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[Hermeticity inspection for wafer bonding process of MEMS Device - Hiromi Shima]

[Hideo Oi]
[r53154@freescale.com - rnm113@freescale.com]
[Tohoku Semiconductor Corp. - Freescale Semiconductor Inc]
[r53154@freescale.com - rnm113@freescale.com]
Phone: +[81] -[22-377-9496]

Abstract

In wafer level packaging process of MEMS (Micro Electro Mechanical Systems) devices, the seal failure detection was examined at the early stage after the bonding process. The MEMS device must be maintained into hermetic space, and the hermeticity is guaranteed by the seal width. Figure 1 shows the wafer structure after the bonding and the IR (infrared) image of the defective seal. This defect is caused by two synthesized processing histories. The defect is influenced from the following factors. The first one is characteristics (viscosity etc.) of bonding material printed on cap wafer as lid of package. The second one is the bonding material film thickness uniformity on the cap wafer. Moreover, it is the temperature distribution on the wafer during bonding process. The defect is resulted by an integrated factor of those processes, and has the tendency in a part of area on the wafer. However, it is not able to reproduce defective seal each chip at this moment. Therefore, it is difficult to control the defective seal appearance only by the tool interlock and FDC (Fault detection classification). Further, unit probe (electrical specification) on the wafer after the bonding, cannot detect the defective seal failure after sawing (Cut from wafer to each chip). These defects were at least detected in final test after assembly. However, it is a waste of the packaging cost relatively high ratio in total product cost. And, the defect production is continued until the final test feedback. It is a reason the delay of defective detection. Figure 2 shows our MEMS product process flow from the wafer bonding to final test. We introduced automatic IR inspection just after wafer bonding. It is capable to measure sealing width and defects on each die and to inspect 100% dice on a wafer. For bonded wafers, IR capability is needed to see the interface part of Si and bonding material through the Si wafer. The inspection pass/fail judgment is usually the difference comparison with a golden sample (good chip image). On the other hand, we introduced the specification limit judgment method in the control parameters. The parameters were chosen from the IR image. They are important information for specific of the defective generation factor in the bonding process. And they are shown by the numerical value. Table 1 shows the relation between the parameter and the factor process. The parameters are No seal breach, Minimum seal width, Bubble count, Total bubble area, Largest bubble area, and NPZ (None print zone) area. These are explained in Figure 3. It had become possible to manage the bonding process before an increase in defective number (%) using SPC (Statistical Process Control) method on parameters. Additionally, the inspection result is stored in small-size file by conversion into the numerical data. As the result, it is simplified to handle the data and to keep in storage media easily. An example is shown in Figure 4 as a graphical wafer map of NPZ area. The part where NPZ Area is large can be seen in left and right of wafer edge (Figure 4-i), and inside (Figure 4-ii). From the wafer map, we could recognize a structural performance of the wafer bonding tool.

The IR inspection enabled to reject of a defective chip within wafer fab, before shipping to assembly site. As a result, number of hermeticity defect at assembly site has been reduced. A necessary thing for the wafer bonding process management is to know the interaction of all parameters and materials. Therefore, such inspection tool should have capabilities to measure the process result numerically, not only pass/fail judgment. It will be effective to understand the above process parameter interaction and to motivate the process improvement.

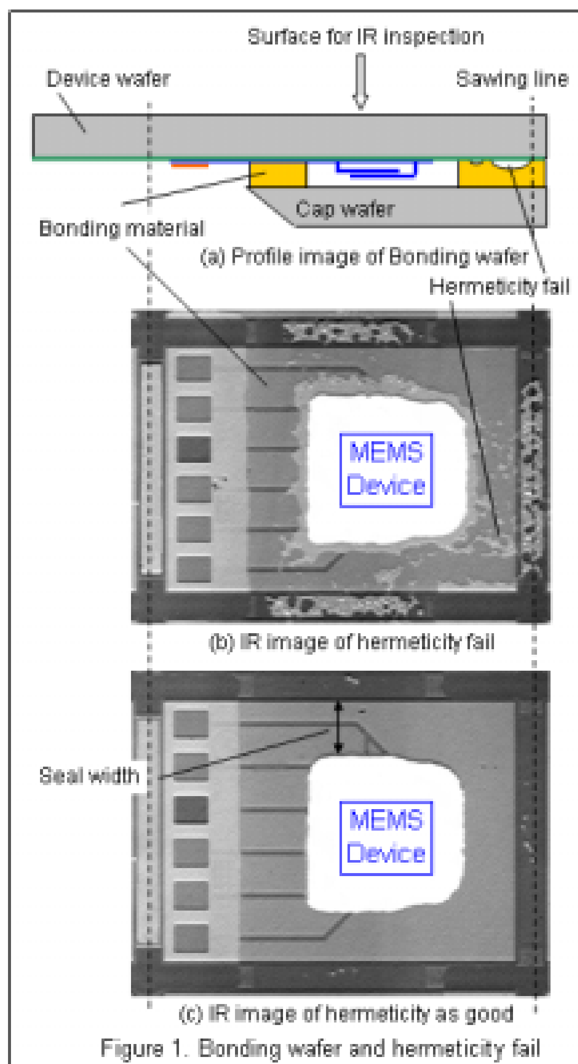
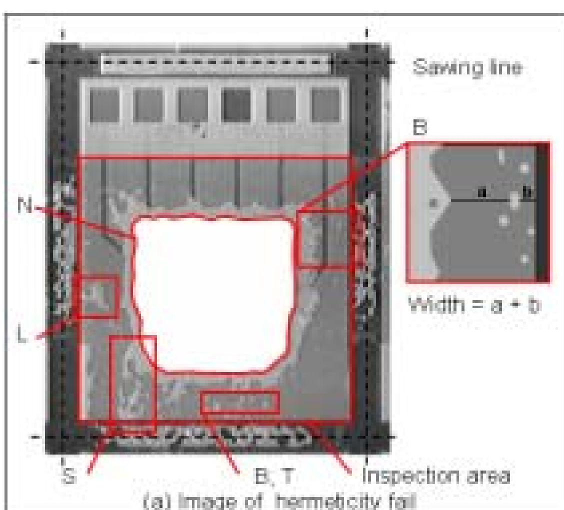


Figure 1. Bonding wafer and hermeticity fail

Table 1. Relation between control parameter and process

Control parameter	Bonding material	Printing	Wafer bonding
Seal breach	x	x	xxx
Minimum seal width	x	xxx	xx
Bubble count	xxx	x	xx
Total bubble area	xxx	x	xx
Largest bubble area	x	xxx	x
None print zone area	xxx	x	xxx

Strong xxx > xx > x Weak



(a) Image of hermeticity fail

Control parameter		Unit	Remark
S	Seal breach	None	Connected between Sawing line and MP2 area
M	Minimum seal width	μm	Width without Bubble
B	Bubble count	#	Counting size is specified
T	Total bubble area	mm^2	Area of all of bubbles
L	Largest bubble area	μm^2	Area of a largest bubble
N	None print zone area	mm^2	Area without bonding material

(b) Remark of control parameter

Figure 3. Control parameter

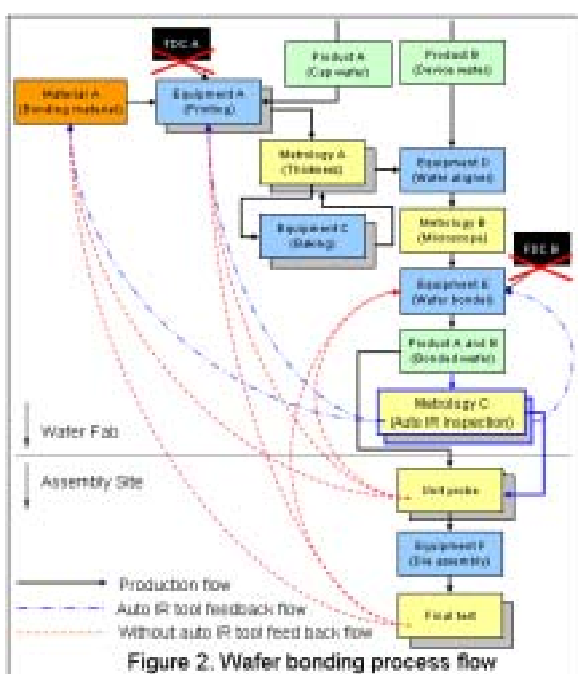


Figure 2. Wafer bonding process flow

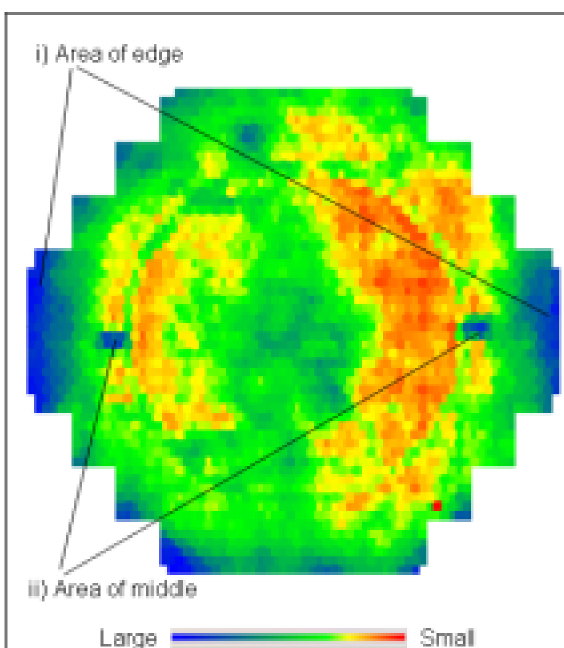


Figure 4. Trend of None print zone area in wafer
Used data by auto IR inspection tool