파일렉스 #7740 글라스 매개층을 이용한 MEMS용 MCA와 Si기판의 양극접합 특성

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Anodic bonding characteristics of MCA to Si-wafer using Pyrex #7740 glass intermediatelayer for MEMS applications

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Abstract: This paper describes anodic bonding characteristics of MCA to Si-wafer using evaporated Pyrex #7740 glass thin-films for MEMS applications. Pyrex #7740 glass thin-films with the same properties were deposited on MCA under optimum RF sputter conditions (Ar 100 %, input power 1 W/cm^2). After annealing at 450℃ for 1 hr, the anodic bonding of MCA to Si-wafer was successfully performed at 600 V, 400℃ in 110^{-6} Torr vacuum condition. Then, the MCA/Si bonded interface and fabricated Si diaphragm deflection characteristics were analyzed through the actuation and simulation test. It is possible to control with accurate deflection of Si diaphragm according to its geometries and its maximum non-linearity being 0.05-0.08 %FS. Moreover, any damages or separation of MCA/Si bonded interfaces did not occur during actuation test. Therefore, it is expected that anodic bonding technology of MCA/Si-wafers could be usefully applied for the fabrication process of high-performance piezoelectric MEMS devices.

Key Words: anodic bonding, MCA, Pyrex #7740 glass, intermediate layer, MEMS

1. INTRODUCTION

Piezoelectric ceramics are being widely used to fabricate the MEMS devices with high-performance as well as electronic devices. Particularly, they have several advantages, such as a larger generative force, quick response, and smaller drive voltage more than electrostatic, electro-magnetic, pneumatic forces. Additionally, many works are widely in progress to use piezoelectric ceramics for micro-control units such as medical drug delivery systems or chemical analysis systems[1]. Recently, these MEMS devices have been fabricated by using piezoelectricthin-film type ceramics are employed as the driving principle. However, piezoelectric thin-film type ceramics have some problems such as a slow response, insufficient driving forces and low resonance frequency. Therefore, in the future, it is expected that multilayer ceramic actuators (MCA) would be substituted for piezoelectric thin-film ceramics to use actuating part in MEMS devices with a good thermal-loss quality, displace-ment accuracy and low power consumption[2].

Currently, MCA and Si bonding techniques become more important to keep the MCA accurate deflection and a formation of perfect bonding in a non-bonded area. Up to now, the organic adhesive materials (e.g. epoxy) have been mainly used when MCA/Si bonding process is need. However, the adhesive materials used in the bonding process have their inherent disadvantages. Consequently it is impossible or too difficult to control the adhesive materials thickness and the bond strength is variable as a function ofthe rate of the hardener. Meanwhile, anodic bonding of Si to glass is required for many MEMS devices (typically Pyrex #7740 is used), which has dielectric characteristics. The several advantages of anodic bonding have been previously reported in some papers[3-5]. Anodic bonding can be used in low temperature below 500℃, and heat resistance and reliable bond strength (more than 350 psi) of bonded sample was larger than other methods.

The aim of this work is to analyze the anodic bonding propertiesbetween MCA and Si, and to develop the high-performance MEMS devices without deterioration of the bond characteristics. Thus, in this paper, the Pyrex #7740 glass thin-film wasformed onto MCA surface in various RF sputtering conditions, and surface roughness and composition ratio of the glass thin-films analyzed by AFM, XPS and Profilometer, respectively. Finally reliability of the anodic bonded samples was evaluated through the actuation and simulation test using FEM modeling

2. EXPERIMENTAL

A sodiumcontaining Pyrex #7740 glass was deposited onto a MCA surface by RF sputtering. The MCA and the Si substrate put through the bonding process in the anodic chamber for 30 minutes when a voltage of 600 V was applied at a temperature of 400℃. And then, we evaluated the interface characteristics between MCA, Pyrex #7740 glass thin-film and Si substrate.

3. RESULTS AND DISCUSSION

Our experiment, between the MCA and the hydrophilic disposed Si substrate, the bonding process was performed at 400℃, 600 V. Fig. 1 shows SEM image of successfully bonded MCA/Si interface. It is confirmed that the MCA/ Si samples are perfectly bonded by electrostatic forces in a non-bonded surface. Also, anodic bonding is successful 1.5 ㎛ glass thickness at least,because surface roughness is more decreased with increasing glass thickness. Thus, when forming the intermediate layer, the glass thin-films deposited a minimum of 1.5 ㎛ to improve glass surface roughness.

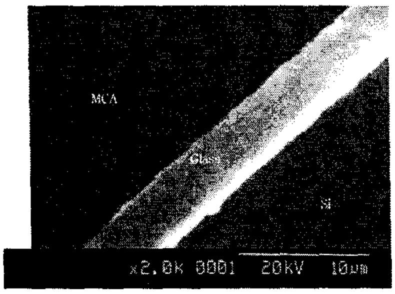
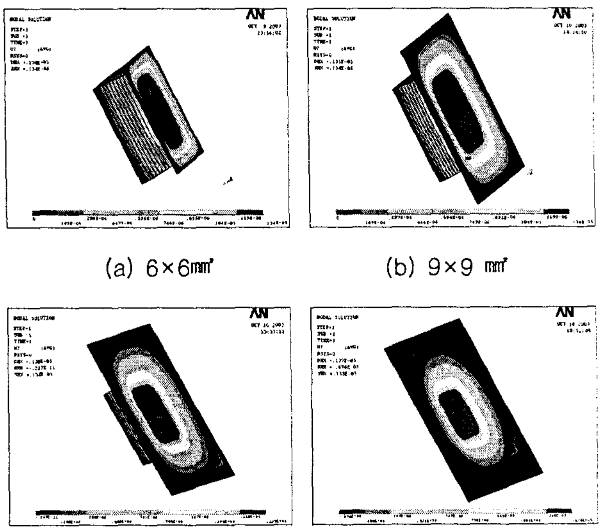


Fig. 1. SEM image of the MCA/ Si bonded interface.

Fig. 2. shows simulation results of MCA deflection as a function of the Si diaphragm dimensions. Although Si diaphragm dimension was changed from 66 mm^2 to 1515 mm^2, MCA deflection was almost constant. But, in experiment results, measured values slowly increased as a function of Si diaphragm thickness. It is confirmed that simulation results are agree with measurement value from 1010 mm^2 to 1212 mm^{2}diaphragm dimension



(a) 6×6㎟ (b) 9×9 ㎟

(c) 12×12 ㎟ (d) 15×15 ㎟

Fig. 2. Deflection results of the MCA/actuator die as a function of Si diaphragm dimension.

The analytical comparison between the simulation and the experiment results are shown in Fig. 3. With increasing diaphragm thickness up to 500 ㎛, the maximum deflection values at the center were much smaller than the simulation results. It looks as though used material properties in simulation were little different, such as a Si Young's modulus and boundary conditions. Meanwhile, any damage or separation of MCA/Si anodic bonded samples did not occur during actuation test. Based open the experiment results, MCA/Si anodic bonding technology will need to meet the fabrication of the actuating part using MCA/Si diaphragm structures, which have a good bond strength, perfectly bonded area and accurate deflection control.

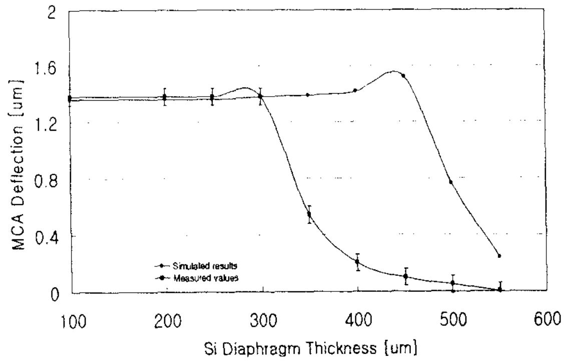


Fig. 3. Analysis of the deflection at the Si diaphragms as a function of diaphragm thickness.

4. CONCLUSIONS

In this work, we have shown that successful bonding using the sputter deposited Pyrex glass #7740 thin-films carried out for MEMS applications. IUsing these deposited glasses, the MCA/Si samples were perfectly bonded by electrostatic forces in a non-bonded surface at 400℃, 600 V conditions. Also, we evaluated the linear characteristics and deflection distributions of MCA/Si bonded samples through the actuation test. As simulation results of thick diaphragm over 400 ㎛, the partial cracks did occur MCA/Si bonded surfaces. But during the actuation test, separations of MCA/Si bonded samples were not observed. In conclusion, it is expected that the MCA/Si bonding process could be usefully applied for MEMS applications.

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