Preparation Process of Through Glass Via Based on Laser Induced Deep Etching

Dongming Xing, Chuncheng Che*, Xuecheng Hou*, Xiaodong Li*, Yunlong Ning*, Hailong Lian*， Qi Wang *,Hongjie Zhao*

*** Beijing BOE Sensor Technology Company, Ltd., Beijing, China**

Abstract

In this paper, the process of preparing through glass via (TGV) by laser induced deep etching(LIDE) was studied, the TGV prepared by laser induced deep etching was characterized and analyzed, the relationship between glass characteristics and TGV properties was explored, the influence mechanism of wet etching process on TGV morphology was analyzed ， and the characterization standard of TGV was established.

Author Keywords

LIDE; TGV; Glass characteristic；Wet etching process； The characterization standard.

1.Introduction

The proportion of advanced packaging in the semiconductor industry has steadily increased, and its development is closely related to the evolution of through-hole interconnect technology and the improvement of processing accuracy. In the era of high-density, highly integrated advanced electronic systems, it is critical to realize the intermediary layer and substrate for high-performance SiP and AiP applications[1,2]. Glass substrate has the advantages of high heat resistance, low coefficient of thermal expansion, high electrical insulation, high mechanical strength and small link spacing, and is expected to achieve cost reduction after large-scale production, and will become an innovative force leading the development of substrate. Through Glass Via (TGV) is a vertical electrical interconnection technology that passes through a glass intermediate layer or chip and acts as an alternative to TSV. Large glass panels are easy to obtain, reducing process complexity and processing costs, so TGV is expected to replace TSV in some scenarios, and thus become one of the core evolution directions of advanced packaging in the AI era.[3-5]

One of the main difficulties restricting the development of TGV technology is the TGV hole forming technology, which needs to meet a series of requirements such as high speed, high precision, narrow pitch, smooth side wall, good verticality and low cost. Over the years, a lot of research work in the industry and academia has been devoted to the development of low-cost, rapid and large-scale production of pore formation technology, which has formed at least seven process methods, including sandblasting, photosensitive glass, focused discharge, plasma etching, laser ablation, electrochemical and laser induced etching[6,7]. The laser induced etching method induces continuous denaturation zone of the glass by pulsed laser, changes the Si-O bond energy bond Angle, forms a nano channel, and increases the corrosion rate of the glass material in the channel in HF/NaOH and other solutions[8,9]. Based on this characteristic, TGV can be formed on the glass with a thickness of 50-500μm. The technique has the advantages of uniform pore quality, good consistency, no crack, fast pore formation rate, adjustable TGV morphology, and large scale application prospect.

There is a lack of systematic research on the preparation of TGV by laser-induced deep etching. In this paper, the TGV of various types of glass prepared by laser-induced deep etching is characterized and analyzed, aiming to study the relationship between the characteristics of glass and the properties of TGV and the mechanism of the effect of etching on the morphology of TGV.

2. Experiment Process

Experimental materials were selected from Six kinds of 8-inch glass,which were Type1, Type2, Type3, Type4, Type5 and Type6. The glass thickness was 560μm. The laser equipment used in the experiment is LPKF Vitrion S5000. Wet etching equipment is RENA BatchGlass N50/ ZSE ZCWB-A3, etching liquid 50% NaOH / 6% HF.

Laser induced by deep etching process (LIDE) preparation of glass hole, as shown in Figure 1. First, the glass raw material is thinned to make standard glass that can make TGV thickness, as shown in Figure 1a. Glass cleaning to remove the glass surface impurities, and then for laser induced modified, as shown in Figure 1b. Finally, the TGV was prepared by wet etching (50% NaOH at 100℃ / 6% HF at 22℃), as shown in Figure 1c.

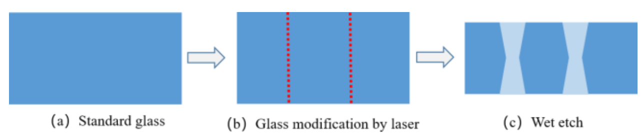
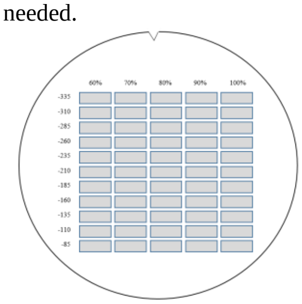


Figure 1. Process flow of laser induced deep etching (LIDE) to prepare through glass via.

To determine the laser parameters, it is necessary to use focus job to find the optimization conditions, as shown in Figure 2, that is, adjust the laser variable parameter Offset/Energy, control the modification depth and the roundness of the etch hole. On a single substrate, hundreds of Split Settings and verification can be achieved at a time. After wet hole opening, the optimal laser conditions are selected through the test of each split CD and cross. Because the Focus Job area on the substrate is small, the selected main needs to be enlarged and verified again to confirm whether fine-tuning is needed.



Via	Glass		Focus Job Parameter				Main Parameter	
TGV	Type	THK (um)	Offset (um)	Step (um)	Energy (%)	Step (%)	Offset (um)	Energy (%)
	A	560	-85 ~ -335	25	60~100	10	x	y

Figure 2. Laser Focus Job and parameter selection

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3.Experiment results

3.1 Relationship between glass properties and TGV properties

Table 1 shows the physical properties of each glass substrate (Type1 is licate glass and other glasses are Alkali free boral aluminosilicate glass), the etching rate of 50% NaOH wet etching at 100℃ and the TGV measurement results.

Etching rate of each type of glass, as shown in Figure 3a. ER(Hole) of licate glass is faster than ER(Face). Alkali free boral aluminosilicate glass is ER(Face) faster than ER(Hole). ER and waist diameter there is negative correlation, as shown in Figure 3b, the ER (Face) is in the ER (Hole) increases, the more of the TGV waist, the smaller the diameter, the longitudinal etching faster than lateral etching, the more the faster aperture shrinkage, The smaller the waist diameter formed.

As shown in Figure 3c,in Alkali free boral aluminosilicate glass, the larger the Hardness, the larger the TGV waist diameter, it can be understood that the greater the hardness, the more the longitudinal etching of the glass will be inhibited. The larger the waist diameter forming the TGV. According to the experimental results, it is found that Density is positively correlated with Roundness. As shown in Figure 3d, the roundness of TGV aperture formed by glass substrate with higher density is greater.

Table 1 The physical properties of glass substrate, the etching rate and the TGV measurement data were obtained

Items	Project	Type1	Type2	Type3	Type4	Type5	Type6
Characteristic of glass substrate	Density ρ[g/cm^3]	2.23	2.38	2.59	2.38	2.38	2.48
	Young modulus E[GPa]	64	73.6	83	73.6	73.2	71.3
	Poisson ratio	0.2	0.23	0.23	0.23	0.22	0.26
	Hardness [kgf/mm^2]	480	640	643	640	646	600
	CTE	3.25	3.4	3.7	3.17	3.3	3.8
ER (50% NaOH 100℃)	Face [µm/h]	3.7	5.6	4.3	5.7	5.9	5.8
	Hole [µm/h]	3.8	4.9	3.7	5	5.2	4.8
TGV Data	Top CD [µm]	62.7	61.3	56.03	59.66	61.19	47
	Top Roundness	95.2%	97.5%	98.0%	97.0%	96.5%	97.1%
	Top CD Tol [µm]	1.62	2.8	2.33	2.46	2.1	1.72
	Bottom CD [µm]	60.23	61.25	61.73	56.48	50.91	47.3
	Bottom Roundness	93.8%	97.1%	97.8%	95.9%	96.1%	96.1%
	Bottom CD Tol [µm]	0.42	1.95	2.67	4.21	1.56	0.83
	Taper Angle	0.8 °	2.9 °	2.7 °	2.6 °	2.5 °	3.8 °
	waist radius [µm]	56	37	35	36	40	31

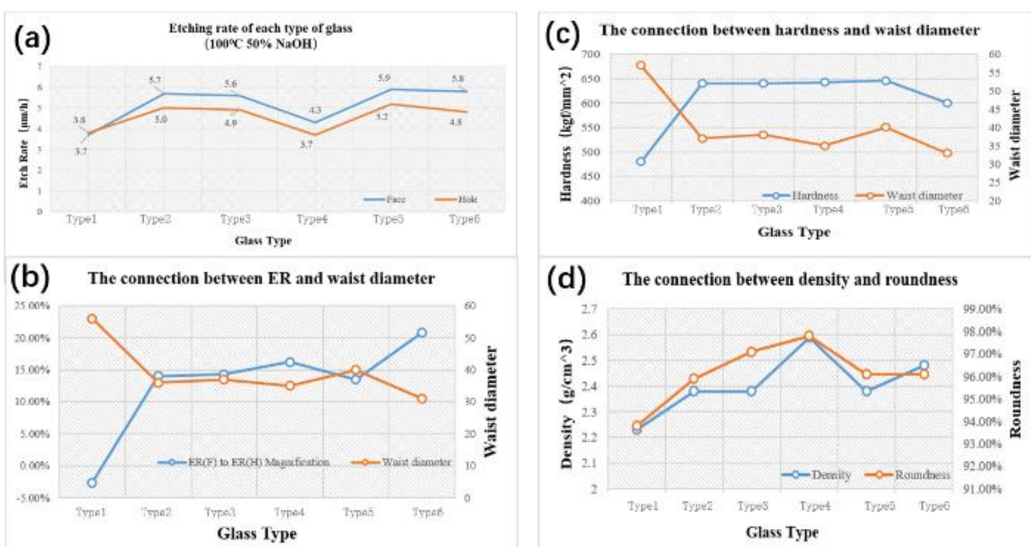

Figure 3. (a)Etching rate of each type of glass(100℃ 50% NaOH);(b) The connection between ER and waist diameter;(c) The connection between hardness and waist diameter;(d) The connection between density and roundness

3.2 Effect of etching process on TGV morpholog

TGV wet etching includes high-temperature alkali solution etching and hydrofluoric acid solution etching. The principle of etching is that the solution is modified by laser induction to generate nano holes, and the longitudinal laser induced damage area is quickly removed to form initial long holes, and the solution is carried out transverse etching after entering the depth of TGV. The reaction ionizer in the TGV pore depends on the circulation rate of the solution and the concentration difference of the solution to make the outer ionizer move inward and replenish. As the thick degree lower will cause the TGV hole of charged ions in a timely manner to fill the experiment is made of 100 ℃ and 50% NaOH solution, 22 ℃ 6% HF solution Type1 etching rate are respectively 3.8 mu m/h and 10 mu m/h, The etching rates of Type2 are 5μm/h and 60μm/h, respectively. The microstructure of Type1 glass TGV etched by NaOH solution and HF solution is shown in Figure 4a and b. The microstructure of Type2 glass TGV etched by NaOH solution and HF solution is shown in Figure 4c and d.

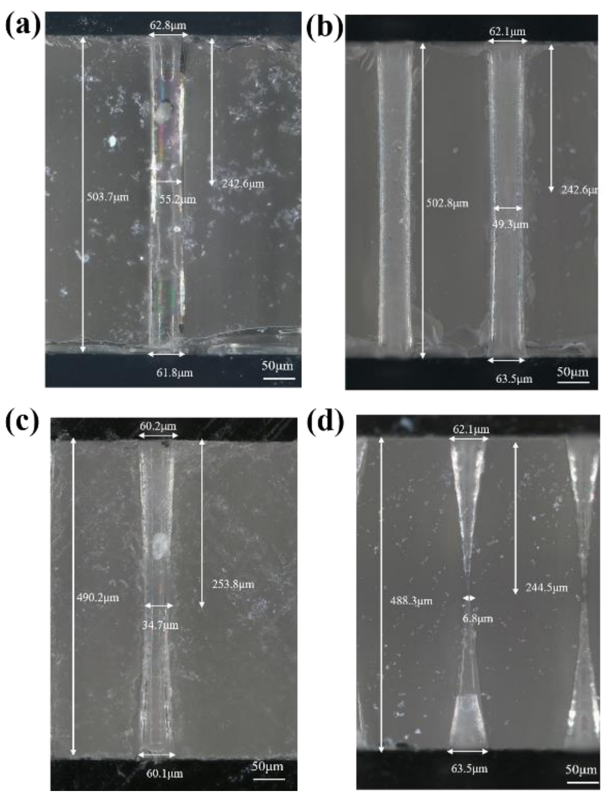

Figure 4. (a)Microstructure of Type1 NaOH etching; (b) Microstructure of Type1 HF etching;(c) Microstructure of Type2 etching;(d) Microstructure of Type1 HF etching

The Taper Angle of TGV prepared by NaOH solution is small and the waist diameter is larger. The main reasons are slow etching rate, long transverse etching in the TGV hole, fast solution circulation and OH- diffusion at high temperature, resulting in more transverse etching. The TGV Taper Angle prepared by HF solution is large and the waist diameter is small, which is due to fast etching rate, short transverse etching time in TGV hole, slow circulation of normal temperature solution and slow diffusion of F- into hole. The mechanism diagram is shown in Figure 5.

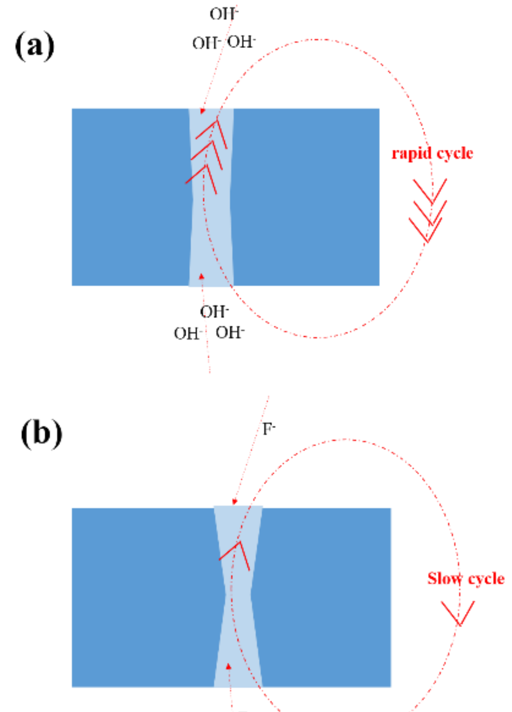

Figure 5 . (a)Schematic of NaOH etching; (b) Schematic of HF etching;

3.3 Standard of TGV representation

Through experimental summary, the characterization standard of TGV has been established, as shown in Table 2. 1) The incoming inspection of glass substrates, including Pre-etching thickness and RA; 2) Procedural Test, including Top & Bottom CD, Tol., Roundness and Thickness/RA after etching, 3) Wafer Fracture Test: waist radius, Waist diameter position taper angle and pore wall morphology and defects.

Table 2 Standard of TGV characterization

NO.	Items	Spec	Tool	Test Result	Remark
Incoming Quality Control	Pre-etching thickness	/	Wafer geometry		
	Pre-etching RA	< 100nm	AFM		
Procedural Test	Thickness after etching	500±5μm	Wafer geometry		
	CD (Top & Bottom)	Top & Bottom 62.5±3μm	Optical Microscope		
	CD Tol.	±3	Optical Microscope		
	Roundness	> 95%	Optical Microscope		
	RA after etching	< 100nm	AFM		
Wafer Fracture Test	waist radius	37.5±3μm	Optical Microscope /SEM		
	Waist diameter position	250±20μm	Optical Microscope /SEM		
	Taper Angle	< 2°	Optical Microscope /SEM		
	Pore wall morphology and defects	Smooth side wall No dirt, cracks, particles, etc.,	Optical Microscope /SEM		

4. Conclusion

The TGV of several types of glass prepared by laser induced deep etching was characterized and analyzed in this paper. The results were got as following:

(1) Glass properties have an important relationship with TGV morphology: a) In Alkali free boral aluminosilicate glass, we can predict the waist diameter and Roundness of TGV according to the Hardness and hardness of the new glass substrate. Hardness was positively correlated with TGV waist diameter; Density was positively correlated with Roundness. b) waist diameter of TGV can be judged based on ER(Face) and ER(Hole). There is a negative correlation between the large increase of ER(Face) and ER(Hole), and the larger the increase of ER(Face) compared with ER(Hole), The smaller the TGV waist diameter that is formed.

(2) The Taper Angle of TGV prepared by NaOH solution is small and the waist diameter is larger. The main reasons are slow etching rate, long transverse etching in the TGV hole, fast solution circulation and OH- diffusion at high temperature, resulting in more transverse etching. The TGV Taper Angle prepared by HF solution is large and the waist diameter is small, which is due to fast etching rate, short transverse etching time in TGV hole, slow circulation of normal temperature solution and slow diffusion of F- into hole.

(3) Standard of TGV representation have been established, including incoming glass substrate testing, process testing and fragment testing. Each part has a detailed characterization list and specification, and it is recommended to be promoted as an industry standard.

5. References

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