Three-dimensional stacking IC packaging technology for NAND-flash memory

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Introduction

The solid-state drives (SSD) are the advanced high-speed storage technology.

One of the way to reduce data storing cost and to increase data density is the multi-chip packaging (three-dimensional packaging).

We present the technology of three-dimensional multi-chip packaging and testing of NAND memory module implemented at GS Nanotech in collaboration with Petrozavodsk State University.
Manufacture: pre-assembly

1. Thinning NAND memory wafers down to less than 100 microns in free steps:
   1. rough grinding,
   2. fine grinding,
   3. dry polishing

   Auto:
   ✓ thickness control at each step
   ✓ operations of unloading/loading wafers from/into the cassettes

2. Attaching thinned wafers to frames with a die attach film (DAF)

3. Dividing wafers into separate dies in two steps by saw with different thickness.

4. DAF irradiation by UV

5. The visual control of cut quality, chipping, cracks, and damaged dies.

The method of automation of the backside chipping inspection is described in our previous work [7].

Manufacture: attach print

1. The dies with the adhesive layer of DAF are
   1. pushed up by the ejection system with needles
   2. lifted from the base layer using a vacuum pick-up tool.

2. The dies are placed on the stack:
   ✓ offset (contact pads are open)
   ✓ automatic control of die placing coordinate and angle

3. The DAF film is polymerized in the oven.
Manufacture: attach print

Compared with liquid adhesive, the DAF **reduces the risk** of:

- ✔ contamination of the dies contact pads in case of adhesive excess,
- ✔ formation of air voids under the dies, in case of its insufficiency.

**Important:**

- ✔ ejection system configuration (needles may pierce the DAF or break the die)
- ✔ the choosing of a pick-up tool rubber
  - it should provide enough force during die lifting
  - do not bend the thin die by vacuum, as it may lead to void formation
- ✔ planarized substrates are needed to be used to avoid voids formation
Manufacture: wire bonding

The electrical interconnections methods:

✓ Thermosonic ball-wedge (die-to-substrate connections)
✓ Thermosonic wedge-on-ball (die-to-die connections)

1. Plasma cleaning
2. The wire is threaded through capillary
3. At the wire end, the ball is formed by an electrical spark
4. The ball is pressed to the die pad under application of heat and ultrasound.
5. The “wedge” is formed at substrate’s pad or at the ball on another die’s pad by the rim of the capillary under application of the same forces
6. Inspection: wire pull test and ball shear test
Manufacture: molding

Protecting dies and interconnections from:

✓ Mechanical
✓ Chemical
✓ Electrical
✓ Other negative impacts

Steps:

1. Plasma cleaning
2. Sealing by epoxy molding compound
3. Compound polymerization in the oven

Inspection:

✓ X-ray inspection (detect breaks and jams of the wire interconnections)
✓ Acoustic microscopy (reveal the air voids and delamination)
✓ Warpage measurement
Manufacture: ball placing and singulation

1. Plasma cleaning
2. Coating the contact pads on the substrate’s bottom by flux
3. Placing balls to the contact pads
4. Automatic check for defects of ball placing
5. Balls reflow
6. Division into individual NAND memory BGA modules
Testing

Using FPGA-based testing system of NAND-memory multi-chip modules [8]

1. Open/short, power consumption, leakage currents test

2. Functional verification test (program/read operation, bad-block detection)

3. Moisture sensitivity level (MSL) test (JESD22-A113)

4. Division lots into two groups:
   1. Thermal cycling (TC) test (JESD22-A104)
   2. High-temperature storage life (HTSL) test (ESD22-A104)

5. Repeated functional verification test

Conclusion

The developed and proven technology of three-dimensional multi-chip packaging and testing of NAND memory module is presented.

The technology provides:

- utilizing advanced NAND-flash memory
- high data density
- high reliability complying with international standards

These memory modules can be used for SATA, M.2, U.2, and other advanced solid-state drives production.