

SPECIFICATION

METHOD OF MANUFACTURING SUBSTRATE

TECHNICAL FIELD

[0001] The present invention relates to a method of manufacturing a substrate having a microscopic structure by forming the microscopic structure on a glass substrate, a resin substrate, a metal substrate or a ceramic substrate.

BACKGROUND

[0002] In order to form a microscopic structure of a micrometer or less order on the surface of a glass substrate, the surface of the glass substrate is processed via lithography and dry etching since mechanical processing exhibits processing inferior accuracy (for example, Patent Document 1, and Patent Document 2).

[0003] Dry etching is a method by which a substrate is processed with reactive ions or radicals, and is accompanied with chemical reaction. For this reason, a high-purity glass containing no impurity is desired to be used, whereby a quartz substrate is utilized.

[0004] Synthetic quartz is synthesized from powder having been chemically prepared in order to reduce impurity quantity. The synthetic quartz synthesized in this way exhibits high transparency, heat resistance, and resistance to chemicals, since it contains little impurity. However, since impurities are to be removed from the synthetic quartz, a quartz substrate can not be manufactured by a method in high productivity. As a result, use of the quartz substrate results in high cost. Therefore, the quartz substrate is to be unsuitable for an element at low cost.

[0005] On the other hand, there is an example of a glass substrate containing impurities, previously having been subjected to dry etching. A glass substrate (produced by Corning Inc.) as Pyrex (registered trademark) has been specifically subjected to dry etching (For example, Patent Document 1).

[0006] However, in the case of conventional glass such as Pyrex (registered trademark) glass, it is difficult to bring about chemical reaction with reaction gas during dry etching, since the glass contains impurities such as boron, sodium, potassium and so forth. As a result, there appeared problems such that etching did not proceed; an etching rate thereof was low; a selectivity ratio could not be taken with an etching mask; and the surface was roughened since impurities are deposited because of those being

nonvolatile. For this reason, it was not possible to be industrially utilized that an inexpensive glass substrate containing impurities is microscopically processed via dry etching.

[0007] Incidentally, impurities can be contained in a glass substrate to increase productivity of the glass substrate, to adjust a refractive index of the glass substrate, and to adjust a thermal expansion coefficient thereof. For example, since sodium carbonate or potassium carbonate is capable of dissolving a silicic acid as a main component of a glass material, productivity of the glass substrate can be improved. Lead oxide is also capable of increasing a refractive index of the glass substrate. Further, since a boric acid is capable of decreasing a thermal expansion coefficient, heat resistance of the glass substrate can be improved. In this way, properties of the glass substrate can be adjusted in response to the item for which the glass substrate is applied, by containing impurities in the glass substrate. For example, when a glass substrate is used for an optical element such as diffraction grating and so forth, properties of the glass substrate can be adjusted in response to properties desired for the optical element, by containing impurities in the glass substrate.

[0008] However, as described above, since a glass substrate containing impurities is difficult to be processed via dry etching, a desired microscopic structure is difficult to be formed on the glass substrate.

[0009] Further, a microscopic structure is also desired to be formed on a resin substrate. For example, an optical element such as diffraction grating and so forth, a microchip for analysis, a substrate used for a magnetic recording medium and so forth can be prepared by forming a microscopic structure on the resin substrate.

[0010] The microchip is a chip for analysis by which a fine flow path is formed on a substrate, and a liquid sample such as blood or the like is chemically reacted in a fine space region, and analyzed. A trial to manufacture the microchip with the resin substrate is made by forming fine patterns on the resin substrate.

[0011] Further, a trial to use the resin substrate as a magnetic recording medium substrate is made. Proposed is a so-called discrete medium or patterned medium with which grooves are formed in the circumferential direction of the magnetic recording medium, and physically separated by a nonmagnetic region (non-recording region) incapable of writing data between tracks. A trial to manufacture the patterned medium with a resin substrate is made by forming fine patterns on the resin substrate. Since it is difficult to form fine patterns used for the patterned medium or the like on the resin substrate via mechanical processing, the fine patterns have to be formed via dry etching.

[0012] However, in the case of dry etching conducted on to the resin substrate, it is isotropic etching, and anisotropic etching is difficult to be conducted, resulting in difficult formation of a desired microscopic structure on the resin substrate.

[0013] Formation of a microscopic structure on a metal substrate is also demanded. For example, a trial to manufacture a patterned medium or the like is made by forming fine patterns on an aluminum substrate. However, it is difficult to form fine patterns via mechanical processing. On the other hand, fine patterns are formed via dry etching, but it is difficult to form fine patterns on a metal substrate via dry etching.

Patent Document 1: Japanese Patent O.P.I. Publication No. 11-218631

Patent Document 2: Japanese Patent O.P.I. Publication No. 2006-127590

Non-Patent Document: Sensors and Actuators A87 (2001) 139 – 145

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0014] The present invention is made to solve the above-described problem, and it is an object of the present invention to provide a method of manufacturing a substrate, which is capable of forming a microscopic structure on a glass substrate, a resin substrate, a metal substrate or a ceramic substrate containing impurities.

MEANS TO SOLVE THE PROBLEMS

[0015] Structure 1 of the present invention: A method of manufacturing a substrate, comprising the steps of forming an SiO₂ film on a surface of a glass substrate having an impurity content of 10 – 50% by weight, a resin substrate, a metal substrate or a ceramic substrate via a liquid phase deposition process, forming an etching mask having predetermined patterns on the SiO₂ film, and dry-etching the SiO₂ film after forming the etching mask to pattern the SiO₂ film.

[0016] Structure 2 of the present invention: The method of Structure 1, wherein the liquid phase deposition process comprises the steps of immersing the substrate in an aqueous solution, and hydrolyzing a metal-fluoro complex in the aqueous solution to form the SiO₂ film on the surface of the substrate.

[0017] Structure 3 of the present invention: The method of Structure 1 or 2, wherein the glass substrate comprises at least one selected from the group consisting of boron, sodium, potassium, lead, aluminum and lithium as an impurity.

EFFECT OF THE INVENTION

[0018] In the present invention, it is possible to form a microscopic structure on a substrate by forming an SiO₂ film on the surface of the substrate via a liquid phase deposition process, and dry-etching the SiO₂ film to pattern the SiO₂ film, even though a glass substrate, a resin substrate, a metal substrate or a ceramic substrate containing impurities is used as the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Figs. 1a, 1b, 1c and 1d each are a cross-sectional view of a substrate to explain a method of manufacturing the substrate in an embodiment of the present invention.

EXPLANATION OF NUMERALS

- [0020]
- 1 Substrate
 - 2 SiO₂ film
 - 3 Etching mask
 - 4 Concavo-convex shape

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] A method of manufacturing a substrate in an embodiment of the present invention will be described, referring to Figs. 1a, 1b, 1c and 1d. Figs. 1a, 1b, 1c and 1d each are a cross-sectional view of a substrate to explain a method of manufacturing the substrate in an embodiment of the present invention. Fig. 1a shows a cross-sectional view of a substrate, and Fig. 1b shows a cross-sectional view of a substrate of which an SiO₂ film is formed on the surface. Further, Fig. 1c shows a cross-sectional view of a substrate having an SiO₂ film thereon, wherein an etching mask is formed on the SiO₂ film, and Fig. 1d shows a cross-sectional view of a substrate having an SiO₂ film thereon, wherein concavo-convex shape 4 corresponding to an etching mask is formed on the surface of the SiO₂ film.

[0022] A glass substrate, a resin substrate, a metal substrate or a ceramic substrate containing impurities is used as substrate 1 as shown in Fig. 1a. For example, substrate 1 is plate-shaped. The shape of substrate 1 is not specifically limited. Substrate 1 may be disk-shaped, and may also be rectangle-shaped.

[0023] Soda glass, crystal glass, borosilicate glass or the like is used for a glass substrate. Components other than SiO₂ as a main component of glass are designated as impurities. Examples of

the impurities include components such as boron, sodium, potassium, lead, aluminum and lithium. At least one selected from the group consisting of the above-described components is (are) contained in a glass substrate. An impurity content in the glass substrate is preferably 10 – 50% by weight. For example, borosilicate glass containing B₂O₃, Na₂O or K₂O, and Al₂O₃ other than SiO₂ as well as glass containing Al₂O₃, LiO₂, Na₂O and other impurities is used for a glass substrate.

[0024] Further, a thermoplastic resin, a thermosetting resin or an actinic ray-curable resin is used for a resin substrate. Usable examples of the resin material include PMMA (polymethacrylate), PC (polycarbonate), PET (polyethylene terephthalate), cyclic polyolefin (COP), PI (polyimide), and so forth, but the present invention is not limited thereto.

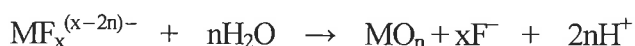
[0025] Further, Al (aluminum), Ni (nickel), Ta (tantalum), W (tungsten), SUS (stainless) or the like is used for a metal substrate, but the present invention is not limited thereto.

[0026] Further, Al₂O₃ (aluminum oxide), TiO₂ (titanium dioxide), Si (silicon), SiC (silicon carbide), SiN (silicon nitride) or the like is used for a ceramic substrate, but the present invention is not limited thereto.

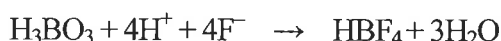
[0027] And, as shown in Fig. 1b, SiO₂ film 2 is formed on the surface of substrate 1 (film-forming step). In the present embodiment, SiO₂ film 2 is formed on the surface of substrate 1 via a liquid phase deposition process by which an SiO₂ film is deposited from a liquid phase. Specifically, substrate 1 is immersed in an aqueous solution to form SiO₂ film 2 on the surface of substrate 1.

[0028] The liquid phase deposition process is a process by which a metal oxide film is directly formed on a substrate by utilizing equilibrium reaction of a metal-fluoro complex in an aqueous solution. This reaction can be represented by the following chemical formulae.

Chemical reaction formula (1)



Chemical reaction formula (2)



Chemical reaction formula (1) exhibits the main reaction, and symbol M represents a metal.

[0029] The metal-fluoro complex is hydrolyzed to produce a metal oxide. In this case, as shown in chemical reaction formula (2), fluoride ions are consumed by adding a boric acid into the system. When the fluoride ions are consumed, the equilibrium reaction in chemical reaction formula (1) is shifted to the right side, whereby deposition reaction of the metal oxide is accelerated. As shown in Fig. 1b, high-purity SiO₂ film 2 is formed on the surface of substrate 1.

[0030] And, as shown in Fig. 1c, etching mask 3 having predetermined patterns is formed on SiO₂ film 2 (mask-forming step). For example, etching mask 3 is formed by a method disclosed in Japanese Patent O.P.I. Publication No. 2006-131954. Specifically, after coating a resist on SiO₂ film 2, the resist surface is exposed to electron beams to make predetermined patterns, and developing is conducted with a predetermined developing material to form etching mask 3 having predetermined patterns. In addition, etching mask 3 may also be formed by utilizing photolithography or an imprinting method other than electron beams.

[0031] And, after forming etching mask 3 having predetermined patterns on SiO₂ film 2, substrate 1 on which etching mask 3 has been formed is subjected to dry etching to form concavo-convex shape 4 corresponding to patterns of etching mask 3 on the surface of SiO₂ film 2 as shown in Fig. 1d (etching-processing step). In addition, an etching process such as reactive ion etching, reactive gas etching or the like may be used as dry etching.

[0032] It is possible to form concavo-convex shape 4 on the surface of a glass substrate in etching accuracy and etching property identical to those of a quartz substrate by forming high-purity on the surface of substrate 1 via a liquid phase deposition process, even though a glass substrate containing impurities is used as substrate 1. As a result, manufacturing cost is possible to be reduced by forming a microscopic structure on an inexpensive glass substrate containing impurities to manufacture an element. Further, since a microscopic structure can be formed on a glass substrate while controlling glass substrate properties by containing impurities in the glass substrate, the glass substrate containing impurities is possible to be applied to an optical element and so forth.

[0033] Further, in the case of a liquid phase deposition process, it is possible to form a metal oxide film in a liquid phase at room temperature, whereby resin and metal may also be used in addition to glass as a material used for substrate 1, as described above.

[0034] For example, it is difficult to form fine patterns on the surface of a resin substrate via dry etching, but it is possible to form desired patterns on a resin substrate by dry-etching SiO₂ film 2 after forming SiO₂ film 2 on the surface of a resin substrate (substrate 1). In this way, the resin substrate is possible to be applied to a magnetic recording medium substrate used for an optical element, a microchip for analysis, a patterned medium or the like, since a microscopic structure can be formed on the resin substrate.

[0035] Further, also in the case of metal, it is possible to form desired patterns on a metal substrate by dry-etching SiO₂ film 2 after forming SiO₂ film 2 on the surface of a metal substrate (substrate 1). In

this way, the metal substrate is possible to be applied to a magnetic recording medium substrate used for a patterned medium or the like, since a microscopic structure can be formed on the metal.

[0036] Further, a ceramic substrate may be employed for an element or a substrate exhibiting higher hardness to be used than that of a glass substrate. For example, the ceramic substrate is possible to be applied to a nano-imprinting mold or a magnetic recording medium substrate. In the case of ceramics, desired patterns are possible to be formed on the ceramic substrate by forming SiO₂ film 2 on the ceramic substrate, and dry-etching SiO₂ film 2 thereof. In this way, since microscopic processing can be conducted on the surface, the ceramic substrate is possible to be applied to a magnetic recording medium substrate used for a nano-imprinting mold and a patterned medium.

[0037] Further, when a substrate containing impurities is washed with a hydrofluoric acid, defects and protrusions tend to be generated on a substrate because of the impurities. For example, since a magnetic recording medium substrate is often washed with a hydrofluoric acid, defects and protrusions are possibly generated on a glass substrate in cases where impurities are contained in the glass substrate. In contrast, in the case of a method of manufacturing a substrate in the present embodiment, since high-purity SiO₂ film 2 is formed on the surface of substrate 1, it is possible to suppress generation of defects and protrusions caused by impurities.

[0038] Further, since substrate 1 is immersed in an aqueous solution, SiO₂ film 2 can be formed on both surfaces of substrate 1 and edge faces present around the surfaces at the same time. In this way, since SiO₂ film 2 can be formed on the entire surface of substrate 1 in a single film-forming process, SiO₂ film 2 can be easily formed without increasing the number of film-forming processes to be carried out. For this reason, time consumed for film-forming cost and film formation can be reduced.

[0039] Specifically, since a hard disk uses both surfaces of a magnetic recording medium as the recording region, in the case of the present invention, a magnetic recording medium substrate is possible to be effectively prepared without increasing the number of film-forming processes to be carried out. In addition, in Fig. 1b, for ease of explanation, SiO₂ film 2 provided on one surface of substrate 1 is shown.

[0040] Further, the surface is possible to be smoothed by forming SiO₂ film 2 on the surface of substrate 1 via a liquid phase deposition process. For example, SiO₂ film 2 is filled in fine grooves and so forth formed on the surface by forming SiO₂ film 2 on the surface of substrate 1, even though substrate 1 has a large surface roughness Ra, for example, so that surface roughness Ra is lowered, resulting in smoothness of the surface possibly achieved.

EXAMPLE

[0041] Next, specific examples of the foregoing embodiments will be described.

(Substrate 1)

In the present Example, a plate-shaped glass substrate is used as substrate 1. Borosilicate glass is used for this glass substrate. Pyrex (registered trademark) glass, produced by Corning Inc. is specifically used. This Pyrex (registered trademark) glass contains 81% by weight of SiO_2 , 13% by weight of B_2O_3 , 4% by weight of Na_2O or K_2O , and 2% by weight of Al_2O_3 as a composition.

[0042] Dimensions of substrate 1 are also shown below.

[0043] Outline of substrate 1: A square, 30 mm on a side
Thickness of substrate 1: 1 mm

(Film formation of SiO_2 film 2)

SiO_2 film 2 was formed on substrate 1 (glass substrate). Specifically, substrate 1 was immersed in a mixture solution in which 0.5 mol/L of an aqueous $(\text{NH}_4)_2\text{SiF}_6$ solution and 0.2 mol/L of an aqueous H_3BO_3 solution were mixed, at room temperature for one hour. In the present embodiment, substrate 1 was immersed in the mixture solution having a volume of 500 mL. As a result, a 100 nm thick SiO_2 film was formed on the surface of substrate 1.

[0044] In addition, when an SiO_2 film is formed on a plurality of substrates at once, a larger volume of a mixture solution is arranged to be used, and substrate 1 is immersed in the mixture solution while circulating the mixture solution.

(Dry etching)

Next, concavo-convex shape 4 is formed on SiO_2 film 2 via dry etching. In Example 1, SiO_2 film 2 was etched via inductive coupling type reactive ion etching (ICP-RIE; Inductive Coupled Plasma-Reactive Ion Etching) employing an ICP-RIE etching apparatus. SiO_2 film 2 was etched by plasma-discharging CHF_3 gas at a pressure of 2.66 Pa to form a pillar array structure. Specifically, formed was a pillar array structure in which a pitch between pillars was 100 nm, and each pillar had a height of 50 nm.

[0045] As described above, in the present Example, the same etching property as that of a quartz substrate was possible to be obtained by forming an SiO_2 film on the surface of a substrate, even though a glass substrate containing impurities is used as substrate 1.

[0046] In addition, Pyrex (registered trademark) glass produced by Corning Inc. was used in the present Example, but the same etching property as that of a quartz substrate was possible to be obtained, even though employing TEMPAX glass (produced by SCHOTT AG) having the same composition as that of Pyrex (registered trademark) glass.

[0047] Further, in the present Example, borosilicate glass is used for a glass substrate, but the same etching property as that of a quartz substrate can be obtained by forming a SiO_2 film on the surface of a substrate similarly to the present Example, even though glass other than borosilicate glass is used for a glass substrate. For example, the same effect as in Example can be produced even though soda glass or crystal glass is used for a glass substrate. Further, in the present Example, the glass substrate is used, but the same effect as that of the glass substrate can be produced even though employing a resin substrate, a metal substrate or a ceramic substrate.

CLAIMS

1. A method of manufacturing a substrate, comprising the steps of:
forming an SiO₂ film on a surface of a glass substrate having an impurity content of 10 – 50% by weight, a resin substrate, a metal substrate or a ceramic substrate via a liquid phase deposition process,
forming an etching mask having predetermined patterns on the SiO₂ film, and
dry-etching the SiO₂ film after forming the etching mask to pattern the SiO₂ film.
2. The method of Claim 1,
wherein the liquid phase deposition process comprises the steps of:
immersing the substrate in an aqueous solution, and
hydrolyzing a metal-fluoro complex in the aqueous solution to form the SiO₂ film on the surface of the substrate.
3. The method of Claim 1 or 2,
wherein the glass substrate comprises at least one selected from the group consisting of boron, sodium, potassium, lead, aluminum and lithium as an impurity.