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# Polymers for Permanent Wafer Bonding

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## ABSTRACT

Wafer bonding with polymers is a cost effective method for packaging many MEMS devices. The seals are resistant to moisture and offer several benefits not common to other bonding methods. The polymer materials generally come in both photo patternable and non-photosensitive formulations. Patterning of the polymer then is a rather simple mask and photolithography step which is an industry standard for MEMS production. There is no need for etching of polymer which is necessary for metal seals. In addition stripping of the polymer for rework is also a simple process flow that does not damage the underlying structures or materials. The polymers are compliant and some experience reflow. This is a great advantage for devices with surface topography or roughness issues. All the bond temperatures are below 300C and process times are very rapid; generally 10 minutes or less.

Niklaus et. al., has described the four main manufacturing areas using permanent wafer bonding techniques in great detail.(1) These areas are 3D IC's, MEMS and IC integration, wafer level packaging, and BioMEMS/µTAS. The diversity of applications translates into a large choice of materials for adhesive selection that can be tailored to specific device requirements. Table 1 highlights the adhesive choices that are most commonly used for the mainstream products.

Interface thickness of the polymers varies from submicron layers used in 3D IC's products to several 100's of microns for SU8 and CRX2580P layers in microfluidic applications. The bonding conditions have matured to the extent that void free bonds of sufficient strength to survive post bond processing are quite successful and numerous examples in production will be shown. In fact combining methods of adhesive bonding with metal diffusion enable 3D IC interconnects while adhesive bonds coated with metal layers as diffusion barriers are used for polymer friendly hermetic packaging.

Alignment accuracy also varies with application, material thickness and processing temperatures. While most applications do not require less than ~5µm post bond applications the 3D IC market using BCB techniques has demonstrated 1µm post bond alignment overlay with proper equipment and processing.

**TABLE 1. Properties Comparison of Common Polymers Used in Permanent Wafer to Wafer Bonding Applications.**

| **Company** | **Dow** | **Toray** | **Sumitomo** | **Sumitomo** | **Dow Corning** | **HD-Micro** | **HD-Micro** | **MicroChem** |
|---|---|---|---|---|---|---|---|---|
| **Trade Name** | Cyclotene | PWDC-1000 | CRC-8000 | CRX 2580P | WL-5000 | HD-2771 | HD-3003XP | SU8 |
| **Material** | BCB | PI | PBO | PI | Silicone | PI | PI | Epoxy |
| **PhotoPatternable** | Both Negative | Positive | Positive | Yes | Yes Negative | Yes Negative | Both | Negative |
| **Residual Stress (MPa)** | 28 | 28 | 60 |  | <6.4 |  |  |  |
| **Moisture Uptake (%)** | 0.23 | 0.6 | 0.3-0.9 | 0.06 | ~0.2 | >1.0 | 0.08% |  |
| **Coefficient of Thermal Expansion (ppm/°C)** | 52 | 36 | 51 | 100 | <236 | 42 | 124 | 52 |
| **Glass Transistion Temperature (°C)** | >350 |  |  | 295 |  | 294 | 188 | 50-55 |
| **Cure Temperature (°C)** | 210-250 | 250+ | 320 | 200 | <250 | >350 | 220 | 95 |
| **Dielectric Constant** | 2.65 | 2.9 |  | 2.65 | <3.3 | 3 | 3.4 |  |
| **Modulus (GPa)** | 2.9 | 2.9 | 2.9 | 1.6 | 0.15-0.335 | 2.7 | 2.4 | 4 |
| **Thermal Stability (%loss at 350C/1hr)** | 2 |  | <1 | 5 | <6 | <1 | <1 |  |
| **Shrinkage During Cure (%)** |  |  |  | 2.5 | <2 | 40-50 | <0.04% |  |
| **Minimum Thickness (µm)** | 1 | 3 | 3 | 10 | 2 | 4 | 1 | 5 |
| **Storage Temperature (°C)** | -15 | 4 |  |  | -15 | r.t. or -18 |  |  |
| **Shelf Life (mos.)** | 6 | 6 |  |  | 6 | 12 @ -18C |  |  |

## References

Niklaus et.al., J. Appl. Phys., 99 (1) 20006.