

MEMS PACKAGING 2017

Market & Technology report - October 2017

How is the evolution of MEMS devices driving packaging and test strategies?

KEY FEATURES OF THE REPORT

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- MEMS market forecast in value, wafers, and units for 2016 - 2022
- Major trends and evolution for the MEMS industry and markets, by devices (pressure, microphone, inertial, micro mirror, bolometer, RF MEMS, antenna tuner, oscillator, gas sensor, fingerprint sensor) and applications (aeronautics, automotive, consumer, defense, industrial, medical, telecom)
- Overview of the different package types, by MEMS device (QFN, LGA, TSV, flip chip, ceramic, thin-film, etc.)
- MEMS packaging's evolution over the past years, and a roadmap for future MEMS packaging solutions
- Dedicated MEMS reverse engineering report showing the different package types
- MEMS packaging forecast for 2016 - 2022 in volume and value for the different package elements: encapsulation, interconnect, substrate, etc.
- MEMS packaging supply chain analysis
- MEMS testing trends

WHAT'S NEW

- Updated 2016 - 2022 MEMS packaging market forecasts, in units and \$USM by:
 - MEMS type
 - Packaging platform
- Overview of 2016 - 2022 MEMS markets
- Updated OSAT market share for MEMS packaging
- Updated MEMS packaging roadmaps and trends
- Complementary report from System Plus Consulting with a packaging teardown analysis on MEMS-based devices

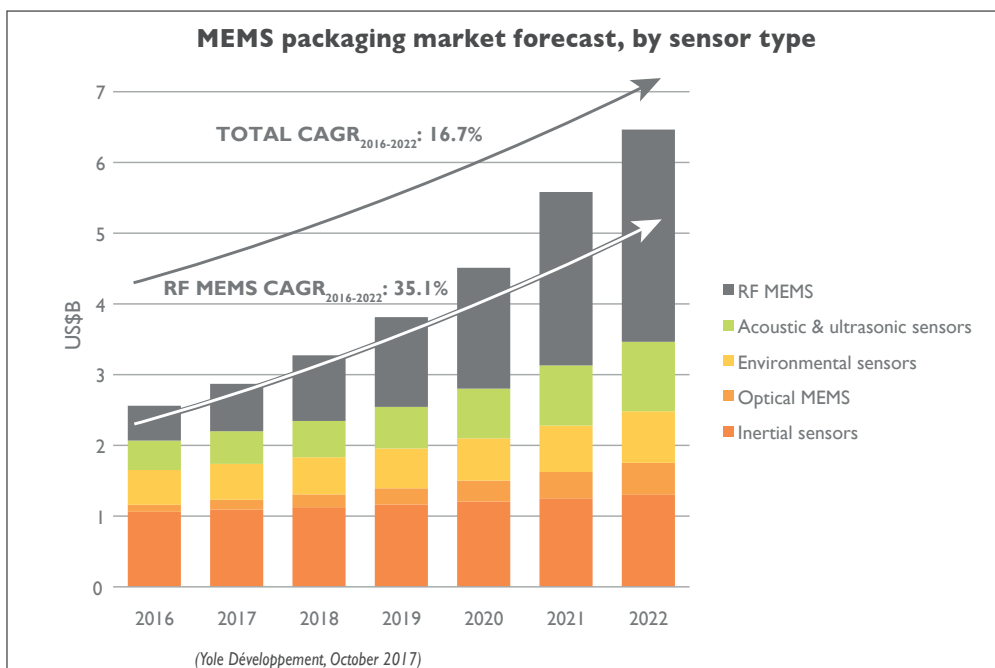
MEMS PACKAGING'S VALUE IS GROWING FASTER THAN THE MEMS DEVICE MARKET

MEMS are characterized by a wide range of different designs and manufacturing technologies, with no standardized processes. MEMS' application scope is broad and also very fragmented and diversified - thus, MEMS packaging must always cope with different end-application requirements (i.e. protection in different media, hermeticity, interconnection type, and thermal management). This creates many challenges for the packaging industry, which faces different package configurations (open, closed) for many different application constraints: from the need for low-cost packaging in consumer applications, to the ability to withstand high temperature and harsh environments for automotive and aeronautics packaging.

We estimate that the MEMS packaging market will grow from a market value of \$2.56B in 2016 to \$6.46B in 2022 - a 16.7% CAGR over this period. Driven by the complexity associated with the move to 5G and therefore the increasing demand for RF filters in 4G/5G, the largest MEMS growth will be for RF MEMS (BAW filters). Optical MEMS (including micro mirrors and micro bolometers) are second with a 28.5% CAGR, driven by consumer,

automotive, and security applications. Acoustic and ultrasonic (including microphones) are third. Demand for audio processing is particularly strong, with high unit growth for MEMS microphones targeted at increasingly sophisticated applications that use the microphone to continuously sense what is happening around it, i.e. for smartphones or inside/outside the car, factory, or home.

The MEMS packaging market's value is growing faster than the MEMS device market's value: respectively, a 16.7% 2016-2022 CAGR for packaging versus 14.1% for devices. The first reason for this is that OSATs already have very low package margins due to fierce competition, and it will be difficult for them to lower the cost further. The second reason is the importance of testing. Because every MEMS is different, testing strategies are usually dedicated to one device type and account for a significant fraction of the final cost. The third reason is linked to the packaging's material cost (i.e. gold and copper), which follows the global cost of raw materials. And the fourth reason is the strong CAGR for certain devices, for example RF MEMS.



IDM VS. OSAT: WHICH ONE WILL ENJOY A BIGGER SLICE OF CAKE?

Depending on the type of MEMS, either IDMs or OSATs oversee packaging. Today, OSATs own 55% of the MEMS packaging market's value, while IDMs

own 45%. The exact breakdown depends on the MEMS device type. In general, internal tests are conducted by IDMs since functional tests are very

MEMS-specific/dependent, and thus confidential. Thus, an OSAT cannot use the same test strategy for different customers.

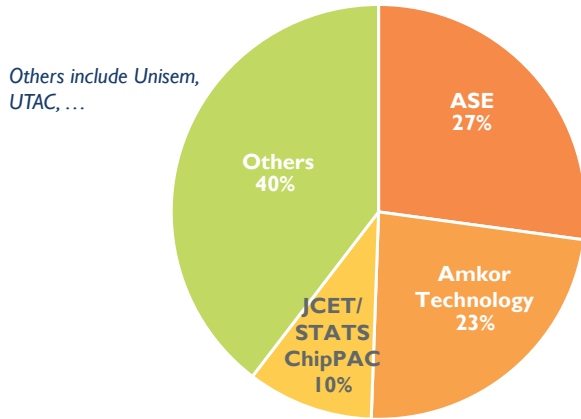
For RF MEMS, the market leader (Broadcom) does its own packaging. OSATs are involved in oscillators and antenna tuners for fabless and fab-light players,

and in some cases for BAW filters. Microbolometers are complex sensors, so packaging and testing is generally done internally by IDMs (Ulis, FLIR) that have developed their own test strategies. Optical MEMS also require special packaging, usually with an optical window. Testing is very complex, so IDMs (i.e. Texas Instruments) usually do the packaging and testing. Indeed, the limited number of players and low volume doesn't justify subcontracting at OSATs.

For large-volume applications like consumer and automotive, packaging is cost-driven. The inertial MEMS supply chain is quite fragmented: some IDMs keep testing and calibration internal but outsource packaging and assembly, while others do it all. For environmental MEMS, OSATs are involved in gas, pressure, and combo Packaging, Assembly & Test (PA&T). And for acoustic MEMS, many microphone vendors outsource to OSATs for packaging and testing.

In MEMS packaging, the market leaders are ASE and Amkor Technology (respectively 27% and 23% market share), followed by JCET/STATS ChipPAC. There are also many other companies with less than 10% market share.

OSAT market share - MEMS packaging activity



Breakdown available in the report

(Yole Développement, October 2017)

MEMS PACKAGING: A STEADY EVOLUTION

Packaging platform - Breakdown by MEMS device

		Done by OSATs and IDMs			Mainly done by IDMs		
		INERTIAL SENSORS	ENVIRONMENTAL SENSORS	ACOUSTIC & ULTRASONIC SENSORS	OPTICAL MEMS	RF MEMS	
First-level package	WLP					X	
	Thin film	X					
Interconnects	TSV					X	
	Wire bonds	X				X	
	Bumps	X				X	
	Conductive glue						
Final package	DFN, QFN					X	
	LGA	Molding	X			X	
		Metal lid					
		Laminate lid					
		Stacked die					X
	CLGA						
	SOIC	X					
	WLCSP	X				X	
SMT							
Hi-Rel (ceramic, metal)	X						

Data available in the report

(Yole Développement, October 2017)

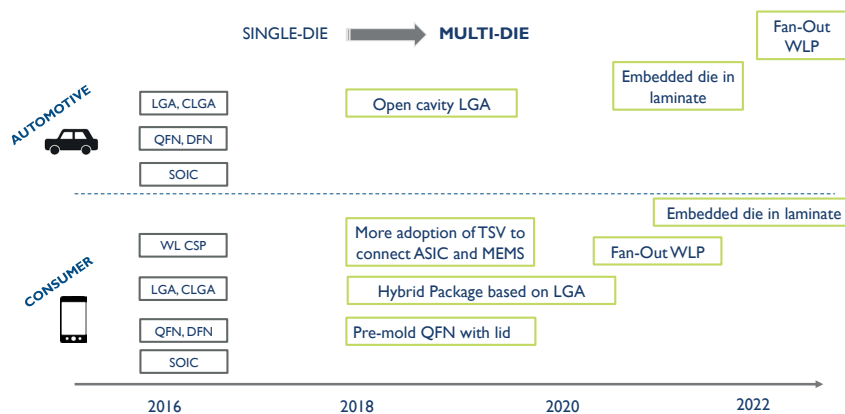
MEMS packaging already has innovative approaches like TSV and open-cavity packages to expose a die to the outer environment (suitable for TPMS, humidity, temperature, gas sensors). And in the long-term, fan-out could also be used in some inertial MEMS and pressure sensors.

Packaging platforms will follow a steady evolution, with changes in the complexity of the existing platforms responding to the growing needs of sensor fusions. Combining several inertial or several environmental sensors in a package is now a reality, and the next step will be to combine inertial and environmental sensors in the same package, similar to how LEDs and photodiodes are integrated today. Thus, the MEMS packaging roadmap will need to integrate the shift from single-die packaging to multi-die packaging.

For automotive applications, packaging and assembly are even more important and could represent an opportunity for OSATs. Automotive tests require dedicated equipment and may be an interesting opportunity for ATE equipment suppliers. Besides packaging trends, Yole Développement analyzed the test strategy of IDMs and OSATs. Test equipment suppliers are improving testing tools with the implementation of parallel tests for numerous devices, adding new features (i.e. wafer-level tests for known-good die selections) as the big driver for reducing cost.

Yole Développement and System Plus Consulting have combined their MEMS and packaging expertise to offer a comprehensive report filled with detailed information. Our MEMS Packaging 2017 report comes with a complementary report from System Plus Consulting that includes a MEMS packaging review and a packaging teardown analysis of MEMS devices.

MEMS packaging roadmap



(Yole Développement, October 2017)

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REPORT OBJECTIVES

- Offer an understanding of the various MEMS markets' dynamics
- Provide a forecast in units and value for the different packaging platforms, by MEMS device
- Discuss trends concerning MEMS packaging's future
- Furnish insights regarding the MEMS packaging supply chain and the roles of IDM vs. OSAT
- Highlight MEMS testing trends



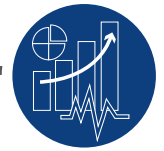
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Any notices under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party. The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.