Selective over-molding of a CMOS TSV wafer with the flexible 3D integration of components and sensors.

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Abstract

The Wafer Level Packaging (WLP) and the Through Silicon Via (TSV) technology in combination with side by side Multi Chip packaging is miniaturizing the packages in size and height. The packaging and the over-molding of system on wafer for a diversity of sensor packages is an extraordinary challenge.

Smart Systems for Indoor and Outdoor or an Wearable wrist watch application have to do environmental monitoring of for example (toxic) gasses like CO, CO2, VOC's,, Infrared sensors ,Infrared sensors for fire detection , temperature sensors , light sensors , UV-A/B sensors and humidity sensors.

This paper will highlight the packaging and over-molding technology of the recent developments of a CMOS TSV wafer with the flexible 3D integration of sensors (57) on a CMOS platform.

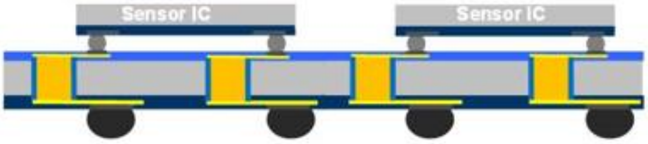


Fig.1. Example of 3D-stacked devices using TSV and BRDL as basic building blocks for sensors

The Film Assisted Molding in combination with the developed Dynamic Insert Technology creates the solution for selective over-molding of all types of sensor applications on a CMOS platform chip or wafer with 3D-stacked dies. The process flow, assembly, packaging, and over-molding challenges of the Multi Sensor Platform will be discussed.

A most suitable approach for the heterogeneous system integration and allows the development and fabrication of miniaturized smart sensor systems with significant advanced technologies.

Introduction

Smart Sensor Systems for Indoor and Outdoor or wearable applications do need a diversity of Sensor Systems and Packages. To fulfill all the different functions in an integrated system a diversity of sensor applications and package types must be assembled and selective over-molded. Selective over-molding is required to create the opening on the chip for the sensing function.

The traditional way of protecting dies on a wafer is the over-molding with the compression molding technology-Fig.2. The molding compound is put in the bottom mold and slowly pressed against the top mold and squeezed over the total surface of the wafer.

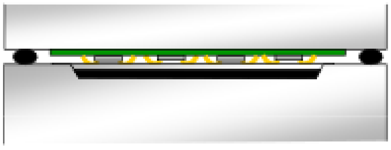
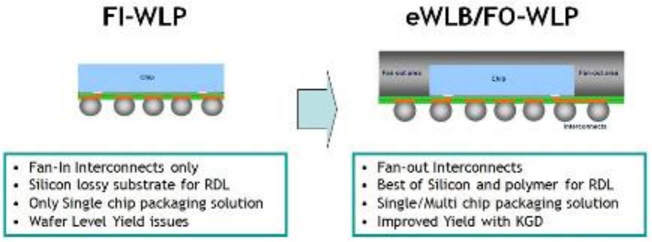


Fig.2. Compression molding

The technology of compression molding is the solution for the complete over-molding of a wafer of the various Fan In and Fan Out packages and the complete over-molding of 3D-stacked packages on a TSV wafer. See Fig.3.



- Fan-In Interconnects only
- Silicon lossy substrate for RDL
- Only Single chip packaging solution
- Wafer Level Yield issues

- Fan-out Interconnects
- Best of Silicon and polymer for RDL
- Single/Multi chip packaging solution
- Improved Yield with KGD

Fig. 3. Fan In and Fan Out for Wafer Level Packaging.

The environmental monitoring requires for all sensing elements a window to the world for their specific sensing function. A gas sensor-Fig.4.- for example has a heated uHP sensing element of just a few microns thickness and requires a very sensitive method of micro-assembly and selective over-molding.

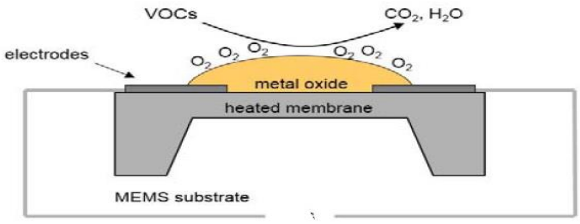


Fig.4. Gas sensor with heated membrane of 5-8 um.

Compression molding cannot be applied for this type of sensitive sensors; the sensor area would be covered or damaged by the molding compound. The transfer molding in combination with FAM and the Dynamic Insert technology is the solution for the selective molding for this type of 3D stacked sensors on a CMOS TSV wafer.

Selective over-molding

Selective over-molding creates the possibility to micro assembly a variety of sensor packages on the CMOS wafer platform. The process flow, the assembly, molding and packaging is especially complicated when different package types have to be assembled on the CMOS wafer platform.

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An overview of the sensor devices, which are 3D-integrated into the CMOS platform chip is presented in Table 1 and describes the kind of stacking. 12 different sensor chips comprising a maximum of up to 57 gas sensors will be integrated to the multi-sensor module:

Sensor type	Targeted for	Kind of stacking
3 gas sensor µhp array	CO, CO_2, VOC	TSV (3D), overmolded
2 gas sensor µhp chip	CO, VOC	Wire bonds
1 gas sensor µhp chip	O_3	Wire bonds
1 gas sensor µhp chip	NO_2	Wire bonds, overmolded
1 humidity sensor	humidity	Wire bonds
1 IR sensor chip	IR light	Wire bonds
1 UV A/B sensor chip	UV light	Wire bonds
1 V-light sensor	Vis light	TSV (3D), overmolded
1 temperature sensor	Temp	Flip chip, overmolded

Table.1. Listing of the 12 different sensor chips.

Many different processing steps are needed for realization of a fully 3D-integrated system such as the CMOS platform with different types of stacked sensor devices. The micro- assembly of the different parts must be done in 2 steps.

In Step1 the micro assembly is done for a limited number of sensor chips (see Fig.5.) followed by the molding process.

The sensor chips of Step 1 are designed for the open window molding with FAM or for the complete over-molding like the temperature sensor.

In Step 2 the sensor chips, which are not fitted for the FAM molding process, are die bonded and wire bonded and are placed in the open areas on the molded CMOS platform.

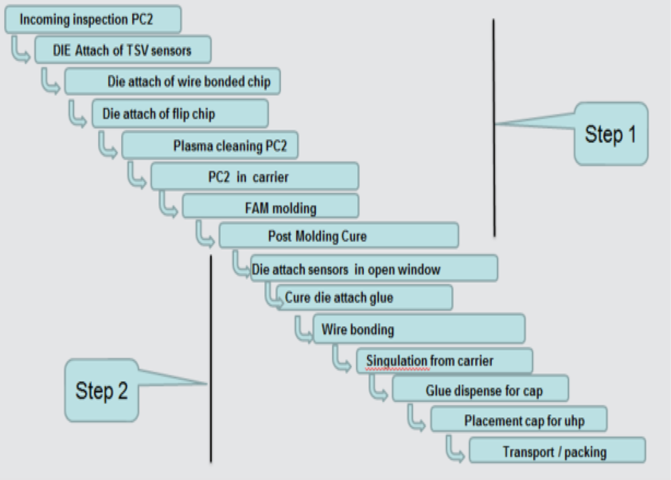


Fig.5. Process steps

Film Assisted Molding and Dynamic Insert technology

The FAM technology is a microelectronic transfer molding technology with film lining the mold parts. The increasing use of the Film Assisted Molding (FAM) technology confirms the importance of this new encapsulation technology to the semiconductor industry. FAM deals with challenges of releasing components from the mold and keeping die or specific surfaces clear from molding compound. The applications can be general chips and MEMS/sensors with open windows.

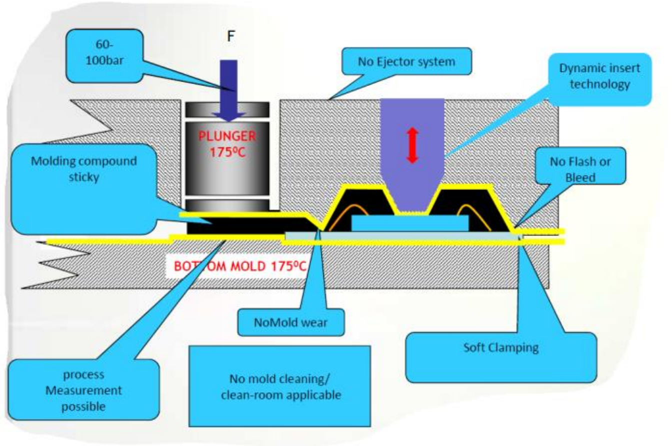


Fig.6.Film Assited Molding with top and bottom film

An open window is needed to access to the environment for encapsulated sensor packages like gas and liquid sensors. Generally, the exposed die, MEMS/sensor, is brittle and cannot withstand large stress.

Film technology lends itself to encapsulate exposed die in such applications, especially when the FAM technology is used in combination with the Dynamic Insert technology.

The Dynamic Insert technology controls the force, see Fig.6 during the encapsulation process, from a low force to a higher force which is compound pressure related during the transfer process. The Dynamic Insert technology allows over-molding of already mounted chips with different heights and can leave open cavities in the mold for subsequent attachment of die and wire bonded chips on the CMOS wafer platform.

The design rules of such a platform, to accommodate all the different sensors, are developed for the over-molding technology with Film Assisted Molding and the Dynamic Insert technology.

The dimensioning of the open window of a sensor package is direct related with the requirements for the Film Assisted Molding technology. The micro assembly tolerances, positioning of the sensor chip on the wafer and for example the wire bonding require special attention regarding the over-molding dimensioning of the chip. A minimum distance (sw) is required from sensing area to the wire bonds.Fig.7.

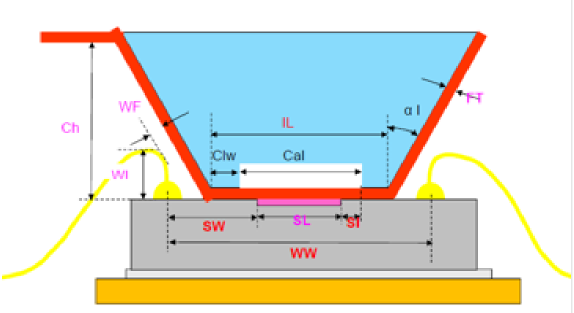


Fig.7. Design rules for open window.

The micro assembly of a number of dies on the CMOS platform wafer requires also special design rules to guarantee a reliable wire bonding of the platform surface. Fig .8.

Special consideration must be given to equipment related parameters for the bonding equipment as well the Dynamic Insert technology related parameters.

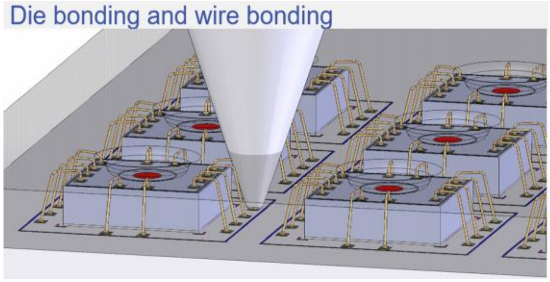


Fig.8. Bonding, molding, open window.

Besides the micro assembly packaging rules also the Dynamic Insert Technology specifies the density of assembled sensor chips on the wafer platform. Design rules for the mold tooling with the Dynamic Inserts results in different design densities and is direct related to the design lay-out of the different sensor chips on the wafer platform.

Based on the developed design rules for the wafer platform the concept layout was made for the micro assembly and the over-molding, Fig.9.

Fig.9. Concept design for micro assembly and over-molding

As presented in Table 1. not all the sensors were fitted for the over-molding. In total 6 sensor chips were micro assembled on the platform before molding, 4 Sensor chips are with TSV bonding on the wafer, one with flip chip bonding on the wafer and one with die and wire bonding. The other 6 are die bonded and wire bonded on the platform after the molding operation.

In the final floorplan the sensor chips A, B, D and E are micro assembled before the molding and the sensor chips C, G and F are assembled after the molding in the open areas on the wafer platform, Fig.10.

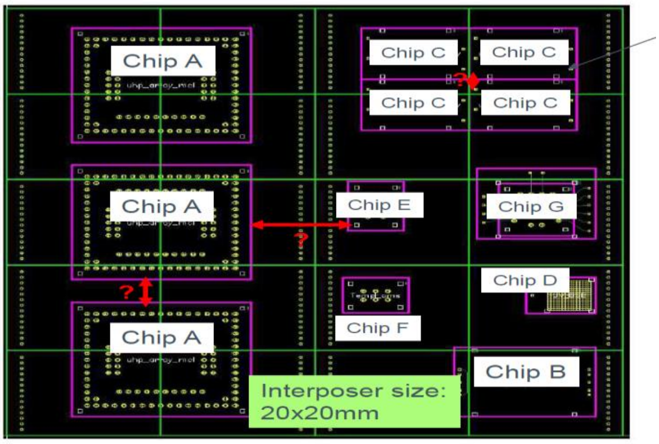


Fig.10.Final layout from the ball side of the wafer platform.

The 2-step assembly of the dies is the reason the tool design was made with fixed Clamping F and Dynamic Insert Clamping D, individual controlled in Z height, Fig.11.

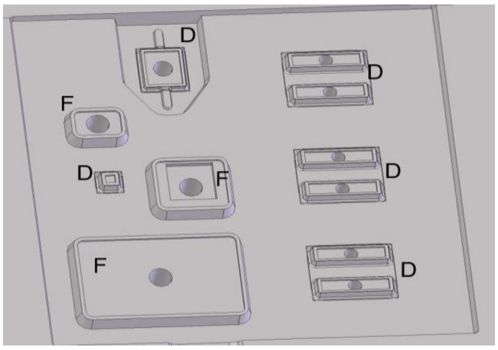


Fig.11. Tool design with static inserts.

The first step in the micro assembly, 3D stacking flow is the bonding of the sensors, which are not wire-bonded, TSV chips and flip chip.

Those are the 3 μHP array chips, V-light sensor, temperature sensor. Fig.11. shows the basic flow of this flip chip processing.

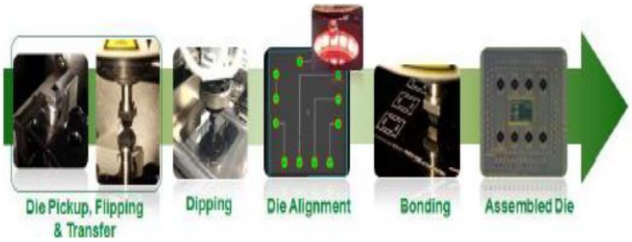


Fig.11. Stacking flow TSV chips and flip chip.

One gas Sensor was also die attached and wire bonded before the molding step.Fig.12.

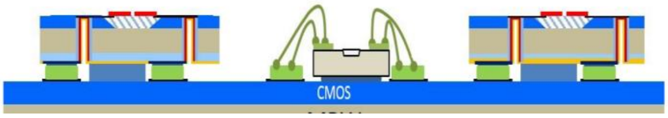


Fig.12.Situation before the over-molding step.

To prove the principles of the over-molding and to optimize the transfer molding parameters tests were done with dummies. Fig 13.

Fig.13. Dummies for optimization the molding process.

After the over-molding, the die and wire bonding did take place on the CMOS wafer to complete the number of 12 chips.

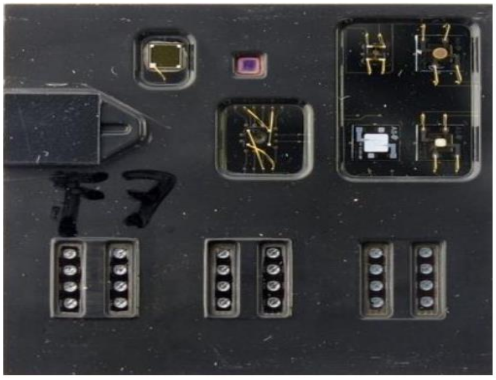


Fig.14. Over-molded 3D-integrated CMOS wafer platform including a total of 57 sensor devices.

Fig..14. shows the unique highly complex full manufacturing process flow for 3D-stacking of the 12 sensor devices on the CMOS wafer platform in a 2-step solution.

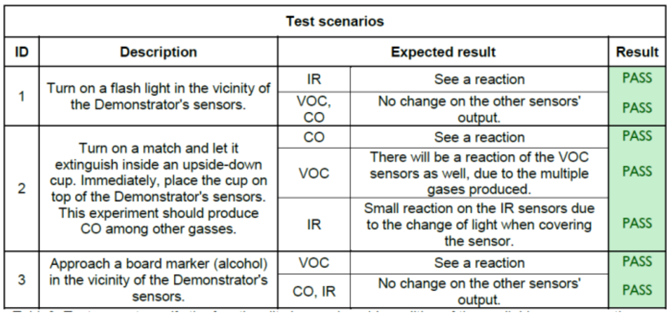
Wearable wrist watch system

To prove the functionality of the CMOS wafer platform the platform was mounted on a PCB as carrier to fit in the housing of the wearable wrist band device. Fig 15.

Fig.15. Wearable wrist band device.

The wearable wristband device with integrated CMOS platform a sensor system comprising a total of 53 sensor, a unique device worldwide and complex system never realized before.

Tests where done to verify the reaction from the available sensors on the wearable wrist band (Table2). A successful transmission of different data packets over BLE from the wrist band to the Wearable Control GUI was confirmed.



Test scenarios				
ID	Description	Expected result		Result
1	Turn on a flash light in the vicinity of the Demonstrator's sensors.	IR	See a reaction	PASS
		VOC, CO	No change on the other sensors' output.	PASS
2	Turn on a match and let it extinguish inside an upside-down cup. Immediately, place the cup on top of the Demonstrator's sensors. This experiment should produce CO among other gasses.	CO	See a reaction	PASS
		VOC	There will be a reaction of the VOC sensors as well, due to the multiple gases produced.	PASS
		IR	Small reaction on the IR sensors due to the change of light when covering the sensor.	PASS
3	Approach a board marker (alcohol) in the vicinity of the Demonstrator's sensors.	VOC	See a reaction	PASS
		CO, IR	No change on the other sensors' output.	PASS

Table 2. Test cases.

Fig.16. shows a successful transmission of different data packets over BLE from the wearable wrist watch to Wearable Control.

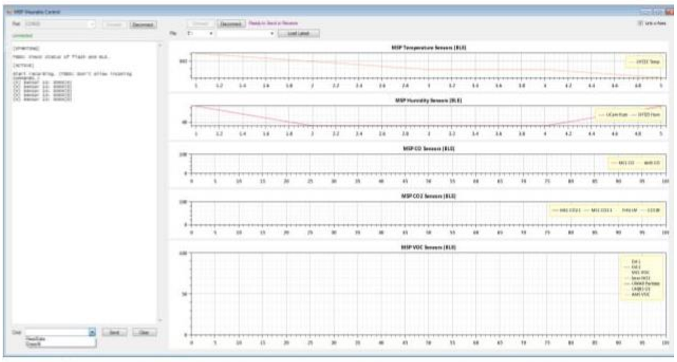


Fig.16.Sensing temperature and humidity values.

Conclusions

A unique highly complex full manufacturing process flow for 3D-stacking of the sensor devices on the CMOS TSV wafer platform including over-molding of the 3D-integrated system was realized in the study.

The multi sensor system on the CMOS TSV platform level comprising a total of 57 sensor devices is a unique device worldwide. By using the transfer molding process with the Film Assisted Molding and the Dynamic Insert technology the open windows on chip surface were realized notwithstanding the big diversity in thickness of the different sensor chips.

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