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Study on Lithium niobate wafer bonding and thinning

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Abstract. LN is a kind of pyroelectric material. It can be made into a sensitive layer belonging to photoelectric detector's sensitive element. Usually, the thickness of LN wafer is 0.5mm and that is beyond the requirement for thickness of photoelectric sensitive element. Due to that, LN wafer must be disposed of by bonding, thinning and polishing process. The process mainly contain RZJ-304 photoresist bonding, grinding, polishing, stripping liquid stripping and acetone cleaning. After processed, the dimension of LN wafer is 10㎜×10mm×50um. The surface of LN is very smooth, and the surface roughness is 1.63nm.The test shows that the disposed wafer's peak value of pyroelectric signal is four times as much as that of undisposed one.

Introduction

As a kind of multi-functional material, lithium niobate crystal[1,2] is provided with excellent thermoelectric, piezoelectric dielectric, ferroelectric, nonlinear optics, optical elasticity, mechanical and physical properties. Its low price, high temperature resistance, corrosion resistance and easy processing are widely available in photoelectric technology.

Take LN crystal as an example to study the pyroelectric performance. The pyroelectric coefficient of LN crystal is smaller than other pyroelectric crystals. Since it has high Curie temperature(1260℃), low hardness (Mohs 5), low relative dielectric constant and the stable chemical and physical performance, it has been greatly concerned in the optical detection[3], especially as a photoelectric sensitive element. The crystal should be thinned to the level of tens of microns to prepare photoelectric sensitive element. Because of the temperature variation, ΔT leads to a pyroelectric current which flows at short circuit of the electrodes of the sensitive element. This pyroelectric current arises under consideration of the definition of the pyroelectric coefficient and thermal conditions:

$$i = \frac{\alpha p \varphi}{c d} T_R \tag{1}$$

Where: α absorption coefficient, p pyroelectric coefficient, φ the incident radiation flux, c volume-specific heat capacity, d thickness of the responsive element, T_R the dimensionless function.

Obviously, thickness of the responsive element d and current i is inversely proportional. However, the thickness of LN crystal is 0.5mm, so thinning processing is necessary.

The methods of wafer [4,5] thinning usually include: milling, reactive ion etching, ion milling, wet etching, etc. Considering rapidly removing a large number of LN crystals to get LN film, we chose to use lapping principle. The paper introduces a kind of process on polishing and thinning LN wafer. SKCH -1 precise thickness gauge tests the thickness of the thinned wafer, and CMPS-5500 AFM tests and analyses wafer surfaces morphology. Finally, pyroelectric signal of the thinned and polished LN wafer is tested. After test, it indicates that LN wafer is not caused internal damage .

Experimental method

Fig 1 Flow chart of the progress introduces a kind of new method about wafer bonding[6], thinning and polishing.

1) Use RZJ - 304 glue to combine silicon chip with LN wafer. Gluing speed is 2000 r/min. Bonding tempe- rature is100℃. Bonding time is 90s.

2) Utilize UNIPOL-802 and GPC-50 precise polishing controller to process LN wafer. In the process, polishing paste is used as abrasives, and synthetic resin film is used as polisher.

3) The thinned LN wafer will be peeled off from silicon slice by the relevant stripping liquid.

4) Utilize acetone to clean LN wafer twice by ultrasonic.

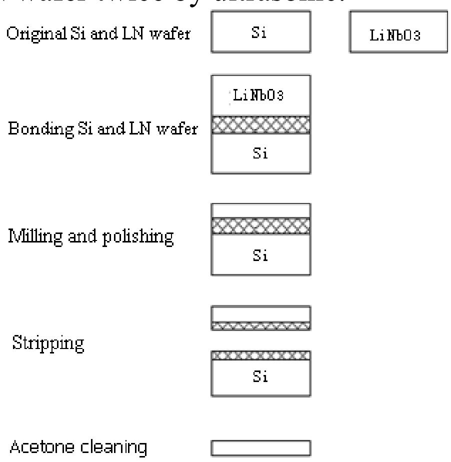

Fig1. Flow chart of the progress

The process have the following advantages：

1) It is simple, low cost and easy achievement.

2) It is simple to produce large and thin LN wafer

3) It is convenient to peel off and clean bonding wafer.

4) RZJ-304 glue possesses high thermal stability. It has the following advantages in wafer bonding: a. Curing temperature is low; b. Leveling ability is strong; c. Curing process does not need catalysts and produce by-products; d. Adhesion is high; e. Contractibility rate is small in solidified process. After bonded by RZJ-304, LN wafer's bearing stress is small and LN wafer is not broken easily.

Experimental results and analysis

After thinning and polishing, test thickness of LN wafer and surface roughness. At last, design preamplifier circuit[7] to test pyroelectric performance.

Thickness measurement. Thickness as the purpose of wafer thinning is very significant to pyroelectric sensitive element. When it is made into pyroelectric sensitive element, LN wafer has the thinner thickness, the smaller value of thermal capacitance and the shorter response time. Utilize SKCH-1 precise thickness gauge to test thickness measurement of LN wafer. Take five points on the surface to test in 10mm×10mm. As shown in table 1, the thickness of LN wafer is about 50um, and so it shows that the thickness of thinning wafer is relative uniform.

Table 1 Thickness at different points after Grinding

Position	1	2	3	4	5
Thickness	50um	51um	52um	50um	51um

The measure of surface morphology. Fig2 and Fig3 are respectively two-dimensional and three-dimensional morphology figure images of LN wafer tested by CMPS-5500 AFM[8]. Through CSPM imager 4.60 software observing and analysing images, we can know its surface is very smooth, its quality is good and the surface roughness is 1.63nm. Fig 4 shows that, after thinning and polishing, the biggest peak of LN wafer surface morphology value is 16nm.

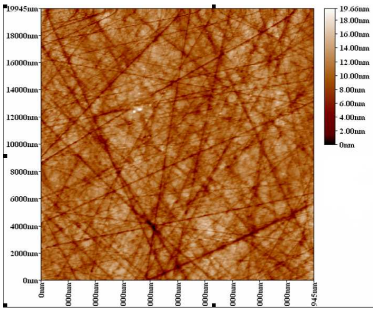
Fig2. 2D morphology figure images by AFM in LN wafer after thinning

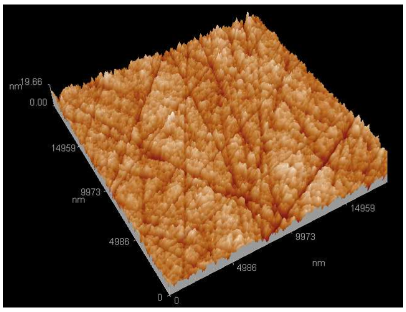

Fig3.3D morphology figure images by AFM in LN wafer after thinning

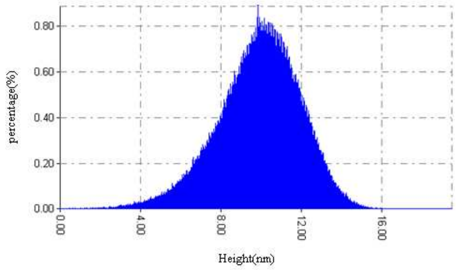

Fig4. The altitudinal analysis in LN wafer

There are six reasons leading to surface[9,10] of LN wafer to damage: a. the crystal orientation of LN crystals; b. the size of the abrasive; c. Grinding pressure; d. Grinding curvature radius; e. Grinding time; f. Grinding speed.

To solve these problems, we choose glass grinding plate to decrease grinding pressure; we must also choose the small hardness and good morphology abrasive as polishing materials. In grinding and polishing process, configure the appropriate concentration abrasive and ensure sufficient abrasive supply, and meanwhile decrease grinding curvature radius and the grinding speed so that we can reduce LN wafers' direct scratches by grinding plate.

Pyroelectric performance test. There is no doubt that LN wafer is a promising pyroelectric material[11]. Whether it still possesses pyroelectric performance after thinning and polishing is we mainly concern about. Fig 5 is Schematic diagram of LN wafer pyroelectric characteristics. When the pyroelectric materials absorb infrared radiation, its temperature will have a small change and so does its spontaneous polarization. At the same time, there will have charge change on both sides of the wafer that is pyroelectric phenomenon. Measurement principle is described as above. First the preamplifier circuit turns pyroelectric current into voltage signal which will be amplified. Then, show it on an oscilloscope。

Pyroelectric current expression is:

$$i = PA\frac{dT}{dt} \tag{2}$$

Where: i is pyroelectric current; p is the pyroelectric coefficient of wafer; A is the electrode area of wafer; dT/dt is wafer' change rate of temperature with time; As equation (2) shows that pyroelectric current changes can be measured when dT/dt changes.

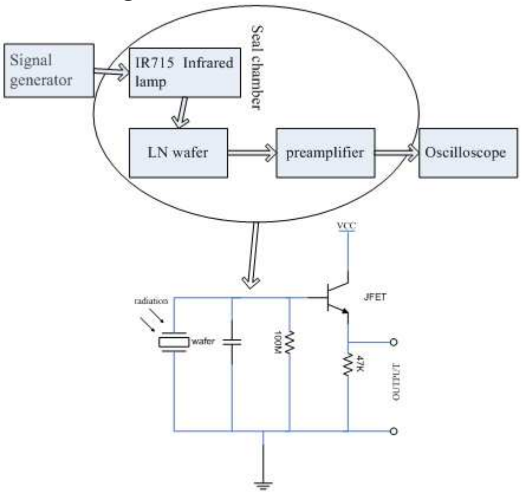

Fig5. Schematic diagram of LN wafer pyroelectric characteristics

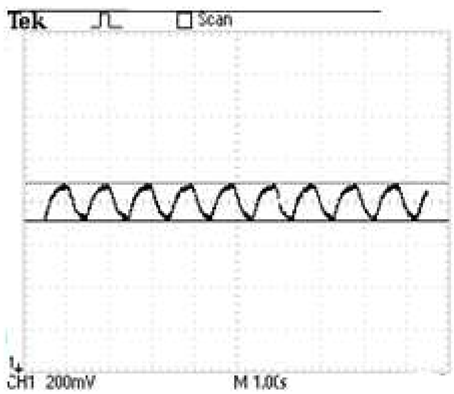

Fig6. The pyroelectrc response of LN wafer

In the experiment, the thickness of LN wafer is 50um, the area of electrode is 25mm^2. The signal generator gives a sinusoidal signal whose frequency is 1HZ and peak value is 5V. Pyroelectric signal is 176 mv on the oscilloscope, as shown in Fig 6.The results show that after the thinning and polishing process, there is no damage to the crystal and pyroelectric performance is good.

Conclusions

The paper introduces a kind of process about wafer bonding, thinning and polishing. The method is simple, low-cost and easy for industrial production. It can also realize the large LN wafer to be thinned and polished. The thickness of LN wafer can be reduced to 50um. After polished, the surface roughness can achieve 1.63 nm. The application of RZJ-304 makes the LN wafer and Si wafer which have been bonded and thinned separated easily and won't cause any damage to LN wafer. Finally, the concrete test method is put forward to verify the existence of processed LN wafer's pyroelectric characteristics. This process can offer some references for wafer's polishing and thinning.

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