MOLECULARLY FLEXIBLE EPOXY FLEXIBLE CIRCUIT SUBSTRATE

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ABSTRACT

Solderable substrate suitable for fine-line and spacing semiconductor area-array substrates have been limited to the use of the high cost polyimide-metal clad. Besides the high cost that is rapidly becoming stifling to its growth, the excessive moisture absorption and its performance at higher frequency also make it less than perfect. Even though PTFE flex-tape is great for the higher frequency use, the cost is even more prohibitive. [1,2]

Since 1985, AI Technology pioneered the use of flexible epoxy for de-coupling the mismatched coefficient of thermal expansion induced stresses of microelectronic devices from substrates in die-attach and substrate-attach. The company has recently developed a molecular flexible self-bonding substrate as interposer and flex-tape at 1/5 of the cost of the current technology. [3,4,5]

This molecular flexible dielectric substrate, COUPLER™ has all of the essential characteristics to enable better performance as semiconductor array-area substrate. It has less than 0.3% of moisture absorption in comparison to the 3% or more for most of the polyimide substrate. It has the same dielectric constant as loss as that of the typical polyimide. It has the thermal expansion coefficient average to approximately 10 ppm/°C in comparison to the 20 ppm/ °C of polyimide. Its thermal stability is better than most FR-4 and FR-5 substrates with major thermal degradation onset at around 430°C.

COUPLER™ based substrate is directly solderable and contains no silicone molecules. Other than mechanical strength and rigidity, COUPLER™ has better electrical characteristics than the polyimide flex-tapes and at a fraction of the cost. More importantly, there is no capacity limit in availability and easier processing cost in manufacturing. Thermally conductive versions of the COUPLER™ laminates and multi-layer circuit adhesive laminates are also available.

COST OF MATERIALS

The basic cost of flexible substrates may be summarized in the following Table 1:

Table 1: Material Cost of Different Flex-Tapes

	Cost Per Sq. Ft.	Comments
Polyimide	· $0.7-$1.0	o Based on 1 mil thick polyimide o Lower moisture absorption versions may cost more
Polyimide with Acrylic Adhesive	· $2.6-$3.0	o Based on 1 mil thick polyimide o Lower moisture absorption versions may cost

		more
Polyimide/Acrylic/Copper Laminate	· >$2.6 (1 oz Cu) · >$5 (½ oz Cu)	o Based on 1 mil thick polyimide o Lower moisture absorption versions may cost more
Polyimide/Copper Laminate (Without Acrylic Adhesive)	· >$8.0 (1 oz Cu) · >$20 (½ oz Cu)	o Based on 1 mil thick Polyimide o Available is major problem
COUPLER™ ("Adhesive-less")	· $1.3 (1 oz Cu) · $3.8 (½ oz Cu)	o Based on 3 mil thick COUPLER flexible substrate o Availability is unlimited
COUPLER™-HDS (With 1 mil Polyimide)	· $2.3 (1 oz Cu) · $5.8 (½ oz Cu)	· Based on COUPLER flexible substrate with 1 mil polyimide for high dielectric strength-HDS
COUPLER™ Pre-Preg (With B-staged Adhesive)	· $2.8 (1 oz Cu) · $4.8 (½ oz Cu)	· 3 mil B-stage COUPLER pre-preg · Used for multi-layer circuit board applications
COUPLER™-HDS Pre-Preg (With 1 mil Polyimide)	· $2.8 (1 oz Cu) · $4.8 (½ oz Cu)	· Based on B-staged thick COUPLER flexible pre-preg on 1 mil polyimide for high dielectric strength
T-COUPLER™ Pre-Preg (B-staged thermal adhesive)	· $3.8 (1 oz Cu) · $4.8 (2 oz Cu)	· 3 mil thermally conductive pre-preg

It is obvious that the cost of materials for using the molecularly flexible dielectric COUPLER™ and T-COUPLER™ in comparison to the standard polyimide represents 100-1000% saving.

COST OF SUBSTRATE FABRICATION

The two basic factors that determine the cost of fabrication are the cost of circuit etching or other formation processes and the cost of via "drilling or etching". The COUPLER™ molecularly flexible substrate uses the same chemical etching and wet chemistries such as plating of precious metals and tin-solder depositions that are commonly used for the standard FR-4 and Polyimide flex-tape and thus incur the same cost factor.

In the case of via formation, standard laser and plasma etching methods are also applicable with slightly faster and easier process.

There is still another process that is not available when standard polyimide flex-tapes are used is that vias may be preformed into COUPLER™ flex-tape. The result is that blind vias can be formed with high accuracy before circuit traces are etched and formed. These vias can actually be pre-plated with heavier copper slugs for higher current carrying applications than otherwise available to standard through-hole vias and blind vias techniques. These blind vias can also be filled with reflow solder slugs that also allow direct soldering interconnection between two-metal laminates.

This special processing capability of two-metal substrate improves high-speed transmission and impedance control. The built-in via formation capability helps to lower the cost of routing capability.

The versatility and flexibility in vias and interconnection processes can open up many different packaging options. Thus, using COUPLER™ flex-tape not only contributes to higher performance but also to lower costs.

CIRCUIT FEATURES CAPABILITIES

COUPLER™ flex-tape has the same performance as that of the best polyimide-copper flex-tapes. The thickness of copper layer can be as low as ½ oz and still maintain the low cost advantage.

The availability at lower thickness such as 3/8 oz and ¼ oz copper flex-tape are also available on special order in 2 feet by 2 feet panel format at a fraction of the polyimide flex-tape costs.

The proximity of circuit traces is only a factor of the processes available. The state-of-the-arts pitch and spacing of down to 10-micron pitch for the best of polyimide flex-tapes are also available.

The 0.5-mm PTH pitch for solder pads can readily achieved with the COUPLER™ and T-COUPLER™ flex-tapes similar to other high performance polyimide flex-tapes.

ELECTRICAL PROPERTIES

COUPLER™ flex-tape has slightly lower dielectric constant and dissipation loss than standard FR-4 and Polyimide flex-tapes but not as low as PTFE flex-tape. The following Table 2 is a tabulation of typical dielectric properties of these substrates that may be critical for designing higher frequency applications.

Table 2: Dielectric Properties of Flex-Tapes

	Dielectric Constant/Loss (@ 1 MHz)	Dielectric Strength (V/mil)
Polyimide	3.3/0.005	>6000
FR-4	3.5/0.01	>750
PTFE	2.6/0.002	>750
Build-up Flex	3.3/0.005	750-6000
Polyester (PET)	3.3/0.005	>750
COUPLER™	3.2/0.005	>750
T-COUPLER™ (High thermal core)	3.5/0.01	>750
COUPLER™-HDS (1-mil Polyimide core)	3.2/0.005	>6000

While the dielectric constant is typically measured at 1 KHz to 1 MHz, they are typically maintained for most flex-tape even at the GHz frequency.

For most microelectronic and semi-conductor packaging, dielectric constant and loss are much more important than dielectric strength. Almost all of the flex-tapes and standard substrates are much more than adequate in dielectric strength.

The same technology and price goal is achieved for the RFID tags working at 915 MHz and 2.45 GHz.

Figure 4 is an illustration of the soldered interconnection for a typical flexible circuit.

MOISTURE ABSORPTION AND LONG-TERM RELIABILITY

COUPLER™ and T-COUPLER™ flex-tapes have far superiority properties in this important aspect of material performance. The following Table 3 is a listing of the saturated moisture absorption of the flex-tapes based on polyimide and other substrate materials.

Table 3: Moisture Absorption of Flex-Tapes

	Moisture Absorption (Saturation)	Effects on Reliability
Polyimide	>3.0%	-Measling -Corrosion and migration
Acrylic Adhesive	>4.0%	-Measling -Corrosion and migration
FR-4	>2.5%	-Corrosion and migration