Wafer bonding challenges for 3-D integration

Anne Jourdain, Andy Miller and Bart Swinnen

imec
Outline

- Thin wafer handling for 3D integration: Requirements
- Current solutions
- Carrier-based thin wafer handling: generic learning
- Ideas / Questions for standardization
Thin wafer handling for 3D integration: Requirements

- Provide sufficient mechanical stability for backside processing
- Compatible with product integration flow
  - Temperature budgets
  - Chemical compatibility
  - Cleanliness
- Compatible with standard processing tools
- Reasonable COO

Requirements apply to
Carrier + adhesive + device system
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
Carrier based approaches: General process flow lay-out

1. Si device wafer
2. Etch trim wafer
3. Particle cleaning
4. Wafer to Carrier bonding
5. Wafer thinning by grinding
6. Grinding damage removal (Wet/dry/CMP) and cleaning
7. Thin wafer backside process
   - Backside passivation
8. Wafer / carrier debonding
   - clean & recycle carrier
9. Dicing thin wafer on tape
   - Particle clean
10. 3D stacking

Temporary glue layer coating
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
CARRIER WAFER SOLUTION – LASER ABLADABLE GLUES

UV Cure Adhesive

Process Flow Mounting:
- Spin coating adhesive
- Mounting support glass
- UV curing adhesive

Figures courtesy of 3M
CARRIER WAFFER SOLUTION – LASER ABLADABLE GLUES

Raster Laser Across Wafer

- Laser marking

LTHC Layer
Support Glass
Dicing Tape & Frame

Lift Glass Off Wafer

- Glass pick up

Peel Adhesive

Process Flow Demounting:
- Adhesive peeling

Figures courtesy of 3M
CARRIER WAFER SOLUTION – LASER ABLADABLE GLUES

Mounter
mount wafers to glass plate

Demounteer
remove thinned wafers onto dicing tape

Glass Recycler
Clean Glass Coat LTHC

Figures courtesy of 3M
CARRIER WAFER SOLUTION – LASER ABLADABLE GLUES

Key Features:

- CTE matched, transparent carriers
- Process:
  - Deposition on both carrier & device wafer
  - Vacuum bonding + UV-cure
  - Low-T, light assisted release
- Carriers recyclable
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
CARRIER WAFER SOLUTION: THERMOPLASTIC GLUE MATERIALS

Figures courtesy of Brewer Science
CARRIER Wafer Solution: Thermoplastic Glue Materials

- Equipment available from various suppliers

**SUSS XBC300**
(Picture source: imec)

**EVG® 850DB Platform**
(Picture courtesy of EVG)
CARRIER WAFER SOLUTION: THERMOPLASTIC GLUE MATERIALS

Key Features:

- Compatible with different carrier types
- Process:
  - Single sided deposition
  - T-assisted bonding
  - T-assisted release
- Carriers recyclable
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature deh儆able glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
CARRIER WAFER SOLUTION: PEELABLE GLUE MATERIALS

Preparation of silicon wafer
- Spin Coating
- PECVD
- Release Layer
- SemicoSil
- Si-Wafer

Preparation of carrier
- Spin Coating
- Adhesive
- Carrier

 bonding and thinning
- Bonding
- Thinning

TSV Processing
- Lamination to dicing tape or permanent bonding
- De-Bonding

De-Bonding and Cleaning

Figures courtesy of Thin Material AG
CARRIER WAFER SOLUTION: PEELABLE GLUE MATERIALS

Figures courtesy of Thin Material AG
CARRIER WAFER SOLUTION: PEELABLE GLUE MATERIALS

Key Features:

• Compatible with different carrier types
• Process:
  – Deposition on both carrier & device wafer
  – T-assisted bonding
  – Release by carrier peeling
• Carriers recyclable
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
CARRIER WAFER SOLUTION: RT SEPARATION PROCESS & MATERIALS

Basic Process Flow:
1. Coat polymer adhesive on Device
2. Fabricate Zone 1 of Carrier → Release Zone
3. Bond face to face
4. User processes, thin, pattern, etc.
5. Remove adhesive from Zone 2 (Stiction Zone)
6. Peel Carrier from adhesive left in Zone 1
7. Clean adhesive from Device

NOTE: Edge trimmed device is shown in figures

Figures courtesy of Brewer Science
CARRIER WAFER SOLUTION: RT SEPARATION PROCESS & MATERIALS

Key Features:

• Compatible with different carrier types

• Process:
  – Deposition on both carrier & device wafer
  – T-assisted bonding
  – Release by chemical dissolution (edge) + carrier peeling

• Carrier can be recycled several times before requiring new treatment
Outline

- Thin wafer handling for 3D integration: Requirements
- Current solutions
  - General process flow
  - Carrier wafers – Laser ablatable glues
  - Carrier wafers – Thermoplastic glue materials
  - Carrier wafers – Peelable glue materials
  - Carrier wafers – Room Temperature debondable glue materials
  - Carrier wafers – Chemically removable glues
  - Carrierless – Patterned support ring
- Carrier-based thin wafer handling: generic learning
- Ideas / Questions for standardization
Carrier wafer solution: Chemically removable glues

Adhesive spin coating → Bake → Bonding. A very simple process.

- Low Bonding pressure (0.012 MPa)

Figures courtesy of TOK
Carrier wafer solution: Chemically removable glues

- Dissolution
- Pick up
- Cleaning

Solvent injection
Detachment of handler
Residue removal

Low stress debonding by dissolving adhesive
No residue on device wafer

Figures courtesy of TOK
Carrier wafer solution: Chemically removable glues

Key Features:

• Micromachined carriers

• Process:
  – Single sided deposition + Bake
  – Temperature assisted, Low Pressure bonding
  – Chemical release

• Carriers recyclable
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions
  – General process flow
  – Carrier wafers – Laser ablatable glues
  – Carrier wafers – Thermoplastic glue materials
  – Carrier wafers – Peelable glue materials
  – Carrier wafers – Room Temperature debondable glue materials
  – Carrier wafers – Chemically removable glues
  – Carrierless – Patterned support ring

• Carrier-based thin wafer handling: generic learning

• Ideas / Questions for standardization
Carrierless Patterned support ring

(Backside process integration demonstrated)

Figures from Florian Bieck et al., Proceedings of the ECTC 2010 Doublecheck Semiconductors GmbH, Fraunhofer IZM and DISCO HI-TEC EUROPE GmbH
Carrierless Patterned support ring

Key Features:

- No Carrier
- No tool modifications required
- Process:
  - Creation of non-radial slits in wafer edge
  - TAIKO grinding
Outline

• Thin wafer handling for 3D integration: Requirements

• Current solutions

• Carrier-based thin wafer handling: generic learning
  – Significance of bondline defects
  – Solutions for bondline Inspection
  – Notch-to-notch alignment accuracy & notch deformation after thinning
  – Post thinning inspection and metrology
  – Wafer stack height / weight
  – Standard vs. Oversized carriers
  – Controlling thin wafer edge quality
  – Wafer transport
  – FOUPS & FOSBS
  – Post debonding inspection

• Ideas / Questions for standardization
Significance of Bondline defects

- Defect free
- Gap between 2 wafers
- Bubble in glue layer
Solutions for bondline Inspection

SAM

IR

Glue layer defects

Backside defects

Figure source: imec

Figure courtesy of KLA
Solutions for bondline Inspection

Surface acoustic Microscopy (SAM)

C-Scan

B-Scan
Notch-to-notch alignment accuracy & notch deformation after thinning
Wafer stack height / weight

Bonded wafer pairs or thinned wafers on carrier do not comply with SEMI M1 300mm wafer standard

⇒ Some tools may need adjustment to deal with:
  • Excess wafer stack height
  • Excess wafer stack weight
Standard vs. Oversized carriers

- Wafer edge
- 50 um
- Device wafer
- Carrier
- Device wafer
- Carrier

7/14/2010 Event, Venue information
Alternative ways to control thin wafer edge quality: edge trimming

- Implications for wafer edge clamping?
Inpsection after thinning

- Backside defects
- Thickness and uniformity
FOUPS and FOSBs

Weaker region

Cassette
FOUPS and FOSBs

Testing transport of thin wafers on carriers in harsh conditions

- No impact on wafer rotation, door closure force, latch torque measured

Figures courtesy of Entegris
FOUPS and FOSBs

Transport of stand-alone thin wafers requires dedicated solutions due to:

- Gravitational sag
- Wafer edge fragility

Figures courtesy of Entegris
Wafer transport

Wafer breakage during transport after edge trimming
Inspection after debonding

- Inspection of debonded interface for glue residues
  - On secondary carrier (e.g. e-carrier)
  - Thin wafer on tape in film frame
Outline

• Thin wafer handling for 3D integration: Requirements
• Current solutions
• Carrier-based thin wafer handling: generic learning
• Ideas / Questions for standardization
Ideas / Questions for standardization

• SEMI M1 300mm wafer standard:
  – Carrier diameter
  – Wafer stack weight
  – Impact of wafer notch deformation after thinning
• Edge trim dimensions
  – Impact on wafer handling? Edge gripping?
  – Impact on FOUP / FOSB design?
• Inspection and metrology standards
• Thin wafer shipping
THANK YOU!