Research of temporary bonding for 3D integrational Microsystem

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Abstract. Due to the thickness of current interposer must be very small, the thickness of active and passive wafers are no more than 200\,um, even less than 100\,um, sometime even less than 50\,um. So handing the thin wafer is the key problem for 3D stack. In this paper, designed and experimented the temporary bonding for 3D stack and substrate thinning, analyzed the result of the experiment, and the foundation for the 3D integration technology in the future.

Keywords: Three dimension integration, Temporary bonding, Interposer.

1. Introduction
The temporary bonding is important for 3D stack and thin wafer handing, the results analysis of the different temporary bonding material. The temporary bonding between the device wafer and the carry wafer used a special polymer material as an intermediate layer to bonded the two wafers together, then the carry wafer support of device wafer complete at the process such as the thinning of the device wafer, for this technology 3D integration was widely used in microsystem, such as multi-wafers permanent stacked\cite{3}. After the permanent stacked the temporary bonding between the device wafer and the carry wafer will be released. The polymer bonding layer on the surface of carry wafer removed by chemical. The temporary bonding of polymer materials and equipment must be fully compatible with later process in the device manufacture, for example, the de-bonding temperature is preferably lower than 200 \,\degree C and the temporary material is required to have high stability of thermal and chemical, the temporary bonding also required sufficient adhering strength and lower bond stress. After the process completed, the temporary bonding material must be able to removed by the method of laser, heat or chemical etching, easy to de-bonding and surface cleaning. The basic process of temporary bonding shown in Figure 1, first step is through spin coating the temporary material on the surface of carry wafer, in some cases the device can also be coated the temporary bonding material, then handing temporary bonding material at 60\,\degree C for 2\,min before baking, then handing the temporary bonding material at 200\,\degree C to remove the solvent in temporary bonding material, and reached the initial curing; then the carry wafer and device wafer attached and aligned together then heated temperatures material at 200\,\degree C to completely bonding the two wafer together. Mostly temporary bonding material is in liquid form, By spin coating and spray coating method, the thickness is usually 10 \sim 50\,\mu m, the uniformity of the TTV is less than 10\%, during bonding in order to reduce surface bubbles requires a certain vacuum conditions, such as 5 \times 10^{-2}\,mbar; bonding temperature varies depending on the material, but the temperature uniformity requires less than 1\%, the interfacial
energy of temporary bonding can generally up to 2J / m², completely reach to the requirements of the follow-thinning and other process.

![General process flow for temporary bonding](image)

**Figure 1** General process flow for temporary bonding

2. Temporary bonding material

Research applied to the application solution of temporary bonding and de-bonding material system by three-dimensional integrated. Temporary bonding is one of the key steps in the three-dimensional integration, there are many materials and equipment suppliers to supply mass type production of temporary bonding materials and equipments. Temporary bonding material eventually require removal of the auxiliary wafer, so it is necessary to use biodegradable polymer material as the temporary bonding material. The thermoplastic and thermosetting of temporary bonding of materials for bonding and de-bonding properties has a significant impact, the characteristics of thermosetting temporary bonding material is cross linking after heated, can no longer be cleaved or softening by heating. The thermoplastic polymer material can be repeatedly softened by heating and solidified after cooled. Such materials are solid polymer at room temperature, no intermolecular cross-linking, with only by Vander Waals or hydrogen bonds attract each other. This material is heating softens and flows after heating and pressure, chemical cross linking does not occur, cure after cooled. Using temporary bonding material must be properly selected according to the subsequent process. Temporary bonding material mainly applied is in Table 1 [1].

| Material name | Material type | Tolerable temperature/°C | Thickness /μm | carrier | Coating | Debond | Debond Type | Debond temperature |
|---------------|---------------|--------------------------|---------------|---------|---------|--------|-------------|-------------------|
| TMAT Slilia gel | ~250 | 20~200 | silicon/glass | Spin-coating | Spin-coating | Mechanical debond | Room Temperature |
| Brewer HT10.10 resin | ~220 | <100 | silicon/glass | Spin-coating | - | Mechanical debond | 180°C |
| Brewer Zonebond - | ~250 | <120 | silicon/glass | Spin-coating | - | Mechanical debond | Room Temperature |
| 3M resin | ~250 | <125 | glass | Spin-coating | Spin-coating | Laser debond | Room Temperature |
| HD/DuPont polymde | >350 | 2~20 | glass | Spin-coating | - | Laser debond | Room Temperature |
| TOK - | ~250 | <130 | Silicon/glass | Spin-coating | - | Mechanical debond | Room Temperature |

3. Temporary bonding process
Because of the high strength of the temporary bond, the gap of the device wafer and carrier (the thickness of temporary bonding layer) is very small, coupled with restrictions on the compatibility of materials and temperature, how to remove the temporary bonding material to achieve de-bonding is the main difficulties, different methods for removing of different temporary bonding material varies. The project intends to adopt the HT10.10 temporary bonding material, by the temporary bonding material is heated and softened, use the edge of the opened (peeled) or transverse passage way for the detachment between device wafer and slide. After spin-coating, requiring to baking the film and remove the solvent. The process of before baking is generally at 120 ~ 180 °C and during 3 ~ 5min [2]. The temperature of before drying has a very big influence on the bonding parameters and bonding quality. At the same time the temperature of before baking is higher, the temperature of bonding is more higher. While the main drawback of a lower temperature of before baking is not fully volatilize the solvent, not completely volatile solvent during the high temperature process of bonding temperature is released, resulting in the presence of air bubbles at the surface of bonded, affecting the bond quality. The topic by the temporary bonding of silicon and glass Pyrex7740, observe the bonding interface quality to analysis the effect of temporary bonding, preliminary results is mainly existence of bubble figure 2. By improving the bonding temperature and pressure and the chamber pressure to avoid the cavity on the surface.

4. Thinning process

Thinning process is mainly to achieve precise thickness by removal of substrate material, in the integrated circuit on thinning process on the substrate is only for chip packaging needs. But for the microsystems, 3D stack height requirements the interposer thickness extended from a few microns to several hundred microns[5], for the microwave and radio frequency device signals transmission, the thickness of interposer has been desired exactly to less than 1μ m, therefore, for the thickness of different device layers requires very precise nano-thinning process. The interposer thickness is generally less than 100μ m in this 3D integration, it is need to use carry wafer handing thinned interposer, therefore, the first step of interposer thinning process is temporary bonding the device wafer to the carry wafer. Mechanical grinding include the coarse grinding and fine grinding two steps. The particle on coarse grinding wheel is relatively large, so it can be thinning very fast to the target thickness. Because coarse grinding can damage wafer surface and produce residual stress, so we must use fine grinding to thin 10 ~ 20μ m [8] on the wafer surface after coarse grinding. After grinding mechanical grinding, there will be some lattice defects and damage on the wafer show in the figure 3, so the surface damage layer can be removed by chemical mechanical polishing or wafer dry and wet etch.

Figure 2: Temporary bonding between silicon and glass
Figure 3 Result of interposer grinding

CMP can obtain a very good surface, the surface damage layer can be removed completely, but the cost of the process is very high. Wet chemical etching method can be used to remove the surface damage layer and is the most effective method, but the after wet-etch, the surface roughness is a little poor, in this paper, HF/HNO$_3$ mixed solution was used for surface wet-etch[4]. Dry-etch was able to completely remove the surface damage layer, and relatively easy to control, so in this paper ,we used dry-etch to remove the damage layer.

Also after the thinning process ,the interposer surface cleaning is a key step, since the grinding process [6] will be left a lot of silicon cutting and polishing on the surface of the silicon interposer, H$_2$O$_2$,DHF,SC1 are used to clean the interposer [7]. Figure 3 show the surface after the debond and cleaning, the surface is smooth and the Cu pillar for interconnect are bring out show in figure 4.

Figure 4 The smooth surface and the Cu pillar

5. Summary
In the paper we introduced a temporary bond method for 3D integrational interposer and thinning the wafer to 200um. Also introduced the wafer surface treatment and cleaning after grinding and debond. This experimental results can be used for 3D integration.

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