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Toward the Foundry Model in Packaging for the Semiconductor Industry

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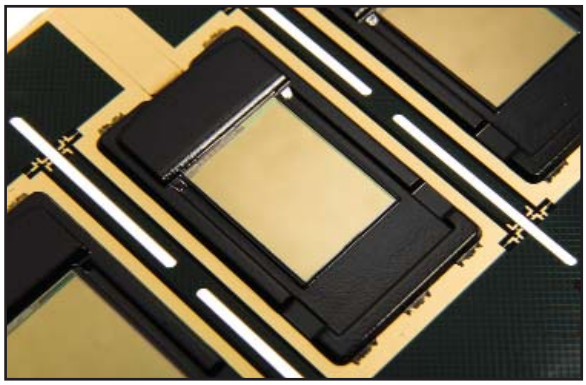
When TSMC opened the first dedicated semiconductor foundry in 1987, it represented a major change in the industry. The design force of a whole new sector of fabless design houses was released into the marketplace. Historically, packaging — the back-end of the process — has not followed the same route. Although the founding of some of the largest packaging companies in the world preceded TSMC's opening, their business models have focused primarily on production of "legacy packages" and not on design.

The complexity of semiconductor products is ever-increasing, and so are the requirements for packaging. There is a growing need for customers to have access to design knowledge in packaging, similar to the foundry model in the front-end industry. In the Netherlands, Advanced Packaging Center (APC) is aiming to provide this service, together with device sampling and low- to mid-volume production capabilities.



Fingerprint sensor.

Since the transistor first emerged from Bell Labs in 1947, the semiconductor industry has been completely driven by its front-end, and for good reason. The functionality of devices entirely depends on the front-end as the back-end is usually considered "easy and straightforward." Initially, the power of innovation was owned by large corporate organizations with integrated business models. They incorporated the business, circuit fabrication, as well as packaging and assembly processes. It wasn't until Milton Chang founded IC-foundry TSMC, that thousands of small design houses sprang up. Today, six of the top 20 semiconductor companies are fabless. TSMC alone, the largest foundry at present, ranks as the third largest semiconductor company in the world. The foundry model has since become a recognized standard in the front-end semiconductor world.

Toward the Foundry Model

Packaging developments in the semiconductor industry have always lagged behind, and were dictated by the front-end. For the most part, packaging only allowed the device to be handled and gave it some protection. Recently, the level of complexity and integration of circuits is causing a shift in the packaging industry. The industry is moving toward three-dimensional stacking, packaging and integration of chips for increased functionality, and the overall miniaturization and cost reduction of systems. Packages have more I/Os, are made of more advanced materials, and are now called upon to function separately from the front-end device.

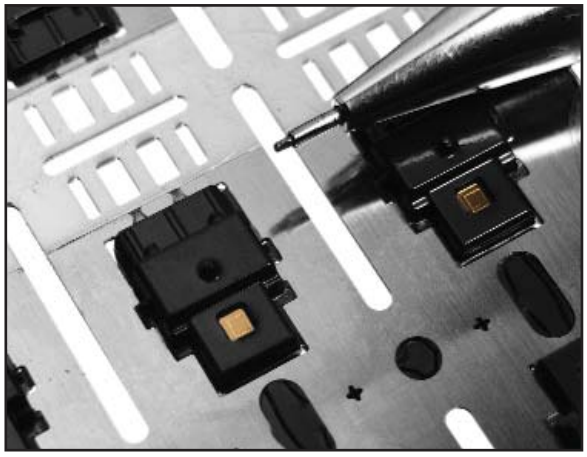
Designers of front-end devices now have to take package requirements into account for device-package interaction. Designing and producing a package has become, in some cases, comparably difficult to the front-end device. It is no longer within the reach of a fabless design house, or some packaging facilities. Thus the development of an advanced packaging foundry became a necessity.

A packaging foundry, analogous to an IC foundry, would enable its customers to make full use of its base of equipment according to well-defined design rules. Using established software, a customer could design packages for individual devices that would then be produced within the foundry.

Unfortunately, this is not yet a reality. For starters, there is no such thing as integrated design software for packaging. Nor is there any level of standardization in the different processes available in the back-end industry that would allow a packaging foundry to offer generic design features to customers. However, there are several companies that have begun to offer generic design packages with the intention of

standardizing designs for a foundry business model. These include such companies as Amkor Technology, Hana Microelectronics, Advanced Semiconductor Engineering, and others. These companies also provide design services to create new packages, as long as they are similar enough to existing designs. Several of these companies even precede TSMC.

Since the founding of back-end companies from the 1960s to 1980s, little changed in the next several decades. This is mainly due to the lack of standardization in the companies' methods. Now an intermediate level is available. Packaging companies now offer the ability to design new and complex packages that can run either in low- to mid-volume production, or be transferred to a larger manufacturer for high-volume production. Typically smaller in size, these companies hope to bring about the wave of innovation that accompanied the IC foundry movement, including fabless design houses.



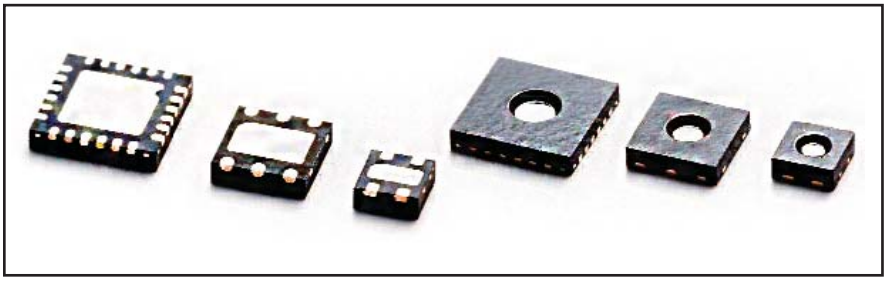
Pressure sensor.

Now the foundry model for the packaging industry is moving toward the IC foundry system. Although without widespread standardization of processes in the back-end industry, this new foundry model will remain the next best thing.

The APC Approach

Advanced Packaging Center, located in Duiven, the Netherlands, is a packaging company that uses this new foundry model. The company is a one-stop-shop supplier for packaging development solutions, including die-attach, sintering, wire-bond, and molding.

The company also provides low-to-mid-volume production of ICs, PICs, MEMs, power, sensors, and medical devices. It focuses on large, complex packages, or low-to-mid-volume packages designed for more flexible use and added value.



QFN sensor packages.

The company provides consultancy services, package design and development, sample workshop service, package production and support, and accomplishes each of these tasks in-house. In addition to these capabilities, the company also works with others to complement its services. By using these partnerships, APC is able to offer laser marking as well as a full selection of tests and analysis.

Film Assist Molding

The company also relies on film assist molding (FAM) to offer design flexibility to its customers. Initially developed by Boschman Technologies, FAM is a variation on the transfer molding process. It uses one or two plastic films in the mold, which are sucked down onto its inner surface before being loaded.

The film helps to protect the mold over time, and also allows for compounds of high stickiness to be shaped. FAM makes it possible to create packages that expose a specific area of the chip by having inserts placed in the bottom or top mold. This keeps wires overmolded and protected. The technology allows for creative package designs that are otherwise not possible.

Ag-sintering

Silver (Ag) sintering offers new void-free die-attach technology. The bond created is strong and has high thermal and electrical conductivity (200-300 W/mK and 2-2.5 μΩcm. The Ag-sintering process is defined either by temperature and time, or temperature, time and pressure.

Using dynamic insert technology, APC has been able to industrialize the process. Specifically, power applications including IGBTs, RF power, power MOSFETs, and thyristors benefit from the technology.

Through-polymer Vias

The microelectronics industry is moving towards three-dimensional (3D) stacking, packaging and integration of chips. Devices are constantly being pressed for more functionality in a smaller form, and to be less expensive. This increasing complexity requires new approaches to the fabrication of vertical-interconnections (vias) to connect chips, devices, layers, and wafers. Since 3D technology is relatively undeveloped, the technology is difficult to employ and carries a high cost.

The company has worked together with Delft University of Technology to develop a robust method of fabricating dense, high-aspect-ratio, conductive through-polymer vias. The project was conducted to meet the needs of 3D stacking, packaging and heterogeneous integration of semiconductor dies and wafers. The approach relies on patterning micro-pillars in a thin layer of photoresist on a carrier wafer or substrate. The pillars are then conformally coated with a metal film and encapsulated by an epoxy molding compound. The metal pillars then conduct electricity through the layers of substrate. For subsequent interconnect processing, a clean top surface of the pillars is crucial, which the company achieved with FAM. Even for thin pillars with extreme aspect ratios of less than 15, clean connection surfaces can be made.

Some advantages of this technology include: easily exposed pillars which are wetted by the plating solution, faster metallization than bottom-up plating, no voiding or trapping of plating chemicals, suitable for parallel fabrication, and since the process is lithographically designed, the layout can be varied and the vias can be placed accurately.

APC is just one example of a company that pushes toward the future. By studying the path of semiconductor design and fabrication over the years, it is positioning itself to bring about similar change in the world of packaging. Focused on flexibility, and putting package design information in the hands of many, the company is bringing the workforce together to share common progress.

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