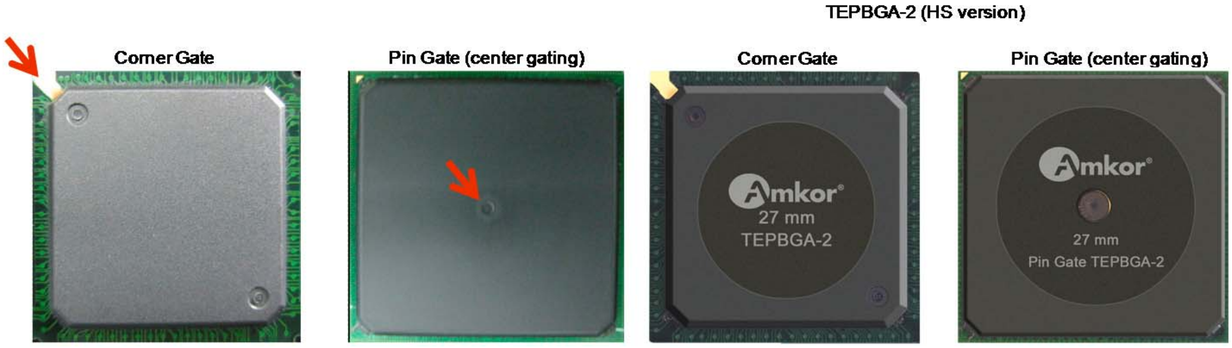
Amkor Converting to Pin-Gate Molding Process to Meet Industry Low Cost Demand

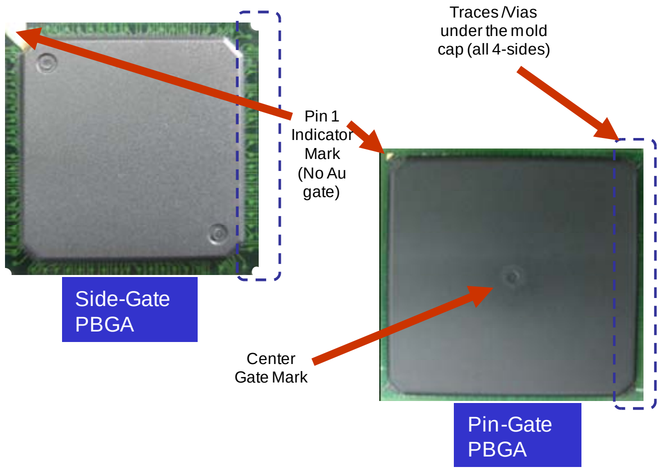
Introduction

Nearly 75% of the PBGA cost structure is driven by the cost of substrates and Au wire, with the cost split nearly equally between the two. Amkor's pin-gate mold (PGM) process aggressively attacks these 2 specific areas of cost. In this paper, we will dive into the reasons why Amkor's PGM process has brought life back into an aging product.

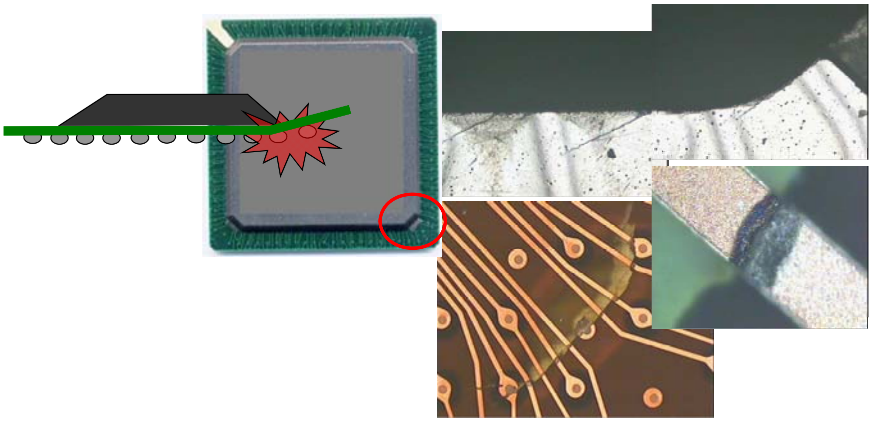
To start, let's get familiar with PGM process. Current PBGAs are molded using transfer mold with the mold gate located in the corner of the package. The PGM process is also a transfer mold process, with the gate located in the top center of the package. Even with the mold gate located in the top center of the mold cap, Amkor's PGM process can support the TEPBGA-2 structure (drop-in heat spreader). This is accomplished by creating a clearance hole in the center of the heat spreader, allowing the top gate process. With Amkor's knowhow, we can support both standard PBGA and TEPBGA-2 in the same mold systems, using the same mold tooling.



So, what exactly are the changes? To start, the mold gate is located in the top center of mold cap. Because of this, the mold cap has a "donut shaped" recessed area where the gate interfaces with the mold cap. Secondly, PGM takes advantage of a larger mold cap area, which provides many advantages that we will explore later in this paper. Next, there is no Au feature requirement in the corner since that Au gate feature is specifically required only on corner gate mold processing. The Au gate feature has been replaced by a smaller "pin 1" triangular feature. In addition, the ejector pin marks typically located on the top of the corner gate mold cap, are no longer required on the mold cap itself. Thus, the mold cap marking area has increased in surface area from both the larger mold cap size as well as the removal of the ejector pin artifacts. Lastly, Amkor's PGM process has converted to package saw singulation instead of punch singulation, which has also eliminated many legacy issues that we will discuss later on in this paper.



So let's drill into the reason why PGM has single handily revitalized the PBGA market offering. Specifically, what are the benefits? For starters, the larger mold cap allows designers to route all active traces and via within the mold cap dimensions. The larger mold cap also covers more of the substrate surface area, protecting it from soldermask cracking. So why is this important? Historically, trace and soldermask cracking have plagued the PBGA industry from the very beginning. Over many years of dealing with these soldermask cracking occurrences, the industry has yet to eliminate the concern, until now. Amkor's PGM provides superior soldermask coverage, and mechanical stiffness to the structure, protecting the active traces. Even the exposed flange around the perimeter of the package is mechanically robust due to the larger mold cap to package size, leaving only a small exposed flange on the perimeter that is resistant to mechanical damage and bending.



Not only does the larger mold cap provide enhanced mechanical performance, it enables larger die sizes as well as more area for MCM layouts and integrated passive under the mold cap. The same is true for the TEBGA-2 version since the heat spread has also been expanded to accommodate larger die sizes.

Incorporating the package saw process into the PGM process flow, provides enhancements due to the smooth edge. So why is a smooth edge an enhancement? If you look closely at the corner gate package edge, you will notice that the edges are not as straight as you would expect. That is due to the way the slots are manufactured at the substrate level. This irregular edge has a higher probability of binding in the test socket and/or the shipping tray. The smooth edges of the PGM structure reduce the potential for binding during these process steps. The net result is higher yields. A secondary benefit of the larger mold cap is the extended marking area, even with the 4mm diameter marking stay-out area in the center, the overall area is larger than the corner gate area.

But the real benefit behind PGM is the cost savings. To start PGM uses higher density substrates, and enables wire diameter reduction down to 0.5mil. Recall, ~75% of the over cost of a PBGA is substrate and Au wire costs. PGM address both items, making the Amkor PGM structure the most cost effective PBGA structure in the world. By coupling PGM with Cu wire enables the maximum amount of savings.

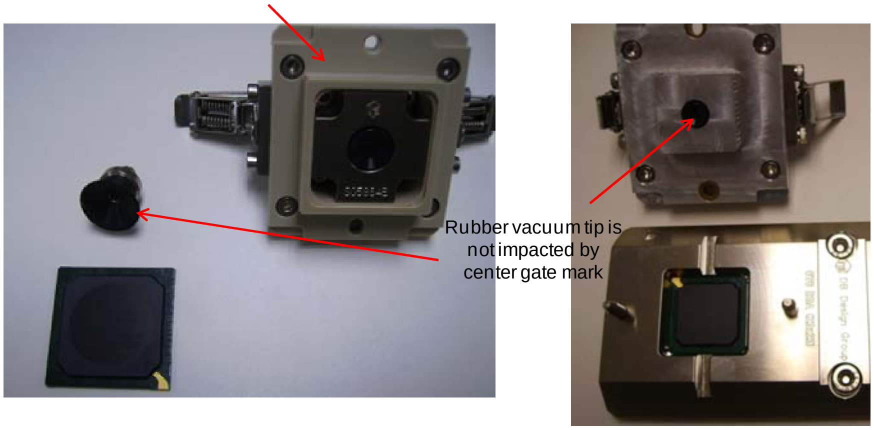
Besides the obvious cost savings for thinner wire, thinner wire can extend the W/B technology in advanced Si nodes. Specifically, as Si node shrink, the BPP and BPO's shrink, driving smaller and smaller wire diameters, to a point where only FC structure are realistic. But with the introduction of PGM, Amkor can now extend this down to 0.5mil wire diameter capabilities (0.6mil diameter is HVM today).

For example:

Standard PBGA with 1.2mil Au wire max length = 250mils

Pin Gate PBGA with 0.7mil Au wire max length = 250mils

Now that we discussed the changes and benefits from the package and assembly perspective, we need to look at what the larger mold cap impact is on test, board level reliability and warpage control. For test, the short answer is, the impact depends on pick up tip configuration. There are two types of pick-up tools, one tool uses the side walls of the mold cap for gross alignment (left photo), and the other used the substrate edges for gross alignment (right photo). For the one on the right, there is no impact. The pick-up tool simply picks-up on the center of the mold cap using the vacuum tip. Even with the small donut shaped recess area, the vacuum tip does its job. For the pick-up tool shown on the left, the insert requires minor modification to accept the larger mold cap dimension.



New plastic housing needed

No Change Needed

Rubber vacuum tip is not impacted by center gate mark

Now let's discuss the effects that the larger mold cap of the PGM structure has on board level reliability (BLR). Simulation of the 31mm x 31mm PGM PBGA results are shown in the table. For reference, the Modeling Scope was: BLR simulation for TC1 condition (-45c- 125c)

Key Factors:

1) Mold cap size: 26mm vs 29.7mm

2) Die size: 12.1x10.6mm vs 6x6mm

3) PBGA and TE2-PBGA

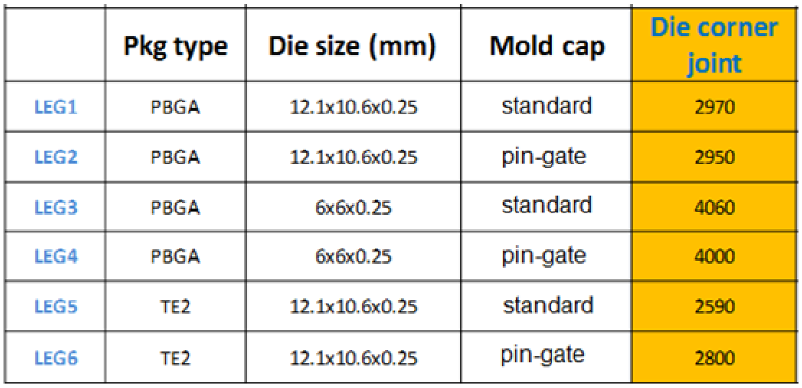
Bill of Materials (BOM):

1) Substrate 101366701, 4layer. 0.56mm suing HL832-NXA core and AUS308 soldermask

2) EMC Nitto GE100LFCS-V

3) DA Ablestik 2300

4) Ball Dia 0.61mm



	Pkg type	Die size (mm)	Mold cap	Die corner joint
LEG1	PBGA	12.1x10.6x0.25	standard	2970
LEG2	PBGA	12.1x10.6x0.25	pin-gate	2950
LEG3	PBGA	6x6x0.25	standard	4060
LEG4	PBGA	6x6x0.25	pin-gate	4000
LEG5	TE2	12.1x10.6x0.25	standard	2590
LEG6	TE2	12.1x10.6x0.25	pin-gate	2800

The table summarizes the first solderball failure (Simulated Mean Fatigue Life (50%)), is located under the die corner joint, which matches the corner gate molded PBGA first failure location. Since simulation and actual 2nd level reliability testing has a strong correlation, we consider the PGM PBGA to be equivalent to that of the corner gate PBGA.

The detailed conclusions of the BLR simulation is that for PBGA, there is almost no difference in BLR fatigue life between PGM and corner gate mold. This holds true for both 12mm and 6mm die sizes. For TEPBGA-2, the PGM structure is slightly better than the corner gate structure, but the difference is small. This is because the first failure is the joint under the die corner instead of the package corner. In conclusion, the difference in mold cap size has little impact on those critical joints under the die corner which are far away from the mold cap edge.

So what about warpage impact? At 25C, there is little difference in warpage between pin gate and side gate, independent of the die size as well as for the package style of the PBGA and TEPBGA-2. However, at reflow temperature (260C), we see differences in the simulation. The PGM PBGA has slightly higher warpage than corner gate, but the PGM TEPBGA-2 has slightly lower warpage than corner gate. See summary table.

				Simulated Package Warapge (within ball array area)	
	Pkg type	**Die size (mm)**	**Mold cap**	**25c**	**260c**
LEG1	PBGA	12.1x10.6x0.25	26 mm	-82	+128
LEG2	PBGA	12.1x10.6x0.25	29.7 mm	-85	+151
LEG3	PBGA	6x6x0.25	26 mm	-46	+198
LEG4	PBGA	6x6x0.25	29.7 mm	-47	+219
LEG5	TE2	12.1x10.6x0.25	26 mm	-110	+98
LEG6	TE2	12.1x10.6x0.25	29.7 mm	-108	+91
LEG7	TE2	6x6x0.25	26 mm	-53	+86
LEG8	TE2	6x6x0.25	29.7 mm	-51	+81

In all cases, the difference is not very significant. However, warpage depends on many factors that cannot be simulated in a generic way. Thus, it is best to perform shadow moiré characterization when warpage control is critical (this is the same comment for corner gate devices as well).

High Volume Manufacturing Status:

Amkor has been using Pin Gate molding on etCSP and bottom PoP (PSvfBGA) for over a decade with hundreds of millions units shipped. For PBGA, the PGM process has been running mass production since the beginning of 2009, in which more than 25M units in 23x23mm body size has been shipped. 19x19mm, 23x23mm, 27x27mm, 29x29mm and 31x31mm body sizes are all available now, with 21x21mm, 25x25mm body sizes to be added as needed. Thus the Amkor standard PGM offering is between 19x19mm and 31x31mm body sizes, every 2mm increment.

Amkor’s PCN announces the conversion of the 19-31mm body sizes, to PGM in the K4 factory. The existing 19-31mm corner gate process will also be discontinued, to be completely replaced by the PGM process. Target conversion is end of 1Q13 for the transition to happen.

In conclusion, Amkor’s PGM process provides superior quality and reliability performance, as well as significant cost reduction by enabling wire reduction. The PGM process is considered a re-birth, providing a new structure to fuel the future.