

METHOD FOR PROCESSING LARGE-SIZE ULTRATHIN HIGH-PRECISION LITHIUM NIOBATE WAFER

5 TECHNICAL FIELD

The present invention relates to the technical field of semiconductor material processing, and in particular to a method for processing a lithium niobate crystal substrate.

10 BACKGROUND

Lithium niobate (LiNbO_3) is a compound of niobium, lithium and oxygen, and is a negative crystal ($n_0 > n_e$). Lithium niobate has a relative density of 4.30, with lattice constants $a = 0.5147 \mu\text{m}$ and $c = 1.3856 \mu\text{m}$, a melting point of 1240°C , a Mohs hardness of 5, refractive indexes $n_0 = 2.297$ and $n_e = 2.208$ ($\lambda = 600 \mu\text{m}$), and a dielectric constant $\varepsilon = 44$, $\varepsilon = 29.5$, $\varepsilon = 84$, or $\varepsilon = 30$.

15 Lithium niobate is a ferroelectric crystal having a curie point of 1140°C , an intensity of spontaneous polarization of $50 \times 10 \text{ C/cm}^2$, and a thermal conductivity of 0.056 (W/cm K) . The distorted lithium niobate crystal has materials having multiple performances of piezoelectricity, ferroelectricity, photoelectricity, nonlinear optics, thermoelectricity and the like, and simultaneously has a photorefractive effect. Its single crystal is an important material for use in
20 optical waveguides, mobile phones, piezoelectric sensors, optical modulators and various other linear and nonlinear optical applications. Lithium niobate crystal is one of the most widely-used novel inorganic materials at present, and is a good piezoelectric transduction material, a ferroelectric material and an electro-optic material. Lithium niobate, as an electro-optical material, plays a role of optical modulation in optical communication.

25 A high-performance electronic element has extremely high requirements on the integrity of crystal lattices on the surface of a lithium niobate wafer which not only needs to have an extremely high flatness, but also needs to be free of damage, ultra-smooth and have no deviation of crystal orientation. The common wafer has a problem of static electricity accumulation on its surface, and
30 this problem can be solved through a blackening process which can also enable the wafer to generate a low pyroelectric effect, so that the wafer will be more in line with the rules and requirements of the development in the semiconductor industry.

With the rapid development of the semiconductor industry, demands of lithium niobate
35 wafers have been gradually increased. In order to increase the yield and decrease the cost, a large-

size wafer needs to be developed. Therefore, on one hand, the construction of a general process platform of large-size lithium niobate wafers can be improved, and on the other hand, the restriction of semiconductor machine equipment of manufacturers on products can be eliminated. Since the size of an 8-inch lithium niobate wafer is larger than that of a conventional wafer, a larger processing stress is generated during processing, and thus defects such as edge cracking, chipping and splintering are easily caused. Moreover, the larger the wafer size is, the more difficult the indexes of TTV, WARP, BOW, PLTV and the like can reach the equivalent level of wafers having the conventional size during processing.

The Chinese Patent Application CN111230598A discloses a preparation method for an 8-inch lithium niobate wafer, a triple corrosion method is adopted, solving the problem that the lithium niobate wafer is seriously deformed due to internal stress and thus is easy to break in its production process; the polishing process adopts a porous ceramic disc for adsorption, solving the problem that TTV is difficult to control in a conventional wax sticking process. However, in actual operation, an acid solution used for corrosion has potential safety hazards to the environment and human body, the porous ceramic disc adopted for adsorption has an extremely high precision requirement on equipment and parts, and only single-side polishing can be realized.

The applicant discloses in CN107665813A a method for processing a lithium tantalate crystal substrate, comprising steps of slicing, chamfering, blackening, grinding, rough polishing and fine polishing, wherein a diamond polishing solution is adopted in the steps of rough polishing and fine polishing and consists of diamond micro powder, ethylene glycol, glycerol, ethanol ammonia and deionized water, with a PH value of the diamond polishing solution of 9–11, wherein a content of the diamond micro powder is 20–25%, a content of the ethylene glycol is 8–15%, a content of the glycerol is 3–5%, a content of the ethanol ammonia is 0.1–0.3%, and a content of the deionized water is 60–65%. The present invention can greatly improve surface smoothness of a lithium tantalate wafer, reduce surface roughness thereof, eliminate stress and achieve a mirror polishing effect, thereby decreasing production cost and increasing a qualification rate of products. However, lithium tantalate and lithium niobate have very different physical properties, and the processing method for lithium tantalate is not suitable for lithium niobate.

SUMMARY

The present invention is intended to provide a method for processing a large-size ultrathin high-precision lithium niobate wafer, which can be used for producing 8-inch lithium niobate wafers in batches and realizes double-sided processing, so that the production efficiency is greatly improved, the method is safe and reliable, the performances and the quality of the wafer are ensured, the production cost is saved, the qualification rate of products is increased, the stress of large-size wafers is reduced, and the restriction of semiconductor equipment of manufacturers on products is eliminated.

In order to achieve the above-mentioned purpose, the present invention provides the following technical solutions.

Provided is a method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising steps of slicing, chamfering, grinding 800, blackening, grinding 2000 and polishing; wherein

a double-sided grinder is adopted in the steps of grinding 800 and grinding 2000, and a staged slow-pressurization mode is adopted in a grinding pressurization mode at 22 ± 2 °C;

wherein, the staged slow-pressurization mode of grinding 800 is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 2 g/cm² per minute; and pressurizing for 2 min in a third stage at a rate of 3 g/cm² per minute and pressurizing for 2 min in a fourth stage at a rate of 4 g/cm² per minute to 20 g/cm²;

the staged slow-pressurization mode of grinding 2000 is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 4 g/cm² per minute; pressurizing for 2 min in a third stage at a rate of 6 g/cm² per minute; and pressurizing for 2 min in a fourth stage at a rate of 8 g/cm² per minute to 40 g/cm²; wherein a flow rate of a mortar is 5 L/cm²–15 L/cm², and a maximum rotation speed of equipment is 6–10 rpm;

a double-sided polishing machine is adopted in the step of polishing, a maximum rotation speed of equipment is 6–10 rpm at 22 ± 2 °C, a polishing solution of Compol 403 of FUJIMI is adopted and has a main component of SiO₂, a specific density is 1.06–1.20, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is as follows: a 1-min first stage without pressurization; pressurizing for 4 min in a second stage at a rate of 10 g/cm² per minute; pressurizing for 4 min in a third stage at a rate of 15 g/cm² per minute; pressurizing for 5 min in a fourth stage at a rate of 20 g/cm² per minute to 200 g/cm²; wherein a flow rate of the polishing solution is 10 L/cm²–12 L/cm².

The staged slow-pressurization mode means that a lower disc is started firstly before a grinding disc is subjected to pressure application to make the mortar uniformly distributed, and whether the wafer and a clamp are fixed or not can be checked, and after running for a period of time, the pressurization is performed in a slow and gradual pressurization manner.

FIGs. 2–4 are diagrams comparing the processing pressure versus the processing time in grinding 800, grinding 2000 and polishing processes for the direct pressurization mode and the staged pressurization mode, respectively, and it can be seen from the figures that:

the direct pressurization mode of grinding 800 is to pressurize for 5 min at a rate of 4 g/cm² per minute to 20 g/cm²; the direct pressurization method of grinding 2000 is to pressurize for 5 min at a rate of 8 g/cm² per minute to 40 g/cm²; the direct pressurization mode of the step of polishing is to pressurize for 10 min at a rate of 20 g/cm² per minute to 200 g/cm².

Compared with the staged pressurization mode, the direct pressurization mode is too stiff and mechanical, easy to cause scratching, splintering and other problems, and unfavorable for observation and remedy of the problems, while time is reserved for observation and adjustment in the staged pressurization mode, a pressurization speed is slow and mild, the processing quality can be effectively ensured, and the possibility of scratching and splintering is reduced.

In the staged pressurization mode, a mortar ground in the step of grinding 800 consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L; the mortar ground in the step of grinding 2000 consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L;

the polishing solution has a main component of SiO₂, and a specific density is 1.06–1.20; the step of grinding 800 has a grinding effect of TTV ≤ 5 μm and Bow ≤ 30 μm, and the step of grinding 2000 has a grinding effect of TTV ≤ 4 μm and Bow ≤ 25 μm;

the step of polishing has a polishing effect of wafer TTV ≤ 3 μm, Bow ≤ 20 μm, WARP < 40 μm and PLTV > 95%, a mirror effect and no stress;

the lithium niobate wafer is an 8-inch lithium niobate wafer.

A clamp adopted in the steps of grinding 800, grinding 2000 and polishing is a planetary wheel, and a wafer placement position in the planetary wheel adopts an eccentric design;

the wafer placement position is circular, and a rubber ring having a diameter of 200.2 mm and a width of 5 mm is arranged at an edge of the wafer placement position;

five circular drainage holes are distributed around the wafer placement position, with one having a diameter of 60 mm, two having a diameter of 40 mm and two having a diameter of 20 mm, a circle having a diameter of 290 mm is made by taking a center of the planetary wheel as a center of the circle, and the wafer placement circle and the drainage holes are internally tangent with the circle, wherein a center of the wafer placement circle and a center of the 60-mm drainage are on the same diameter line and are positioned on two sides, centers of the 40-mm drainage holes are positioned in places obtained by deflecting a reference edge leftwards and rightwards by 60 degrees, respectively, wherein the reference edge is a radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole, and centers of the 20-mm drainage holes are positioned on places obtained by deflecting the reference edge leftwards and rightwards by 110 degrees, respectively, wherein the reference edge is the radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole. The appearance of the planetary wheel is shown in FIG. 1.

The step of slicing specifically comprises cutting a lithium niobate crystal bar into wafers having a thickness of 250–300 μm by utilizing linear cutting equipment at a linear velocity of a steel wire of 400–1000 m/min and at 22 ± 2 °C, with a TTV of the wafers ≤ 10 μm ;

the step of chamfering specifically comprises chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about R 0.1 at a rotation speed of the grinding wheel of 600–1000 rpm/min and at 22 ± 2 °C, which can effectively reduce the probability of edge cracking, chipping and splintering;

the step of blackening specifically comprises placing the wafer in a blackening furnace for blackening, with a temperature of 300–380 °C, a flow rate of protective gas of 3–11 L and a reduction time of 4–24 h, which can effectively reduce the probability of warping and splintering.

Provided is a lithium niobate wafer prepared by the method for processing a large-size ultrathin high-precision lithium niobate wafer described above.

Compared with the prior art, the present invention has the following beneficial effects.

The method for processing a large-size ultrathin high-precision lithium niobate wafer, together with a clamp, has an excellent treatment effect on an 8-inch lithium niobate wafer, greatly improving the production efficiency. The novel staged pressurization mode is adopted in the pressurization mode of grinding and polishing, and in this mode, a slow and gradual pressurization

mode is adopted during pressurization, greatly reducing the possibility of scratching, chipping, splintering and the like, and meanwhile, with the additional use of the clamp disclosed herein, the possibility of edge collapse, edge cracking, insufficient grinding and the like can be effectively reduced, the yield of products is greatly increased, and the restriction of semiconductor equipment of manufacturers on products is eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the clamp used in the present invention;

FIG. 2 is a diagram comparing the direct pressurization mode and the staged pressurization mode in the step of grinding 800;

FIG. 3 is a diagram comparing the direct pressurization mode and the staged pressurization mode in the step of grinding 2000;

FIG. 4 is a diagram comparing the direct pressurization mode and the staged pressurization mode in the step of polishing;

FIG. 5 is a test result by using the clamp in the staged pressurization mode according to the present invention;

FIG. 6 is a test result by using the conventional planetary wheel in the staged pressurization mode;

FIG. 7 is a test result by using the clamp in the direct pressurization mode according to the present invention; and

FIG. 8 is a test result by using the conventional planetary wheel in the direct pressurization mode.

DETAILED DESCRIPTION

The technical solutions in the embodiments of the present invention will be clearly and completely described below with reference to the drawings in the embodiments of the present invention, and it is obvious that the described embodiments are only a part of the embodiments of the present invention, and not all of them. Based on the embodiments in the present invention, all other embodiments obtained by those skilled in the art without making any creative effort belong to the protection scope of the present invention.

Example 1: Use of Clamp (Planetary Wheel) Disclosed Herein and Staged Pressurization

As shown in FIG. 1, the clamp adopted in this embodiment is a planetary wheel 1, and a wafer placement position 2 in the planetary wheel 1 adopts an eccentric design; the whole wafer can be processed to the maximum extent, and meanwhile, the processing precision is ensured.

The wafer placement position 2 is circular, and a rubber ring 4 having a diameter of 105 mm and a thickness of 5 mm is arranged at an edge of the wafer placement position, so that the wafer can be effectively protected, the probability of edge cracking, edge collapse, splintering, chipping, disc collapse and the like can be greatly reduced, and the yield of products and the stability are greatly improved.

Five circular drainage holes 3 are distributed around the wafer placement position 2, with one having a diameter of 60 mm, two having a diameter of 40 mm and two having a diameter of 20 mm, a circle having a diameter of 290 mm is made by taking a center of the planetary wheel as a center of the circle, and the wafer placement circle and the drainage holes are internally tangent with the circle, wherein a center of the wafer placement circle and a center of the 60-mm drainage are on the same diameter line and are positioned on two sides, centers of the 40-mm drainage holes are positioned in places obtained by deflecting a reference edge leftwards and rightwards by 60 degrees, respectively, wherein the reference edge is a radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole, and centers of the 20-mm drainage holes are positioned on places obtained by deflecting the reference edge leftwards and rightwards by 110 degrees, respectively, wherein the reference edge is the radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole.

Provided is a method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising the following steps of:

1) slicing: cutting a lithium niobate crystal bar into wafers having a thickness of 290 μm by utilizing linear cutting equipment at a linear velocity of a steel wire of 600 m/min and at a temperature of 22 $^{\circ}\text{C}$, with a TTV of the wafers $\leq 10 \mu\text{m}$;

2) chamfering: chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about R 0.1 at a rotation speed of the grinding wheel of 800 rpm/min and at a temperature of 22 $^{\circ}\text{C}$;

3) grinding 800: grinding by adopting a double-sided grinder at a temperature of 22 °C, wherein a mortar consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a staged slow-pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 2 g/cm² per minute; pressurizing for 2 min in a third stage at a rate of 3 g/cm² per minute; and pressurizing for 2 min in a fourth stage at a rate of 4 g/cm² per minute to 20 g/cm²; wherein a flow rate of a mortar is 10 L/cm², and a maximum rotation speed of equipment is 8 rpm; a grinding clamp adopts a planetary wheel, with a grinding effect of TTV ≤ 5 μm and Bow ≤ 30 μm;

4) blackening: placing the wafer in a blackening furnace for blackening, with a temperature of 340 °C, a flow rate of protective gas of 7 L and a reduction time of 16 h;

5) grinding 2000: grinding by adopting a double-sided grinder at a temperature of 22 °C, wherein a mortar consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a staged slow-pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: pressurizing for 3 min in a first stage at a rate of 4 g/cm² per minute; pressurizing for 2 min in a second stage at a rate of 6 g/cm² per minute; and pressurizing for 2 min in a third stage at a rate of 8 g/cm² per minute to 40 g/cm²; wherein a flow rate of a mortar is 11 L/cm², a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts a planetary wheel (same as the planetary wheel in the step of grinding 800), with a grinding effect of TTV ≤ 4 μm and Bow ≤ 25 μm; and

6) polishing: polishing by adopting a double-sided polishing machine at 22 °C and at a maximum rotation speed of equipment of 9 rpm, wherein a polishing solution of Compol 403 of FUJIMI is adopted and has a main component of SiO₂, a specific density is 1.12, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is as follows: pressurizing for 4 min in a first stage at a rate of 10 g/cm² per minute; pressurizing for 4 min in a second stage at a rate of 15 g/cm² per minute; and pressurizing for 5 min in a third stage at a rate of 20 g/cm² per minute to 200 g/cm²; wherein a flow rate of the polishing solution is 11 L/cm², a polishing clamp adopts a planetary wheel (same as the planetary wheel in the step of grinding 800), with a polishing effect of wafer TTV ≤ 3 μm, Bow ≤ 20 μm, WARP < 40 μm and PLTV > 95%, a mirror effect and no stress.

Comparative Example 1: Use of Conventional Planetary Wheel and Staged Pressurization

Provided is a method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising the following steps of:

1) slicing: cutting a lithium niobate crystal bar into wafers having a thickness of 290 μm by utilizing linear cutting equipment at a linear velocity of a steel wire of 600 m/min and at a temperature of 22 $^{\circ}\text{C}$, with a TTV of the wafers $\leq 10 \mu\text{m}$;

2) chamfering: chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about R 0.1 at a rotation speed of the grinding wheel of 800 rpm/min and at a temperature of 22 $^{\circ}\text{C}$;

3) grinding 800: grinding by adopting a double-sided grinder at a temperature of 22 $^{\circ}\text{C}$, wherein a mortar consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a staged slow-pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 2 g/cm^2 per minute; pressurizing for 2 min in a third stage at a rate of 3 g/cm^2 per minute; and pressurizing for 2 min in a fourth stage at a rate of 4 g/cm^2 per minute to 20 g/cm^2 ; wherein a flow rate of a mortar is 10 L/cm^2 , a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts a conventional planetary wheel, with a grinding effect of TTV $\leq 9 \mu\text{m}$ and Bow $\leq 35 \mu\text{m}$;

4) blackening: placing the wafer in a blackening furnace for blackening, with a temperature of 340 $^{\circ}\text{C}$, a flow rate of protective gas of 7 L and a reduction time of 16 h;

5) grinding 2000: grinding by adopting a double-sided grinder at a temperature of 22 $^{\circ}\text{C}$, wherein a mortar consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a staged slow-pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 4 g/cm^2 per minute; pressurizing for 2 min in a third stage at a rate of 6 g/cm^2 per minute; and pressurizing for 2 min in a fourth stage at a rate of 8 g/cm^2 per minute to 40 g/cm^2 ; wherein a flow rate of a mortar is 11 L/cm^2 , a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts a conventional planetary wheel, with a grinding effect of TTV $\leq 8 \mu\text{m}$ and Bow $\leq 30 \mu\text{m}$; and

6) polishing: polishing by adopting a double-sided polishing machine at 22 $^{\circ}\text{C}$ and at a maximum rotation speed of equipment of 9 rpm, wherein a polishing solution of Compol 403 of FUJIMI is adopted and has a main component of SiO_2 , a specific density is 1.12, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is

as follows: a 1-min first stage without pressurization; pressurizing for 4 min in a second stage at a rate of 10 g/cm² per minute; pressurizing for 4 min in a third stage at a rate of 15 g/cm² per minute; and pressurizing for 5 min in a fourth stage at a rate of 20 g/cm² per minute to 200 g/cm²; wherein a flow rate of the polishing solution is 11 L/cm², a polishing clamp adopts a planetary wheel, with a polishing effect of wafer TTV ≤ 6 μm, Bow ≤ 20 μm, WARP < 40 μm and PLTV > 95%, a thickness of 250 ± 15 μm, a mirror effect and no stress.

In this case, the conventional planetary wheel lacks a rubber ring at an edge of a wafer placement position, as compared with the planetary wheel of Example 1.

Comparative Example 2: Use of Clamp (Planetary Wheel) Disclosed Herein and Direct Pressurization

Provided is a method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising the following steps of:

1) slicing: cutting a lithium niobate crystal bar into wafers having a thickness of 290 μm by utilizing linear cutting equipment at a linear velocity of a steel wire of 600 m/min and at a temperature of 22 °C, with a TTV of the wafers ≤ 10 μm;

2) chamfering: chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about R 0.1 at a rotation speed of the grinding wheel of 800 rpm/min and at a temperature of 22 °C;

3) grinding 800: grinding by adopting a double-sided grinder at a temperature of 22 °C, wherein a mortar consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a direct pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: pressurizing for 5 min at a rate of 4 g/cm² per minute to 20 g/cm², wherein a flow rate of the mortar is 10 L/cm², a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts the planetary wheel of Example 1, with a grinding effect of TTV ≤ 9 μm and Bow ≤ 35 μm;

4) blackening: placing the wafer in a blackening furnace for blackening, with a temperature of 340 °C, a flow rate of protective gas of 7 L and a reduction time of 16 h;

5) grinding 2000: grinding by adopting a double-sided grinder at a temperature of 22 °C, wherein a mortar consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a direct pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: pressurizing for 5 min at a rate of 8 g/cm² per minute to 40 g/cm², wherein a flow rate of the mortar is 11 L/cm², a maximum rotation speed of equipment is

8 rpm, and a grinding clamp adopts the planetary wheel of Example 1, with a grinding effect of $TTV \leq 8 \mu\text{m}$ and $Bow \leq 30 \mu\text{m}$; and

6) polishing: polishing by adopting a double-sided polishing machine at 22°C and at a maximum rotation speed of equipment of 9 rpm, wherein a polishing solution of Compol 403 of FUJIMI is adopted and has a main component of SiO_2 , a specific density is 1.12, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is as follows: pressurizing for 10 min at a rate of 20 g/cm^2 per minute to 200 g/cm^2 , wherein a flow rate of the polishing solution is 11 L/cm^2 , a polishing clamp adopts a planetary wheel of Example 1, with a polishing effect of wafer $TTV \leq 6 \mu\text{m}$, $Bow \leq 20 \mu\text{m}$, $WARP < 40 \mu\text{m}$ and $PLTV > 95\%$, a thickness of $250 \pm 15 \mu\text{m}$, a mirror effect and no stress.

Comparative Example 3: Use of Conventional Planetary Wheel and Direct Pressurization

Provided is a method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising the following steps of:

1) slicing: cutting a lithium niobate crystal bar into wafers having a thickness of $290 \mu\text{m}$ by utilizing linear cutting equipment at a linear velocity of a steel wire of 600 m/min and at a temperature of 22°C , with a TTV of the wafers $\leq 10 \mu\text{m}$;

2) chamfering: chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about $R 0.1$ at a rotation speed of the grinding wheel of 800 rpm/min and at a temperature of 22°C ;

3) grinding 800: grinding by adopting a double-sided grinder at a temperature of 22°C , wherein a mortar consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a direct pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: pressurizing for 5 min at a rate of 4 g/cm^2 per minute to 20 g/cm^2 , wherein a flow rate of the mortar is 10 L/cm^2 , a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts a conventional planetary wheel, with a grinding effect of $TTV \leq 15 \mu\text{m}$ and $Bow \leq 40 \mu\text{m}$;

4) blackening: placing the wafer in a blackening furnace for blackening, with a temperature of 340°C , a flow rate of protective gas of 7 L and a reduction time of 16 h;

5) grinding 2000: grinding by adopting a double-sided grinder at a temperature of 22°C , wherein a mortar consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L, a direct pressurization mode is adopted in a grinding pressurization mode, and the pressurization mode is as follows: pressurizing for 5 min at a rate of 8 g/cm^2 per minute to 40

g/cm², wherein a flow rate of the mortar is 11 L/cm², a maximum rotation speed of equipment is 8 rpm, and a grinding clamp adopts a conventional planetary wheel, with a grinding effect of TTV ≤ 13 μm and Bow ≤ 30 μm; and

6) polishing: polishing by adopting a double-sided polishing machine at 22 °C and at a maximum rotation speed of equipment of 9 rpm, wherein a polishing solution of Compol 403 of FUJIMI is adopted and has a main component of SiO₂, a specific density is 1.12, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is as follows: pressurizing for 10 min at a rate of 20 g/cm² per minute to 200 g/cm², wherein a flow rate of the polishing solution is 11 L/cm², a polishing clamp adopts a conventional planetary wheel, with a polishing effect of wafer TTV ≤ 10 μm, Bow ≤ 20 μm, WARP < 40 μm and PLTV > 95%, a thickness of 250 ± 15 μm, a mirror effect and no stress.

The 8-inch lithium niobate wafers prepared in Example 1 and Comparative Examples 1–3 described above are subjected to various tests using a TROPEL flatness tester, and test results are shown in FIGs. 4–8.

In addition, data in Example 1 and Comparative Examples 1–3 are summarized as shown in Table 1.

Table 1

Experimental group	TTV	Thickness	WARP	BOW
Example 1: planetary wheel disclosed herein + staged pressurization	1.247μm	242.033μm	8.612μm	7.268μm
Comparative Example 1: conventional planetary wheel + staged pressurization	5.015μm	237.400μm	16.424μm	13.663μm
Comparative Example 2: planetary wheel disclosed herein + direct pressurization	5.524μm	238.531μm	14.745μm	12.249μm
Comparative Example 3: conventional planetary wheel + direct pressurization	9.665μm	241.362μm	19.242μm	13.426μm

As can be seen from the above results, by use of the planetary wheel disclosed herein and a staged slow-pressurization mode, parameters can be adjusted within a controllable range, the effects of grinding and polishing can be ensured, with TTV < 3 μm and BOW ≤ 10 μm. By use of the planetary wheel disclosed herein + a direct pressurization mode and use of a conventional planetary wheel + a staged slow-pressurization mode, TTV is > 5 μm and BOW is > 10 μm. However, by use of the conventional planetary wheel + the staged slow-pressurization mode, the TTV reaches 9.665 μm and is far greater than a best processing effect of 1.247 μm.

The number of experimental wafers in Example 1 and Comparative Examples 1–3 and the proportion of defective wafers are shown in Table 2.

Table 2

Experimental group	Number of experimental wafers	TTV exceeds standard	Insufficient grinding	Edge collapse	Edge cracking	Chipping	Qualification rate
Example 1:	120	4	1	0	0	2	94.166%
Comparative Example 1:	120	8	2	2	3	4	84.166%
Comparative Example 2:	120	7	3	2	1	3	86.666%
Comparative Example 3:	120	10	5	5	3	6	75.833%

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As can be seen from the above results, in Example 1, the defective fraction can be effectively reduced in terms of TTV, polishing sufficiency, edge collapse and edge cracking, thereby improving the yield of products.

10 Although the embodiments of the present invention have been shown and described, it will be understood by those skilled in the art that various changes, modifications, substitutions and alterations can be made in these embodiments without departing from the principle and spirit of the present invention, and the scope of the present invention is defined in the appended claims and equivalents thereof.

WHAT IS CLAIMED IS:

1. A method for processing a large-size ultrathin high-precision lithium niobate wafer, comprising steps of slicing, chamfering, grinding 800, blackening, grinding 2000 and polishing; wherein

the step of grinding 800 uses a mortar ground comprising silicon carbide sand GC800#, and the step of grinding 2000 uses a mortar ground comprising silicon carbide sand GC2000#;

a double-sided grinder is adopted in the steps of grinding 800 and grinding 2000, and a staged slow-pressurization mode is adopted in a grinding pressurization mode at 22 ± 2 °C;

wherein, the pressurization mode of grinding 800 is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 2 g/cm^2 per minute; and pressurizing for 2 min in a third stage at a rate of 3 g/cm^2 per minute and pressurizing for 2 min in a fourth stage at a rate of 4 g/cm^2 per minute to 20 g/cm^2 ;

the pressurization mode of grinding 2000 is as follows: a 1-min first stage without pressurization; pressurizing for 3 min in a second stage at a rate of 4 g/cm^2 per minute; pressurizing for 2 min in a third stage at a rate of 6 g/cm^2 per minute; and pressurizing for 2 min in a fourth stage at a rate of 8 g/cm^2 per minute to 40 g/cm^2 ; wherein a flow rate of a mortar is 5 L/cm^2 – 15 L/cm^2 , and a maximum rotation speed of equipment is 6–10 rpm;

a double-sided polishing machine is adopted in the step of polishing, a maximum rotation speed of equipment is 6–10 rpm at 22 ± 2 °C, a polishing solution of SiO_2 is adopted, a specific density is 1.06–1.20, a staged slow-pressurization mode is adopted in a polishing pressurization mode, and the pressurization mode is as follows: a 1-min first stage without pressurization; pressurizing for 4 min in a second stage at a rate of 10 g/cm^2 per minute; pressurizing for 4 min in a third stage at a rate of 15 g/cm^2 per minute; pressurizing for 5 min in a fourth stage at a rate of 20 g/cm^2 per minute to 200 g/cm^2 ; wherein a flow rate of the polishing solution is 10 L/cm^2 – 12 L/cm^2 .

2. The method according to claim 1, wherein the mortar ground in the step of grinding 800 consists of: silicon carbide sand GC800#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L; the mortar ground in the step of grinding 2000 consists of: silicon carbide sand GC2000#: water: mortar dispersant = 13.5 KG: 30 L: 1.7 L.

3. The method according to claim 2, wherein the step of grinding 800 has a grinding effect of $\text{TTV} \leq 5 \text{ } \mu\text{m}$ and $\text{Bow} \leq 30 \text{ } \mu\text{m}$, and the step of grinding 2000 has a grinding effect of $\text{TTV} \leq 4 \text{ } \mu\text{m}$ and $\text{Bow} \leq 25 \text{ } \mu\text{m}$.

4. The method according to claim 1, wherein the step of polishing has a polishing effect of wafer TTV $\leq 3\ \mu\text{m}$, Bow $\leq 20\ \mu\text{m}$, WARP $< 40\ \mu\text{m}$ and PLTV $> 95\%$.

5. The method according to claim 1, wherein the lithium niobate wafer is an 8-inch lithium niobate wafer.

6. The method according to claim 1, wherein a clamp adopted in the steps of grinding 800, grinding 2000 and polishing is a planetary wheel, and a wafer placement position in the planetary wheel adopts an eccentric design;

the wafer placement position is circular, and a rubber ring having a diameter of 200.2 mm and a width of 5 mm is arranged at an edge of the wafer placement position;

five circular drainage holes are distributed around the wafer placement position, with one having a diameter of 60 mm, two having a diameter of 40 mm and two having a diameter of 20 mm, a circle having a diameter of 290 mm is made by taking a center of the planetary wheel as a center of the circle, and the wafer placement circle and the drainage holes are internally tangent with the circle, wherein a center of the wafer placement circle and a center of the 60-mm drainage are on the same diameter line and are positioned on two sides, centers of the 40-mm drainage holes are positioned in places obtained by deflecting a reference edge leftwards and rightwards by 60 degrees, respectively, wherein the reference edge is a radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole, and centers of the 20-mm drainage holes are positioned on places obtained by deflecting the reference edge leftwards and rightwards by 110 degrees, respectively, wherein the reference edge is the radius of the circle taking the center of the planetary wheel as the center of the circle and simultaneously passes through the center of the 60-mm drainage hole.

7. The method according to claim 1, wherein the step of slicing specifically comprises cutting a lithium niobate crystal bar into wafers having a thickness of 250–300 μm by utilizing linear cutting equipment at a linear velocity of a steel wire of 400–1000 m/min and at $22 \pm 2\ ^\circ\text{C}$, with a TTV of the wafers $\leq 10\ \mu\text{m}$.

8. The method according to claim 1, wherein the step of chamfering specifically comprises chamfering by utilizing a T-shaped grinding wheel, and chamfering a right angle of the lithium niobate wafer into a fillet of about R 0.1 at a rotation speed of the grinding wheel of 600–1000 rpm/min and at $22 \pm 2\ ^\circ\text{C}$.

9. The method according to claim 1, wherein the step of blackening specifically comprises placing the wafer in a blackening furnace for blackening, with a temperature of 300–380 °C, a flow rate of protective gas of 3–11 L and a reduction time of 4–24 h.