Action for a Total Solution that Reinforces the Packaging Materials Business

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In recent years, advances have been made with respect to information and communications systems (most notably, 5G technology), marking the coming of the era of IoT (Internet of Things), where everything is connected to the internet. At the same time, there are limitations in increasing the density of semiconductors, and the semiconductor packages mounted in electronic devices used in various environments are required to have a more complicated structure (such as three-dimensional Jisso) and higher reliability.

We have relocated the open laboratory established in Tsukuba in 2014 to Kawasaki City, where it is now called the "New Open Laboratory". At the New Open Laboratory, not only do we propose conventional total solutions for material combination and processing, but we also promote open innovation projects that center on the laboratory and that are carried out with the cooperation of other companies and organizations. Through open innovation, the laboratory accelerates the realization of next-generation semiconductor packages. In this paper, we introduce some of the new innovations and activities of the New Open Laboratory.

1 Introduction

The sudden high functionality of information terminal electronic apparatus represented by smartphones and tablet PCs in recent years is accelerating the rapid miniaturization and high densification of packages. Therefore, the structure is more complicated as shown not only by the high densification of surface mounting but also by the realizations of three-dimensional package with devices having penetration vias and by the fan-out wafer level package (hereafter referred to as FO-WLP) that enabled high density Jisso in Jisso process by rewiring technology, and the Jisso process is also diversified.

On the other hand, since the product cycle is shortened, in order to realize such complicated package in a short period of time, it is important not only to timely propose new Jisso materials but also to speedily propose a total solution from the viewpoint of customers, including the Jisso process and material combination.

In 1994, Hitachi Chemical Co., Ltd. established the Jisso Center for the purpose of performing the evaluation and analysis of semiconductor Jisso materials by ourselves first in the world and has promoted developing various types of Jisso materials. Thus, we are enlarging the product lineup from the frontend to the backend.

In June 2014, in order to deal with large changes in the above-mentioned package structures and Jisso processes, we renewed the Jisso and evaluation facilities in the Jisso Center and established the semiconductor Jisso open laboratory (hereafter referred to as the "Open Laboratory") based on a variety of Jisso material technologies, Jisso evaluation and analysis technologies. The Open Laboratory enabled the Jisso and evaluation of various advanced packages of the customers using various material lineups including our new materials.

In addition, using the Open Laboratory as a core base, we are promoting construction of new materials and processes positively in cooperation with manufacturers of equipment, processes, and components. Furthermore, using abundant material data bases accumulated, we perform various simulations to deal with the customer's next generation package structure that is still in the design phase, and we promote the proposals of the optimum material combination, the productivity improvement of the customers, and the new processes contributing to suppressing new investment.

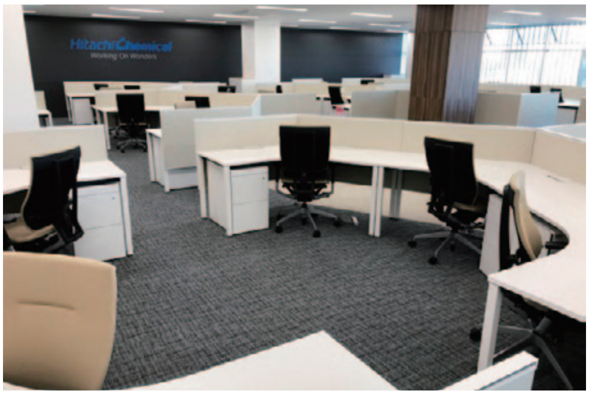
2 Expansion and Relocation of Open Laboratory to Shin-Kawasaki District

During four years since the establishment, the customers from 600 or more companies visited the Laboratory. We developed materials using the above-mentioned scheme in cooperation with these customers and acquired the approval of about 90 of new materials through the proposal of total solutions and through the activities that shorten the customer's approval period. Thus, our Semiconductor Jisso Open Laboratory has contributed to our business. However, since there were major problems concerning geographic inconvenience for overseas customers and the limitation of functional expandability due to restrictions on space, we enlarged the size to about three times to complete the relocation to Shin-Kawasaki District, Kawasaki, Kanagawa. The features and outline of the new Open Laboratory are shown below:

Appearance of building

Building entrance

Floor entrance



Office area

(1) Wafer process and assembly areas

In the wafer process and assembly areas, we installed a stealth laser dicer manufactured by DISCO Corporation in addition to the conventional blade dicer. The new dicer is used for processing ultrathin wafers of 50 μm or less, and high efficiency of evaluation is expected by the processing time reduction using device wafers and the improvement of yield by crack reduction.

A new type of die bonder manufactured by Fasford Technology Co., Ltd. was installed for the die bond process. This bonder is used for high speed continuous bonding because the improvement of UPH of 20% as the ratio to the conventional machine enabling the evaluation in the reproduced process environment of customer's mass production machine concerning the thermal history of materials and circuit boards. Furthermore, since the bonder is provided with bonding accuracy as high as 10 μm and a micro crack detection function, higher evaluation efficiency, package assembly integrity, and improvement of evaluation accuracy are expected.

The existing facilities also realized the functional improvement by renewal to a new type of machine. We will flexibly and quickly deal with diversified customer's processes by realizing improvements in processing quality by installing a new type of blade dicer with enhanced detergency, installing a dicer capable of processing large-size circuit boards in sizes up to 600 mm × 600 mm considering panel process, and constructing a pure water circulating system to be used for them.

Wafer process area

Assembly area

(2) Advanced process evaluation area

FO-WLP has attracted attention in recent years because it can realize the miniaturization, thinning and its high frequency characteristic by shorter wiring length. FO-WLP has various construction methods, which can be basically classified into two methods. The die first method that forms re-distributed layer (RDL) for fan-out on semiconductor devices and the RDL first method that mounts semiconductor devices on the previously formed RDL. Our Open Laboratory in Shin-Kawasaki can implement both diversified construction methods, and the trial manufacturing line capable of processing from the wafer level to the panel level (fan-out panel-level-package: hereafter referred to as FO-PLP) was constructed in this laboratory. The processes for fan-out package mainly consist of the RDL forming process, encapsulant molding process, carrier debonding process, and chip mounting process. The Shin-Kawasaki site has a group of facilities capable of performing a series of processes from the 12” wafer carrier size to the maximum 510 mm × 515 mm size panel and can evaluate various materials and processes related to fan-out packages.

Advanced process evaluation area

The RDL forming process is applied to a series of processes, such as the liquid material coating for applying and forming RDL insulation materials, film material lamination, exposure and development of photosensitive materials, seed metal sputtering, plating resist forming, Cu electroplating forming, resist stripping, and seed metal etching. In particular, we installed a stepper exposure machine (Sc6k manufactured by Cerma Precision, Inc.) with high resolution of the minimum line / space = 2 μm / 2 μm to handle the above large-size panel to enable application to further high densification RDL in the future.

Concerning the encapsulant molding process, we installed a new compression molding machine (CPM1180-S manufactured by TOWA CORPORATION) to manufacture the maximum 320 mm × 320 mm size circuit boards at the Tsukuba site, thus enabling the manufacture of up to 510 mm × 515 mm size boards. Similarly concerning the sputtering process, we installed a new sputtering facility (SIV-500 manufactured by ULVAC,Inc) to manufacture the same size boards.

Concerning the die mounting process, the Tsukuba site applied flip chip bonding (FCB) to panels of the circuit board in sizes up to 300 mm × 300 mm, and the Shin-Kawasaki site installed a new flip chip bonder (MD4000 manufactured by Toray Engineering Co., Ltd.) capable of manufacturing the maximum 600 mm × 600 mm size boards, a new flip chip bonder (FC3000W manufactured by Toray Engineering Co., Ltd.) with loading accuracy of ±2 μm and loading ability of the maximum 1,600 UPH, and a die mounter (NXT-Hw manufactured by FUJI Corporation) with mounting accuracy of ±8 μm and loading ability of 4,000 UPH to match panel enlargement and higher accuracy mounting in the future.

(3) Photosensitive material evaluation area (yellow room)

In order to construct a micro wiring forming line to be essential for next generation packaging technology realizing higher densification, the yellow room area can now deal with up to 600 mm × 600 mm from the conventional 12” wafer size by installing a slit coater, a vacuum laminator, and a exposure machine. In addition, the new installation of the above-mentioned stepper

exposure machine Sc6k manufactured by Cerma Precision, Inc. in the newly established clean room of Class 100 allowed us to expect the realization of stable micro pattern processing of L / S = 2 / 2 μm. In addition, the installation of large-size sputtering equipment and plating-related facilities enabled Cu wiring forming on various substrates.

We constructed the evaluation line leading to the micro wiring forming using photosensitive materials, the application to the next-generation Cu wiring plating, and the promotion of applied material and process development by concentrating these facilities in the above clean room.

Yellow room

(4) Evaluation and analysis area

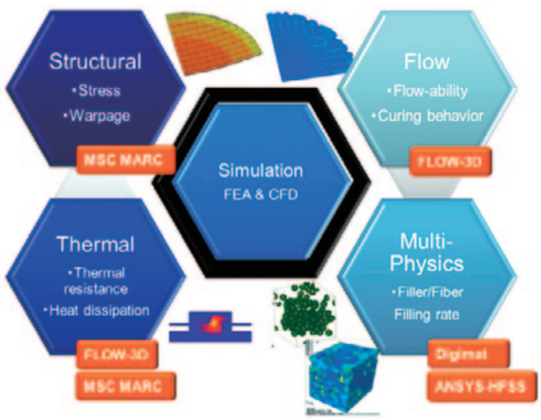
We newly installed an advanced evaluation facility to improve the accuracy of analysis in the minute region and increase the speed of failure analysis. We installed a field emission type of scanning electron microscope (FE-SEM) capable of magnifying up to 2 million times and a high-performance focused ion beam (FIB) capable of high-speed and large area processing using a high current beam of 90 nA, thus having constructed assemble method evaluation and precision analysis lines concerning micro wiring of L / S = 2 / 2 μm or less. We installed an ultrasonic flaw detector, a semi-automatic prober, and a laser displacement gage as evaluation and analysis equipment for FO-PLP of which adoption is hereafter expected to increase. All the equipment has an inspection range of 600 mm × 600 mm or more of which utilization enabled the identification of problem occurrence timing during forming of the rewiring layer and the measurement of warpage after encapsulation while keeping the panel size as it is. Furthermore, the correction of warpage by an ultrasonic flaw detector with a water flow adsorption stage enabled non-destructive visual inspection of voids and deramination.

Evaluation and analysis area

(5) Simulation area

The Open Laboratory have performed analyses of warpage and stress, fatigue life analysis, and heat dissipation analysis using non-linear structure simulation (Marc: MSC Software Corporation) by fully utilizing abundant material databases accumulated by Hitachi Chemical Co., Ltd. to support material development. Since the utilization of CAE (computer aided engineering) has progressed in recent years, we newly installed a flow simulator (Flow3D: Flow Science Japan), a composite material simulator (Digimat: MSC Software Corporation), and an electromagnetic field simulator (Ansys HFSS: Ansys Japan). In flow analysis, the resin that flows inside a mold chase while causing the curing reaction and the pressure bonding behavior of film-like materials can be analyzed. In addition, in composite material analysis, composite materials that were conventionally handled as an integral

Simulation area



Capability of simulation

part can be analyzed by dividing into individual components, and the reproduction of stress of the microstructure and accurate property generation of material having anisotropy and the reverse engineering in which microscopic structure is estimated from macroscopic properties of composite materials can be performed. In electromagnetic analysis, the effects of relative dielectric constant and dielectric loss tangent of materials affecting radiation and the eye pattern of circuits can be analyzed. Shin-Kawasaki aims to contribute to the promotion of high-level material development by fusing these analysis technologies.

(6) Fukuoka IST (Fukuoka Industry, Science & Technology Foundation) area

In the relocation to Shin-Kawasaki this time, we are promoting the construction of a trial manufacturing system to respond to large-size FO-PLP. However, it was difficult to relocate the large-size plating facility and the etching facility necessary for rewiring forming because there were issues of large amounts of chemicals, waste liquid treatment, and space. Therefore, we newly installed plasma equipment (AP-1500: Nordson Corporation), stripping equipment (ASEP-S600: Japan Create Co.,Ltd) and etching equipment (SEP-S600: Japan Create Co.,Ltd) in Research Center for Three-Dimensional Semiconductors (Fukuoka IST, Fukuoka) having excellent technologies for three-dimensional Jisso and circuit boards with built-in parts, and constructed the rewiring forming line applicable to 510 mm × 515 mm size. Thus, fine rewiring (L / S = 2 / 2 μm) forming responding to the large-size with various material combination can be implemented. In addition, the utilization of knowledge in the Fukuoka IST enables the expectation of a synergistic effect in the development of new processes.

Research Center for Three-Dimensional Semiconductors

Batch type stripping equipment

3 Consortium JOINT

In June last year, the consortium JOINT: (Jisso Open Innovation Network of Tops) consisting of 17 companies involved in the development of semiconductor Jisso materials and equipment was established, and activities were started using our semiconductor Jisso open laboratory as a base. This consortium contributes to reductions in labor and time of the customer in the speedy development of packages by providing the customers of semiconductor manufacturers with total solutions, including from the development of advanced Jisso technology to Jisso processes using materials and equipment owned by participating companies.

In recent years, as the utilization of artificial intelligence (AI) and IoT that connects everything to the Internet and the market of automatic operation and electric vehicles (EV) are expanding, high performance sensors, radio terminals, and base stations enabling high speed data communication, and servers and data centers capable of processing huge amount of information at high speed, are highly required. Since this circumstance diversified the functions required for semiconductors loaded to various appliances and their structure is more and more complicated, larger numbers of materials and devices are now used for manufacturing packages. Therefore, there were problems where a lot of work and time are required when the customers develop packages because the customers must procure materials and equipment from many supplying companies and evaluate them individually.

Considering this situation, Hitachi Chemical Co., Ltd. established the consortium JOINT where semiconductor Jisso technology is developed in order to quickly provide customers with a comprehensive one-stop solution by combining various materials and processes. Although the conventional semiconductor Jisso open laboratory was based on a cooperation system of one-to-one, namely Hitachi Chemical Co., Ltd. and an equipment manufacturer or Hitachi Chemical Co., Ltd. and a material manufacturer,

JOINT can mutually utilize technology and information between Hitachi Chemical Co., Ltd. and multiple enterprises depending on the development theme.

Specifically, it is now possible to quickly provide customers with total solutions, such as the optimum combinations of various materials and processes required for manufacturing of packages and new packages. In addition, since the combination of such materials and equipment enables the evaluation of materials and equipment in the condition close to that of semiconductor evaluation test conducted by the customer, the labor for evaluation individually performed by the customer for each supplier can be omitted. This enables the contribution to the reduction of labor and time in the development of packages for which the speed is essential.

Logo of consortium JOINT

Office dedicated to consortium members

4 Future Business Development

Hitachi Chemical Co., Ltd. will continuously approach the creation of new products and new businesses in the high-end field by further polishing a variety of our advantageous technical abilities. We will assume the relocated and functionally enhanced Open Laboratory as the strategic base for the Jisso material business, approach the promotion of further open innovation together with the customers and the consortium-participating cooperative companies as one-stop solution provider in addition to providing various materials, and contribute to the realization of new advanced packages.