IMAPS 2006 LED PACKAGING WORKSHOP

IMPROVED THERMAL PERFORMANCE WITH POLYIMIDE BASED LAMINATE SUBSTRATES

By Gary Briney, David Sutton, and Dan Amey
DuPont Electronic Technologies
14 T.W. Alexander Drive
Research Triangle Park, NC 27705

Introduction

Thermal performance has always been a significant factor in the choice of materials for Electronic Packaging. However, new demands are being placed on packaging and interconnecting substrates in applications that have historically had the need for high thermal performance materials such as Power Supplies and Inverters, automotive under-the-hood modules and military electronics. New applications are also emerging that require high thermal performance materials in displays, commercial lighting, automotive headlights and even consumer products. In addition to thermal performance, materials must meet regulatory agency requirements, more stringent reliability performance and be environmentally friendly, all at lower cost.

Recognizing these new thermal performance needs, Dupont Electronic Technologies has developed a thermal management material technology building on 40 years of experience of electronics industry use of polyimide (Kapton®) films in high temperature and high reliability applications. Composite structures using this material have been demonstrated to be able to meet these increasingly stringent thermal requirements.

Material Technology

The Polyimide platform was chosen for the development of a thermal interface material for it's excellent mechanical properties, property stability at high temperatures, compatibility with Lead free solder processing, Halogen free chemistry, UL 94V-O flammability rating and the ability to fabricate thin films. When thin Polyimide films are filled with high thermal conductivity material and applied to Aluminum heat sinks, for example, very low thermal impedance can be achieved. The family of thermally conductive structures has been designated as CooLam™. The basic construction of CooLam™ is shown in Figure 1.

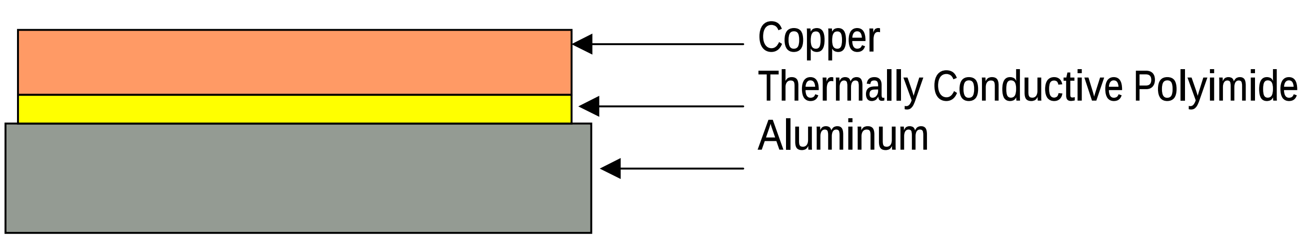

Figure 1: Basic CooLam™ Construction

CooLam™ is offered with a 17 micron filled Polyimide dielectric with electrodeposited (ED) or rolled annealed (RA) Copper with a variety of Copper thickness' (35 to 140 microns or 1oz to 4oz), and either 5052 or 6061 Aluminum. Typical properties are:

Dielectric Strength	4300 VAC/mil
Dielectric Constant	5.5 @ 1 MHz
Moisture Absorption	< 1%
Tg	225 °C
CTE x-y	31 ppm/ °C
Copper Adhesion	>16 PLI for 1 oz. Cu, >12PLI for Aluminum
Dielectric thickness	17 microns
Thermal Impedance	2.15 x 10^{-5} °C-m^2/watt for 17micron film
Thermal Conductivity	0.8 W/m-K

The thin dielectric material results in a very low thermal impedance, a measure of the total opposition to heat flow of the assembly which includes the material and material interfaces. When benchmarked against comparable structures using alternative thicker epoxy based materials with a higher thermal conductivity, the thin dielectric produces lower thermal impedance as shown in Table 1.

TABLE 1 – Thermal Conductivity and Thermal Impedance Comparison

Dielectric Material	Thickness	Thermal Conductivity	Thermal Impedance	
	microns	W/m-K	C°-in^2/Watt	C°-m^2/Watt
CooLam™	17	0.8	0.033	2.15 x 10^{-5}
Epoxy "A"	75	2.2	0.053	3.46 x 10^{-5}
Epoxy "B"	150	3	0.078	5.08 x 10^{-5}

The thickness reduction using CooLam™ vs epoxy based materials can be seen in Figure 2 comparing a typical 150 micron epoxy dielectric vs a 17 micron CooLam™ dielectric each with double sided clad 4 ounce Copper.

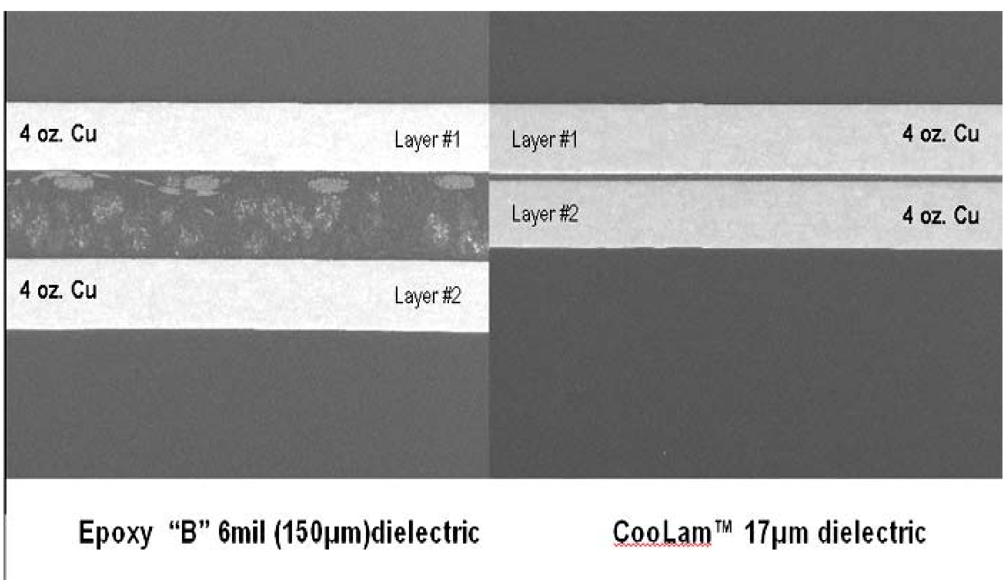

FIGURE 2: Thickness comparison

Table 2 is a comparison of data sheet properties of 17 micron CooLam™ with comparable structures using thicker epoxy based material. Note that the Thermal Impedance of the thinner, CooLam™ structure is lower than the thicker, higher thermal conductivity material.

TABLE 2 – Material Property Comparison

Property	Units	CooLam™	Epoxy "A"	Epoxy "B"
DielectricThickness	microns	17	75	150
Thermal Conductivity	W/m-K	0.8	2.2	3
Thermal Impedance	ºC-m^2/watt	2.15 x 10^{-5}	3.46 x 10^{-5}	5.08 x 10^{-5}
Thermal Impedance	ºC-in^2/watt	0.033	0.053	0.078
Dielectric Strength	VAC/mil	4300	2000	800
Tg	ºC	225 ºC	150 ºC	105 ºC
CTE (x-y)	ppm/ºC	31	25	37
Flammability (Clad)	UL94	V-O	V-O	V-O
Adhesion to 1 oz Copper	PLI	> 16	8	6

Material Characterization

Accelerated stress testing and aging tests were performed on the 17micron thick Polyimide composite film under temperature, humidity, and thermal cycling demonstrating the reliability of the material. Thousand hour tests at 85 °C / 85%RH, -40 °C soak, +150 °C soak and Thermal Cycling for 1000 cycles from -40 °C to +150 °C were performed.

Figure 3 plots the copper adhesion under the stress conditions as measured using IPC-TM-650 2.4.9 Method B.

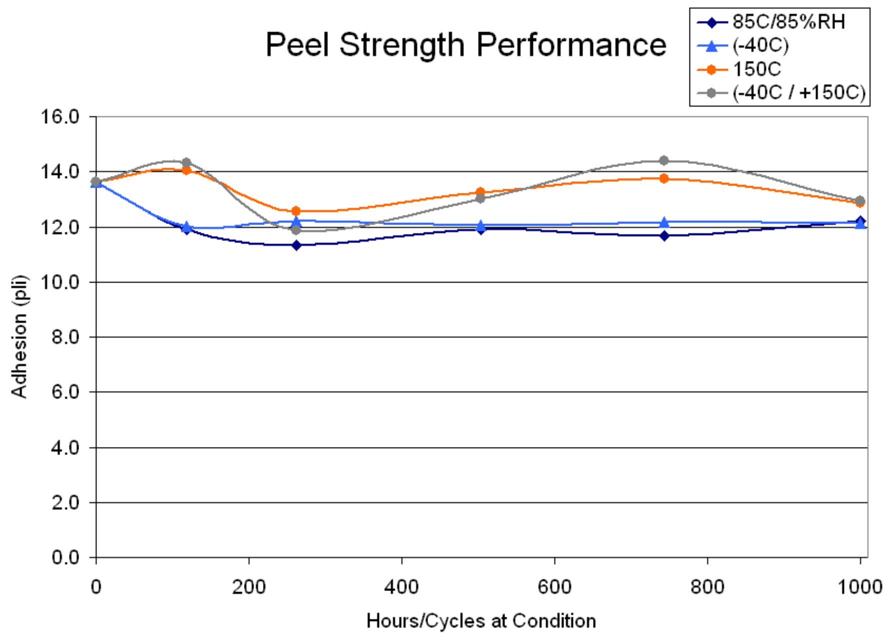

FIGURE 3: Copper Adhesion

Figure 4 plots the film Breakdown Voltage under the stress conditions, tested in accordance with ASTM-D149. The testing was performed in air using 60 Hz VAC with a ramp rate of 500VAC/Sec.

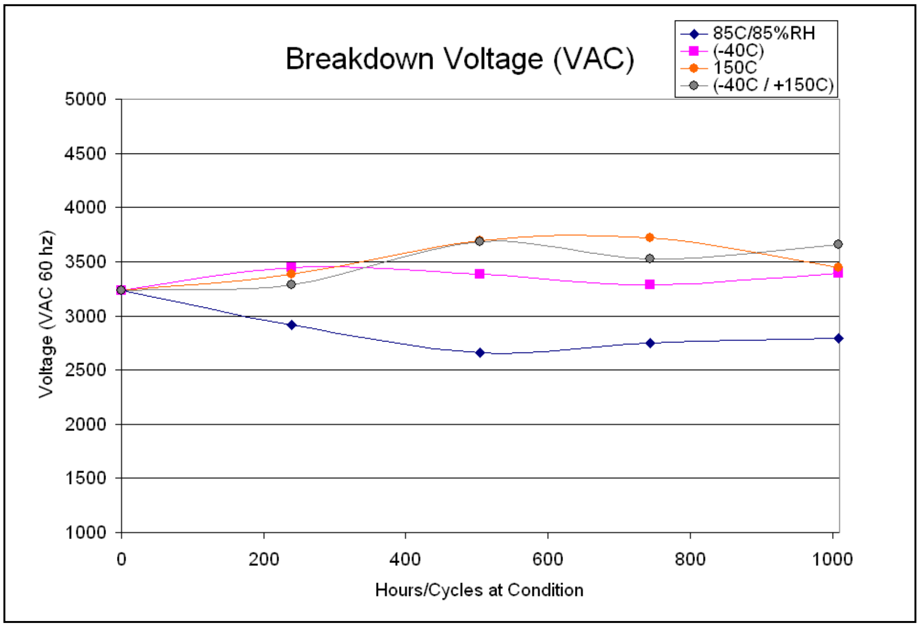

FIGURE 4: Breakdown Voltage

Figure 5 charts the results of the thermal aging tests on the film. This testing was performed in accordance with IPC-TM-650 2.5.6.3 using 60 Hz VAC. Independent groups of films were subjected to 10 day exposure at 230 °C, 250 °C and 300 °C.

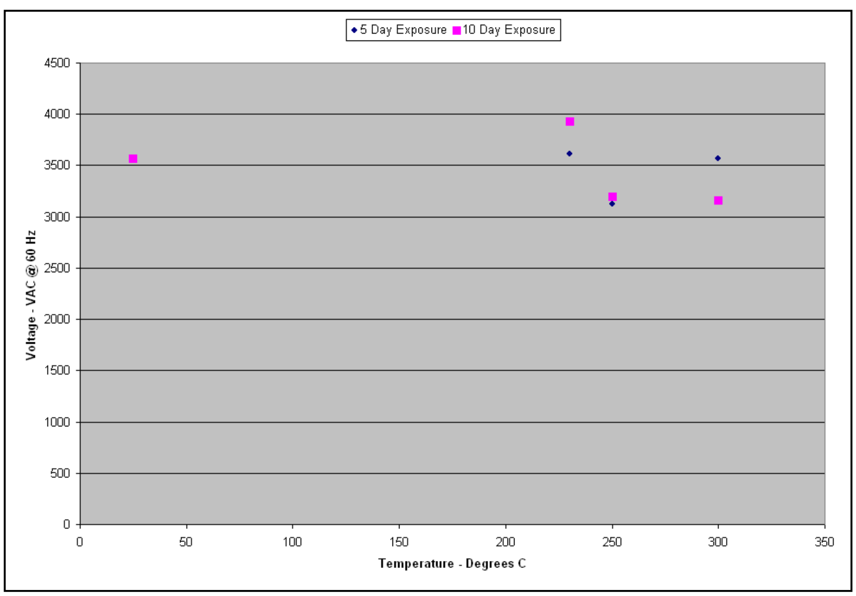

FIGURE 5: Thermal Aging

Figure 6 plots the film's Thermal Conductivity under the stress conditions in accordance with ASTM E1461 using a Netzsch Nanoflash thermal properties test instrument

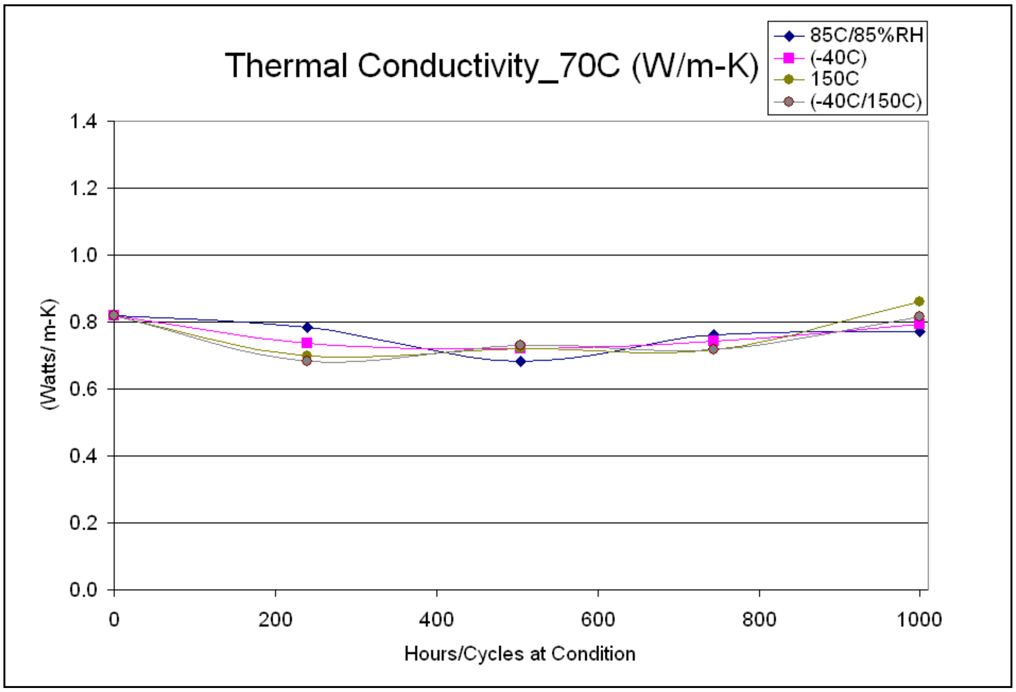

FIGURE 6: Thermal Conductivity

All of the testing demonstrates the outstanding performance and property stability of the CooLam™ material under accelerated stress conditions.

SUMMARY

Key properties of a Kapton® polyimide-based thermal interface material, CooLam™ were presented and benchmarked against alternative material systems. Thermal conductivity, thermal impedance and dielectric properties were reviewed. Dielectric strength, copper adhesion, thermal conductivity reliability test results were presented demonstrating the reliability of the material system, and suitability for use in demanding LED and power electronics applications.

For further information please contact michael.j.green@usa.dupont.com