Better Thermal, Mechanical and Physical Properties of Cured Polymer Using Low Pressure Vacuum Cure Processing

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In the past few years, tremendous effort has been devoted to increasing the capabilities of high-density backend processing by increasing the number of redistribution layers (RDLs), shrinking the dimensions of the metal lines' width and spacing (L/S), and reducing the pad size and pitch. During the next few years, we also expect to see an increased level of Heterogenous Integration (HI). Heterogeneous Integration uses packaging technologies to integrate dissimilar chips with different functions from a wide variety of fabless houses, foundries, wafer sizes, and feature sizes into a system and sub-system. With the advancement of Heterogeneous Integration, multi-layer RDLs are used to connect these dissimilar chips on organic, glass, silicon or fan-out substrates. Given this added complexity and increased layer processing, the importance of polymer or Photo Imageable Dielectric (PID) curing is significant in yielding not only lower cure temperature and shorter cure time, but also resulting in better film properties. While there are a number of different polymer cure processes, selection of the specific process can have a significant effect on the quality and performance of cured polymers, applicable to the FOWLP Multi-level Metallization Process.

In this paper, mechanical, thermal, physical and dielectric properties were studied for different types of Polyimide and PBO materials as a function of different process parameters of time and temperature under sub-atmospheric process conditions using YES VertaCure system. Polyimide and PBO films cured under different process conditions were characterized using different methods such as FTIR, GC-MS, C-V measurement, as well as Tensile and Thermal properties measurement.

The cure study was completed for HD4100 and HD8820 at both atmospheric and vacuum cure conditions. Even though the cure time was reduced by 40% with the vacuum cure process compared to atmospheric cure, both cured films appeared to be spectrally identical in FTIR analysis and no difference in chemical composition and/or degree of cure could be detected within the detection limit of FTIR. This demonstrated identical bonding and cross-linking achieved after either vacuum or atmospheric cure. Comparisons of the amount of outgassing at

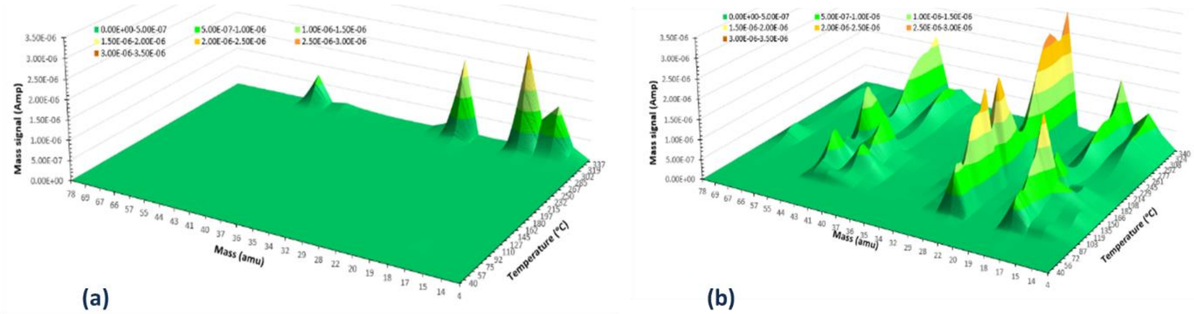

Fig. 1: Outgassing of (a) YES Vacuum cured and (b) Atmospheric cured of HD4100 film. No outgassing was observed until 300°C anneal for 1(a).

metallization under vacuum and atmospheric process conditions (Fig. 1), supported the concept that vacuum cure is a more complete process. As the vacuum was applied during HD4100 cure process, the level of trapped gas decreased to almost background levels shown in Fig. 1 (a) in comparison to the atmospheric cure shown in Fig. 1 (b).

A comparative results of the mechanical and thermal properties were also made by measuring tensile strength and elongation as well as glass transition temperature (T_g), coefficient of thermal expansion (CTE), and 1% and 5% weight loss temperature for HD8820 and HD4100, shown in Table 1. Although elongation was similar for both films processed under atmospheric and vacuum cured conditions, tensile strength of vacuum cured films for HD8820 and HD4100 showed 10% better performance compared to atmospheric cured ones. Furthermore, thermal properties of vacuum cured films consistently showed better performance. In addition to higher glass transition temperature (T_g), 1% and 5% weight loss temperatures were 4-6% better for vacuum cured films – demonstrating better film performance.

PI and Conditions		Mechanical		Thermal			
		Tensile Strength	Elongation	Tg	CTE	Td 1% wt loss	Td 5% wt loss
		MPa	%	°C	ppm/°C	°C	°C
10um HD8820	Atmospheric Cure	137	48	278	49	378.1	472.5
	YES Vacuum Cure	153	64.3	284	51	404.3	487.8
9um HD4100	Atmospheric Cure	233.2	50.7	286	51	399	463
	YES Vacuum Cure	249.4	46.8	319	48	421	498

Table 1: Comparison of mechanical and thermal properties of atmospheric and vacuum cured HD8820 and HD4100 showing better elongation and thermal performance

Capacitance-Voltage measurements were also done to characterize dielectric performance of these films using Hg probe analysis. Although dielectric constants were the same, vacuum cured film showed a 10% lower dissipation factor compared to atmospheric films due to more complete curing under vacuum.

In conclusion, the importance of the vacuum cure process is presented offering better dielectric properties and almost no outgassing for current FOWLP with respect to multi-level metallization.