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A Novel Laboratory Anodic Bonding Device for MEMS Applications

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Abstract:
The article deals with a novel laboratory anodic bonding device. This device is used for MEMS creation. The anodic bonding is a method for joining glass with silicon. It is one of the important steps of MEMS components packaging. The bonding mechanism joins the glass and silicon by heating them above 400 °C and by applying an external DC electric field in a range of 500 – 1000 V. The bonded region can be seen easily through the glass because it changes the color to gray. The measured bonding strength is over 15 MPa and the cracks occur on the glass, i.e. the bonding strength is over the mechanical strength of the glass.

INTRODUCTION

An anodic bonding is a method for joining glass with silicon. It is one of the important steps of micro electro-mechanical systems (MEMS) components packaging. The method is utilized in the production of numerous MEMS, like inertial sensors, pressure sensors, micro fluidic systems and optical systems [1].
The bonding mechanism joins the glass and silicon by heating them above temperature of 400 °C and by applying an external DC electric field in a range from 500 to 1000 V. When the external electric field is applied beyond the bonding temperature, the positive ions in the glass start to move through the electrostatic field from silicon/glass interface into the cathode (glass) where they are neutralized. This leaves a Na+ depletion layer in the glass near the silicon surface [2]. The electrostatic force and the migration of ions lead to an irreversible chemical bond at the boundary layer between the individual wafers.

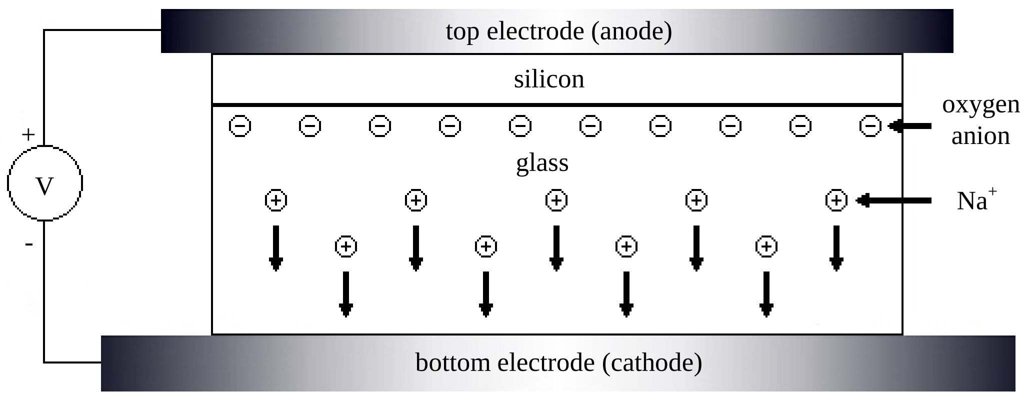

Fig. 1: A cross-sectional view of the Si-glass bonding pair demonstrating the charge distribution during the bonding process.

The voltage should be applied for enough long time to allow the current to settle in a steady state for bonding [3]. The bonded region can be seen easily through the glass because it changes the color to gray.

EXPERIMENTAL

The next chapters describe the experimental process of device fabrication using anodic bonding procedure and the results of this fabrication as well. It is also shown the novel anodic bonding device designed for these purposes.

The anodic bonding process

The schematic of the anodic bonding process is shown in Fig. 1. The Si–glass stack is sandwiched between two electrodes, in which the bottom electrode also acts as a hot plate providing the required temperature for bonding. A special type of glass named SIMAX® is usually used in anodic bonding because of its large sodium cation content and the matched thermal expansion coefficient with that of silicon. The sodium cation plays a key role in this process, as it can migrate under an applied external electric field.

The novel anodic bonding device

The novel anodic bonding device was designed and produced for the fabrication purposes in the experimental. Fig. 2 shows a block scheme of the anodic bonding device. It consists of three stages. The first is control unit with display, the second is circuitry for generation of bonding voltage and last is temperature measurement stage.

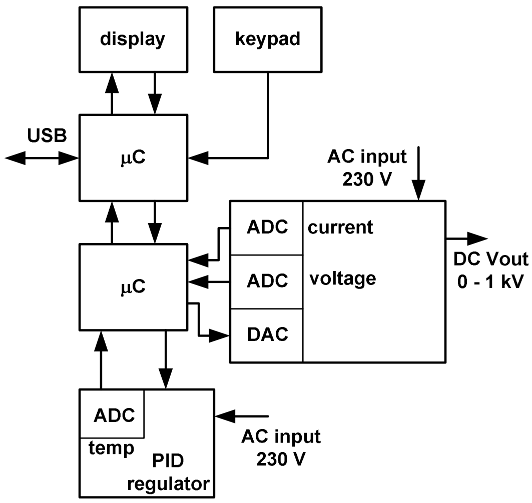

Fig. 2: The block scheme of novel laboratory bonding device.

The photograph of the fabricated laboratory bondinc device is shown in Fig. 3.

Fig. 3: The novel laboratory bonding device.

The control unit with display is user-friendly stage, where user could set various parameters important for anodic bonding. They are temperature and working voltage and bonding time as well. The user can also save the data and proceed them on computer.
The second block consists of many power devices such as transistors, set of capacitors and power transformer. This stage is controlled via user control unit. The important variables – voltage and current are measured by accurate 16-bit ADCs. The accuracy of the voltage and temperature settling is above 1 V and 1 °C respectively.
The third circuitry serves for bonding temperature control. The control, communication (USB standard) and measurement are covered by ATMega microcontrollers.
As can be seen from the photograph, there are three working positions. It means it is possible to fabricate three devices simultaneously. Since the devices suffer from electrostatic charge during the fabrication the Faraday cell is used to avoid such problem.

The fabricated samples

The materials used in the experiment are N-type silicon wafer of 525 µm thickness and also SIMAX® glass wafer of 1 mm thickness. The silicon and glass wafers are cut onto about 5 mm × 5 mm square-shaped dice using a diamond cutter at the beginning. They are ultrasonic cleaned for 5 minutes in water and then ultrasonic cleaned in alcohol for 5 minutes again. Finally the specimens are putted on the graphite cathode electrode and the thermal controller is turned on to heat them up to 425 °C.

When the temperature reaches 425 °C, the DC power supply is turned on to 750 V. The current is monitored during the bonding process to determine whether the bonding process is finished or not. When the current falls to zero, the bonding process is finished. After this the substrates are cooled onto room temperature. The bonded region can be seen easily through the glass, because it changed the color to gray.

RESULTS AND DISCUSSION

The results of the anodic bonding process are shown in Fig. 2.

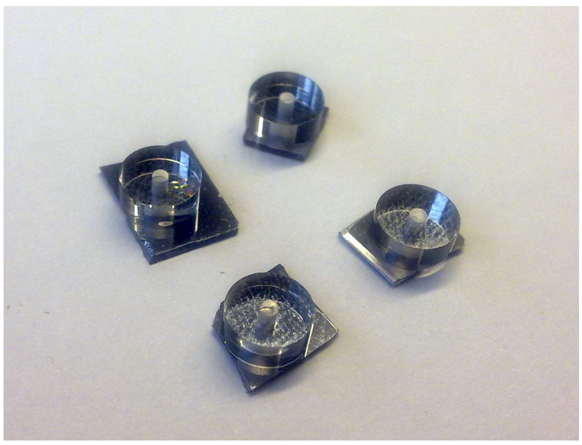

Fig. 4: The testing fabricated devices.

For evaluating the bonding strength, the bonded substrates are glued on holders for tensile testing. The measured bonding strength is over 15 MPa and the cracks occur on the glass, i.e. the bonding strength is over the mechanical strength of the glass. This result shows that the tensile strength is large enough for most MEMS packaging.

The novel laboratory bonding device was fabricated for these purposes.

ACKNOWLEDGEMENTS

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