Semiconductor Assembly and Chip Mounting Machines Designed for High-speed Operation and High Product Quality

Hideaki Fukushima
Tomiji Suda
Yasushi Ishii
Katsuyuki Seto

OVERVIEW: In April 2010, Hitachi High-Tech Instruments Co., Ltd. merged with the Equipment & Engineering Division of Renesas Eastern Japan Semiconductor, Inc. and in doing so added die bonders as a new second pillar of its business operations, complementing the chip mounters that had previously been its mainstay. In order to meet the ever-growing diversity of demands being placed on assembly machines as the performance of the LSIs used in IT equipment continues to improve, the company is embarking on a planned program of new product development involving the multi-faceted fusion of technologies built up in the fields of die bonders and chip mounters.

INTRODUCTION

IN recent years, the demands from digital electronic devices such as mobile AV (audio-visual) players and smartphones have been for smaller size, lighter weight, and high-speed data processing. In addition to the progress being achieved in making the LSI (large-scale integration) circuits used in these devices smaller with more advanced functions, slimmer profiles, and faster signal processing, more is also being asked of assembly machines.

Meanwhile, in addition to productivity during high-volume production, things like maximizing plant utilization and shortening production startup times to cope with shorter product cycles are becoming important requirements for production equipment.

The DB-800HS is the mainstay of Hitachi High-Tech Instruments Co., Ltd.'s die bonder business and the CM-700MX has the top share of its global market. This article describes the market trends, system concepts, and equipment design of these machines along with the Σ-G4 and Σ-G5 chip mounters and the Σ-P4 screen printer. It also looks at synergetic products that fuse bonder and chip mounter technologies.

DIE BONDER TECHNOLOGIES

Die bonders are machines used in the finishing and assembly processes for semiconductors. Technologies used in die bonders to handle smaller package sizes and thinner profiles include more accurate die positioning, die bonding techniques that work with die thicknesses of 50 μm or less, and multi-layer bonding techniques.

Hitachi High-Tech Instruments has developed the DB series of die bonders for producing LSI packages in which these technologies are becoming steadily more diverse and advanced, and also the CM series of special-purpose machines for DRAM (dynamic random access memory) assembly.

DB-800HS Die Bonder

It bonds dies supplied from trays and wafers onto substrates using epoxy paste and DAF (die attach film). Fig. 1 shows a photograph of the die bonder that has the following features.

Fig. 1—DB-800HS.
This precision high-speed die bonder for 300-mm wafers is designed for SiP (system in package) assembly. It achieves high levels of productivity and quality thanks to a newly developed high-speed, low-vibration mechanism.

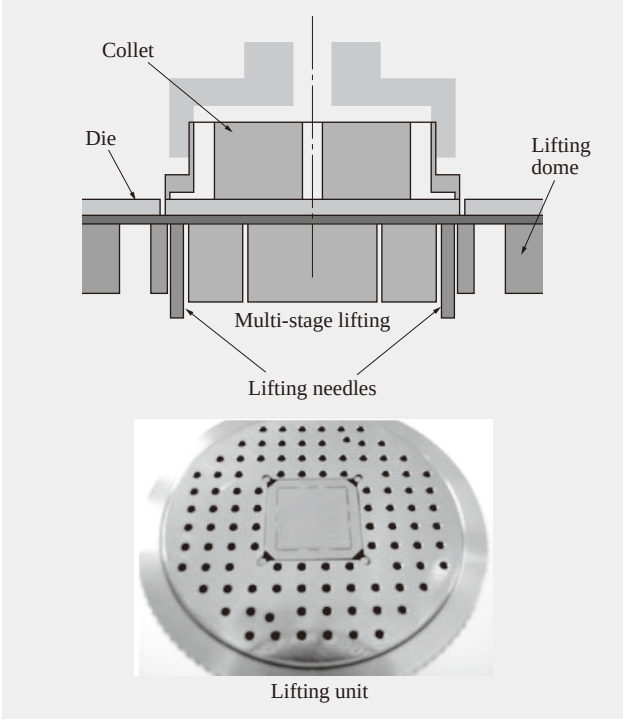

Fig. 2—New Lifting Mechanism.
The lifting mechanism allows thin dies to be layered. A feature of the mechanism is that it minimizes stress due to bending of the die.

(1) Precise positioning technique with a bonding accuracy of ±10 μm
(2) High-quality bare die handling technique able to pick up dies as thin as 15 μm
(3) Bonding system uses a split bonding process with high productivity.

TABLE 1. DB-800HS Specifications
The DB-800HS is a high-speed, high-precision die bonder suitable for assembly of memory cards such as the SD (secure digital) card (layering of thin dies).

Item	Specification	
Workpiece specification	• Die size	XY: 0.8 to 25 mm Thickness: 0.025 to 0.6 mm
	• Wafer ring	for 200 or 300 mm diameter
	• Lead frame (carrier jig)	Thickness: 0.1 to 1.0 mm Length: 100 to 275 mm Width: 32 to 95 mm
	• Magazine	Length: 100 to 280 mm Width: 37 to 110 mm Height: 60 to 150 mm
Bonding method	• Both epoxy paste adhesive and thermal compression bonding	
Production capacity	• Paste 8,000 IC/Hr DAF 4,000 IC/Hr	
Bonding accuracy	• Paste XY: 15 μm/θ: 0.1°(3 σ) • DAF XY: 10 μm/θ: 0.1°(3 σ)	

IC: integrated circuit DAF: die attach film

*1 microSD is a trademark of the SD Association.
*2 μBGA is a registered trademark of Tessera, Inc. in the USA.

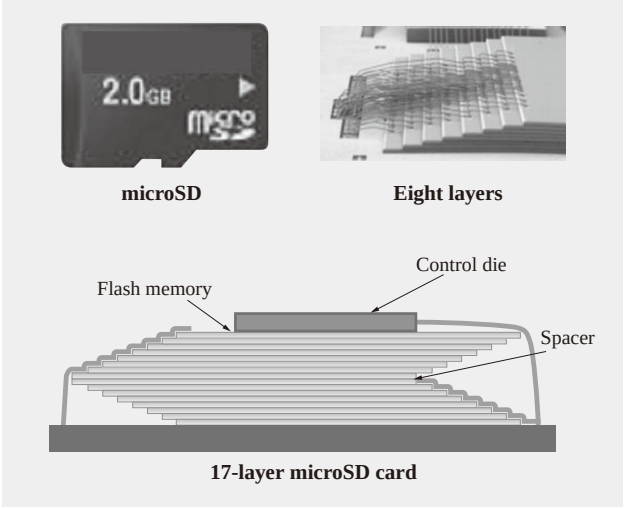

Fig. 3—External View and Interior Structure of Memory Card. A photograph of a microSD card, a SEM (scanning electron microscope) image of its interior (eight layers), and a diagram of its structure (17 layers) are shown. Bonding a large number of identical dies together in a single package allows higher memory capacities to be achieved.

Pickup of a thin die is a two-stage process in which peeling off is first encouraged by lifting up the four corners by a small amount and then the central region of the die is lifted up (see Fig. 2).

Table 1 lists the main specifications of the DB-800HS.

Adoption of these technologies has made possible multi-layered bonding in small slim packages such as microSD*1 cards (see Fig. 3).

The DB Series continues to face the same market requirements for productivity improvement, process expandability, and similar. Hitachi High-Tech Instruments intends to make further enhancements designed to satisfy these needs which will be released on the market.

CM-700MX Dedicated DRAM Assembly Machine

The packages used for DRAM are changing from wBGA (window bonding ball grid array) to μBGA*2 in conjunction with the higher transfer speed provided by DDR (double data rate) and the market as a whole is achieving higher speeds, slimmer package profiles, higher densities, greater functionality, and lower power consumption. DRAM manufacturers, meanwhile, are demanding higher performance (greater precision and better productivity) to cope with changing production processes and falling prices.

To satisfy these market requirements, Hitachi High-Tech Instruments has released the CM-700MX that supports new production processes and

Fig. 4—CM-700MX.
The CM-700MX is a mounter for 300-mm wafers used in the assembly of the advanced packages required for high-speed DRAM (dynamic random access memory). It incorporates a precise positioning technique and lamination technique and achieves high productivity.

higher production capacities and features precise technology for ensuring stability. The CM-700MX, shown in Fig. 4, is based on the CM-700 which is the main assembly machine used internationally in DRAM production.

The CM-700MX bonds a die to a strip of tape with an elastomer tape by performing thermal compression bonding from below the underside of the tape. Table 2 lists the main specifications of the machine.

TABLE 2. CM-700MX Specifications
This fast and precise bonder for assembly of the µBGA packages typically used for high-speed DRAM supports carrier-less thin tape transport.

Item	Target specification	Remarks
Workpiece specification	µBGA	Width: 74 mm
		Length: 247 mm
		Thickness: 0.075-mm film
		Matrix: 6 columns × 7 rows (max.)
Bonding	Bond accuracy	±15 µm, Cpk = 1.33 or better
	Voids	Eliminate
	Delamination	Eliminate
	Elastomer wetness	5 µm or more
Production capacity	UPH	1,600 or more
Other	Elastomer scratching	Eliminate
	Clamper function	Top: Vacuum clamp
		Bottom: Non-contact clamp
	Carrier-less tape transport	Supports variable-pitch transport.

UPH: units per hour BGA: ball grid array Cpk: process capability index

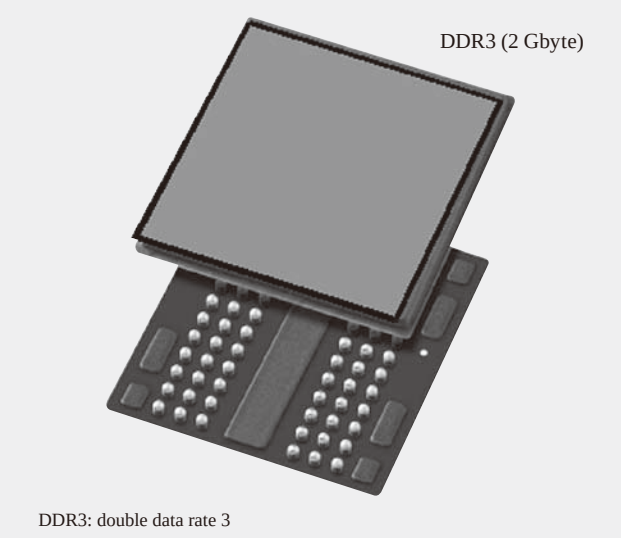

Fig. 5—DRAM.
This 2-Gbyte DDR3 is a typical high-speed DRAM. It has a BGA mounting and a data transfer speed of 1.3 Gbit/s.

The features of the CM-700MX are as follows.
(1) Highly reliable positioning and handling technology for 75-µm thickness TAB (tape automated bonding) tape
(2) Bonding system has high productivity and supports use of a two-stage bonding process.
(3) Precise positioning technique capable of a bonding accuracy of ±15 µm and a Cpk (process capability index) of 1.33

These technologies allow the machine to be used to produce the µBGA DDR3 (double data rate 3) (2 Gbyte) memory chip shown in Fig. 5. With strong demand for high performance machines capable of supporting new processes, Hitachi High-Tech Instruments is working on further improvements and developments for the CM Series to meet user needs and is delivering machines to the market in a timely manner.

SURFACE MOUNTING MACHINES

The trend toward higher mounting densities and smaller component sizes is accelerating against a background of demand for smaller sizes and more advanced functions in multimedia products such as mobile phones and digital cameras. On the other hand, the rapidly expanding market for the use of LEDs (light-emitting diodes) for lighting or as TV (television) backlights has created requirements such as the ability to process large substrates of 600 mm or more and the ranked mounting of LEDs. This is placing new demands on mounting machines that

Fig. 6—Σ-G4, Σ-G5, and Σ-P4.
The Σ series machines share a common ease of use and external appearance. The adoption of transparent covers makes the internal operation much easier to see.

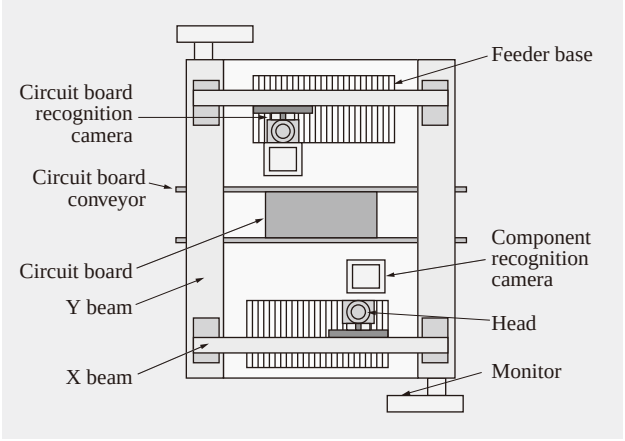

Fig. 7—Σ-G5 Structure.
The machine is available in a range of variations with different heads, component feed methods, and circuit board conveyors. A wide range of different types of production is possible by combining different units.

are significantly different from those of the past. Further, only equipment with the flexibility to handle everything from large production runs of a small range of products to short-run production of many different products can satisfy market needs.

To offer customers the best possible value proposition, Hitachi High-Tech Instruments has developed the Σ-P4 screen printer and the Σ-G4 and Σ-G5 modular mounters which provide industry-leading throughput performance and the LISA (line information support and administration) server that performs centralized management of these machines. These products have been on sale since April 2010. Fig. 6 shows photographs of the Σ Series machines.

Hitachi High-Tech Instruments developed the Σ-G4 (single-side component feed) and Σ-G5 (double-side component feed) mounters in parallel to suit different production configurations at customer sites.

Σ-G4 and Σ-G5 Modular Mounters

These machines are modular mounters able to mount components ranging from very small 0.4 × 0.2-mm chips to large 100 × 26-mm connectors on circuit boards. Fig. 7 shows the structure of the Σ-G5 double-side component feed model.

First, the two front and rear heads use suction to pick up components from the feeder base (component feeder) simultaneously, then the component recognition camera determines the component locations and the heads move at high speed via the X and Y beams. Position correction is then performed and the two heads place the components simultaneously on the correctly positioned circuit board.

To minimize the downtime of machinery on any production line, it is essential to achieve the best possible OEE (overall equipment efficiency) by maximizing the operating capacity of the equipment. In addition to increasing machine throughput, it is also important to reduce non-operating time by eradicating sudden shutdowns and reducing the duration of product changes (time taken to reconfigure for a different product) and unplanned stoppages (scheduled downtime).

The following four technologies were adopted to improve the machines' productivity, resulting in high-speed and high-quality mounting at an industry-leading throughput of 70,000 chips per hour (see Table 3).

TABLE 3. Σ-G4 and Σ-G5 Specifications
The overdrive motion feature provides industry-leading throughput even on the Σ-G4 which uses single-side component feed only.

Item		Specification	
Model		Σ-G4	Σ-G5
Head configuration		2 heads per module	
Throughput (high-speed head)		70,000 Cph (1 module)	
Circuit board size range (mm)	Dual (Σ-G5: option)	50 × 50–610 × 216 (Single use) 50 × 50 to 610 × 381	
	Single	–	50 × 50–610 × 460
Component types supported by heads	High-speed type	0402 (0.4 × 0.2 mm)–44 × 44 mm, T: 12.7 mm or less	
	Multi-function type	1005 (1.0 × 0.5 mm)–55 × 55 mm, 100 × 26 mm, T: 25.4 mm or less	
Number of component types able to be supplied		60 (8-mm tape)	120 (8-mm tape)
Dimensions (mm)		1,280 (length) × 1,900 (width) × 1,450 (height)	1,280 (length) × 2,200 (width) × 1,450 (height)
Weight		1,650 kg approx. (excluding cart)	1,750 kg approx. (excluding cart)

Cph: chips per hour T: thickness

(1) Rotary direct-drive heads
  (a) Reliable one-by-one pick up
  (b) Precise, high-quality mounting without using any transferring mechanisms
(2) X and Y axis linear motor drive
  (a) High-speed positioning technique using Y-axis twin rigid drive
(3) Industry-first overdrive motion
  (a) Each head has flexibility to pick up from front and rear pickup areas.
  (b) Front and rear heads can perform mounting on the same circuit board simultaneously.
(4) Non-stop component recognition
  (a) Eliminates lost time due to component recognition by detecting 15 components at a time.

Also, the extensive range of tools (see below) are intended to maximize OEE as well as providing immediate improvements in productivity by helping to collect production data, minimize product change times, allow non-stop production, and prevent mounting errors.

(1) Production data collection support tools: CAD (computer-aided design) conversion software and off-line data generation
(2) Minimize product change times.: Fully automated setup, product changeover without halting production
(3) Prevent mounting errors.: Check for incorrect components, mounting trace function

Σ-P4 Screen Printer

The Σ-P4 is a screen printing machine for printing solder onto circuit boards. Hitachi High-Tech Instruments developed its own HR (hyper rolling) squeegee to achieve fast and precise printing. Fig. 8 shows how the squeegee works. Because the HR squeegee has less resistance to the solder than a standard flat squeegee, it has good solder rolling characteristics even when the printing rate is as fast as 150 mm/s. This faster printing speed means the Σ-P4 has a printing time of 12 s compared to the 24 s required by Hitachi High-Tech Instruments's previous model (see Table 4).

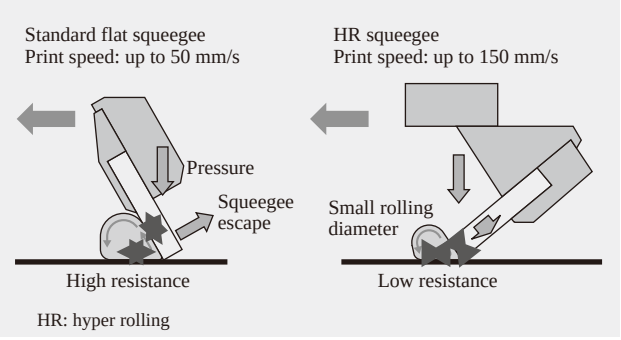

Fig. 8—Overview of Squeegee Operation.
Using HR squeegee can reduce the contact resistance with the solder during rolling and achieve high coverage even under high-speed printing conditions.

TABLE 4. Σ-P4 Specifications
The Σ-P4 was given the capacity to handle circuit board sizes up to 610 × 460 mm to satisfy the growing LED (light-emitting diode) market.

Item	Specification
Circuit board size range (mm)	50 × 50 to 510 × 460 (OP: 50 × 50 to 610 × 460)
Screen frame dimensions (mm)	650 × 550 to 750 × 750
Circuit board transfer time	7.0 s
Print speed	20 to 200 mm/s
Screen separation control	Multi-stage/acceleration control
Squeegee (selection)	Urethane rubber flat squeegee
	Fine-pitch HR squeegee
	Metal squeegee
Dimensions (mm)	1,280 (length) × 1,220 (width) × 1,450 (height)
Weight	1,000 kg approx.

OP: option

LISA Line Management Server

The mounting process for a circuit board is performed by multiple machines in a production line consisting of a printer and a number of mounters operating in tandem. On lines that perform short-run production of many different products, the frequent product changes make it desirable to manage all of these machines centrally. The LISA (line information support and administration) server was developed for the Σ Series to perform supervisory control of the printer and mounters. Fig. 9 shows the block diagram of a LISA system.

In addition to managing the mounting data for each machine centrally, the system can perform product changes for all machines at once. Similarly, the system can collect operational data that is transmitted periodically from each machine to provide an indication of the operational status of all line equipment.

CONCLUSIONS

This article has described the market trends, system concepts, and equipment design of the DB-800HS, CM-700MX, Σ-G4, Σ-G5, and Σ-P4, and also introduced the LISA server which fuses bonder and chip mounter technologies.

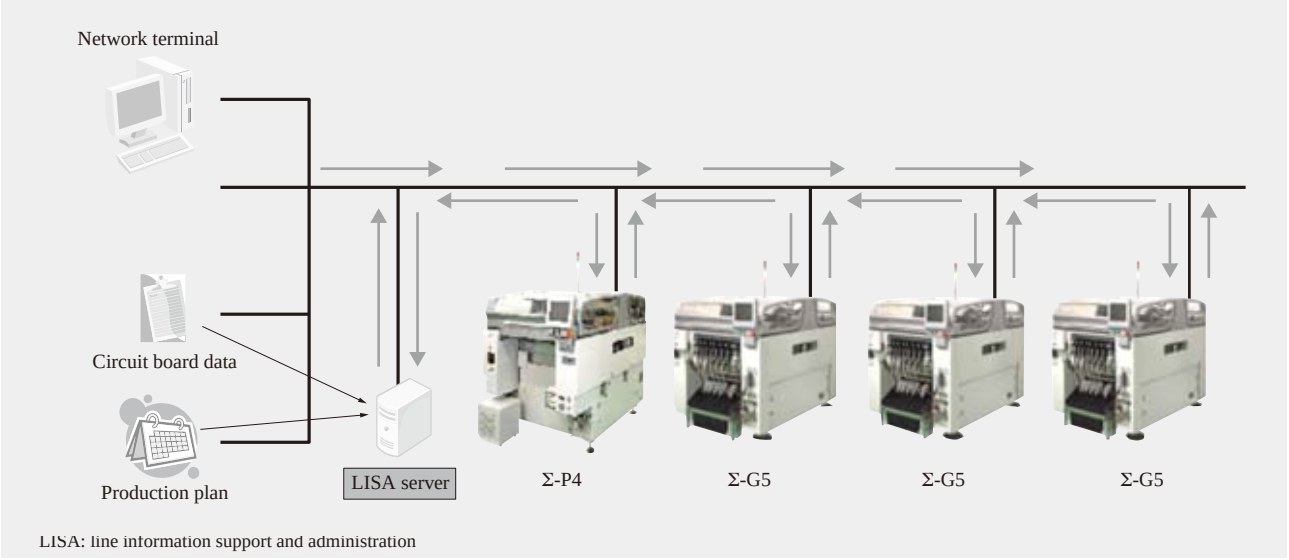

Fig. 9—LISA Block Diagram.
The LISA server and other equipment are connected via a LAN (local area network) which is used to send circuit board and operational data.

Recent times have seen growing demand for faster speeds from the semiconductor finishing market and for bare mounting from the surface mount market. These product requirements play to the strengths of bonders and mounters. Following the acquisition of the bonder business in April 2010, Hitachi High-Tech Instruments Co., Ltd. is now developing synergistic products based on the Σ-G5 but also incorporating thin die supply technology from bonders in order to satisfy these demands.

For the future, Hitachi High-Tech Instruments Co., Ltd. intends to proceed with product developments that take advantage of further synergies and continue to offer propositions that maximize value to their customers.

ABOUT THE AUTHORS

Hideaki Fukushima
Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the SMT&Assembly Systems Division, Hitachi High-Technologies Corporation. He is currently engaged in the coordinating business strategy for mounting machines.

Tomiji Suda
Joined Hitachi High-Tech Instruments Co., Ltd. in 2010, and now works at the No. 3 Design Department. He is currently engaged in the design of die bonders.

Yasushi Ishii
Joined Hitachi High-Tech Instruments Co., Ltd. in 2010, and now works at the Yamanashi Development Department. He is currently engaged in the design of die bonders.

Katsuyuki Seto
Joined Hitachi High-Tech Instruments Co., Ltd. in 2003, and now works at the Chip Mounter Systems Design Department. He is currently engaged in the design of mounting machines.