FFT (Flow Free Thin) Mold Study for 44um Fine Pitch Device Application

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Abstract

The paper introduces the advantages of FFT mold technology, and presents an analysis of granular compound properties and parameters effect on wire sweep. Key mold parameters for 44um fine pitch device are determined based on wire sweep performance and wire sweep can be controlled below 1.5%. Strip warpage after PMC (Post Mold Cure) is resolved through FEM analysis and compound formation improvement.

INTRODUCTION

With the increasing demand on package multi-functionality, wire count has been increased by decreasing bond pad pitch, applying multi-tier staggered bond pad design and PGE (Power Ground Embedded) design. There can be up to 4~5 wire tiers and the highest wire loop can be up to about 10~11mils. This makes the normal transfer molding process very challenging as regards wire sweep performance [1,2].

FFT (Flow Free Thin) mold is a new mold technology in which the wire bonded strip on the upper cavity is slowly dipped into a melted granular compound on the lower cavity without transferring pressure. A granular compound instead of tablet compound is used and mold cap thickness is controlled by compound weight. The main advantages of FFT mold are listed below:

1) It minimizes compound flow and resin injection speed is almost 0mm/sec. It was very effective on fine pitch and long wire device.
2) It is low pressure molding; it will be very helpful for low k die because of low stress.
3) It is maintenance free by adapting release film. It enables to no release compound molding.
4) It has no compound waste because there is no runner and cull material waste as normal transfer molding.

We evaluated FFT molding on a 44um fine pitch device with PGE design (832 wire counts with 4 tiers of wire). Key mold parameters were selected using granular compound properties analysis and parameters optimization in terms of wire sweep performance.

Strip warpage after PMC (Post Mold Cure) was very large on the first trial run. However, this issue was resolved by compound formation improvement.

Further evaluation will include MSL and reliability studies as well as analyzing a low k device in addition to the fine pitch application.

GRANULAR COMPOUND PROPERTIES

It should be noted that a granular compound and not a table compound must be used in FFT mold. Also granular compound must meet specific requirement for a good FFT mold process.

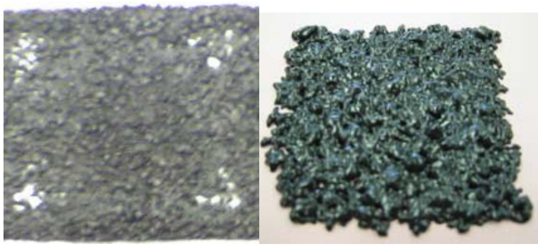
1) Granular size should be larger than 0.1mm and there should be no fine powder generation because fine powder is wont to stick on chase and system, and if the powder accumulates, it will effect machine movement and impact product quality.

Not Desirable (Contains Fine Powder) — Desirable (Uniform Granular)

Fig 1 Compound Form

2) Granular compound must have a long gel time. A thin layer of granular compound is supplied on the cavity, so it is readily affected by heat. A longer gel time is needed to avoid hardening before finishing molding.

3) Granular compound must have a lower melting viscosity and better wetting to reduce the compression on the wires, especially for fine pitch device.
4) Compound needs to have a good melting characteristic: Compound needs to melt and change to liquid condition after melting.



Not Suitable (Soft without Changing to Liquid Condition) | Suitable (Changing to Liquid Condition)

Fig 2 Molten Compound Condition

Wire Sweep Study

Through mold para study on 44um fine pitch device with PGE design (832 wire count with 4 tiers of wire), clamping setting (clamp speed and clamp position), mold start waiting time, and mold PH time were determined to be the main factors affecting wire sweep performance.

1) Clamping Setting: Clamp speed combined clamp position is critical for wire sweep performance. The clamping setting must ensure slow dip-in speed, and simultaneously, ensure that the dip-in time is with good compound melting condition. 5 clamping steps with clamp speed (3%, 0.5%, 0.2%, 0.1%, 0.5% max speed) were used in order to get good dip-in process.
2) Mold Start Waiting Time: The time is defined as waiting time before mold clamping. The proper setting is also for the purpose of getting good dip-in time. When trying mold start waiting time, we put the compound on the cavity and recorded the time using a manual timer once we observed compound melting. We can also obtain the compound viscosity curve for reference as shown in Fig 3. We set the mold start waiting time at 7s.
3) Mold PH time: It is defined as the vacuum time before continuing clamping when the mold chase clamp to the specific position. It is very important for internal void control. Mold PH time is decided as 2~3S, which depends on specific compound type.

When molding with optimized mold parameter, wire sweep performance was good and it can be readily controlled below 1.5% through X-ray check. Fig 4 shows an X ray picture.

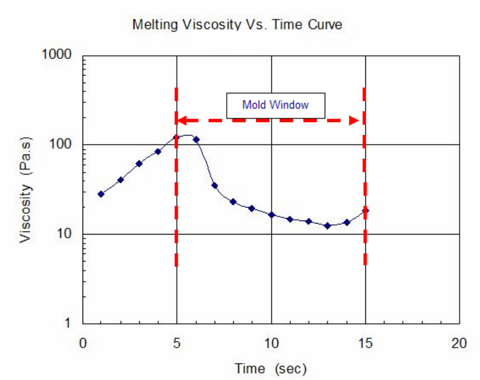


Fig 3 Viscosity Curve

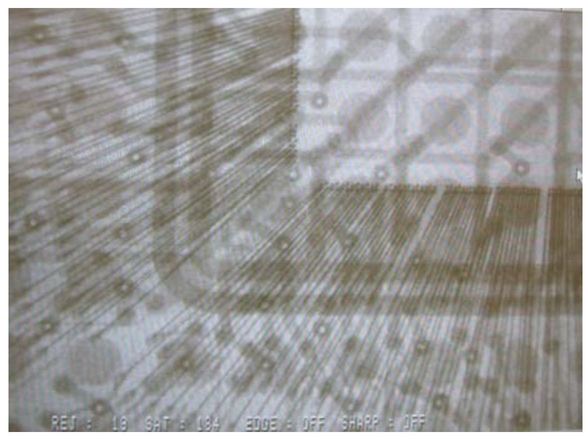


Fig 4 X-ray Picture

Strip Warpage Study

For FFT mold trial run, strip warpage after PMC was very large, up to about 4~5mm. Fig 5 shows the strip warpage picture after PMC.

Fig 5 Strip Warpage Picture

The CTE (Coefficient of Thermal Expansion) plays an important role in the package warpage. CTE equals the ratio of thermal strain by unit temperature change, but the CTE is very different with the temperature, so it must be a function of temperature, so the strain can be written as:

$$\varepsilon = \int_{T1}^{T2} \alpha(t) dt$$

The CTE can be regarded as bilinear properties about Tg (Glass transition temperature), so it also can be written as:

$$\varepsilon = \int_{T1}^{Tg} \alpha(t)dt + \int_{Tg}^{T2} \alpha(t)dt$$

Because **α1**=average CTE below Tg

α2=average CTE above Tg,

$$\varepsilon = \alpha_1 (T_g - T_1) + \alpha_2 (T_2 - T_g)$$

=> $$\varepsilon = \frac{\alpha_1 (T_g - T_1) + \alpha_2 (T_2 - T_g)}{T_2 - T_1}(T_2 - T_1)$$

=> $$\varepsilon = \alpha_{avg}(T_2 - T_1)$$

Here, $$\alpha_{avg} = \frac{\alpha_1 (T_g - T_1) + \alpha_2 (T_2 - T_g)}{T_2 - T_1}$$

Shrinkage is another important factor in the package warpage. Its mechanical effect can be equivalently treated as an added CTE ($\boldsymbol{\alpha_{shrk}}$) for linear mechanical problem. So the equivalent CTE ($\boldsymbol{\alpha_{eqv}}$), which combined with CTE and shrinkage is as below:

$$\alpha_{shrk} = \frac{LinearShrinkage}{T_2 - T_1}$$

$$\alpha_{eqv} = \alpha_{avg} + \alpha_{shrk}$$

FEM (Finite Element Method) was used for strip warpage analysis using the above theory. A 3D mechanical modeling was created for strip warpage simulation. Fig 6 shows the symmetric quarter mechanical modeling.

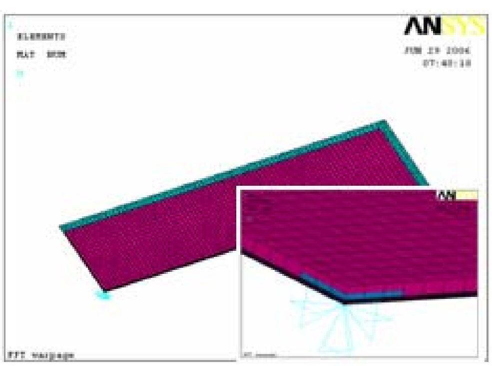


Fig 6 ¼ FEM Model

The simulation assumes that all the layers in the model have ideal adhesion, no delamination or crack failure, and no plastic or viscous deformation are considered, and all material is elastic. The stress free state was set at 175°C. It is static simulation.

Through simulation analysis on current material, the calculated strip warpage is similar to the actual result. So we think that this modeling is right for this analysis.

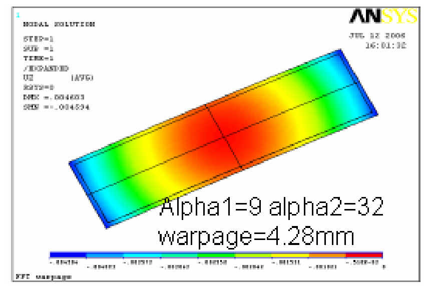


Fig 7 Simulation Result on Original Compound

In order to analyze the effect of CTE (α1 and α2) on strip warpage, a full factorial DOE (Design of Experiment) was selected. Experimental design, warpage simulation results, contour plot, surface plot, and response optimization result are shown in the table following.

TABLE 1 SIMULATION EXPERIMENT DESIGN AND RESULTS

StdOrder	RunOrder	PtType	Blocks	alpha 1	alpha 2	warpage/mm
12	1	0	1	10	40	0.4914
2	2	1	1	12	30	0.9898
13	2	0	1	10	40	0.4914
1	4	1	1	8	30	6.2170
4	5	1	1	12	50	-5.2853
9	6	0	1	10	40	0.4914
8	7	-1	1	10	54.1421	-3.9708
3	8	1	1	8	50	-0.3080
5	9	-1	1	7.1716	40	4.1627
6	10	-1	1	12.8284	40	-3.2309
10	11	0	1	10	40	0.4914
7	12	-1	1	10	25.8579	4.9006
11	13	0	1	10	40	0.4914

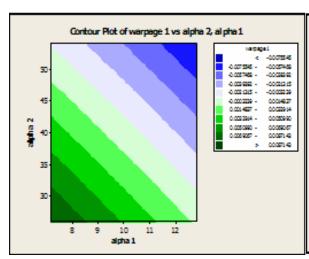


Fig 8 Contour Plot

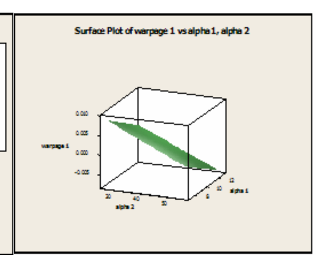


Fig 9 Surface Plot

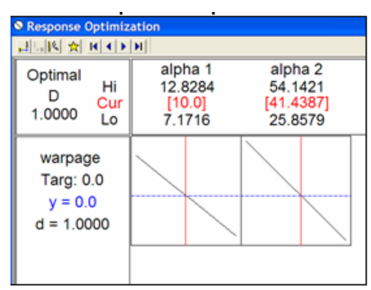


Fig 10 Response Optimization Result

FEM simulation analysis shows that increasing CTE 1 and CTE 2 helps to overcome strip warpage. Warpage will ideally be zero with α1 and α2 as 10ppm and 41.4ppm. After discussions with the compound supplier, reducing filler content was performed to increase CTE value. Original and new improved compound properties are listed in Table 2.

TABLE 2 COMPOUND PROPERTIES

Material Type	Original Compound	Improved Compound 1	Improved Compound 2
Filler Content(wt%)	88.5%	87.5%	86.5%
Tg ©	145	145	145
CTE 1(ppm)	9	9	10
CTE 2(ppm)	32	35	37
Density (kg/mm$^{3)}$	2	1.99	1.98
Thermal conductivity (W/mm.K)	0.98	0.97	0.96
Special Heat (J/kg.K)	0.75	0.74	0.73
Young's Modulus (Mpa)	24000	22900	21900
Poisson Ratio	0.33	0.33	0.33

2 types of new improved compound formation were tested using the original compound as control for FFT mold on the same device. Strip warpage after PMC on both types of new compound could be controlled below 2.0mm.

CSAM CHECK

CSAM(C-mode Scanning Acoustic Microscopy) check was performed on the units after assembly and no delamination was found. The CSAM photos are shown as Figs. 11-13.

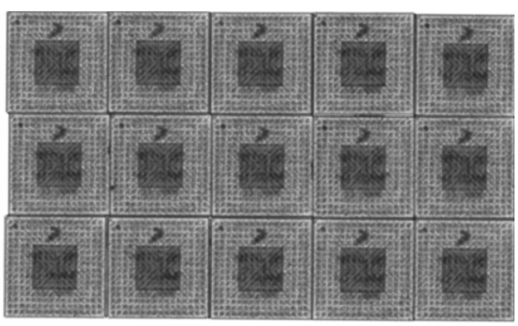


Fig 11 CSAM Photos with Original Compound

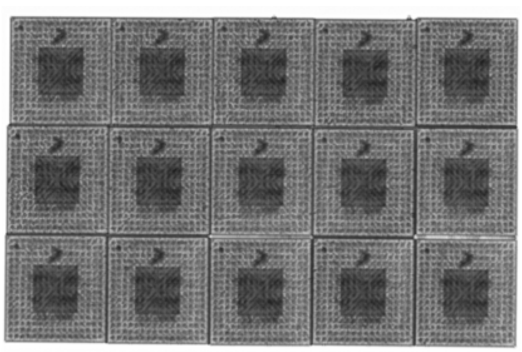


Fig 12 CSAM Photos With Improved Compound 1

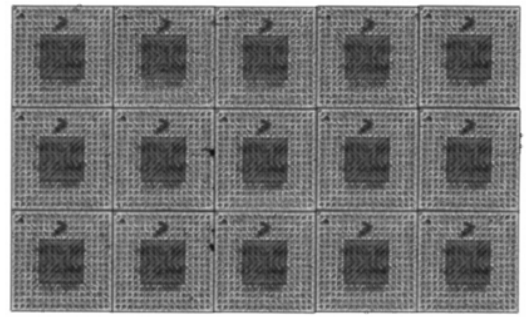


Fig 13 CSAM Photos
With Improved Compound 2

CONCLUSIONS

FFT mold was evaluated using a 44um fine pitch device with PGE design. Wire sweep performance was very good and it was controlled below 1.5%. Strip warpage after PMC (Post Mold Cure) was resolved based on FEM analysis and compound formation improvement. CSAM was checked on original and improved compound types and no internal void or delamination was found. All current study results will be very helpful for further study on MSL and reliability. FFT needs to be tested on a low k device with fine pitch design in the future.

ACKNOWLEDGEMENTS

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REFERENCES

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ACRONYMS

FFT: Flow Free Thin
PGE: Power Ground Embedded
PMC: Post Mold Cure
FEM: Finite Element Method
CTE: Coefficient of Thermal Expansion
DOE: Design of Experiment
CSAM: C-mode Scanning Acoustic Microscopy