BCB Bonding Technology of Back-Side Illuminated COMS Device

Y Wu¹, G Q Jiang¹, S X Jia¹ and Y M Shi²
¹Nanjing Electronic Device Institute, China Electronics Technology Group, Nanjing, Jiangsu Province, China
²Key Laboratory of Infrared Imaging Materials and Detectors, Shanghai Institute of Technical Physics of the Chinese Academy of Sciences, Shanghai, China

wuyan_baade@163.com

Abstract. Back-side illuminated CMOS (BSI) sensor is a key device in spaceborne hyperspectral imaging technology. Compared with traditional devices, the path of incident light is simplified and the spectral response is planarized by BSI sensors, which meets the requirements of quantitative hyperspectral imaging applications. Wafer bonding is the basic technology and key process of the fabrication of BSI sensors. 6 inch bonding of CMOS wafer and glass wafer was fabricated based on the low bonding temperature and high stability of BCB. The influence of different thickness of BCB on bonding strength was studied. Wafer bonding with high strength, high stability and no bubbles was fabricated by changing bonding conditions.

1. Introduction
As a mature technology, spaceborne hyperspectral imaging technology is an efficient mean of ground target detection. Quantified hyperspectral imaging technology requires flat spectrum in response wave band of CMOS image sensor (CIS). However, wave peak and trough exist in spectral response of CIS because of reflection and diffraction of metal layer fabricated by normal CMOS process. Thus, studies focused on Back-side Illuminated CMOS (BSI) have become necessary (Figure 1.). BSI image sensor simplifies the incident light path greatly and avoids the reflection and diffraction of metal layer, which makes the planarization of spectrum response possible. With the enlargement of the scale of CMOS active pixel sensor (APS) chip and the decrease of the size of pixel units, BSI shows its advantage of huge structure and great performance, which includes great decrease of incident light path, small pixel units (<5μm) and improvements of spectrum response and duty ratio[1-3]. The fabrication of BSI device includes wafer bonding, which is the key process, substrate thinning, and sputtering of anti-reflection film. Based on 6 inch bonding technology, bonded wafers with high strength, high stability and no bubbles were fabricated by developing bonding process and improving surface quality of wafer.
2. Formatting the title, authors and affiliations

Photo BCB, which is a kind of organic polymer bonding material with advantages of high stability of process and great light transmission of BSI devices, is used to be the bonding material of BSI devices. The CYCLOTENETM 4000 Series of the Dow Chemical Company have the advantages of low bonding temperature and high stability. Thus, 4022-35 BCB was used as bonding material in our paper report. Figure 2 is the process of BCB bonding, including adhesion promoter coating, adhesion promoter baking, BCB coating, BCB baking, soft cure of BCB and bonding. The detailed bonding process is as follows:

1. Wafer cleaning by using megasonic cleaning with acetone and alcohol in order to remove organic particles.
2. Adhesion promoter coating by spinning AP8000, with a spin speed of 2000rpm, a spin acceleration of 1000r/s and a spin time of 30 seconds. The time of baking adhesion promoter is 2 minutes.
3. 4022-35 BCB coating with a spin speed of 2000rpm, a spin acceleration of 1000r/s, and a spin time of 30 seconds.
4. Using T1100 to remove the BCB on the edge of wafer for 30 seconds. The rotation speed of wafer is 800rpm and the acceleration is 1000r/s.
5. Baking BCB for 2 minutes with a temperature of 110 degree.
6. Soft cure of BCB with a chamber pressure of $10^{-5}$ mBar and a heating rate of 8 degree per minute. Figure 3 is the heating curve of soft cure.
7. BCB bonding with a chamber pressure of $10^{-5}$ mBar, a heating rate of 8 degree per minute and a tool pressure of 5000 mBar (approximately 11000N). Figure 4 is the heating curve of bonding.

Plenty of water molecules exist on the wafer surface, which decreases the adhesion of BCB. Thus, adhesion promoter was used with AP8000 (used for most surfaces, including silicon oxide, silicon nitride, silicon oxynitride, aluminum, copper, titanium and chromium) before BCB coating and bonding. After adhesion process of wafer that increases the adhesion of BCB effectively, high bonding strength and stability are received. Because of plenty of wires on the wafer, the flatness of wafer is low and spin uniformity and step coverage are concerned when spinning BCB. In order to get a flat surface, a proper spin speed of 2000rpm was chosen. The thickness of BCB with different spin speed is as Figure 5 shows. The thickness of BCB was 4μm after soft cure with a spin speed of 2000rpm.
3. Optimization of bonding process
The process of low temperature wafer bonding is used to improve the flatness of bonding surface and make the disappearance of bubbles possible. Due to bonding temperature that higher than the temperature of soft cure, the viscosity of BCB become lower and the flowability of BCB stronger, which causes BCB bonded through Van der Waals force between wafers[4]. Very high pressure is applied to plate to enhance bonding strength and bonding stability.

Because of the existence of bubbles caused by these reasons that obvious difference exists between the refractive indexes of bubbles and BCB and the path of incident light includes the bonding area, huge changes of optical property appear when the device turns to work. The bubbles is mainly cause by three reasons: 1) When heating the plate the gas that BCB releases during heating has no way to escape because of the adhesion of wafers, then bubbles appear after bonding; 2) Due to the low flatness of wafer surface that caused by plenty of wires, the BCB between wafers aren’t bonded completely within the limited deformation range; 3) The deformation of BCB becomes lower during bonding process because of high temperature of soft cure. We confirm that the first two points are the main reasons. For these reasons, solutions are provided as follows: 1) Optimization of bonding process was studied by adding EBR process that operated on wafers coated by BCB. Before wafer bonding, wafers are separated and heated for five to ten minutes at 180 degree by inserting spacers until gas escapes completely. 2) Through PECVD of silicon nitride and CMP process, the flatness of wafer is improved. 3) In order to get lower crosslinking ratio of BCB, lower temperature of soft cure is adopted, which causes the softening degree and deformation limit of BCB increased.
Figure 5. Thickness of BCB with different rotating speed.

Figure 6. Bonding strength with different thickness of BCB.

4. Results and conclusions

Figure 6 is the bonding strength with different thickness of BCB (after soft cure). Bonding strength is improved obviously when increasing the thickness of BCB. When the thickness of BCB is 4μm, the mean value of bonding strength is greater than 15 kgf, and the maximum value of bonding strength is greater than 20 kgf. Even if the thickness of BCB is less than 2μm, the minimum value of bonding strength is greater than 5 kgf, which meets the requirements of applications. Figure 6 are the bonded BSI device and bonding area before and after the optimization of bonding process. The bubbles disappear through the optimization of bonding process, which improves the performance of BSI devices. In addition, reducing the quantity of bubbles increases the bonding area and then improves the bonding strength further.

5. References

[1] Pain B, Sun C, Vo P, Hancock B, Cunningham T J, Wrigley C, Toda R, White V, Banerjee A, and Misra D 2007 Wafer-Level thinned monolithic CMOS imagers in a bulk-CMOS technology *International Image Sensor Workshop Proceedings* pp158-61

[2] Pain B 2005 Fabrication and initial results for a back-illuminated monolithic APS in a mixed SOI/bulk CMOS technology *IEEE Workshop on CCD & AIS* pp102-4

[3] Fontaine R 2011 A Review of the 1.4 μm Pixel Generation *Proc of International Image Sensor Workshop* pp5-8

[4] Zheyao W 2014 Three-Dimensional Integration Technology *Tsinghua University Press* chapter 3