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Hermetic cavities using gold wafer level thermocompression bonding

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Summary

This paper presents the study of gold/gold thermocompression bonding at silicon wafer level. The first samples contains sealing rings and electrical pads and are characterized on pull and shear test showing bond strength similar to silicon/glass anodic bonding (10MPa-80MPa). A sealed cavity and a piezoresistor on a 30 μ m-thick silicon membrane are added in the second samples. Helium test, membrane deflection and piezoresistor signal monitoring after aging 14 days at 250°C confirm the vacuum stability inside the cavity after bonding.

Motivation and results

Several bonding techniques [1-5] exist to ensure hermeticity and protection of sensor inside micro-cavities. The analysis of gold thermo-compression bonding performed here contains both sealing ring and electrical contacts. To qualify our process, two different structures are realized to test bond strength (Figure 1) and hermeticity (Figure 2). For both structures, two 4 inches 500 μ m-thick, double-sided polished silicon wafers with 200nm-thick thermal SiO₂ are used. On each wafer, a diffusion barrier followed by 50nm/500 nm Ti/Au evaporated seed layer is deposited. Then a 3 μ m-thick electroplating gold is deposited inside a patterned resin mold in order to define sealing rings and electrical pads. For the second structure, a square membrane (30 μ m-thick and 2000 μ m-side) and piezoresistors are added. For both structures, we used a SUSS-SB6 bonder to perform the thermocompression bonding (420°C, 5.7MPa, 50 minutes). We include spacers between the wafers during alignment to obtain vacuum inside the cavity (5.10⁻³mbar). After bonding and dicing, some dies are polished to observe the gold structure at the interface (Figure 3). No delamination is observed between the different materials showing a complete atomic diffusion at the gold interface bonding. Batches of 20 dies are then selected from different wafer areas for pull and shear tests. Most of the dies exhibit cohesive fracture in silicon with tensile strength comparable or superior to silicon/glass anodic bonding (figure 4). Even if pull tests are often used for the qualification of bond strength, this technique don't give reproducible results compared to shear test. High rate leakage through bonding interface has been evaluated with structure 2 by monitoring the membrane deflection several hours after bonding with a mechanical profiler. Measurements show deflection between 4 μ m and 5 μ m for 75% of the cells, which is consistent with simulation and technological process variations. In order to check more precisely the leakage, the dies (after breaking the thin silicon membrane) are glued on a special tool where one side of the die is exposed to He and the other side is connected to vacuum (1.10⁻⁹ mbar) detector equipment (Figure 5). The mean leak measured by He detector was 10⁻⁸ mbar.l/s for the best dies structure bonded which correspond to an excellent hermeticity. The hermeticity reliability has been characterized by following the response of a piezoresistor placed on the membrane after aging at 250°C during 14 days for 6 cells (Figure 6). The piezoresistance shift is lower than 250 ppm for the best cell which correspond to a 75mbar variation inside the cavity.

Word count: 486

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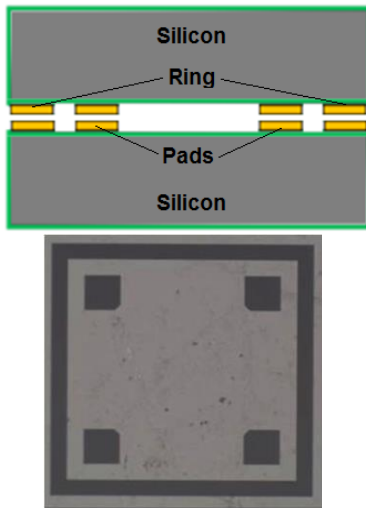


Figure 1: Test structure 1. Cross section & top view

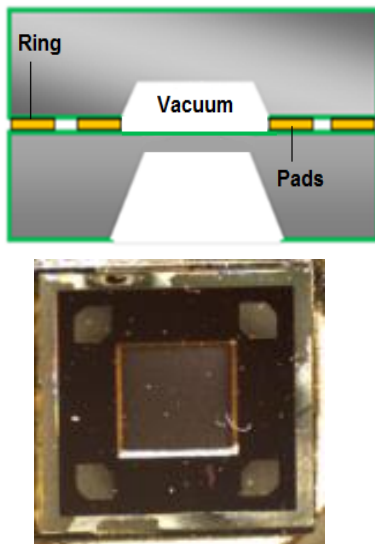


Figure 2: Test structure 2. Cross section & top view

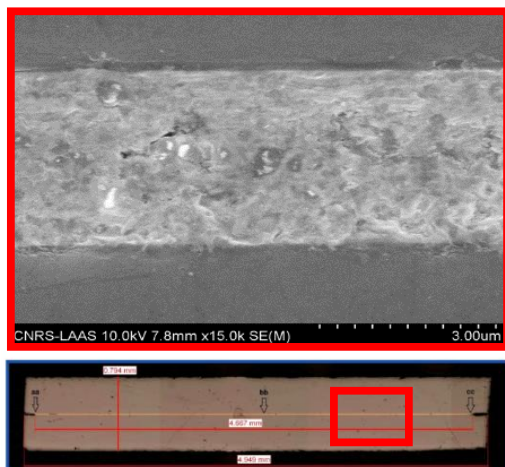


Figure 3: Gold optical and SEM cross section after dicing and polishing

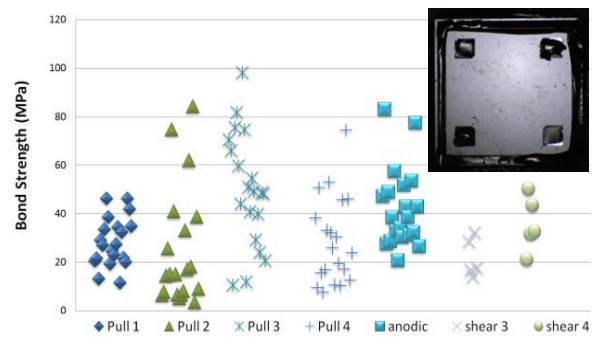


Figure 4: Cohesive fracture on silicon die and bond strength obtained with pull and shear tests

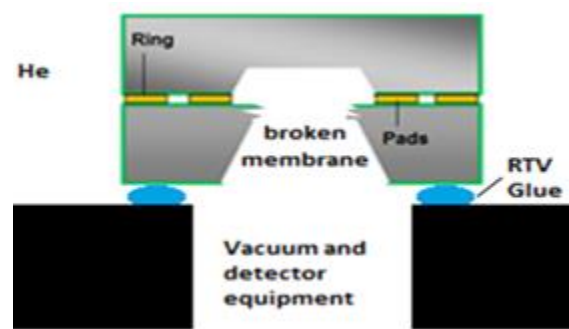


Figure 5: He hermeticity setup

Cell Number	1	2	3	4	5	6
$\Delta R / R$ (ppm)	248	568	333	3770	2370	1070

Figure 6: Piezoresistor shift after aging 14 days at 250°C for 6 different cells