The Influence of Belt Furnaces on the Post Mold Cure Process

Introduction

Post mold cure (PMC) is one of the most significant processes in electrical industry. This process exposes part of a mold to elevated temperatures in order to speed up the curing process and to optimize some of the material's physical properties.

The PMC process will expedite the cross-linking process and will properly align the polymer's molecules to make a stronger part with better high temperature characteristics. Much like tempering steel, post curing thermosetting can improve physical properties above what the material would normally achieve at room temperature, such as tensile strength, flexural strength, and can modify the temperature of heat distortion. Moreover, post mold cure process is the most common strategy used today for warpage problem solution. Finally, it can also deal with the outgassing phenomenon during IC package.

Given the benefits of PMC processing, it is widely used in the electrical device industry. It is easy to find the application of PMC in many facilities, and there is a large number of companies using PMC on their products. Figure 1 shows various chips that have been packaged using PMC processes.

Figure 1. *Products of PMC*

PMC Process in IC Encapsulation

There are two major manufacturing steps in IC encapsulation industry. For the first step, the IC chip would be encapsulated into a thermosetting epoxy mold compound (EMC), which is the most common plastic material for IC package manufacture today. This pelletized compound is injected into a hot mold die to form the body around the IC die. After the plastic injection, the mold is cured. The object of this step is to achieve good fill and partial cure of the mold.

The second step of the process is the post mold cure (PMC) process. The goal of this step is to increase degree of cure and reduce warpage in an IC chip. In order to optimize properties, PMC process provides a critical completion of the cure process to complete the chemical cross-linking of the material. During PMC, the material experiences additional molecular rearrangement and greater efficiency of molecular collisions, resulting in a greater degree of cross linking. The heating can also cause any residual peroxide to break apart and initiate some additional chains.

Generally, the PMC heating process can be divided into three heating stages, assuming that heating process in the furnace is uniform. In the first stage, products are heated from room temperature 25 oC to post mold cure temperature of 175 oC in a short time. In the second stage, the temperature is held constant for several hours. In the final stage, the product is cooled from 175 oC to room temperature in a short interval.

Applications of PMC

Post mold cure has been applied by many electronics companies, especially semiconductor designers and manufacturers. Table 1 shows various products that have benefited from PMC to achieve better performance as well as some companies associated with them. From the table, it is easy to see PMC technique is widely used in electronic market by a wide range of corporations. If your company requires better device performance, PMC processing is an easy choice.

***Table 1**. Products and companies using the PMC process*

PRODUCTS	COMPANIES
IC	Intel; Samsung; Toshiba; SK Hynix; IBM; Sony; AMD; Freescale; Marvell; Nvidia; Qualcomm; Anadigics; Cree; Infineon; ST's; Microsemi; Silicon Labs; TI; Vishay; IR; NXP; Intersil; Amkor; Spansion; Renesas;
Packaging	ASE; Intel; TSMC; Microsemi; SPIL; QuickLogic; SMIC; UMC; Globalfoundries; Amkor; UTAC;
RF power amplifier	Skyworks; TI; TriQuint; RFMD; Cree; Anadigics; Maxim Integrated; Infineon; NXP; ST's; Avago; Semtech; ADI; Linear; Macom; Freescale; Microsemi; ONsemi; Lattice;
Memory	Samsung; Elpida; ISSI; Micron; Maxim; Integrated; Microsemi; SK hynix; NEC; Panasonic; Toshiba; SPIL; OSE; Spansion; Winbond;
FPGA	Xilinx; Altera; Atmel; Microsemi; Lattice; QuickLogic; Actel; Vantls; Cypress;
ASIC	LSI Logic; Toshiba;
Attenuators	Skyworks; TriQuint; RFMD; Avago; Peregrine; Analog;
RF passive	Skyworks; TriQuint; RFMD; PPI; Macom; Microsemi; ONsemi; RCD;
Transistor	TriQuint; NXP; ST's; Avago; ONsemi;
Diodes	Skyworks; NXP; ST's; Avago; Macom; Microsemi; Vishay; ONsemi;
Mixers/ multipliers	Skyworks; TriQuint; RFMD;NXP; Avago; ADI; Linear; Peregrine; TI; Vishay; Analog;
Filters	Skyworks; TriQuint; Avago; Macom; TI; ONsemi;
Modulator/	Skyworks; TriQuint; RFMD; NXP; ST's; Micron; Avago; Linear;

demodulator	Microsemi; Analog;
Switches	Skyworks; RFMD; Infineon; NXP; Maxim Integrated; ST's; Avago; ADI; Macom; Peregrine; Microsemi; TI; Vishay; ONsemi; Analog;
Die/wafer	TSMC; TI; Fairchild; Vishay; IR; Cypress; SPIL; SMIC; Amkor;

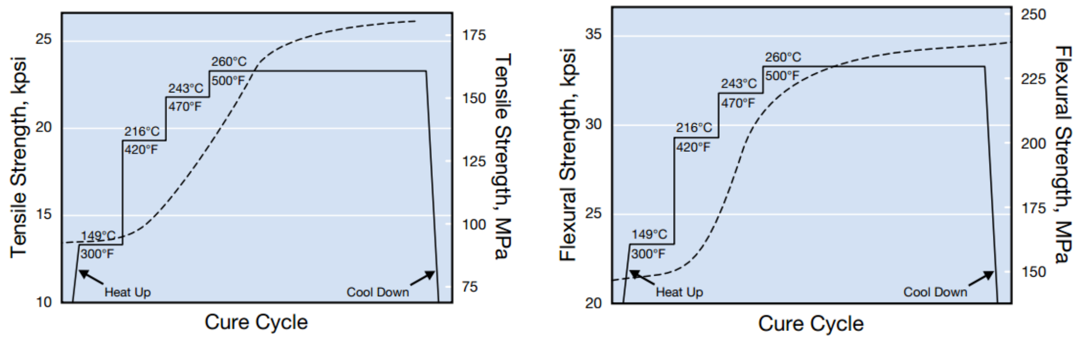
The Influence of PMC on Material Properties

It is the epoxy molding compound (EMC) that determines the properties resulting from PMC process. Epoxy is a vital part of EMC; it will determine the flow characteristics of EMC, and it will impact the EMC thermal performance as well as electrical characteristics. At present, there are several commonly used epoxy resin structures and different types of epoxy resin with different characteristics, such as: o-cresol-type epoxy resin with high thermal stability and chemical stability; bisphenol A type epoxy resin with low shrinkage and low-volatile component; multi-functional-type epoxy resin has excellent thermal stability, fast curing and high Tg and other characteristics; biphenyl-type epoxy resin has a low viscosity, high filling characteristics; tea-type epoxy resin with high T g, high-heat-resistant properties; modified epoxy resin with good flexibility and so on.

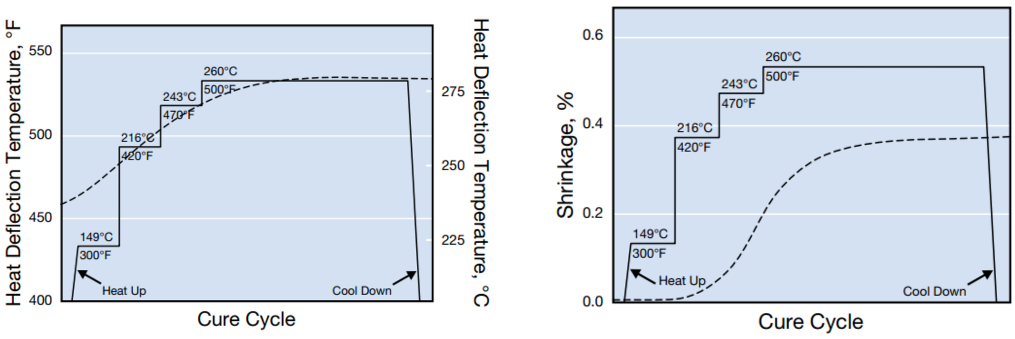
Epoxy resin	Characteristics
O-cresol-type epoxy resin	High thermal stability and chemical stability
Bisphenol A type epoxy resin	Low shrinkage and low-volatile component
Multi-functional-type epoxy resin	Excellent thermal stability, fast curing and high Tg
Biphenyl-type epoxy resin	Low viscosity, high filling
Tea-type epoxy resin	High Tg, high-heat-resistant
Modified epoxy resin	Good flexibility

***Table 2**. Some epoxy resins and their characteristics*

The PMC process involves placing the molded articles in a forced-air furnace and thermally treating them to a series of increasing temperatures for various times. The program of times and temperatures is referred to as the cure schedule or cure cycle. During the PMC process, the molecular weight of the polymer increases by chain extension. As the molecular weight increases, virtually all mechanical, chemical, and thermal properties are affected. Figure 2 illustrates how physical properties change a PMC process. After PMC, the physical properties of objects are substantially increased.



(a) (b)



(c) (d)

Figure 2. *Physical properties changes of cure circle: (a) Tensile strength; (b) Flexural strength; (c) Heat deflection Temperature; (d) Shrinkage; The specimens are Torlon 4203L, 3 mm (1/8 inch) thick.*

PMC can prevent problems such as warpage during encapsulation in chip packages. In IC encapsulation, one of the most prevalent and troublesome EMC defects is warpage. Fortunately, PMC is an efficient method to alleviate the warpage problem during encapsulation. PMC is also one of the principal tools to mitigate outgassing. PMC can remove the volatiles from the cross-linked plastic material. If the volatiles are not removed and the EMC is exposed to elevated temperatures with poor ventilation, one will observe deterioration in strength, elongation, compression set properties accompanied by chemical decomposition. Insufficient or poor PMC can result in “smoke,” bubbling, delamination and unsightly sticky surface deposits.

To achieve a satisfactory PMC process, the furnace must be tuned to optimize the cure process, which can only be achieved through high quality temperature control.

Furnace Selection of PMC

Selecting a suitable furnace requires knowledge of the temperature, time, and atmospheric conditions of the process. Basically, PMC furnaces can be divided into batch furnaces and continuous furnaces. Batch furnaces are suitable for any part size but are limited with respect to production volume. As batch furnaces use the same door to load and unload the part, these furnaces can only produce one batch at a time. Continuous furnaces are suitable for high volume production. A continuous furnace uses a conveyor-belt to continuously move parts through the furnace, making it suitable for high-volume production. Figure 3 shows a Hengli continuous belt furnace on the following page.

Figure 3. *A Hengli continuous belt furnace*

Furnace technology, economics, and part quality influence the decision on whether to use a continuous or a batch operation. The economics questions center around cost of ownership, which can include initial cost, operating costs, repair costs, product yields, and return on investment. Quality issues often are associated with process stability, quality, and consistency, while technology focuses on ease of operation, process definition, thermal cycles, temperature requirements, atmosphere conditions, weight of product, and desired throughput. The issues and their relative importance depend on the specific situation.

Most producers are still using batch furnaces for the PMC process today, but as many studies and discussions have pointed out, it is better to use continuous furnaces for PMC process if one wants to get a steady flow of incoming parts. This is because continuous furnaces are extremely versatile and can be employed to perform a multitude of processes. They are an excellent choice for manufacturing medium and high volume products. There are a great number of advantages of converting the batch process to continuous, such as:
1) Superior art to part temperature uniformity;
2) Increased throughput;
3) Process combination;
4) Lower up-front investment;
5) Reduced changeover times;
6) Part loading flexibility.

A continuous furnace is ideal for processes requiring high-production volumes, process consistency, and precision control. All components can go through the furnace smoothly. During the furnace process, as the continuous furnace can serve consistent heating process, the consistency of products could be ensured in a high level. The defects will also be effectively prevented and eliminated. Furthermore, a continuous furnace can greatly improve the production efficiency by being continuously available, rather than intermittently (as is the case for the batch furnace, which must heat up and cool down). In addition, a good continuous furnace is often much more compact than a batch furnace, which is beneficial for floor space considerations and facility costs. Moreover, a continuous furnace is easily used for automation offers.

When choosing continuous furnace, the air convection heating function should be considered as well. Unlike the traditional furnaces that use radiative heating, a hot air convection furnace can elevate the temperature through convective heating which offers an extreme uniformity to PMC process. Figure 4 illustrates the difference between traditional radiative heating and convective heating. More importantly, the hot air convection furnace can get high energy efficiency up to 70% saving over conventional ovens. Additionally, a convection furnace is always environmentally friendly and has neither noise nor pollution operation.

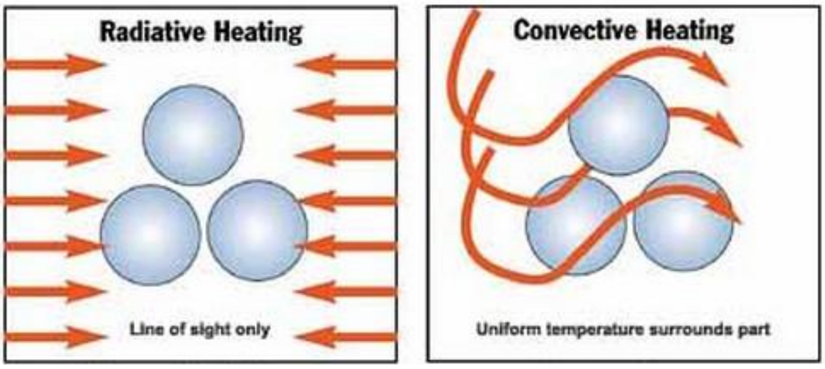


Figure 4. *Radiative heating process and convective heating process*

Furnace Control of PMC

For most PMC process, the longer cure profiles require longer furnaces. These furnaces are more suitable for the inline, integrated manufacturing line used by many printed circuit board assemblers. The PMC process needs specific control of temperature and time, which is critical for getting excellent performance after PMC process. If the temperature of furnace during PMC is higher than the setting point, components are likely to be damaged, which will cause production failure. If the furnace temperature cannot reach the required point, the post curing would be insufficient, which will lead to a great reduction of PMC quality. Consequently, it is vital for furnace temperature control to achieve high quality PMC performance.

As the PMC process is sensitive to the temperature, uniform furnace temperatures are essential for the PMC process. In most cases, 5.6°C (10°F is the greatest temperature difference between the hottest and coolest point in an oven that can be tolerated. Generally, a hot point occurs near the air intake while a cold point occurs near the exhaust vent.

Controllers programmed to raise the temperature by 0.3°C (0 .5°F) per minute are recommended. Automatic shut-off and manual reset features are also desirable. A good oven is supposed to cut off automatically when the temperature reaches 2 .8°C (5°F) above the set point. This is required to avoid distortion of the parts, which can occur if the temperature exceeds the deflection temperature of the part.

Belt Furnace for PMC

The HSF series hot air convection furnace is an efficient belt furnace designed and used for post mold cure process. This furnace can make temperature to 400°C. It can heat by infra-red and/or hot air circulation heating depending on your process. Parameters and requirements as well as the temperature profiles are able to run at the desired heating rate in order to meet the required PMC temperatures under controlled atmosphere. Its air or nitrogen atmosphere can serve a completed curing process. Temperature control zones offer precise control, allowing the furnace to run at the proper heating rate to meet the needs for curing. The HSF series belt furnace can offer uniform temperature distribution to meet the qualifications of the PMC process. Its conveyor system allows proper heating across the belt with little temperature variations. The HSF series furnace comes with an ultra-clean heating chamber, which can give rapid thermal response. Figure 5 shows an HSF series furnace.

Figure 5. *A Hengli HSF series hot air convection belt furnace*

The furnace is long enough to handle the PMC process. To ensure proper practice for continued use, technical information and training will be given upon installation of the furnace. A microprocessor based PID controller provides appropriate system control. Type K thermocouples are used in determining the zone temperatures. The central processing unit (CPU) is located at the entrance table and is available with a Windows operating system for ease of use, and the program is installed ready to control furnace parameters such as belt speed, zone temperatures, and atmospheric conditions. Temperature profiles can be stored and retrieved as well for future purposes. There are programs for capturing/storing, displaying, and printing out the furnace profile which are already included in the software. Additionally, the furnace is equipped with a redundant overheat safety protection system which incorporates an additional type “K” thermocouple in the center of each controlled zone and the multi-loop alarm.

Conclusion

PMC is an important technology for electrical industry. It can highly improve the properties of chips and is widely used by a great number of companies. A large number of electronic products and companies have used PMC for better performance. The quality of the PMC process is deeply influenced by the temperature and time, which are strongly influenced by the furnace. A good continuous belt furnace with precise control and convective heating will offer great conditions for the PMC process.