Advanced MEMS Manufacturing Technology

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Introduction

MEMS technology is facing new challenges since thin wafer handling will be used more and more to archive smaller dies. Packaging the next device on the top of the first and so on called package on package (POP), first to reduce the wire bonding as the connections will be via through vias that run through the bulk silicon and second the size of the second (third, fourth …) can have the same size of the first one. All that means more space for the Die but less additional work to connect the Dies to each other. Perhaps the most significant is the substantially larger market size and the drive toward lower costs.

CMOS Image Sensors, Memory, Mixed Signals, FPGA (Flexible Program Gate Array), and Microprocessors are the used applications for thinned 3D wafers with interconnections. The bonding method therefore is thermo compression bonding with Cu-Cu bond layer material for the interconnections. Another method is fusion bonding. Both methods require very precise alignment accuracy. The very precise alignment is really challenging as the needed alignment is in the sub micron area.

Advanced MEMS Bonding Requirements

New MEMS devices are intended for products that require much smaller sizes. That means the pitch to pitch also getting smaller and that results that more accurate alignment will be needed to match the interconnections. This is a big challenge for machine manufacturer as it means the machines has to work on submicron accuracy. Only to develop new hardware isn't sufficient as the mechanic isn't able to work in that sub micron area. Special software was developed together with special algorithmic to handle alignment in submicron area.

Design of Alignment Targets

The design of the targets is important as well, as it will have big influence in the final align and post bond accuracy. Figure 2 illustrates the used design to achieve best accuracy via automatic alignment with vision system. The illustrated design was chosen also because of recommendation from Cognex for their PatMax system which was used in the SUSS BA300UHP. The design was important to implement all necessary parameter for vision recognition system.

Alignment Techniques

Different types of alignment techniques were used to test and get best accuracy out for 300mm wafers. BSI (bottom side microscope couldn't be used as the second (lower wafer in the aligner) wafer didn't have alignment targets on the non bond surface. IR cannot be used for all wafers as the wafer can have thick oxide or can be highly doped and that means the wafers aren't IR transparent. ISA (inter substrate alignment) was best as the microscope doesn't need back side target nor IR transparent layer.

ISA microscope moves in between the upper and lower wafer after loading them into the aligner. Both targets (upper and lower) are live images and can be seen all time during alignment. While the upper wafer is fixed on the chuck and the left and right microscope show the targets on the monitor, the lower wafer mounted onto the alignment chuck via vacuum can be moved in all directions like X, Y and theta.

SUSS BA300UHP (ultra high precision) was used for the test. A special hardware to achieve very precise movement together with very complex software control and last but not least target design for automatic pattern recognition shown in Figure 1. The z movement is a critical part as the lower wafer has to move up to the cap wafer and it's also covered via software. A self calibrating system is also part of the software and improves the alignment reliability. After the alignment the fixture (Figure 3. wafer carrier) moves with the aligned wafer stack from the aligner into the bonder for final bond (depends on bond type. Not necessary with fusion bonding as this method needs annealing in a Furness).

Additional Considerations

The alignment is one part which has to be take care for the machine manufacture. Another is the handling of the wafer as it can influence the accuracy as well. For Fusion test it was not necessary to transport the aligned wafer stack as they were pre bonded right after the alignment. For Cu-Cu bonding it was necessary to transfer the aligned wafer stack from aligner to bonder. Therefore the fixture (wafer carrier shown Figure 3) must take care of the aligned stack and protect against any movement during transfer. Also the area where the aligned wafers are hold during transport and bonding is important. The shown fixture in figure 3 illustrates a full area for a 300mm wafer stack.

Summary

The MEMS industry will use smaller pitch and therefore need higher alignment accuracy to achieve functional interconnect dies. At the test with the SUSS BA300UHP alignment for thermo compression bonding in the BA300UHP <350nm post bond alignment accuracy could be achieved for a Cu-Cu 300mm Si wafer stack and <200nm was achieved for fusion pre bond. This achieved accuracy is even more as the industry need right now. Looking forward to about 2012-2013 then the achieved accuracy will be needed as shown by several semiconductor forecast magazines like Yole reports.

References

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2. SUSS MicroTec,
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Figure 1. Suss BA300UHP

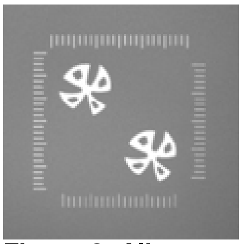

Figure 2. Alignment Targets

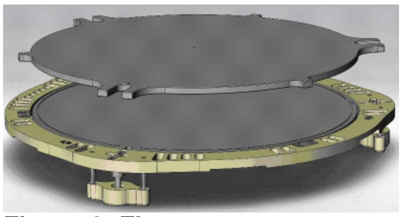

Figure 3. Fixture

Table I. Alignment accuracy results

		101230 (GCD)			
				3-SIGMA	
X um	**Y um**	**T mDeg**	**X**	**Y**	**T**
0.149	0.154	0.053	0.174	0.252	0.040
0.076	0.088	0.033			
0.104	0.155	0.038		**RANGE**	
0.176	0.153	0.034	0.233	0.406	0.048
0.218	0.257	0.051			
0.133	0.083	0.048		**MAX / MIN**	
0.083	0.068	0.039	0.268	0.240	0.087
0.143	0.049	0.052	0.035	-0.166	0.039