A New Thermally Stable Polyimide Film for Advanced Microelectronics Packaging

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1. Introduction

Recently, the requirement for higher packaging density of semiconductor devices has been accelerated with the necessity of information capacity increase. Accordingly, the interconnection between a silicon chip and a wiring board has been changing rapidly from peripheral to area array layout, resulting in the drastic configuration change from a conventional face-up attachment to a flip-chip bonding as a more practical chip packaging protocol.[1]

One of the most critical issue to design such configuration is to consider the difference in the CTE between copper (17ppm/K) and silicon (3ppm/K), which causes the interfacial stress between the semiconductor chips and the package substrate. Conventionally, in order to overcome such a problem, die-bonding adhesives layer and/or bonding wires are designed to have a role to absorb interfacial stress caused by a CTE difference between the chip and the package substrate. However, in case of flip-chip bonding, conductive pads at a chip and electrode bumps on a substrate are designed to be connected directly. Therefore, in the case of flip-chip bonding, the interfacial stress is likely to causes a crack or a break at the bonding. Therefore, it should be quite important to eliminate the difference in CTE between a chip and a wiring board in order to achieve higher thermal reliability of electronic products especially used for the higher packaging density applications.[2]

On the other hand, recently, environment issue should be taken into consideration for any kind of production process. Especially, more thermally -stable and halogen-free organic materials which allow a reflow process at a higher temperature has been required. Moreover, in order to achieve an integrated denser packaging in electronic products, packaging components have begun to be allocated three-dimensionally rather than two-dimensionally, where semiconductor chips are stacked in Z-direction. In a more desired case, passive components are embedded in circuit boards which used to be surface-mounted. In fact, an attempt of embedding components used to be developed only in multi-layer ceramic substrates fabrication. However, in considering application of this idea to design of new print circuit board, more thermally-stable substrate materials are required to form inorganic thick or thin films comprising capacitors.[3]

2. Polyimide Films

Polyimide is known to have the highest level of heat resistance and flame retardancy among various organic materials, and have been widely applied for print circuit board and semiconductor packaging. The most known synthesis route is a two-step poly(amic acid) process. Tetra-carboxylic acid dianhydride is reacted with a diamine in a dipolar aprotic solvent such as N-methylpyrrolidone (NMP) or N,N-Dimethylacetamide (DMAc) to yield the corresponding poly(amic acid), which is followed by a cyclization reaction into polyimide products. Two types of polyimides can be available as the commercial grades, namely thermoplastic type and non-thermoplastic type. Non-thermoplastic

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Polyimides are mostly infusible and insoluble due to their rigid molecular backbone. Therefore, normally the solution casting process is employed for the fabrication. In addition, non-thermoplastic polyimides may be classified into two types, namely one is mechanically flexible polyimides made of pyromellitic acid dianhydride (PMDA) and 4,4'-oxydianiline (ODA), which is widely used in FPC and COF applications, and the other type is rigid polyimides made of biphenyl-tetracarboxylic acid dianhydride (BPDA) and p-phenylene diamine (PDA), mainly used in TAB tapes.[4][5]

XENOMAX® which TOYOBO developed for advanced electronics is a new polyimide film, whose chemical structure is totally different from those of such conventional polyimides. With introducing polybenzazole structure in polymer backbones, low CTEs, which are almost equal to that of silicon, are successfully achieved over a wide range of temperature, while keeping the original heat-resistance and flame-retardancy.

☆ 結晶性はどうか?
☆ 膜厚方向のCTEは?
☆ 誘電率の異方性はどうか?

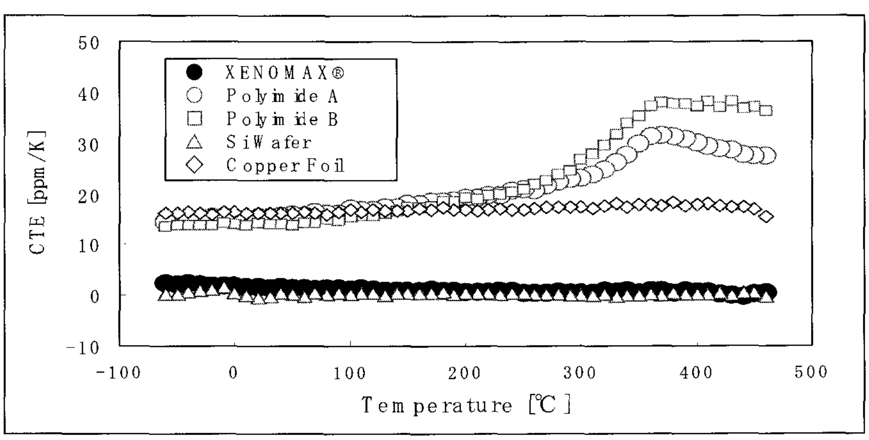
3. Characteristics of XENOMAX®

3-1 Heat shrinkage

Table 1 compares the heat shrinkages among XENOMAX®, conventional Polyimide A and Polyimide B. Two measurement conditions were employed, namely the condition-1 is at temperature of 200 ℃ with elapsed time of 10 minutes, and the condition-2 is at the temperature of 400℃ with the elapsed time of two hours. With condition-1 (lower temperature condition) all samples exhibit similar thermal shrinkage ranging from 0.01% to 0.05%. On the other hand, with the condition-2 (higher temperature condition), XENOMAX® film exhibits extremely lower shrinkage value than those of other polyimide films.

3-2 CTE

Figure 1 shows the temperature dependence of CTEs of XENOMAX® in comparison with those of conventional Polyimide A, Polyimide B, silicon wafer and copper foil, respectively. XENOMAX® film demonstrates very flat temperature dependence of CTE as well as very low absolute value of CTE over a wide temperature range. This homogenous dimension stability in a very wide temperature range especially in higher temperature area than 300℃ should be the one of the most critical characteristics of XENOMAX® film. In the case of XENOMAX®, the CTE is significantly low and stable until 400℃, which is around 3ppm/K. This value is almost equal to that of silicon. Clearly this distinction shows that XENOMAX® is much more desirable than other polyimides to be used nearby silicon



CTE 3ppm/K.

Fig. 1. Comparison of temperature dependence of CTE in XENOMAX®, Polyimide A, Polyimide B, silicon wafer and copper foil

chips in semiconductor packaging. However, on the other hand, since the CTE gap between copper and XENOMAX® is larger than that between copper and other polyimides, careful design and fabrication are necessary when XENOMAX® is used as a material for typical print circuit boards.

3.3 Viscoelasticity

Fig. 2 shows the dynamic viscoelasticity of XENOMAX® in comparison with those of conventional Polyimide A and Polyimide B. The storage modulus for Polyimide A begins to decrease around 300°C and the value at 400°C falls in one tenth of the value at the original room temperature. Its maximum value of the loss modulus observed at 330°C shows a possibility of structural transition, which may correspond to the inflection point in Fig. 1. A similar tendency of the storage modulus and the loss modulus is also confirmed, which implies a structural change for Polyimide. In the case of XENOMAX®, although an unclear dispersion is observed at around 400°C, the drop of the storage modulus is very much smaller than the case with Polyimide A and Polyimide B. Even at 500°C, XENOMAX® film maintains the storage modulus value more than 1GPa as shown in Fig.2. This clearly shows a significant advantage of XENOMAX® in retention of mechanical strength at high temperatures.

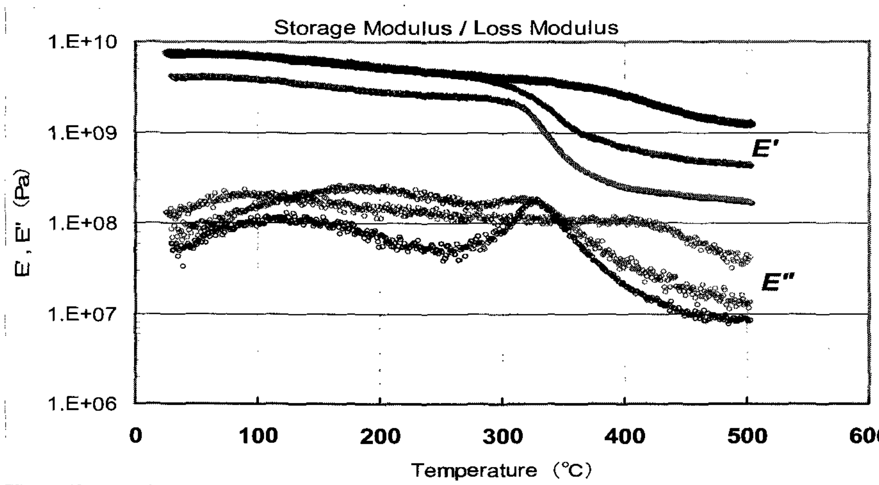


Fig. 2. Comparison of dynamic viscoelasticity in XENOMAX®, Polyimide A & Polyimide B

3.4 Mechanical Properties

Table 1 summarizes the mechanical properties of XENOMAX® in comparison with those of Polyimide A and Polyimide B. XENOMAX® shows similar mechanical properties to those of Polyimide B, which indicates that XENOMAX® does not require special handling for film processing.

3.5 Electrical Properties

Table 1 summarizes the electrical properties of XENOMAX® in comparison with Polyimide A and Polyimide B. The dielectric constant and the dielectric breakdown show that XENOMAX® can be used for an insulating film in most electric/electronic applications.

Table 1. Comparison of characteristics in XENOMAX®, Polyimide A and Polyimide B

Characteristics			unit	XENOMAX□	Polyimide A	Polyimide B	
Heat Shrinkage	Condition 1 200℃ 10min	MD	%	0.01	0.01	0.03	25 μ m
		TD	%	0.01	-0.02	0.05	
	Condition 2 400℃ 2hr	MD	%	0.09	0.74	0.6	
		TD	%	0.03	0.74	0.65	
Mechanical Properties	Tensil Modulus		GPa	9	5	9	25 μ m
	Tensil Strength		MPa	500	360	540	
	Elongation Brake		%	35	65	50	
Electrical Properties	Surface Resistivity		Ω	>1017	>1017	>1017	500v
	Volume Resistivity		Ω·cm	1.5? 016	1.5? 016	1.5? 016	
	Dielectric Constant		—	3.8	3.8	3.5	12GHz
	Dissipation Factor		—	0.014	0.007	0.011	
	Dielectric Brakedown		kV/mm	350	450	390	

3.6 Flame retardancy

5, 10 and 50 micron XENOMAX® films have been already certified by UL as shown in Table 6. Temperature Index is 260℃, which ranks at the top of all organic films.

Table 6. UL certification in XENOMAX® at each film thickness
UL File No.QFZ2, E247930

Thickness	Flammability	HWI	HAI	RTI		D495	CTI
				Elec.	Mech		
[μ m]	UL94	PLC	PLC	[℃]	[℃]	PLC	PLC
5	VTM-0	0	4	220	220	-	-
10	V-0	0	3	240	240	4	3
50	V-0	0	2	260	240	4	3

4. Applications

4-1 Substrate material for semiconductor packaging

Finer-pitch interconnections are strongly demanded for tape substrates applications such as TAB and COF. One of typical promising applications of XENOMAX® would be low CTE substrate for next generation tape applications.

With regard to rigid substrates, advanced design of rigid substrates began to replace prepregs with polyimide laminate because a better thickness control of dielectric layer is required to realize a controlled-impedance matching as the circuit patterns become finer. More importantly, especially for high-end semiconductor device packaging, rapid increase of chip size and power consumption give a big challenge in ensuring of product reliability. They both cause a larger overall stress between a chip and a package substrate, which can seriously lead a break at the connections. Approaches of employing various underfill resins have never been perfect solutions for this issue. A low CTE substrate such as XENOMAX® can be a potential component for advanced IC packaging.

4-2 Substrate material for Thin Film

Besides these potential applications of semiconductor packaging, base material for thin film deposition in flexible flat displays or flexible photovoltaic cells can be other potential applications for

XENOMAX®. Thin film process generally requires high temperature treatment in which the maximum temperature may reach 500℃. Glass or stainless steel is widely used in this application but has not been perfect with respect to flexibility and weight of final products. XENOMAX® can be a desirable heat-resistant substrate material which can stand a high temperature annealing process for a variety of deposited thin films such as silicon and compound semiconductors.

5. Conclusion

Because XENOMAX® shows especially outstandingly low CTE over a wide temperature range, it can be concluded that it is a promising material as a dielectric film for advanced chip packaging, high density rigid print circuit board, and also a new substrate for thin film device for flexible displays or photovoltaic cells. XENOMAX® will deliver the better solutions in various electric/electronic applications, where organic film has not been yet accepted because of its limited dimensional stability and heat resistance.

References

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