PROJECT RESULTS

CT312 | Transforming quality in R&D of 3D integrated circuits into leadership in sustainable 3D IC manufacturing [MASTER_3D]

The project MASTER_3D aimed at reaching excellence in three dimensional, integrated circuit production by developing and implementing methods that raise the quality of manufacturing and also make it cost-competitive. This project focuses on process and equipment innovations, metrology, testing and yield, with a special emphasis on through silicon vias (TSV) and wafer level packaging (WLP).

3D integration is considered a key technology for heterogeneous system integration, and the ongoing merge of semiconductor front-end and assembly and packaging technologies is now part of scaling and functionality roadmaps for 2.5D/3D solutions. In the process, Europe has gained R&D leadership in this field. Before MASTER_3D was conceived, however, there was a risk that Europe would fall behind its Far-Eastern competitors if it did not raise quality levels of its manufacturing as well. This meant creating the right 'production environment' to allow it to play a significant role in the volume manufacture of 3D integrated circuits (ICs), precisely the objective of MASTER_3D. In the process, this project is turning European Union leadership in the R&D of 3D integrated circuits, into one in sustainable 3D integrated IC manufacturing.

Targeting manufacturing excellence

MASTER_3D aimed at quality in 3D IC production through cost-competitive manufacturing methods that deploy through silicon vias (TSV) and wafer level packaging (WLP), as well as in-line and electrical parametric monitoring, with yield enhancement and testing,

Key project activities and deliverables can be summarised as follows:

- Process tools assessment and improvement for mass production: related to the enhancement of the unit process robustness in the context of process specifications and process stability, as well as cost-of-ownership of process equipment;
- Characterisation and metrology: the development and assessment of necessary methods and tools to characterise and control 3D-specific process steps;
- Validating test infrastructure: testing out a product-compatible test infrastructure and its integration into a 3D industrial test-flow;
- Yield modelling and testing: demonstrated the technology and assessed project progress and results.

Information sharing was excellent. The project generated some 45 reports and 50 presentations, and project results and knowledge shared internally, as well as, with academia and industry. Innovation and creativity were not in short supply, with the submission of six patent applications, and two project partners created a common laboratory. Project partners also addressed the issue of standards for memory interfaces, computer aided design (CAD) tool formats, and test interfaces, with many partners initiating their own standardisation initiatives.

Spin-off benefits for project partners

The composition of the consortium meant that partners contributed the right expertise and skill-sets necessary for 3D manufacturing, and ultimately to the success of the project. Excellent collaboration that was established and emphasised in the course of this project also contributed to technical results considered beyond state-of-the-art.

MASTER_3D partners are now well positioned to take advantage of market opportunities.

3D stacked dynamic random-access memory (DRAM) and advanced logic interposers are now in production and most of the tool suppliers involved in the project have already sold tools for these applications. This first TSV adoption phase also provides a good opportunity for all participants to accelerate tool and process improvements and therefore facilitate TSV-based products to become profitable.

However, the main driver of MASTER_3D is coming from heterogeneous integration. More and more opportunities are emerging in the field of silicon photonics (an evolving technology in which data is transferred among computer chips by optical

PROJECT CONTRIBUTES TO

- Automotive and transport
- Energy efficiency
- Sensors and actuators
- Process development
- Manufacturing science
- More than Moore

PARTNERS

ALES
ams AG
AXO
CEA-LETI
CNRS LIRMM
EVG
FhG (IWMH, IKTS-MD, IZM)
Fogale
IMS Bordeaux
Infineon
Sentronics Metrology
NXP
PVA TePla
QUALTERA SAS
Rockwood Wafer Reclaim SAS
SPTS Technologies SAS
STMicroelectronics

COUNTRIES INVOLVED

Austria
France
Germany

PROJECT LEADER

Brigitte Descouts
STMicroelectronics

KEY PROJECT DATES

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rays) internet of things (IoT) and radio frequency (RF), for example. And project partners and other European companies are well positioned to address this huge system-in-package potential market.

Some 3D-specific techniques (such as polymer permanent bonding and stress compensation) are also valuable enablers for new applications. Some projects relying on these techniques (not necessarily real 3D Integration) have already been launched and are now considered key opportunities for innovation.

Broader markets, promising opportunities

There are also wider possibilities. Crucially, not only does MASTER_3D address user requirements and demands, but it can also benefit from markets needed to commercialise and monetise its deliverables. For example, with the implementation of 3D TSV in high-volume production, this memory technology is expected to reach US$4.8 billion in revenues by 2019.In addition to a strong demand for micro-electro-mechanical systems (MEMS), power devices will also continue to play a key role in the electrification of transport and changes to the grid infrastructure. (These two fields are being influenced by the combination of renewable-energy production and storage stations, and by political push towards cleaner transport systems.)

Then there is the lighting industry, which is now investing in LED modules to improve the quality of luminaires, reduce costs and improve value. With more industrial ventures initiating this transition in 2016, 3D CMOS image sensors (CIS) will represent 69% of the total wafer starts in 2019, followed by 3D stacked DRAM reaching 11% and wide I/O with 9%. Regarding revenue, CIS will represent 65% of the total revenue in 2019, followed by 3D stacked DRAM with 17% and 3D logic/memory with 9%.and wide I/O will represent 7% in 2019, but is expected to grow in the future.

Furthermore, advanced packaging is now part of the scaling and functionality roadmaps and providing additional interest in 2.5D/3D solutions. In order to respond to market demands, the advanced packaging segment is focusing on integration and WLP. Emerging packages, such as fan-out WLP, 2.5D/3D IC and related system-in-package solutions, aim at bridging the gap and reviving the cost/performance curve.

Notably, IoT and Si photonics provide additional opportunities. After all, more than half of all major new business processes and systems are expected to incorporate some element of IoT by 2020. Enhanced demand for high data-speed and communications by data centre applications have already resulted in significant growth in the global photonic IC market, which is expected to expand to US$497m by 2020, growing at a CAGR of 27.74% from 2014 to 2020. And the silicon photonics device market is expected to grow from around US$25m in 2013 to more than US$700m in 2024, at a 38% CAGR. Furthermore, emerging optical data centres owned by large internet companies (Google, Facebook and the like) could trigger this market growth in 2018, with Intel, which is very active in this field, contributing to a quick ramp-up of silicon photonics.

MASTER_3D reminds us that a project's success is not only measured by the quality and availability of its deliverables, and how well they mesh with user and industry demands; but also by market opportunities capable of turning them into revenue.

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