A Brief Overview of Various Wafer Bonding Techniques Used in the Fabrication of Micro-Electro-Mechanical Systems Devices

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ABSTRACT

Micro-electro-mechanical systems (mems) fabrication is an extremely exciting endeavor due to the customized nature of process technologies and the diversity of processing capabilities. Wafer bonding is a method for fabricating advanced substrates for mems and integrated circuits (IC). Mems fabrication uses many of the same techniques that are used in the IC domain such as oxidation, diffusion, ion implantation, lpcvd, sputtering etc. and combines these capabilities with highly specialized micromachining processes. This work reports on studies of various techniques of wafer bonding and its use in various applications. Different bonding processes used in microelectronics are briefly described here as well

Keywords: Wafer Bonding, MEMS, Metal Layer, Bonding Techniques

INTRODUCTION

Wafer bonding is a micromachining method that is analogous to welding in the macroscale world and involves the joining of two (or more) wafers together to create a multi-wafer stack. There are three basic types of wafer bonding including: direct or fusion bonding; field-assisted or anodic bonding; and bonding using an intermediate layer. Generally, all bonding methods require flat, smooth and clean substrates for the wafer bonding to be successful and free of voids [1].

WAFER BONDING TECHNIQUES

Direct or Fusion Bonding

Direct bonding or fusion bonding generally means any joining of two materials without an intermediate layer or external force. In principle, most materials bond together if their surfaces are flat, smooth and clean. The principle of this method is simple: two flat, clean and smooth wafer surfaces are brought into contact and form a weak bonding based on physical forces. The physical forces can be Van der Waals forces, capillary forces or electrostatic forces [2, 10-11]. The wafer pair is then annealed at high temperature (in the case of hydrophilic Si at >1000°C) and the physical forces are converted to chemical bonds.

Field-assisted or Anodic Bonding

Anodic bonding is a common method used in MEMS technology for device packaging. It was first introduced by Wallis and Pommerantz in 1969, after Pommerantz found that by
applying an electric field a bond between metal foil and glass could be achieved at lower temperature than with conventional thermal bonding [3]. In anodic bonding, glass wafers can be joined to silicon wafers at low or moderate temperatures (300°C - 450°C) and by applying a high DC voltage to the wafer pair (500 V - 1000 V) [4]. The most common glasses used for anodic bonding are Pyrex 7740 and Schott 8330, which are sodium borosilicate glasses having a coefficient of thermal expansion (CTE) close to the CTE of silicon. Sodium ions are needed for anodic bonding to take place, and matched CTEs help to maintain low stress on the bonded stack.

In anodic bonding the glass wafer is brought into contact with the silicon wafer and an external electrostatic field is applied at elevated temperature. Mobile sodium ions move towards the electrode, leaving a negatively-charged region into glass wafer, and electrostatic forces pull the silicon and glass tightly together. Next an electrochemical reaction takes place and covalent bonds are formed between the glass and silicon. Anodic bonding is less sensitive to surface roughness than direct bonding but it requires one of the wafers as alkali glass. It also requires high voltage and moderate temperatures.

Adhesive & Polymer Bonding
Adhesive bonding, as the name suggests, means that an intermediate adhesive layer is used to form bonding between two different materials. Adhesive bonding requires only low temperature annealing. The bonding process is also cheap and requirements for surface smoothness are low. The disadvantages of these materials are long-term instability, a limited temperature range for their use, and the fact that they are not hermetic. However, the adhesive bonding is commonly used in applications where hermeticity is not needed. In some cases the bond hermeticity is obtained afterwards by using an additional metallization step [5]. Typical adhesives are different photoresists, polyimides and benzocyclobutane (BCB). [6 - 9]

CONCLUSION
Metal wafer bonding is an important technology for MEMS and 3D interconnects applications. Many MEMS factories have severely benefited from choosing the right bonding method at R&D stage. The device requirements have to be clearly outlined before considering a wafer level bonding approach. Going with what is successful in high volume today sometimes seems most attractive as the yield numbers are proven and the limitations are well explored. Certainly some of the newer emerging bonding technologies have to be further developed with the specific MEMS device. The driving force will be new requirements such as lower temperature, high vacuum and CMOS compatibility.

REFERENCES