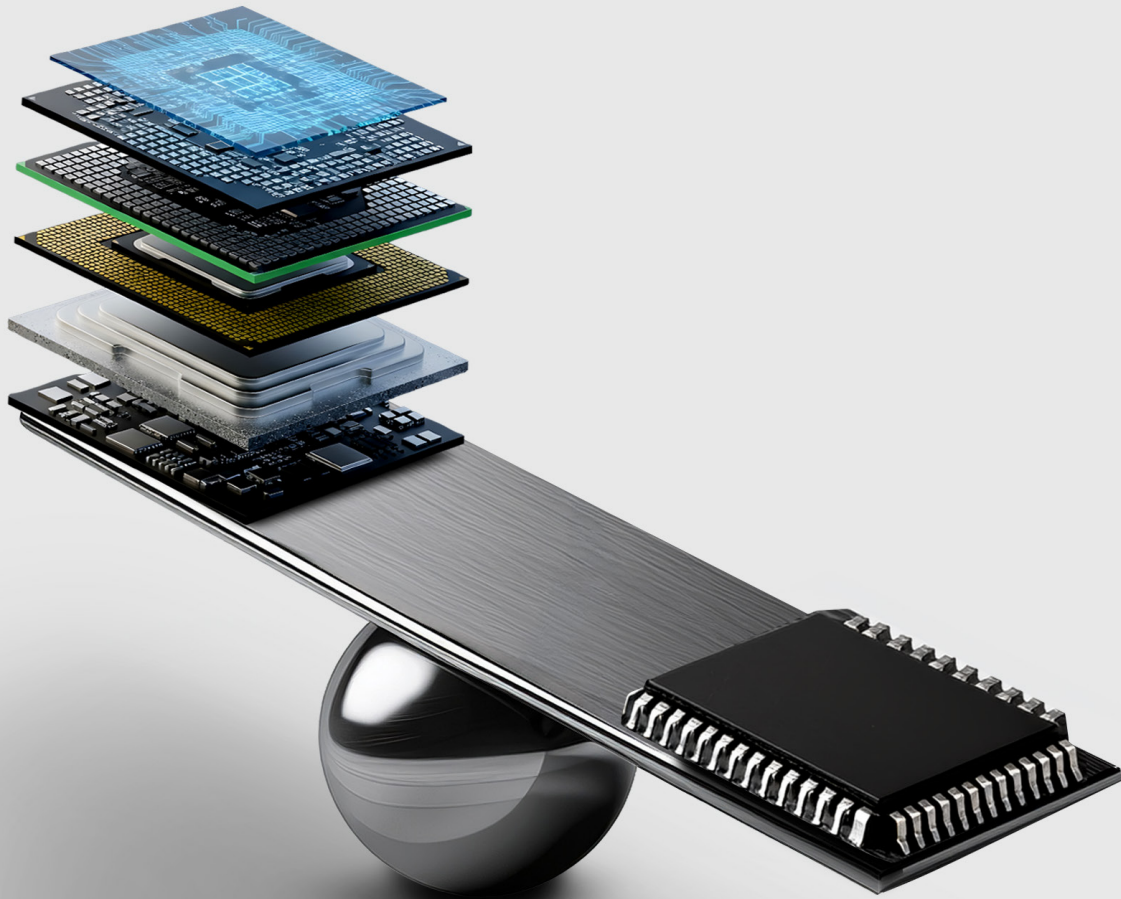




Semiconductor packaging: How to do more with less

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Full speed ahead

The global electronics industry is advancing rapidly. Artificial intelligence, high-performance computing, data centres and digital infrastructure drive the demand for more powerful, reliable and sustainable semiconductor materials. This growth is increasing the need for advanced packaging and assembly materials. From smartphones to industrial automation and cloud data centres, semiconductors form a vital part of the foundation of modern connectivity.

AI is leading the charge. Forecasts estimate global AI spending will exceed US \$2 trillion in 2026. In the Asia-Pacific region, the centre of the industry's growth, spending is expected to reach US \$735 billion by 2030, an increase of nearly 45% from 2023. This expansion is driving demand for more advanced semiconductor materials and packaging solutions.

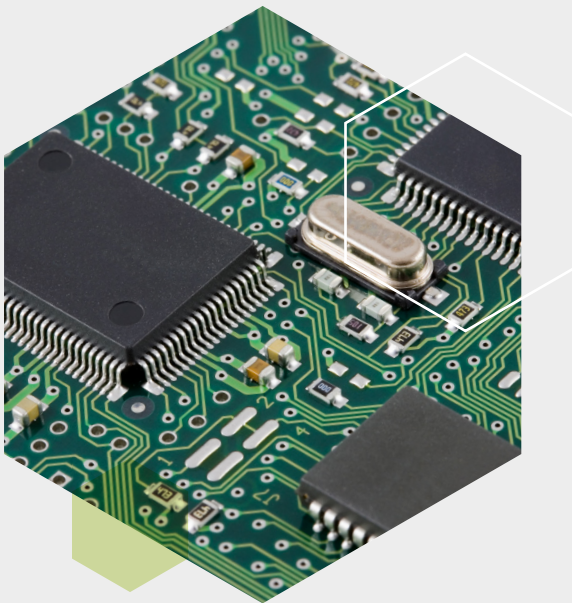
In some sectors of the semiconductor industry, such as smartphones, the focus is on miniaturisation. Developing materials that can work in reduced spaces is a critical challenge. Conversely, the demand for advanced packaging solutions for larger-scale electronics, such as data centres, is expanding, too.

For outsourced semiconductor assembly and test companies (OSATs), integrated device manufacturers (IDMs), original design manufacturers (ODMs) and

fabless companies, the multi-sector trend for reduced-size components on one hand, and improved larger-scale solutions on the other, creates four key challenges:

- Improving product performance
- Effective cost management
- Increasing sustainability
- Ensuring a reliable global supply chain

These pressures raise an important question: how can semiconductor packaging deliver more performance, more reliability and lower emissions while using fewer materials, less energy and less space?



Innovative electronics need innovative materials

Every high-tech device relies on the performance of its components. Working together, they determine how fast data moves, how efficiently heat dissipates and how long equipment lasts. The materials that bond and cool semiconductors enable performance improvements.

While products such as mobile devices rely on solder pastes for standard assembly processes, AI and data centre semiconductors need advanced materials for processes such as thermocompression bonding. That means stronger solutions for higher reliability, longer-term stability and consistency.

For device manufacturers, choosing the right packaging and assembly materials can directly influence yield, reliability, efficiency and a product's environmental profile. Using higher-value metals comes with a cost, but for expensive high-temperature components like AI chips, the enhanced reliability they can deliver can justify selection. The more that material considerations are integrated into the design process, the better the balance between performance, cost and sustainability.

Miniaturisation: pushing precision possibilities

Miniaturisation is a good example of doing more with less. From smartphones and wearables to autonomous driving sensors and photonic transceivers, the drive toward smaller solutions and higher performance continues. But, as pitches become smaller, interconnections multiply, heat dissipation becomes an increasing issue, and the tolerance for error becomes lower.

Designers must integrate more functionality into smaller footprints without compromising yield or thermal stability.

Fine-pitch solder pastes, such as those developed by Heraeus Electronics under the Welco™ brand, are engineered to print features down to 70 microns and below, supporting size reduction and heat dissipation. They combine precisely spherical, uniform powder with advanced flux chemistries to eliminate voiding and residue. The result is high-density, high-yield packaging that supports faster, thinner and more powerful devices.

Miniaturisation isn't just about reducing physical space; it can increase system efficiency, too. Smaller assemblies can lower electrical resistance, shorten signal paths and reduce overall energy consumption. As pitches shrink and interconnect density increases, these gains can contribute to improved performance per watt.

Advanced packaging techniques, such as vertical and traditional loop bonding, package-on-package stacking, and heterogeneous integration, alongside solutions like soldering and sintering materials, are extending the performance limits of semiconductor packaging.

For manufacturers and packaging solution providers, materials innovation will determine who leads their markets.

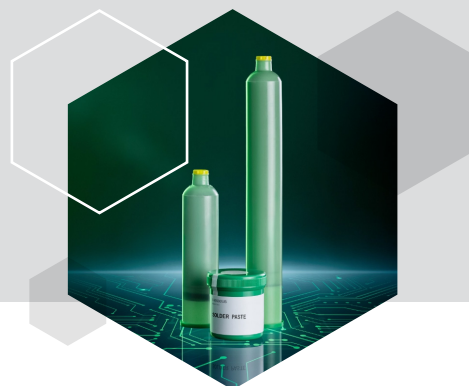
As semiconductor devices shrink and integrate more functionality, the precision and reliability of interconnection materials become critical. As a leader in fine-pitch solder paste for flip-chip and system-in-packaging (SiP) modules for high-density devices, we responded to this challenge by developing our **Welco™ fine-pitch solder paste** series - which has been used in many mainstream 5G smartphones and gadgets - and our advanced **All-in-One printing process**.

Welco™ fine-pitch solder paste (Type 6 and Type 7) delivers perfectly spherical, uniform, and defect-free solder powders, ensuring consistent printing and joint formation for pitches down to **70 microns**. The chemistry ensures low voiding, minimal residue, stable reflow performance, and excellent wetting on fine geometries. This enables **higher yield, longer stencil life and higher throughput to deliver a lower cost of production for customers**. Versions of our fine-pitch solder pastes are

available with **100% recycled tin** for significant carbon reduction while maintaining the performance and reliability required for high-density packaging.

Our **All-in-One printing process** streamlines multiple assembly steps, allowing manufacturers to print the solder paste with a single stencil for all components and flip-chips on the same substrate. The result is **simpler workflows, shorter production times, reduced energy consumption and improved process stability**. It also provides greater design flexibility for compact SiP and multi-chip modules.

For more, visit our website
www.heraeus-electronics.com/en/



Larger-scale electronics: proven power and reliability

In larger-scale electronics such as servers, memory modules, laptops, and automotive power units, achieving more with less can mean increasing energy efficiency, performance and reliability while reducing size and weight.

Gold and copper bonding wires remain essential where conductivity and reliability are crucial. Gold provides excellent conductivity and corrosion resistance. Copper offers high conductivity at a lower cost and with a smaller environmental footprint, particularly when recycled feedstock is used.

The requirement is for materials that can provide increased long-term and stable high-performance reliability and durability, reducing downtime and creating financial savings.

For advanced packaging-related products such as flux, residues must be easily cleanable to avoid downstream yield losses, such as underfill delamination.

Heraeus Electronics is a leader in bonding wire technology. Our range of **gold and copper bonding wires** combines electrical performance, mechanical strength and long-term stability.

Our gold bonding wires enable consistent loop formation and minimise breaks. Their chemical stability means that they can withstand oxidation and sulphur exposure to extend asset lifetime.

Our **carbon-reduced gold wire** is made entirely from recycled precious metals and reduces Scope 3 carbon emissions while preserving performance.

Heraeus Electronics' copper bonding wires provide a high-conductivity and cost-efficient solution. Enhanced surface coatings and micro-alloy formulations improve oxidation resistance and enable stable ball formation, even in fine-pitch or high-temperature processes.

Contact us for more information
www.heraeus-electronics.com/en/





Advancing sustainability

Sustainability is a critical innovation driver in the semiconductor sector. Many companies regard environmental stewardship as essential in advancing commercial competitiveness. It shapes sourcing decisions, manufacturing partnerships, and investor relations.

Semiconductor packaging manufacturers need to demonstrate not only their own sustainability credentials, but also how they can advance their customers' environmental targets as well.

For OSATs, IDMs, EMSs and fabless companies, this engagement with materials manufacturers matters. Sustainability is no longer a 'nice to have'. It's a requirement for future-proofing supplier relationships. As regulatory frameworks and sustainability reporting requirements tighten, being able to source materials from transparent and compliant partners is now the standard.

Materials engineered for cleaner reflow, longer shelf life, and higher process reliability mean fewer defects and less scrap. Against this backdrop, materials partners play a key role in enabling both performance and sustainability outcomes.

Heraeus Electronics: advancing electronics packaging

Heraeus Electronics is a leading global manufacturer of materials for the assembly and packaging of devices in the electronics industry. We develop material solutions for the advanced semiconductor packaging, automotive, and power electronics markets in eight development centres and production facilities in Asia, the USA, and Europe. As a solution provider, we offer a broad portfolio of solutions - from materials and material systems to components and services for the electronics packaging and component industry.



Case study: reducing complexity, increasing efficiency, zero product recalls

A leading fabless manufacturer of radio-frequency (RF) modules approached Heraeus Electronics to help solve persistent quality challenges in its mobile device assembly line. The customer's SiP design used flux materials for flip-chip attachment and a separate soldering material for passive components. This dual-material process often led to higher equipment and labour cost, more complex material management and lower throughput. This meant inconsistent performance, complex reworking, and occasional field recalls that impacted both production costs and brand confidence.

Our engineering team collaborated closely with the customer's process engineers to develop an integrated approach. The solution was to adopt a single fine-pitch solder paste capable of supporting both flip chips and passive components in high-density interconnect designs. This led to the implementation of our **Welco™ AP5112 / AP520 T7 Type 7 fine-pitch solder paste**.

AP5112 and AP520 T7 enable the soldering of both flip chips and passive components for the SiP, which disrupts the traditional process of using flux for flip chip and paste for passive components. This all-in-one printing process simplifies production, increases yield and lowers the overall cost of ownership for our customers.

The chemistry and precise powder morphology enabled uniform printing and consistent solder joint formation across every component on the substrate.

We further supported the customer with application tests in-house and in their subcon factories around the globe to ensure the all-in-one printing process could be successfully implemented and scaled up for mass production.

Shortly after adoption, the customer reported a **dramatic improvement in process stability**. Defects were eliminated, and yield rates rose to record levels. Most notably, since adopting our material, the customer has experienced **zero product recalls**.

The successful outcome was due to collaboration among many parties, including the fabless customer, Heraeus Electronics as the materials provider, OSAT companies, equipment suppliers and cleaning solution companies. It is a good example of how rethinking materials can simplify processes to deliver more output with fewer steps and defects.

As the customer's modules have evolved toward even smaller pitches and higher complexity, we continue to partner with them to deliver effective solutions. This partnership approach, integrating material science, equipment capability, and process optimisation not only helps our client; it's also advancing ongoing innovation in miniaturised RF and mobile electronics.



Our Welco™ paste is used in leading mainstream 5G smartphones worldwide. Our products and services are a key enabler for this technology.

Accelerating performance and sustainability

Heraeus Electronics' products deliver greater reliability across a wide range of electronic applications. Servers and memory stacks that operate around the clock depend on these interconnections to maintain signal integrity over billions of cycles. Our integrated product offering, including recycled precious metals, recycled tin solder pastes, and decarbonized bonding wires, has been adopted by major global manufacturers, proving that sustainability can match the stringent reliability and sustainability standards demanded by critical infrastructure.

Our Sustainability Roadmap 2030 demonstrates how a materials manufacturer can integrate sustainability into every aspect of its operations. The plan commits

to aligning emissions reduction with the Science-Based Targets initiative (SBTi) and the 1.5 °C trajectory of the Paris Agreement. By 2030, we aim to cut Scope 1 and 2 emissions by 25 percent, supported by photovoltaic installations, renewable energy procurement, and energy-efficient projects at our global facilities. For Scope 3 emissions, we engage with suppliers to share carbon data, encouraging the increased use of recycled materials and certified decarbonisation targets.

Improvements in process chemistry, material composition, and supply-chain transparency can deliver measurable improvements in performance, reliability, and carbon efficiency.

Partnering for innovation

For OSATs, IDMs, ODMs and fabless companies, early collaboration with materials manufacturers can ensure that new products are designed with manufacturability, yield, and sustainability built in, to enable performance breakthroughs. Working closely with customers can help packaging providers develop materials suited to their evolving manufacturing needs.

For this to happen, companies must remain open to new ideas in technologies and solutions, too. Progress depends on continually introducing and innovating new materials. Today, advancing material science is more critical than ever. For example, concepts such as heterogeneous integration, which combine different materials and technologies to achieve higher performance, including electronics with photonics, have

been discussed in the industry for many years. In recent years, however, advances in packaging technologies and materials have enabled these approaches to be implemented more effectively and at scale, making them a key driver of semiconductor innovation today.

Heraeus Electronics engages with customers to explore how advanced materials can address emerging challenges. Our global development footprint provides local expertise and application testing that mirrors real production environments. This can help shorten design cycles, reduce risk and accelerate time to market. When companies navigate rapid technology transitions, such collaboration can ensure sustained leadership in innovation.

Empowering the future

The semiconductor industry will continue to accelerate, fuelled by factors such as AI, cloud computing, and the electrification of infrastructure and mobility. The challenge for semiconductor companies will be to ensure they have the right material components to empower them to achieve their growth ambitions efficiently, effectively, and responsibly. Performance, reliability, cost, and sustainability will define the next generation of electronics.

As the semiconductor industry's packaging solutions partner, Heraeus Electronics is advancing technical innovation. Our customers trust us not only to support their packaging and assembly needs today, but to prepare for their challenges tomorrow. By combining advanced materials expertise with a commitment to recycling, decarbonization, and collaborative development, we align with customer and end-user goals.

For manufacturers, working with an innovative partner creates a competitive advantage. For end-users, it means the availability of products that deliver more performance and reliability with less of an environmental footprint. For the industry as a whole, there's an opportunity to demonstrate that commercial success can be achieved responsibly.

The semiconductor journey is gathering pace. While the destination continues to evolve, progress will require collaboration, innovation, resilience and a continued commitment to environmental responsibility as the industry seeks to do more with less.

Let's discuss where we can take you next.
Contact us www.heraeus-electronics.com/en/



ABOUT HERAEUS ELECTRONICS

Heraeus Electronics is a materials innovation partner for the electronics industry with global reach and local presence. The company develops material solutions for the automotive, power electronics and advanced semiconductor packaging market and offers its customers a broad product portfolio – from materials and material systems to services.



Headquartered in
Hanau, Germany



1500+
employees worldwide



More than **60 years**
of experience in providing
materials for the electronics
industry

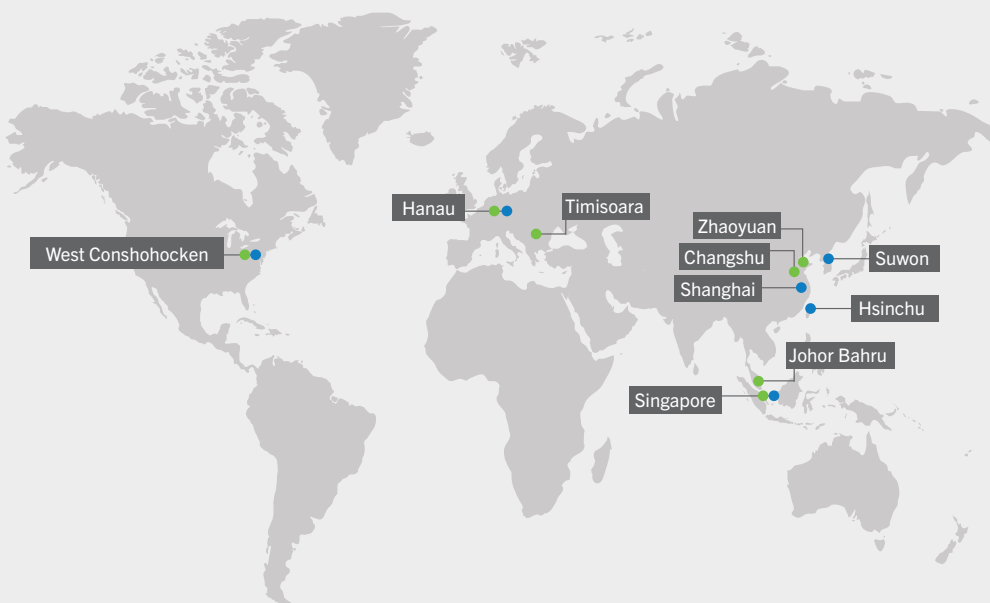


**6 research and development
centers**
and **8 production sites**
in 6 countries



Product distribution to
over 50 countries

Production sites and application centers Strategic locations to support our customers worldwide



PRODUCTION SITES

Hanau, Germany
Timisoara, Romania
West Conshohocken, United States
Johor Bahru, Malaysia
Changshu, China
Zhaoyuan, China
Singapore (2 sites)

APPLICATION CENTERS

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Hsinchu, China (Taiwan)
Singapore
Suwon, South Korea

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