Wafer Bonding Comparison
Permanent Bonding – Physical analysis and Cost Overview
MEMS, Imaging, LED, Packaging report by Audrey LAHRACH
November 2018 – Sample
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Executive Summary

This comparative review has been conducted to provide insights into the structures, processes and costs of the main permanent wafer bonding technologies.

Among these technologies, we have identified two main groups. One, bonding wafers without intermediate layers, includes fusion, copper-copper hybrid and anodic bonding approaches. The second group involves bonding wafers with intermediate layers using an insulator like a glass frit, or a metal in eutectic and thermocompression approaches. In this report, we show examples of each wafer bonding approach in different applications. We analyze and compare each wafer bonding process type to show the benefit in terms of cost and space used.

By switching from glass frit bonding to metal bonding thermo-compression, a manufacturer could reduce component area by up to 30%, reclaiming lost space around the active surface and cutting cost. However, some bonding technologies are currently used only in some market segments. For example, hybrid copper-copper bonding is only used in CIS and glass frit technology is found only in products in automotive and some consumer MEMS applications.

In the comparison, we have analyzed each component’s wafer bonding process, including component dimensions, cost and manufacturing approach. We provide an overview of technology costs and manufacturer choices by application and range. We offer buyers and device manufacturers a unique possibility of understanding permanent wafer bonding technology, evolution, and comparing process costs.
Wafer Bonding

- **Permanent Wafer Bonding:**
  - Wafer bonding consists of joining two wafers surfaces with or without an intermediary layer, depending on the bonding technology.
    - Direct bonding is the process of bonding without an intermediate layer:
    - Indirect bonding is the process of bonding with an intermediate layer:
Technology Description

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Direct Bonding
Without intermediate layer

Indirect Bonding
With intermediate layer

Wafer Bonding Technologies

Fusion bonding/direct or molecular bonding
Cu-Cu/oxide hybrid bonding at RT
Anodic bonding

Insulating interlayer

Glass frit bonding
Adhesive bonding
Eutectic Bonding
Thermo-compression

Metal bonding
Fusion Bonding

- Without intermediate layer
  - Fusion bonding
  - Anodic bonding
- With intermediate layer
  - Insulating interlayer
    - Glass frit bonding
    - Adhesive bonding
- Metal Bonding
  - Cu-Cu/oxide hybrid bonding
  - Eutectic Bonding
  - Thermo-compression

Schematic of the fusion bonding process:

- Hot pressure plate
- Si wafer
Overview / Introduction

Wafer Bonding Technology

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- Without intermediate layer
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- With intermediate layer
  - Insulating interlayer
    - Glass frit bonding
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  - Eutectic Bonding
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Physical Comparison

Cost Comparison

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mCube Accelerometer - Package Cross-Section

Package Cross-Section – SEM View

Fusion Bonding

Photo rotation (180°)

Fusion Bonding

mCube – Die Cross-Section – SEM View
mCube Accelerometer – Process Flow

• Front-End Process:
  o Substrate: x-inch (xxxmm) Silicon wafer
  o Process type: xxxxxxx
  o Metal layers: x (xxxx)
  o Special features: DRIE, fusion & xxxx bondings + TSV xxxxx in MEMS Cap
  o Lithography steps: xx
  o MEMS Area: xxxmm²
Wafer Bonding Technology

Wafer Bonding Definition and Process Description

- Without intermediate layer
  - Fusion bonding
    - Anodic bonding
- With intermediate layer
  - Insulating interlayer
    - Glass frit bonding
    - Adhesive bonding
  - Metal Bonding
    - Cu-Cu/oxide hybrid bonding
    - Eutectic Bonding
    - Thermo-compression

Physical Comparison

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PHYSICAL COMPARISON
Glass frit bonding to Thermo-compression bonding

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MEMS Opening

Accelerometer with Glass-Frit Sealing
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Glass-Frit Sealing Cross section
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Accelerometer with Gold Sealing
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Au-Au Sealing Cross Section
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Glass frit bonding to Eutectic bonding

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C O S T
COMPARISON
# Permanent Wafer Bonding Comparison

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### Cost Comparison

- **Clean Room Cost**
- **Equipment Cost**
- **Consumable Cost**
- **Labor Cost**
- **Wafer Bonding Cost**

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More than Moore devices fueled by megatrend applications will strongly drive the growth of the lithography, permanent bonding, and temporary bonding and debonding equipment market.

KEY FEATURES OF THE REPORT

- Wafer-to-Wafer (W2W) permanent bonding, lithography, temporary bonding and debonding tools for More than Moore (MtM) markets (advanced packaging, MEMS & sensors, CMOS Image Sensors (CIS), RF, LED and power applications) volume and value metrics forecasted for 2017–2023
  > by MtM device
  > by technology type
- Key technical insights into each equipment type covered, including trends, requirements and challenges
- Competitive landscape and 2017 market shares for each bonding and lithography equipment manufacturer by MtM device
- Technology roadmap for W2W permanent bonding, temporary bonding and debonding and lithography for each MtM device

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Over the years, permanent wafer bonding has been a game changer for several applications in the semiconductor world. In radio-frequency (RF) applications, MEMS, and even for CMOS image sensors (CIS), it has reduced the surface area occupied and improved performance hugely. But depending on the application or the goal of the Original Equipment Manufacturers (OEMs), the technology can differ. For example, wafer bonding processes is used to reduce system footprints and signal losses by coupling the MEMS area with the application-specific integrated circuit (ASIC) controller. In this report, we will go through the main permanent wafer bonding technologies to see the pros and the cons of each.

Among these technologies, we have identified two main groups. One, bonding wafers without intermediate layers, includes fusion, copper-copper hybrid and anodic bonding approaches. The second group involves bonding wafers with intermediate layers using an insulator like a glass frit, or a metal in eutectic and thermocompression approaches. In this report, we show examples of each wafer bonding approach in different applications. We analyze and compare each wafer bonding process type to show the benefit in terms of cost and space used.

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✓ Adhesive bonding
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✓ Thermo-compression bonding
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  - MEMS inertial sensor

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