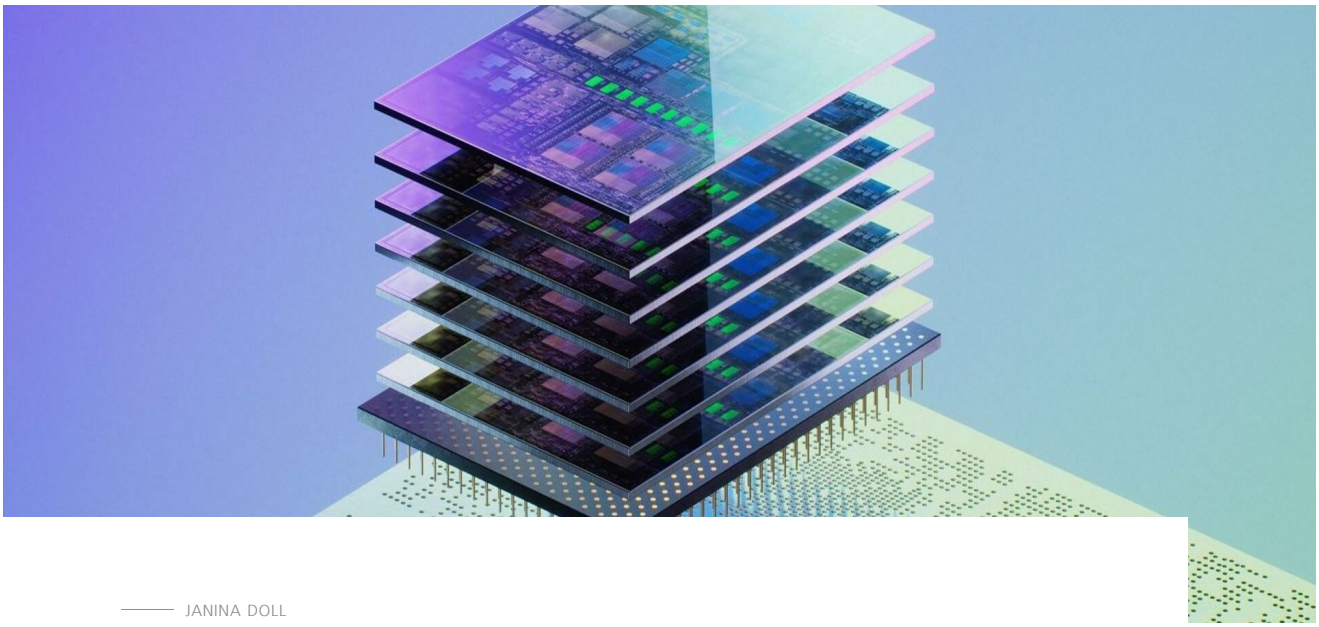


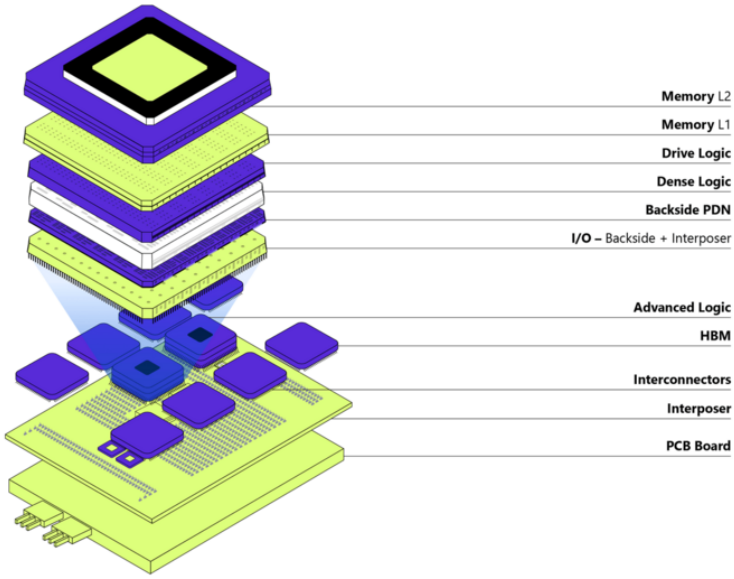
JANINA DOLL

Advanced packaging: Stacking for greater computing power

AI, high-performance computing, and connected devices require ever-increasing computing power. Individual microchips no longer meet these requirements. The solution is advanced packaging: an innovative chip architecture in which chips with different functions are combined into an entire system, stacked on top of one another, and connected using highly complex processes. TRUMPF supplies laser, plasma, and measurement technologies for key process steps during semiconductor manufacturing.

What is advanced packaging?

In what is known as advanced packaging, multiple chips with different functions are integrated into a single, high-performance entire system. Depending on the design, they are either arranged side by side or stacked on top of one another. This makes it possible to combine the processing power, memory, and other functions in a very small space, for example. Extremely fine electrical connections ensure that the individual chips can exchange data quickly and efficiently. At the same time, the generated heat must be dissipated reliably. Advanced packaging is thus much more than just a new design: The technology enables more power and higher energy efficiency in a smaller space, thereby taking microchips to the next power level.



Multiple layers, different functions: In advanced packaging, specialized chip components for the computing power, memory, and other functions are integrated into an entire system in a space-saving way.

Where is advanced packaging used?

Advanced packaging is becoming increasingly important in applications where a high level of processing power is required in a confined space. AI accelerators are one example: specialized chips that process artificial intelligence tasks particularly quickly, such as training large language models or analyzing massive amounts of data in data centers. To do this, processors, memories, and other chip components must exchange data extremely quickly. Advanced packaging shortens these paths making systems more powerful and efficient. This technology also plays an important role in high-performance computing, or HPC for short. This refers to high-performance computers used for particularly complex calculations, such as in research, simulation, weather modeling, medicine, or industrial development. In addition, there are applications in smartphones, smartwatches, vehicles, and connected factories. Everywhere, the demand for compact, fast, and energy-efficient chips is on the increase.

Why is advanced packaging so challenging?

Modern chip packages consist of millions of tiny structures, thin layers, delicate materials, and minuscule contact points. Even minor deviations can impair functionality. During series production, every process must run consistently, be reproducible and ensure a high yield, because every deviation costs a fortune. This is where specialized technology partners come into play. TRUMPF is known to many as a laser specialist in the metalworking sector and a machine manufacturer. However, TRUMPF has long been supplying technologies for process steps in the semiconductor manufacturing sector that make such modern chip packages possible in the first place.



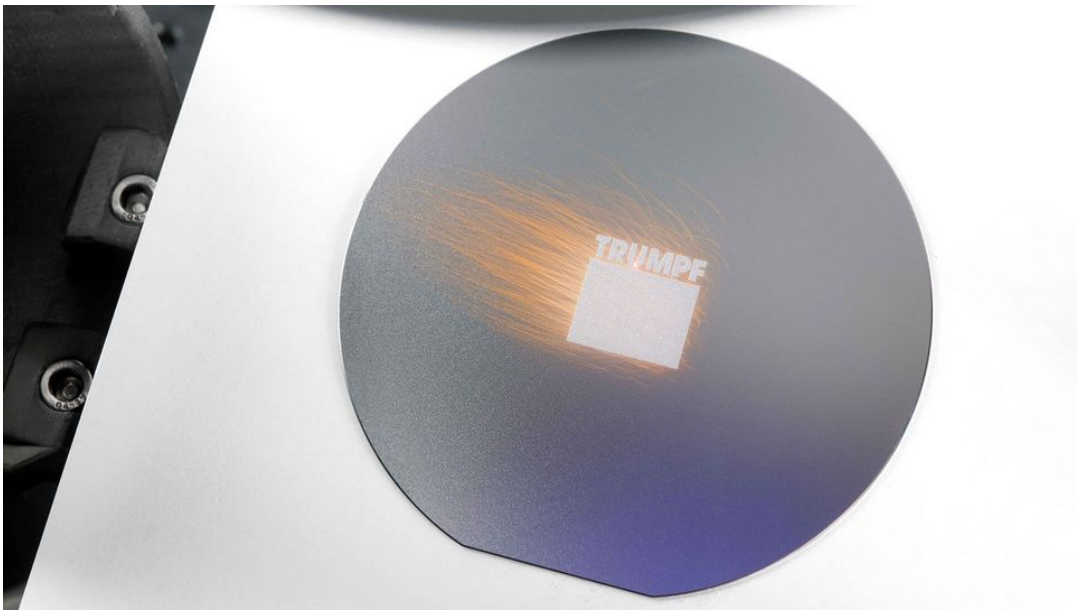
Plasma plays an important role in semiconductor manufacturing. It makes it possible to produce extremely fine structures and to specifically build up or remove wafer-thin layers of material.

What role does plasma play in advanced packaging?

Plasma is an electrically excited gas. In semiconductor manufacturing, it removes material in a controlled manner or builds up layers. In advanced packaging, plasma helps to create fine connecting structures and contact surfaces through which signals subsequently flow between the chip components. TRUMPF plasma generators precisely control the necessary processes on wafers and substrates. This makes it possible to create uniform structures, build up layers in a controlled manner, and establish reliable electrical connections.

Where does the laser really show its strengths in advanced packaging?

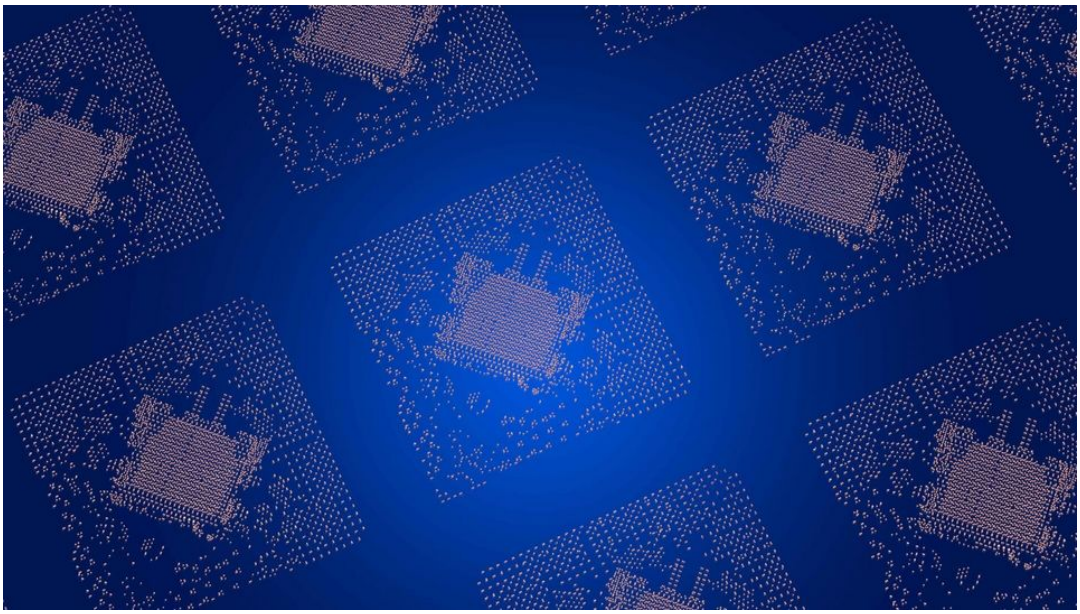
Lasers ensure non-contact processing of materials with high levels of precision. They cut, drill, texture, mark, apply localized heat, or assist with ablation and joining. This is important because new material types, such as glass, thin wafers, dense substrates, and fine interconnect layers, are essential in advanced packaging. One example where the laser really shows its strengths is the production of vias: tiny through-holes that are subsequently filled with metal using our plasma generators. This is how electrical contacts are formed between the layers in the chip package. Ultrashort-pulse lasers from TRUMPF precisely generate such vias in substrates or carrier plates. Lasers also excel at structuring circuit traces and separating chips and packages: They operate locally, quickly, and without subjecting the material to thermal or mechanical stress.



TRUMPF lasers ensure non-contact processing of sensitive materials with high levels of precision. This opens up new possibilities for semiconductor manufacturing.

What materials are suitable for use as chip substrates?

One example of the next development stage in advanced packaging is through-glass vias – i.e. fine connection holes through the glass. Up until now, manufacturers often used silicon for such carrier plates. In certain applications, glass can be used as an alternative: It has favorable thermal properties, can be manufactured with a very smooth finish, and can be processed into rectangular rather than round shapes. This helps save material and increase the yield. The challenge lies in the processing. High-precision laser technology makes it possible to quickly drill very fine holes into the glass in a controlled manner with a high level of quality. Materials used for cooling are also becoming a focus. Silicon carbide could be a promising material for microfluidic cooling channels because it dissipates heat well and is thermally compatible with silicon. In the long term, diamond is also being considered as a material. Research is already underway into its industrial applications: As part of the GrodiaQ project, Fraunhofer IAF is collaborating with industry partners, including TRUMPF, to develop new processes to manufacture diamond substrates.



Ultra-fine copper structures on a panel: The manufacture of modern chip packages requires the highest precision. Even the smallest deviations can impair functionality.

Why are measurement and testing important in advanced packaging?

The denser the chips are connected and the finer the structures become, the more important it is to continuously monitor processes. Measuring and inspecting each step of the production process – a process known as metrology – helps identify deviations early on: for example, in layer thicknesses, surfaces, drilled holes, connection points, or the alignment of individual planes. This is crucial for series production: processes must operate reliably millions of times over and achieve high yields. In addition to plasma and laser technology, TRUMPF also has experience of precise process controls. High-power lasers are indispensable tools, especially when it comes to complex, highly integrated chip architectures.

What role does TRUMPF play in semiconductor manufacturing?

When it comes to chips, the focus is often on designers, chip manufacturers, and their equipment suppliers. However, modern semiconductors also depend on partners who not only develop process steps but also make them feasible on an industrial scale. TRUMPF supports equipment manufacturers and combines three areas of expertise that are particularly important for advanced packaging: plasma technology for stable etching and recoating processes, as well as metrology for process monitoring and quality control. And thirdly, a highly advanced laser technology that covers all relevant applications, ranging from the creation of fine structures within the package to applications involving materials such as glass, and on to processing substrates and 3D architectures. TRUMPF thus enables key steps in semiconductor manufacturing.

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MANAGER FOR SEMICONDUCTOR COMMUNICATION