第 25 卷第 10 期 半 导 体 学 报 Vol. 25, No. 10
2004 年 10 月 CHINESE JOURNAL OF SEMICONDUCTORS Oct., 2004

Applying Double Electric Fields to Avoid Deteriorating Movable Sensitive Parts in MEMS During Anodic Bonding*

Yang Daohong, Xu Chen and Shen Guangdi

(*Beijing Optoelectronic Technology Laboratory, Beijing University of Technology, Beijing* 100022, *China*)

Abstract: Anodic bonding between silicon and glass with double electric fields is presented. By this means, the damage caused by the electric field to the movable part during bonding can be avoided and the experiment results show that.

Key words: micro-electronic machine system; anodic bonding; double electric fields

EEACC: 2575B; 2575F

CLC number: TN365 **Document code**: A **Article ID**: 0253-4177(2004)10-1249-04

1 Introduction

Bonding technology is one of the key steps for bulk MEMS[1]. There are four different technologies for wafer scale bonding: silicon direct, anodic, eutectic, and adhesive bonding. Anodic bonding is often chosen for wafer bonding at moderate temperature (< 500℃), because this technology has been shown to be reliable and reproducible[2~4].

The process of anodic bonding depends heavily on 800~ 2000V DC voltage put on would-be sealed and packaged apparatus. The sealed and packaged parts will bond together under the function of chemical changes caused by the static power. However, this DC voltage is also put on the rest of the movable sensitive parts, which will not be sealed and packaged, therefore the sealed and packaged parts may be deteriorated, in quality and property. So many improvements have been made on anodic bonding[5~10], but none of them is fairly ideal, which greatly limits the use of the anodic bonding method in the field of MEMS.

Applying double electric fields in anodic bonding is proposed in this paper, which brings a solution to the problem mentioned above. In the course of anodic bonding, to protect the movable sensitive parts, we balance the electric field power biased on the movable sensitive parts of the MEMS apparatus by two opposite electrodes. This method is successfully applied in the bonding between silicon with ultrathin sensitive film and glass, and an ideal result is gotten.

2 Theory of double electric fields bonding

The schematic of anodic bonding method with double electric fields is shown in Fig. 1. Assuming the voltages put on the upper glass (or silicon) and the lower glass (or silicon) are V_1, V_2, respectively, and the distances between the movable sensitive part and the glass are respectively D_1, D_2, the electric power on the sensitive films put by the upper

* Project supported by Beijing Committee of Education Foundation (No. KM200310005009)

Yang Daohong male, was born in 1975, PhD candidate. His research interest is in MEMS device design and technics based on silicon. Email: daohongyang@emails.bjut.edu.cn

Received 10 December 2003, revised manuscript received 22 April 2004

and the lower electric fields will be different. If the sensitive movable parts of the apparatus are not damaged in the course of anodic bonding with single electric field, the voltage(V) must satisfy the following condition:

$$V \leqslant \frac{2hD_1}{3R}\sqrt{\frac{\sigma_e}{\epsilon_0\sqrt{\mu^2-\mu+1}}} \qquad (1)$$

where ϵ_0 is the dielectric constant, R is the radius of the membrane, h is the thickness of the film, μ is the coefficient of the film, σ_e is the submitted stress of the silicon film.

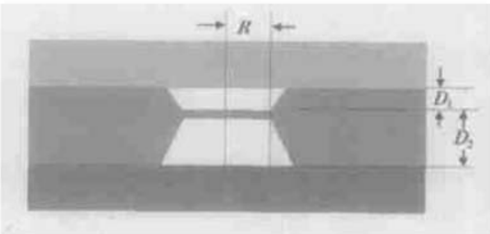

Fig. 1 Schematic anodic bonding method with double electric fields

When the material is crystalline silicon film, the parameters are: the submitted stress of the silicon film σ_e= 7GPa, μ= 0.22. The film thickness often used in MEMS currently is: h= 0.8μm, R= 1500μm, D_1= 3.0μm, then the following can be obtained:

$$V \leqslant 31.435(\mathrm{V}) \qquad (2)$$

However, the voltage biased on conventional anodic bonding cannot be less than 700V, so under the condition of V_1= 700V, if there is no special treatment, the film will be deformed or even damaged by over electric field force. So in the sealing and packaging of some high sensitive MEMS apparatus, glue has to be adopted, which will greatly affect the property index of the apparatus, therefore the using range of anodic bonding is greatly limited[12~17]. If an electric field V_2 is biased on silicon or glass in the course of anodic bonding (as shown in Fig. 1), the result of forces received by the thin film will be greatly reduced. So, while designing the film, we need not consider the damage by static electric force during anodic bonding.

3 Experiment and results

The size of the silicon 〈100〉 sample is 1.5cm × 1.5cm × 360μm with resistanceover 30Ω · cm and with both sides polished. The 3000μm × 3000μm silicon film with 0.8μm thickness was made by stopping etching technique of heavy boron diffusion. The property of the used glass is 1cm × 1cm × 1mm Corning Pyrex7740. The treatment is as follows: after being brushed, the silicon and glass to be bonded were ultraromidly cleaned respectively by acetone and ethanol for about 20min and then were washed several times and dried by infrared bake.

Based on the above fundamental theory of anodic bonding with double electric fields, this thesis adopts the self-fixed equipment (as shown in Fig. 2), which is improved based on the original anodic bonding equipment with single electric field.

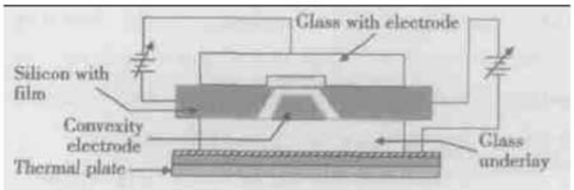

Fig. 2 Structure of anodic bonding method with double electric fields

It has a humidistat as its basic body, which provides the heat it needs. Between the electrode and the humidistat, there is a flake of china. From the top to the bottom in turn, there are heat board, a flake of china, copperplate, glass plated with titanium, silicon slice, and glass would be bonded aiming at the silicon slice.

The needle-mode electrode can increase the contacting strength at the beginning stage of bonding. The voltage of silicon slice in the middle is put on by four tungsten probes from sides. Put the direct electric field V_1 and V_2 respectively between the glass or the silicon slice and the silicon or the glass slice. The relation of V_1 and V_2 is V_1/V_2= $D_2/$

D_1. In the practical course of bonding there are the following conditions: $D_1 = D_2 = 3.0\mu m$, the values of V_1 and V_2 both are 1000V, the voltage is provided by a high and stable tension mains, and the property of electric current can be observed on an ammeter. The temperature in bonding is 350℃.

Put the aimed glass or silicon slice on the china slice, and increase the temperature to 350℃ after adding mass lumps and two pairs of electrodes. Meanwhile V_1 and V_2 are increased to 1000V. Under the same conditions, the time needed to complete the bonding with double electric fields is less than that with a single electric field.

Figure 3 shows the thin film SEM photograph after anodic bonding with double electric fields, while Figure 4 shows the thin film stuck to the glass optical photograph after single electric field anodic bonding.

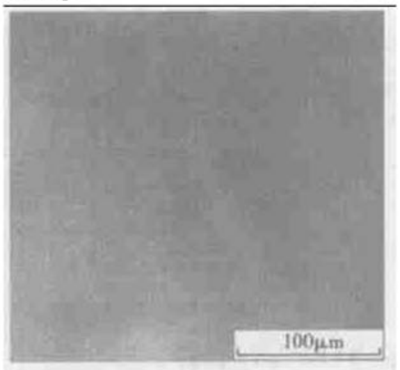

Fig. 3 Thin film SEM photograph after anodic bonding with double eclectics fields

Fig. 4 Thin film stuck to the glass optical photograph (×50) after single electric field anodic bonding

Figure 5 shows the SEM photograph in a cross-sectional view of interface after anodic bonding with double electric fields. There are no interspaces at the interface between silicon and glass. Figure 6 shows the sodium, silicon, and oxygen distribution across the bonded interface between glass and silicon after bonding with double electric fields.

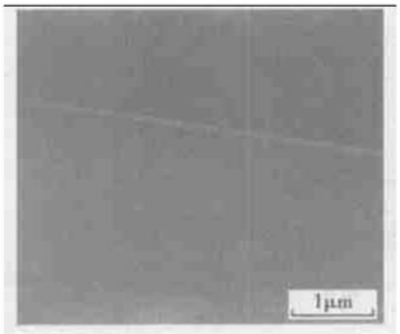

Fig. 5 SEM photograph view of interface after anodic bonding method with double electric fields

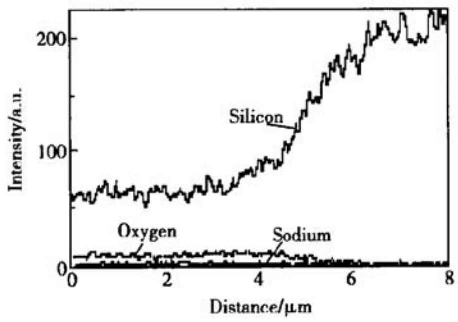

Fig. 6 Sodium, silicon, and oxygen distribution across the bonded interface between glass and silicon after anodic bonding method with double electric fields

Figure 7 shows changes of the anodic bonding current density with double electric fields together with single electric field. The finished bonding time is about 20min.

According to Fig. 3 and Fig. 6, we can come to the following conclusion: after the bonding is completed, the quality of the bonding is equal to that in bonding with single electric field, and the ultrathin sensitive film and its structure are not aberrant.

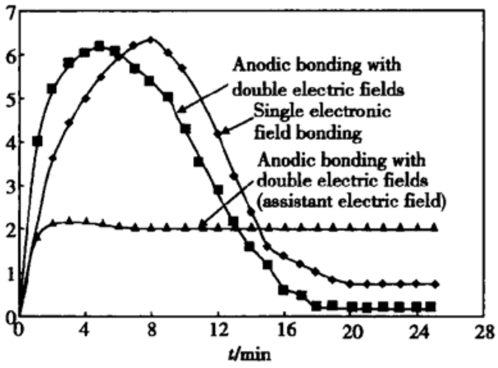

Fig. 7 Anodic bonding current density with double electric fields and single electric field

4 Conclusion

Based on the experimental studies, we find out that the method of anodic bonding with double electric fields not only can completely and effectually overcome the damages to the movable parts of MEMS caused by the anodic bonding with single electric field, but also is simple in operation. The method of anodic bonding with double electric fields is an attractive new method.

References

[1] Wallis G, Pomerantz D I. Field assisted glass, metal sealing. Appl Phys, 1969, 40: 39

[2] Rogers T, Kowal J. Selection of glass, compatibility anodic bonding conditions for silicon-glass capacitive and material sensors. Sensors and Actuators A, 1995, 4H7: 113

[3] Puers B, Peeters E, Van Den Bossche A, et al. A capacitive pressure sensor with low impedance output and active suppression of parasitic effects. Sensors and Actuators A, 1990, 23: 108

[4] Enikov E T, Boyd J G. A thermodynamic field theory for anodic bonding of microelectro-mechanical systems (MEMS). Inter J Eng Sci, 2000, 38: 135

[5] Chauffleur X, Blasquez G, Pons P. Influence of the bonding conditions on the response ofcapacitive pressure sensors. Sensors and Actuators A, 1995, 46/47: 121

[6] Blasquez G, Favaro P. Silicon glass anodic bonding under partial vacuum conditions: problems and solutions. Sensors and Actuators A, 2002, 101: 156

[7] Mescheder U M, Alavi M, Hiltmann K. Local laser bonding for low emperature budget. Sensors and Actuators A, 2002, 97/98: 422

[8] Huang J T, Yang H A. Improvement of bonding time and quality of anodic bonding using the spiral arrangement of multiple point electrodes. Sensors and Actuators A, 2002, 102: 1

[9] Bayrashev A, Ziaie B. Silicon wafer bonding through RF dielectric heating. Sensors and Actuators A, 2003, 103: 16

[10] Despont M, Gross H, Arrouy F. Fabrition a silicon-pyrex-silicon stack by a. c. anodic bonding. Sensors and Actuators A, 1996, 55: 219

应用双电场减小阳极键合过程中MEMS器件可动部件的损伤*

杨道虹 徐 晨 沈光地

(北京工业大学电子信息与控制过程学院, 北京市光电子技术实验室, 北京 100022)

摘要: 提出了采用双电场对硅/玻璃进行阳极键合的方法. 采用这种方法, 能够有效地避免和减少键合过程中的静电力对MEMS器件的可动敏感部件的损伤和破坏, 同时实验结果也验证了该方法.

关键词: 微电子机械系统; 阳极键合; 双电场

EEACC: 2575B; 2575F

中图分类号: TN365 **文献标识码**: A **文章编号**: 0253-4177(2004) 10-1249-04

* 北京市教委资助项目(批准号: KM200310005009)

杨道虹 男, 1975年出生, 博士研究生, 现主要从事半导体光电子学和MEMS研究.

2003-12-10收到, 2004-04-22定稿