FRAUNHOFER INSTITUTE FOR PHOTONIC MICROSYSTEMS IPMS

PRESS RELEASE

Milestone in the European APECS pilot line: Successful implementation of quasi-monolithic integration (QMI)

The Future of Chip Integration: Fraunhofer IPMS Develops High-Density Chiplet Systems at the Wafer Level

Breakthrough in chip manufacturing: As part of the European APECS pilot line, researchers at Fraunhofer Institute for Photonic Microsystems IPMS have developed a method that allows different chip components to be fused almost seamlessly into a single unit. By precisely embedding small chiplets into specially structured silicon pockets, Fraunhofer IPMS succeeded in combining the advantages of a compact single chip with the flexibility of modular systems for the first time. This achievement demonstrates the feasibility of quasi-monolithic integration (QMI) and bridges the gap between traditional chip packaging and cutting-edge semiconductor manufacturing.

Growing demands for greater complexity, computing power and system compactness are calling for a radical rethink of semiconductor manufacturing. The vision for future-proof microelectronics is to create systems that are as powerful as a single chip yet offer the flexibility of modular building blocks. Within the APECS pilot line, which focuses on "Advanced Packaging and Heterogeneous Integration for Electronic Components and Systems", Fraunhofer IPMS is pursuing the quasi-monolithic integration (QMI) approach. The aim is to integrate various chip components, such as control electronics, sensors and microelectromechanical systems (MEMS), at the wafer level, while retaining the benefits of a compact single chip.

From Theory to Reality: Pockets, Placement and Embedding

Researchers at Fraunhofer IPMS have successfully achieved the first critical milestone of the QMI roadmap. "The basis of QMI is silicon wafers with structured recesses, or pockets. For the first time, dummy chiplets have been inserted into these pocket wafers and the surface has been levelled with a passivation layer in preparation for subsequent back-end-of-line wiring," explains Dr. Lukas Lorenz, group leader at Fraunhofer IPMS. "This creates a nearly monolithic system architecture that combines the highest integration density with modular scalability." This success paves the way for the industrial maturity of the entire process chain for future applications.

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Technological advantages: Higher system performance with maximum compactness

QMI technology offers significant advantages over conventional packaging processes. This is due to the way chiplets are arranged on an active or passive wafer substrate with a shared interconnect stack. Since the interconnects are formed in the front-end-of-line process, much higher connection densities can be achieved than with traditional methods. The following benefits result:

- **Higher performance:** Shorter signal paths reduce losses and latency, thereby increasing processing speed at the system level.
- **Reliability:** Reducing mechanical interfaces increases the robustness and operational lifetime of the systems.
- **Compactness:** QMI saves a significant amount of space because the elements are integrated in a nearly monolithic fashion.
- **Cost-efficiency:** Combining modular chiplet approaches enables highly cost-effective integration, short innovation cycles, and high scalability.

These advantages make quasi-monolithic integration ideal for innovations such as highly integrated system-on-chip (SoC) solutions for artificial intelligence (AI) applications and high-bandwidth smart transceivers.

Next Steps Toward Industrial Deployment

Dr. Lukas Lorenz emphasizes: "Although the current demonstrator is based on dummy structures, the process chain can be transferred to real-world customer applications. This enables a scalable integration architecture for future heterogeneous system solutions." Fraunhofer IPMS is targeting industrial partners whose products could benefit from the integration of different high-density technologies. The approaches developed within the APECS framework form the basis for quickly transferring QMI to production-oriented manufacturing environments. Further information is available on the Fraunhofer IPMS website.

Funding

APECS receives funding from the Chips Joint Undertaking and from national grants in Belgium, Germany, Finland, France, Greece, Austria, Portugal, and Spain, as part of the "Chips for Europe" initiative. The total funding for the APECS pilot line is €730 million over four and a half years.

About Fraunhofer IPMS

Fraunhofer IPMS is a world-renowned research and development service provider specializing in electronic and photonic microsystems. Our technologies are used in industries such as mobility, biotechnology, and medical technology. We are also addressing key future fields, such as quantum technologies and neuromorphic computing. Through our research in green microelectronics, we contribute to a sustainable and resource-efficient world.
Fraunhofer IPMS is a member of the Research Factory Microelectronics Germany (FMD).
https://www.ipms.fraunhofer.de/en.html

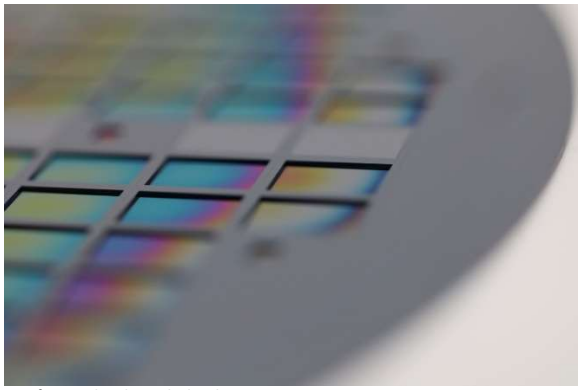
About the APECS Pilot Line

Under the EU Chips Act, the Research Fab Microelectronics Germany (FMD) is implementing APECS, a comprehensive pilot line to support resilient and trusted heterogeneous systems over the coming years. The APECS pilot line enhances the innovative capacity of European industries across various sectors and serve as a crucial foundation for Europe's technological resilience. Through System Technology Co-Optimization (STCO), APECS introduces new functionalities and offers seamless design-to-production capabilities, facilitating the transition of research breakthroughs into scalable manufacturing solutions. As a single point of access, APECS serves stakeholders across nearly all industry sectors, including large enterprises, SMEs, and start-ups. This pilot line brings together the competences, infrastructure, and know-how of ten partners from eight European countries. In Germany twelve institutes from the Fraunhofer-Gesellschaft and two institutes from the Leibniz Association are participating in APECS. APECS is coordinated by the Fraunhofer-Gesellschaft and implemented by FMD.
https://www.apecs.eu/

About Research Fab Microelectronics Germany (FMD)

FMD is a collaboration between 13 Fraunhofer institutes and the Leibniz institutes FBH and IHP. It serves as the central point of contact for all matters related to micro- and nanoelectronics research and development in Germany and across Europe. As a one-stop shop, FMD brings together advanced technologies and system solutions from its cooperating institutes to provide a customized, comprehensive portfolio. Established within FMD's shared virtual framework in 2017, this joint research cooperation has grown into one of the largest of its kind, now comprising more than 5,400 employees and a uniquely broad range of expertise and infrastructure.
https://www.forschungsfabrik-mikroelektronik.de/en.html

Images



Wafer with placed chiplets
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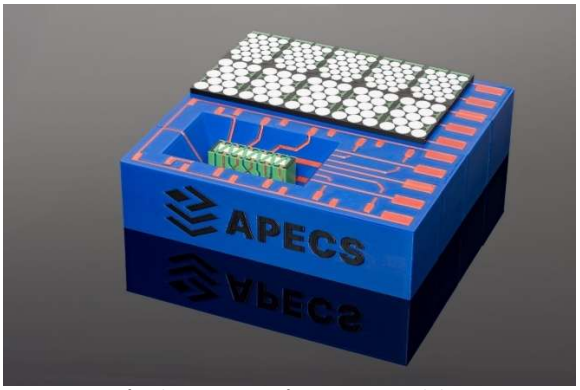

3D printing of a demonstrator for quasi-monolithic integration with a chiplet in the pocket.
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