HETEROGENEOUS INTEGRATION ROADMAP

2019 Edition

Chapter 17: Test Technology

Section 04: Specialty Device Testing

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Section 4: Specialty Device Testing

A classification of specialty devices was defined in industry roadmaps beginning in 2006, driven by strong high-volume market demand, but having odd test requirements. Examples are CMOS image sensors, LCD drivers, MEMS devices (including multimode sensors), actuators, bio-MEMS, and similar non-standard devices.

Trends Impacting this Technology Area

The applications of Mobile personal devices, IOT, Healthcare, Automotive/ADAS and Robotics are key drivers of specialty devices to motivate innovative technologies and the high growth rate of volume.

The trends of technologies: (Near Term < 5 years)

The mobile and wearable devices for IOT and healthcare applications are major drivers, impacting technology trends in the near term.

- The trends for multi-mode MEMS sensors is fusing multiple functionalities together in one device and also reducing the size of the package to be smaller and thinner for adding value in a compact unit. See Figure 1.

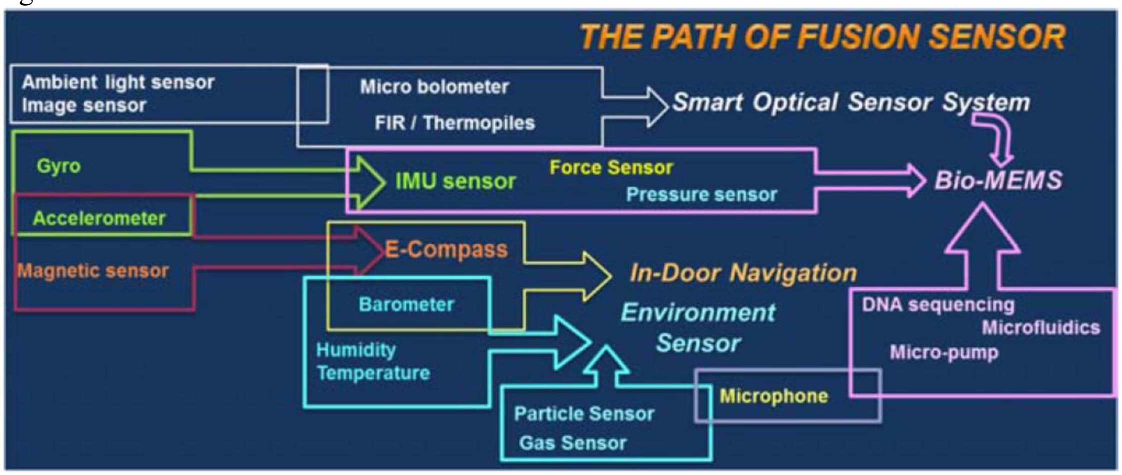

Figure 1: The path of MEMS sensor fusion

- The technology trends for image sensors lead to highly integrated multiple wafers using a 3DS (three-dimensional stacking) process and novel packaging technologies for enhancing image performance with cost-effective mass production solutions. The first successful step involving 3DS wafer processing of image sensors was the BSI (Back Side Illumination) process which bonded a photo-sensor wafer together with a back-side mixed-signal data processing wafer, connecting their signals through TSVs. When image-sensor pixel numbers increased and sensor size shrank below 1.4um, the BSI process had the advantage of a lower signal to noise ratio than the traditional FSI (Front Side Illumination) process. The next step in the image-sensor wafer-integration process adds a memory-cell wafer between the photo sensor wafer and the mixed-signal data processing wafer, which could enhance image performance and the speed of data processing in a variety of imaging applications such as 3D imaging, face recognition, and image capture, with frame rates over 1000 frames/second. See Figure 2.
- Image-sensor packaging innovation began using WLCSP (Wafer Level Chip Scale Package) to develop the glass-based stacking wafer-level package with TSV or Shallcase type processing, as shown in Figure 3.
- The trends for new WLP for image sensors are WLO (Wafer Level Optics) and WLCM (Wafer Level Camera Module) which stack optical systems on the image-sensor wafer using a wafer-level packaging process to reduce the size of optical systems and increase the efficiency of mass production. See Figure 4.

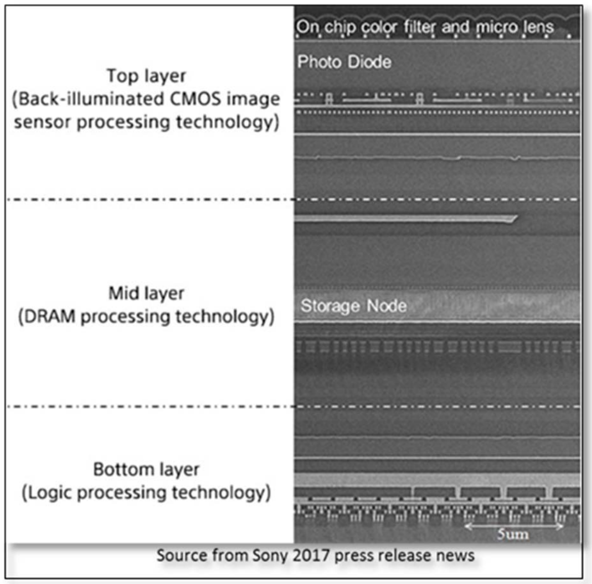

Figure 2: Image sensor 3D stacking wafers
(Backside illumination photo sensor wafer + memory cell wafer+ data processing wafer)

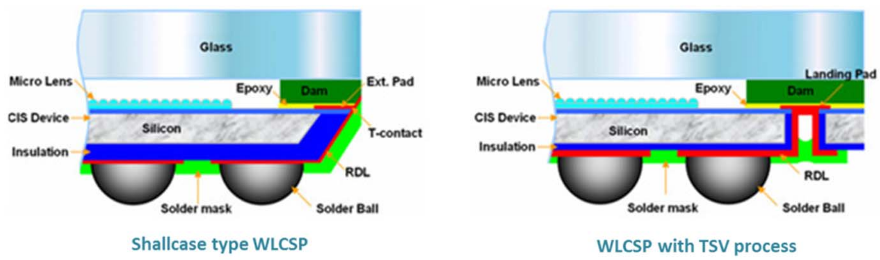

Figure 3: The structure of Image sensor WLCSP(wafer level chip size package)

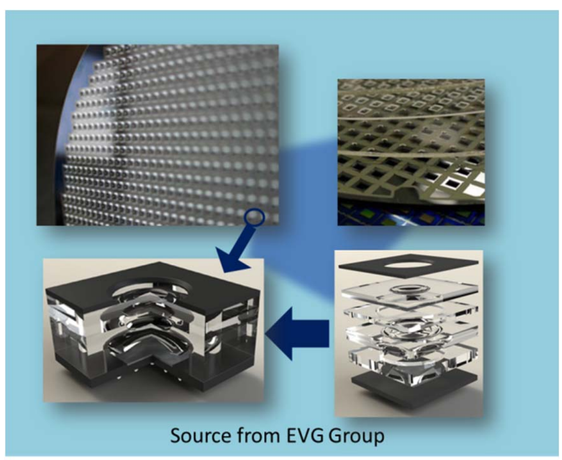

Figure 4: Image sensor WLO (Wafer Level Optics) packaging

The trends in technologies: (Medium to Long Term < 15 years)

The automotive, robotic, medical and intelligent artificial organ fields are the next wave of drivers for specialty devices which impact technologies in the medium and longer term.

- Reliability will become a very important subject for specialty devices. Burn-in and tri-temperature testing will become necessary test procedures during mass production.
- Built In Self-Diagnostic, Self-Calibration & Compensation and Self-Repair technologies will become important design skills to apply on specialty devices for enhancing reliability performance.

Concerns: Test Challenges

LCD display drivers:

LCD display drivers are unique because of their die form factor, which can have larger than a 10:1 aspect ratio and thousands of very narrow gold-bump pads requiring contact for test. In 2017, in-line probing pad pitch for LCD display drivers already was down to 18µm, and stager pad pitch was 13µm. Right now, only the cantilever probe card is a major cost-effective solution for achieving probing of LCD drivers with such narrow and fine pitch pad with gold bump in mass production.

An upcoming test challenge is the data transfer speed of I/O, which will increase to 2.5 Gbps in 2019 and is predicted to be up to 6.5 Gbps within 10 years. We need to overcome the challenges of probing fine-pitch bumping pads with high-speed signals with economical probing solutions.

Image sensor devices:

The testing of image sensor devices needs to consider special test requirements for optical systems and huge image data processing. The innovative technical trends of highly integrated 3DS CMOS image sensors increase the difficulties of special test requirements and challenges.

			Year of Production	2017	2018	2019	2020	2021	2026	2031
Process Integration		**Test Method**	**Challenges**							
Wafer level probe (BSI process + Memory+ ASIC , 3 layer W to W)	CP	Wafer probe with multi-sites	Multi- insertion							
			Single insertion (ATE)							
		Wafer probe by full wafer contact	Optical system (Visible light)							
			Technology of optical asserroy & probe card							
			(ATE) / challenges test system resource			`				
WLCSP (BSI process + Memory +ASIC , 3 layer W to W)	FT	Test after singular (Pkg form)	Multi- insertion							
			Single insertion (ATE)							
		Test after dicing (wafer form)	Optical system (Visible light)							
			Probing methods and accessories, multi-sites							
		Test after dicing with full wafer contact (wafer form)	Optical system (Visible light)							
			Probing methods and accessories							
			(ATE) / challenges test system resource			`				
WLO-P (Multi-layer W to W)	FT	Test after singular (Pkg form)	Single insertion (SLT)							
		Test after dicing (wafer form)	Optical system (Visible light)							
			Probing methods and accessories							
		Test after dicing with full wafer contact (Full functional test under wafer form)	Optical system (Visible light)							
			Probing method and accessory							
			Challenges ATE or SLT test system resource							

Research Required	
Development Underway	
Qualification / Pre-Production	
Continuous Improvement	

Table 1: Specialty device odd test potential solutions table – Image sensor device

Automotive ADAS applications and intelligent machine vision especially need the functionalities of image sensors with a wide spectrum (from UV to FIR), high dynamic range, good S/N (Signal to Noise) ratio, fast data frame rate, better quality and reliability, which challenges test system design. Burn In solutions also need to include optical stress for sorting out defects in the coating process on the photo sensor surface.

MEMS devices (Sensor, Actuator and Biological):

MEMS were successfully applied for various sensors for sensing motion, magnetic field, optics, sound, air pressure and vibration, flow, chemical composition of air, DNA sequencing, and other characteristics, and the market volume is increasing rapidly due to IoT, healthcare and automotive applications. Testing MEMS sensor devices with suitable physical stimulus and cost-effective solutions for the various types of sensors is difficult and tricky. Especially testing the expanding kinds of fusion sensors will bring many test challenges.

			Year of Production	2017	2018	2019	2020	2021	2026	2031
Process integration		**Test Method**	**Challenges**							
IMU sensor (Accelerometer + Gyro)	CP / wafer probe	Probing MEMS wafer (DC only)	Probe card technology/multi-sites vs. cost							
		Probing each wafer with full functions (Multi-insertion)	Motion Prober system and probe card technology/multi-sites vs. cost							
		Probing 3DS wafer with full functions (Single-insertion)	DFT design and implement							
	WLP	Test before dicing (Wafer form)	DFT design and implement							
		Test after singular (Pkg form)	Handling small size package							
	FT	Final test with full functions (Multi- insertion)	Test cost is high							
		Final test with full functions (Single- insertion)	Reduce test coverage rate							
			DFT design and implment							
		Burn In Test	SLT							
			BISX (Build In Selft X) X= (Test, Diag-nostic, Correlation,Compensation/Repair)							
Navigation (G-sensor+ Gyro+ Magnetic sensor + Barometer)	CP / wafer probe	Probing MEMS wafer (DC only)	Probe card technology/multi-sites vs. cost							
		Probing each wafer with full functions (Multi-insertion)	Probing system with situmlus & probe card technology							
	FT	Final test with full functions (Multi- insertion)	Test cost is high							
		Final test with full functions (Single- insertion)	Reduce test coverage rate							
			DFT design and implment							
		Burn In Test	SLT							
			BISX (Build In Selft X) X= (Test, Diag-nostic, Correlation,Compensation/Repair)							
Enviromential Sensor (Pressure + Humidity + Gas) Sensor	CP / wafer probe	Probing MEMS wafer (DC only)	Probe card technology/multi-sites vs. cost							
		Probing each wafer with full functions (Multi-insertion)	Probing system with situmlus & probe card technology							
	FT	Final test with full functions (Multi- insertion)	Test cost is high							
		Final test with full functions (Single- insertion)	Reduce test coverage rate							
			DFT design and implment							
		Burn In Test	SLT							
			BISX (Build In Selft X) X= (Test, Diag-nostic, Correlation,Compensation/Repair)							

Research Required	
Development Underway	
Qualification / Pre-Production	
Continuous Improvement	

Table 2: Specialty device odd test potential solutions table – MEMS Fusion Sensor

DFT for MEMS sensor devices is a new technology and needs research and innovative development for different kinds of sensor structures. MEMS sensors DFT needs to develop the stimulus source and the sensor together in the MEMS structure as a BIST (Build-In-Self-Test) cell. When testing, the cloned control signal of physical stimulus is generated from the MEMS ASIC to enable the MEMS BIST cell to imitate physical stimulus for testing the sensor cell to achieve the DFT concept. This concept could also implement the technologies for BISD (Build-In-Self-Diagnostic), BISC (Build-In-Self-Correlation/Compensation) and BISR (Build-In-Self-Repair) to enhance reliability of MEMS sensors for automotive and medical applications. The key during testing is to make sure the BIST cell works well.

Beyond MEMS sensors, there are also actuator and biological applications such as micro-mirrors, MEMS speakers, RF switches, energy harvesting, microfluidics, micro-dispensers and artificial organs, plus others. The challenges of testing MEMS actuators and biological devices are that test methods are hard to standardize and depend on the structure for each different kind of MEMS device. Especially for the testing of biological devices, the test environment can be severe and needs to pass safety certification based on the laws of different grades and countries.

Summary

Specialty devices as defined need odd test requirements and are driven by strong high-volume market demand. Under these two conditions, the trends of specialty devices will be drive toward highly integrated multi-functions in one smaller unit to overcome ASP (Average Sale Price) erosion, and testing procedures will move toward high parallelism to reduce test cost. Test challenges will follow the same trends to overcome testing evolutionary HI (Heterogeneous Integration) specialty new product through cost effective solutions.

References

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"Xintec 12-inch WLCSP Line Ready for Mass Production in 2H 2015" , DIGITIMES, March 2015

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