetic disk.

Examples of the present invention will be described below with reference to the accompanying drawings.

Brief Description of the Drawings

In the drawings,

Fig. 1 is a top plan view of the state of a landing zone and a data zone formed outside of a central opening of a glass-ceramic substrate for a mangetic disk according to the invention;

Fig. 2 is a sectional view showing the shape of projections and depressions formed in the landing zone;

Fig. 3 is a sectional view showing the shape of projections formed in the landing zone:

Fig. 4 is a sectional view showing the interval of projections and depressions formed in the landing zone;

Fig. 5 is a sectional view showing the height of projections and depressions formed in the landing zone;

Fig. 6 shows an SEM (scanning electron microscope) image of the crystal structure of the glass-ceramic of Example 8 of the present invention after HF etching;

Fig. 7 shows an SEM image of the crystal structure of Comparative Example 2 of a prior art glass-ceramic after HF etching;

Fig. 8 is an SEM image of Example 10 after irradiation of laser beam by a laser diode pumped solid-state laser (Nd-YAG laser with laser wavelength of 1.064 μm);

Fig. 9 is an SEM image of Example 3 after irradiation of laser beam by a CO_2 laser;

Fig. 10 is an SEM image of a prior art alumino-silicate tempered glass after irradiation of laser beam by a CO_2 laser; and

Fig. 11 is an SEM image of a prior art aluminosilicate tempered glass after irradiation of laser beam by a laser diode pumped solid-state laser (Nd-YAG laser with laser wavelength of 0.266 μm).

Examples

Preferred examples of the glass-ceramic substrate according to the invention will now be described. Tables 2 to 4 show exampls (No. 1 to No. 7) of composition relating to the system which includes no coloring agent and the system which includes the V_2O_5 - CuO - MnO_2 coloring agent system together with the temperature of nucleation, temperature of crystallization, predominant crystal phase, grain diameter of crystal grains, color appearance of the glass-ceramic, percent transmission of laser wavelength 1.06 μm of Nd-YAG laser at a plate thickness of 0.635 mm and percent transmission of laser wavelength 10.5 μm, type of laser used, surface roughness (Ra), Ra of the landing zone after laser processing, Ra of the data zone after laser processing, Ra of the data zone after polishing and height of projections or depressions. In the subsequent tables, the amounts of the respective ingredients are expressed in weight percent.

Table 2

(weight %)

	Examples		
No.	1	2	3
SiO_2	79.0	75.8	77.0
Li_2O	10.5	10.0	10.0
P_2O_5	2.0	2.5	2.5
ZrO_2		1.5	
Al_2O_3	3.5	2.5	3.0
MgO	1.2	2.3	2.5
ZnO	0.7	0.5	0.8
K_2O	2.8	3.5	4.0
V_2O_5		0.4	
MnO_2		0.4	
CuO		0.4	
Cr_2O_3			
CoO			
Sb_2O_3		0.2	
As_2O_3	0.3		0.2
nucleation temperature (℃)	520	540	480
crystallization temperature (℃)	730	720	710
color	white	green	white
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm α−cristobalite 0.2μm	$Li_2Si_2O_5$ 0.1μm α−quartz 0.1μm	$Li_2Si_2O_5$ 0.1μm
crystal grain shape	$Li_2Si_2O_5$ globular α−cristobalite globular	$Li_2Si_2O_5$ globular α−cristobalite globular	$Li_2Si_2O_5$ globular
percent transmission 1.06 μmT%	88%	62%	89%
10.5 μmT%	0%	0%	0%
type of pulsed laser	CO_2	YAG	CO_2
surface roughness (Ra) (Å)			
landing zone	20	23	18
data zone	7	2	8
height of projections or depressions (Å)	290Å	300Å	290Å

Table 3

(weight %)

	Examples		
No.	4	5	6
SiO_2	75.8	75.5	76.3
Li_2O	10.0	11.0	10.2
P_2O_5	2.5	2.7	2.5
ZrO_2	1.5		1.5
Al_2O_3	2.5	3.5	2.0
MgO	2.0	2.6	2.0
ZnO	0.5	0.5	0.5
K_2O	3.2	4.0	3.0
V_2O_5	0.6		0.6
MnO_2	0.6		0.6
CuO	0.6		0.6
Cr_2O_3			
CoO			
Sb_2O_3	0.2	0.2	0.2
As_2O_3			
nucleation temperature (℃)	540	450	480
crystallization temperature (℃)	700	690	700
color	green	white	green
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.2μm	$Li_2Si_2O_5$ 0.1μm α−quartz 0.1μm
crystal grain shape	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular α−quartz globular
percent transmission 1.06 μmT%	55%	88%	53%
10.5 μmT%	0%	0%	0%
type of pulsed laser	YAG	CO_2	YAG
surface roughness (Ra) (Å)			
landing zone	22	17	21
data zone	4	3	5
height of projections or depressions (Å)	300Å	280Å	300Å

Table 4

(weight %)

No.	Example 7
SiO_2	76.0
Li_2O	10.5
P_2O_5	2.5
ZrO_2	1.5
Al_2O_3	2.8
MgO	1.0
ZnO	0.5
K_2O	4.0
V_2O_5	0.1
MnO_2	0.1
CuO	NiO 0.8
Cr_2O_3	
CoO	
Sb_2O_3	0.2
As_2O_3	
nucleation temperature (℃)	520
crystallization temperature (℃)	720
color	dark brown
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm α−quartz 0.3μm
crystal grain shape	$Li_2Si_2O_5$ globular α−quartz globular
percent transmission 1.06 μmT%	41%
10.5 μmT%	0%
type of pulsed laser	YAG
surface roughness (Ra) (Å)	
landing zone	20
data zone	3
height of projections or depressions (Å)	280Å

Tables 5 to 8 show examples (No. 8 to No. 17) of compositions relating to the system which includes the NiO - CoO coloring agent system and two comparative examples of the prior art Li_2O - SiO_2 system glass-ceramic (Japanese Patent Application Laid-open No. Sho 62-72547, Comparative Example 1 and Japanese Patent Application Laid-open No. Sho 63-210039, Comparative Example 2) together with the temperature of nucleation, temperature of crystallization, predominant crystal phase, diameter of crystal grains, shape of crystal grains, color appearance of the glass-ceramic, average percent transmission of laser wavelength 0.02 μm - 0.6 μm and 1.05 μm - 1.40 μm of the laser diode pumped solid-state laser at a plate thickness of 0.635 mm, surface roughness (Ra) of the data zone after polishing, type of the laser diode pumped solid-state laser used in the landing zone, wavelength used, and height and surface roughness (Ra) of projections or depressions formed by irradiation of laser beam.

Table 5

(weight %)

No.	Examples 8	9	10
SiO_2	75.7	75.7	75.5
Li_2O	10.5	10.5	10.5
P_2O_5	2.5	2.5	2.5
ZrO_2	1.5	1.5	1.5
Al_2O_3	2.5	2.5	2.5
MgO	1.6	1.2	1.0
ZnO	0.5	0.5	0.5
K_2O	3.2	3.0	2.8
NiO	0.7	0.7	1.0
CoO	0.8	0.8	1.0
MnO_2	0.1	0.1	
V_2O_5	0.1	0.1	
CuO	0.1	0.1	
Cr_2O_3		0.6	1.0
Sb_2O_3	0.2	0.2	0.2
nucleation temperature (℃)	540	540	540
crystallization temperature (℃)	720	730	710
color	dark blue	dark blue	dark blue
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.1μm
crystal grain shape	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular
percent transmission 0.2μm ~ 0.6μm average value	10.0	8.0	4.0
1.05μm ~ 1.40μm 0.635 mm t	35.5	34.0	28.0
type of laser	Nd : YAG	Nd : YVO_4	Nd : YAG
laser wavelength	0.532μm	0.532μm	1.064μm
height of projections or depressions (Å)	250Å	280Å	200Å
surface roughness (Ra) of landing zone	18Å	19Å	15Å
surface roughness (Ra) of data zone	3Å	4Å	3Å

Table 6

(weight %)

No.	Examples 11	12	13
SiO_2	76.5	76.0	75.0
Li_2O	10.0	10.5	11.0
P_2O_5	1.8	2.0	2.5
ZrO_2	0.8	1.0	1.5
Al_2O_3	2.5	2.5	2.5
MgO	0.6	0.5	0.8
ZnO	0.3	0.5	1.0
K_2O	2.0	2.0	3.0
NiO	1.5	2.0	1.0
CoO	1.5	2.0	1.0
MnO_2	0.4	0.2	0.1
V_2O_5	0.4	0.3	
CuO	0.5	0.3	0.3
Cr_2O_3	1.0		0.1
Sb_2O_3	0.2	0.2	0.2
nucleation temperature (℃)	550	540	540
crystallization temperature (℃)	750	740	750
color	blue black	dark blue	dark blue
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.1μm
	α−cristobalite 0.1μm	α−quartz 0.2μm	α−quartz 0.3μm
crystal grain shape	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular
	α−cristobalite globular	α−quartz globular	α−quartz globular
percent transmission 0.2μm ~ 0.6μm average value	5.0	7.0	6.0
0.635 mm t 1.05μm ~ 1.40μm	10.0	13.0	30.0
type of laser	Nd : YAG	$Nd : YVO_4$	Nd : YLF
laser wavelength	1.064μm	1.064μm	1.047μm
height of projections or depressions (Å)	300Å	180Å	150Å
surface roughness (Ra) of landing zone	20Å	14Å	13Å
surface roughness (Ra) of data zone	5Å	7Å	9Å

Table 7

(weight %)

No.	Examples 14	15	16
SiO_2	75.7	76.0	75.5
Li_2O	10.5	10.5	10.7
P_2O_5	2.5	2.2	2.3
ZrO_2	1.5	1.5	1.7
Al_2O_3	2.5	2.3	2.2
MgO	1.6	1.5	1.6
ZnO	0.5	0.5	0.6
K_2O	3.0	3.0	3.0
NiO	0.8	1.0	1.2
CoO	0.8	0.9	0.6
MnO_2	0.1	0.1	0.05
V_2O_5	0.1	0.1	0.05
CuO	0.2	0.2	0.3
Cr_2O_3			
Sb_2O_3	0.2	0.2	0.2
nucleation temperature (℃)	530	500	480
crystallization temperature (℃)	710	730	720
color	dark blue	dark blue	dark blue
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm	$Li_2Si_2O_5$ 0.1μm α−quartz 0.1μm	$Li_2Si_2O_5$ 0.1μm α−quartz 0.1μm
crystal grain shape	$Li_2Si_2O_5$ globular	$Li_2Si_2O_5$ globular α−quartz 0.1μm	$Li_2Si_2O_5$ globular α−quartz 0.1μm
percent transmission 0.2μm ~ 0.6μm average value	8.0	10.0	7.0
0.635 mm t 1.05μm ~ 1.40μm	32.0	36.0	31.0
type of laser	Nd : YAG	$Nd : YVO_4$	$Nd : YVO_4$
laser wavelength	1.064μm	0.532μm	1.064μm
height of projections or depressions (Å)	100Å	150Å	200Å
surface roughness (Ra) of landing zone	11Å	14Å	16Å
surface roughness (Ra) of data zone	3Å	4Å	3Å

Table 8

(weight %)

No.	Examples 17	Comparative Examples 1	2
SiO_2	76.0	71.0	82.0
Li_2O	10.5	12.0	8.5
P_2O_5	2.0	1.9	2.5
ZrO_2	1.0		
Al_2O_3	2.0	9.6	3.1
MgO	1.0	Na_2O	1.5
ZnO	0.3	3.8	
K_2O	3.2	CaO	3.6
NiO	1.5	0.4	Na_2O 1.6
CoO	1.5	SrO	
MnO_2	0.1	0.4	
V_2O_5	0.2	PbO	
CuO	0.4	0.9	
Cr_2O_3	0.1		
Sb_2O_3	0.2		As_2O_3 0.3
nucleation temperature (℃)	480	550	540
crystallization temperature (℃)	730	780	800
color	dark blue	white	white
crystal phase and diameter	$Li_2Si_2O_5$ 0.1μm α−quartz 0.1μm	$Li_2Si_2O_5$ 1.2μm α−cristobalite 0.5μm	$Li_2Si_2O_5$ 1.5μm α−cristobalite 0.3μm
crystal grain shape	$Li_2Si_2O_5$ globular α−quartz globular	$Li_2Si_2O_5$ acicular α−cristobalite globular	$Li_2Si_2O_5$ acicular α−cristobalite globular
percent transmission 0.2μm ~ 0.6μm average value	8.0	45.0	48.0
0.635 mm t 1.05μm ~ 1.40μm	20.0	87.0	86.0
type of laser	Nd : YAG		
laser wavelength	1.064μm		
height of projections or depressions (Å)	80Å		
surface roughness (Ra) of landing zone	10Å		
surface roughness (Ra) of data zone	6Å	14Å	12Å

For manufacturing the glass-ceramic substrates of the above described examples, materials including oxides, carbonates and nitrates are mixed and molten in a conventional melting apparatus at a temperature with the range from about 1350 ℃ to about 1450 ℃. The molten glass is stirred to homogenize it and thereafter formed into a disk shape and annealed to provide a formed glass. Then, this formed glass is subjected to heat treatment to produce the crystal nucleus under a temperature within the range from 450 ℃ to 550 ℃ for about one to twelve hours and then is subjected to further heat treatment for crystallization under a temperature within the range from 680 ℃ to 780 ℃ for about one to twelve hours to produce the desired glass-ceramic. Then, this glass-ceramic is lapped for about 10 to 20 minutes with lapping grains having average grain diameters ranging from 5 μm to 30 μm and then is finally polished for about 30 to 60 minutes with cerium oxide having average grain diamter ranging from 0.5 μm to 2 μm. Then, for forming of projections or depressions in the landing zone, the polished glass-ceramic substrate is subjected to the laser processing with a laser diode pumped solid-state laser or a CO_2 laser fixed in position and pulsed laser being irradiated while the glass-ceramic substrate is rotated.

The irradiation of pulsed laser is performed with

the conditions such as laser wavelength, laser output, laser beam spot diameter, focus and laser pulse width etc. being controlled suitably in accordance with the specific composition of the glass-ceramic substrate.

As to Examples Nos. 1 - 7, the surface roughness (Ra) of the landing zone and the data zone is measured with the surface roughness measuring device Tencor P2 (Trademark).

As to Examples Nos. 8 - 17, the surface roughness (Ra) of the data zone as well as height and surface roughness (Ra) of projections or depressions in the landing zone are measured with the optical surace roughness analyser Zygo (Trademark).

As shown in Tables 2 to 8 and Figs. 6 and 7, the examples of the present invention and the comparative examples of the prior art Li_2O - SiO_2 system differ entirely from each other in the crystal grain diameter and the shape of the crystal grains of lithium disilicate ($Li_2O \cdot 2SiO_2$). In the glass-ceramic of the present invention, lithium disilicate, alpha-quartz and alpha-cristobalite have a globular crystal grain structure with a small grain diameter. In contrast, in the glass-ceramics of Comparative Examples 1 and 2, lithium disilicate has an acicular grain structure with a large grain diameter of 1.0 μm or more. In a situation in which a more smooth surface is required, this crystal grain structure and grain diameter of the

comparative examples adversely afftect the surface roughness after polishing and produce defects due to coming off of the crystal grains from the substrate. Thus, it is difficult to obtain a surface characteristic having an excellent smoothness of surface roughness of 12 Å or less in the glass-ceramics of Comparative Examples 1 and 2.

As regards the surface state shown in Figs. 8 to 11, a laser processing resulting in forming of projections or derpessions having a uniform and desirable shape as shown in Figs. 8 and 9 can be realized in the glass-ceramic substrate according to the invention in contrast to the above described defects produced in the prior art aluminum substrate and chemically tempered glass substrate. As will be apparent from Figs. 10 and 11 showing the prior art chemically tempered glass (SiO_2 - Al_2O_3 - Na_2O, K_2O ion exchange), the chemically tempered glass exhibits an instable and ununiform surface state after the processing by the laser diode pumped solid-state laser. In the chemically tempered glass shown in Fig. 11, sufficient heating was not achieved by laser irradiation at laser wavelength of 1.064 μm and 0.523 μm and the laser processing was made at wavelength of 0.266 μm. The result was an instable and ununiform surface state shown in Fig. 11.

It is considered that the glass-ceramic according to the invention is superior in resistance to heat to the chemically tempered glass which is in an amorphous state, has no strain change between the tempered surface layer and the untempered interior layer which is peculiar to the chemically tempered glass and has a crystal phase which can prevent growth of microcracks which are produced by various external actions and, as a total effect of these advantages, has an improved property of forming projections or depressions by irradiation of laser beam.

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What is claimed is:

1. A glass-ceramic substrate for a magnetic disk having a data zone and a landing zone, said landing zone having a multiplicity of projections or depressions formed by irradiation of laser beam.

2. A glass-ceramic substrate for a magnetic disk as defined in claim 1 wherein a laser used is a CO_2 laser.

3. A glass-ceramic substrate for a magnetic disk as defined in claim 1 wherein a laser used is a laser diode pumped solid-state laser.

4. A glass-ceramic substrate for a magnetic disk as defined in claim 3 wherein said laser diode pumped solid-state laser is an Nd-YAG laser, an Nd-YVO_4 laser or an Nd-YLF laser.

5. A glass-ceramic substrate for a magnetic disk as defined in claim 4 wherein a wavelength of said laser diode pumped solid-state laser is within a range of 0.2 μm - 0.6 μm or within a range of 1.05 μm - 1.40 μm.

6. A glass-ceramic substrate for a magnetic disk as defined in any of claims 1-5 wherein surface roughness (Ra) of a polished surface of the landing zone is within a range from 3 Å to 9 Å and height of the projections or depressions formed by the laser beam in the landing zone is within a range from 50 Å to 300 Å and surface roughness (Ra) of the projections and depressions is within a range from 10 Å to 50 Å.

7. A glass-ceramic substrate for a magnetic disk as



defined in claim 6 wherein interval of the projections or depressions is within a range from 10 μm to 200 μm.

8. A glass-ceramic substrate as defined in any of claims 1-7 wherein a glass-ceramic used is a glass-ceramic of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 system or of a SiO_2 - Li_2O - K_2O - MgO - ZnO - P_2O_5 - Al_2O_3 - ZrO_2 system.

9. A glass-ceramic substrate for a magnetic disk as defined in any of claims 2, 6, 7 and 8 formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2), and said laser being a

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CO_2 laser.

10. A glass-ceramic substrate for a magnetic disk as defined in any of claims 2, 6, 7 and 8 formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
ZrO_2	0.5 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2), and said laser being a CO_2 laser.

11. A glass-ceramic substrate for a magnetic disk as defined in claim 8 including at least two ingredients of NiO, CoO, MnO_2, V_2O_5, CuO, Cr_2O_3 as a coloring agent.

12. A glass-ceramic substrate for a magnetic disk as defined in claim 11 formed by subjecting to heat

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treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
V_2O_5 + CuO + Cr_2O_3 + MnO_2 + CoO + NiO	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-critobalite (alpha-SiO_2), and said laser being a laser diode pumped solid-state laser.

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13. A glass-ceramic substrate for a magnetic disk as defined in claim 11 formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
ZrO_2	0.5 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
V_2O_5 + CuO + Cr_2O_3 + MnO_2 + CoO + NiO	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and



alpha-critobalite (alpha-SiO_2), and said laser being a laser diode pumped solid-state laser.

14. A glass-ceramic substrate for a magnetic disk as defined in claim 12 or 13 wherein percent transmission by a laser diode pumped solid-state laser of a wavelength of 1.06 μm at a thickness of 0.635 mm is 80% to 40%.

15. A glass-ceramic substrate as defined in any of claims 8-14 wherein a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2), crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.1 μm to 0.5 μm, and crystal grains of alpha-quartz have g globular grain structure made of aggregated particles and have a diameter within a range from 0.3 μm to 1.0 μm.

16. A glass-ceramic substrate as defined in any of claims 8-14 wherein a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and alpha-cristobalite (alpha-SiO_2), crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.1 μm to 0.5 μm, and crystal grains of alpha-cristobalite have a globular grain structure made of aggregated particles and have a diameter within a

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range from 0.2 μm to 1.0 μm.

17. A glass-ceramic substrate for a magnetic disk as defined in claim 11 formed by subjecting to heat treatment a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
ZrO_2	0.5 - 5%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
NiO	0.5 - 3%
CoO	0.5 - 3%
MnO_2	0 - 0.5%
V_2O_5	0 - 0.5%
CuO	0 - 1%
Cr_2O_3	0 - 1.5%

a main crystal phase of said glass-ceramic being at least one of lithium disilicate ($Li_2O \cdot 2SiO_2$), a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) and a mixed crystal of lithium disilicate and alpha-critobalite (alpha-SiO_2), and said laser being a

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laser diode pumped solid-state laser.

18. A glass-ceramic substrate for a magnetic disk as defined in claim 17 wherein percent transmission by a laser diode pumped solid-state laser of a wavelength of 0.2 μm - 0.6 μm or 1.05 μm - 1.40 μm) at a thickness of 0.635 mm is 0% to 40%.

19. A glass-ceramic substrate as defined in claim 17 wherin a cristal phase of the glass-ceramic is a lithium disilicate ($Li_2O \cdot 2SiO_2$) or a mixed crystal of lithium disilicate and alpha-quartz (alpha-SiO_2) or a mixed crystal of lithium disilicate and alpha-cristobalite (alpah-SiO_2), crystal grains of lithium disilicate have a globular grain structure and have a diameter within a range from 0.05 μm to 0.3 μm, crystal grains of alpha-cristobalite have a globular grain structure and have a diameter within a range from 0.10 μm to 0.50 μm and crystal grains of alpha-quartz have a globular grain structure made of aggregated particles and have a diameter within a range from 0.10 μm to 1.00 μm.

20. A method for manufacturing a glass-ceramic substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%

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Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%;

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a CO_2 laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

21. A method for manufacturing a glass-ceramic substrate for a magnetic disk having a data zone and a landing zone comprising steps of:



melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
ZrO_2	0.5 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%;

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 780 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a CO_2 laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

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22. A method for manufacturing a magnetic disk substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
V_2O_5 + CuO + Cr_2O_3 + MnO_2 + CoO + NiO	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a



range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a laser diode pumpled solid-state laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

23. A method for manufacturing a magnetic disk substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
Al_2O_3	2 - 5%
ZrO_2	0.5 - 5%

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Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
$V_2O_5 + CuO + Cr_2O_3 + MnO_2$ + CoO + NiO	0.08 - 2.5%
in which V_2O_5	0.02 - 0.8%
CuO	0.02 - 0.8%
Cr_2O_3	0 - 0.8%
MnO_2	0.02 - 0.8%
CoO	0 - 0.8%
NiO	0 - 0.8%

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from 680 °C to 780 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a laser diode pumpled solid-state laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

24. A method for manufacturing a glass-ceramic

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substrate for a magnetic disk having a data zone and a landing zone comprising steps of:

melting a base glass which consists in weight percent of:

SiO_2	70 - 80%
Li_2O	9 - 12%
K_2O	2 - 5%
MgO + ZnO	1.2 - 5%
in which MgO	0.5 - 5%
ZnO	0.2 - 3%
P_2O_5	1.5 - 3%
ZrO_2	0.5 - 5%
Al_2O_3	2 - 5%
Sb_2O_3	0 - 1%
As_2O_3	0 - 1%
NiO	0.5 - 3%
CoO	0.5 - 3%
MnO_2	0 - 0.5%
V_2O_5	0 - 0.5%
CuO	0 - 1%
Cr_2O_3	0 - 1.5%

forming the molten glass into a desired shape;

subjecting the formed glass to heat treatment for producing a crystal nucleus under a temperature within a range from 450 °C to 550 °C for one to twelve hours;

further subjecting the glass to heat treatment for crystallization under a temperature within a range from

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680 °C to 750 °C for one to twelve hours;

polishing the surface of the glass to a surface roughness (Ra) within a range from 3 Å to 9 Å; and

forming in the landing zone a multiplicity of projections or depressions by irradiation of laser beam by a laser diode pumpled solid-state laser, said projections or depressions having a height within a range of 50 Å to 300 Å and a surface roughness (Ra) within a range from 10 Å to 50 Å.

25. A magnetic disk having a film of a magnetic media formed on said glass-ceramic substrate of any of claims 1-19.

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