

RIGID FLEX

AN ANSWER TO DIMENSIONAL STABILITY

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Rigid-flex circuitry has been used primarily in the military and aerospace marketplace for over 20 years. In this market the product has been found to be a reliable and robust way of interconnecting several electronic packages into one continuous substrate allowing for weight and volume reduction with an increase in reliability. Unfortunately, the production volumes for these marketplaces are relatively low giving the manufacturers little opportunity to concentrate on yield and manufacturing issues to assist in reducing costs. Due to the size constraints in many of today's commercial end products, design engineers are turning to this method of interconnection to solve their electronic packing and interconnect needs. Manufacturers must now address the cost of producing the circuits in relatively high volumes to offer the commercial marketplace a product that not only is reliable, but meets the strict cost guidelines established in a more competitive marketplace.

In most rigid-flex boards the circuitry consists of multiple flexible circuit innerlayers selectively bonded together using either a modified acrylic adhesive or an epoxy pre-preg bondfilm. The flexible printed wiring layers consist of a flexible base dielectric, usually a polyimide based unsupported film, with rolled annealed copper bonded on either one side or both sides. This flexible substrate is then imaged and etched using conventional printed wiring processing equipment. A cover layer of flexible dielectric is then applied to encapsulate the copper conductors.

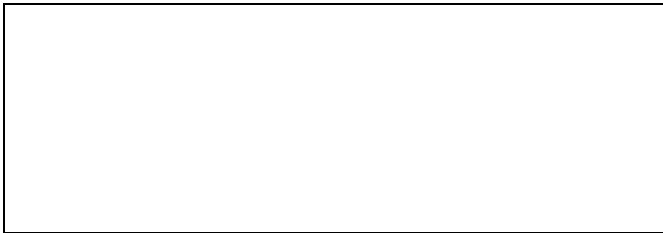
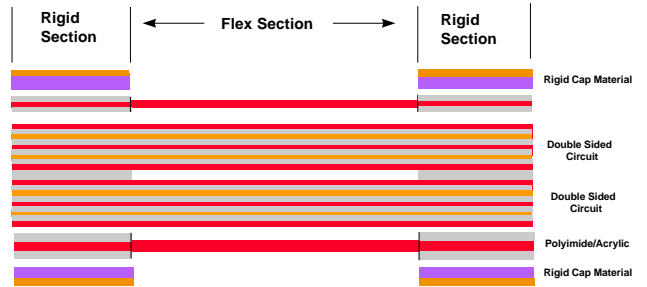


Figure1:
Conventional Flex/right Innerlayer Construction

Figure 1 shows a cross sectional view of a traditional flexible innerlayer for a rigid flex circuit with cover film material. This cover layer provides both electrical insulation and protects the conductors from the environment. A rigid core material is laminated to the outermost top and bottom layers to further add stability and strength to the bonded areas. It is in these bonded areas that the board will be drilled and plated to provide the necessary Z-axis interconnect between the flexible circuit layers. A cross sectional view is shown in Figure 2 showing both the flexible and rigidized layer. Note that the flexible dielectrics extend throughout both the rigid and flexible sections.

Figure 2: Cross-Sectional view Rigid/Flex Multilayer



Rigid-flex circuits can be successfully manufactured utilizing this process and

these materials in limited quantities. However, the flexible dielectric materials and bonding adhesives have properties that limit their use for high volume, low cost circuits. Conventional polyimide based dielectric materials can absorb significant amounts of moisture which will put stress on the plated through hole barrels during soldering operations. Additionally, dimensional instability of these materials in the X and Y axis's causes the flex innerlayers either grow or shrink during processing. This can lead to layer-to-layer registration problems during lamination of high density circuit boards which will adversely affect the manufacturing yields. Figure 3 shows the moisture absorption characteristics of these materials and other materials commonly used in printed wiring board



fabrication.

Figure 3: Moisture Absorption of Various Materials

Another property of the traditional polyimide based materials is the high Coefficient of Thermal Expansion (CTE) of the acrylic adhesive used in these substrates. The CTE of the acrylic adhesive is approximately 425 PPM/Deg. C as compared to approximately 100 PPM for most epoxy pre-preg materials. The chart in Figure 4 compares the coefficient of thermal expansion for materials used in printed wiring board fabrication. A material with a high CTE also will have a higher Z-axis

expansion rate. During thermal rises, such as soldering or reflow, the acrylic adhesive grows at a rate that is considerably higher than the other materials used in the construction. Defects such as barrel cracks and outer layer pad lifting, along with delamination can be attributed to the thermal instability of the acrylic adhesive.

Figure 4 : Coefficient of Thermal Expansion of Various PWB Materials

Another property that needs to be considered is the Glass Transition Temperature (Tg) of the various materials. The Tg of the acrylic adhesive material is very low when compared to other board materials. The Tg of this material is 40 Deg. C (90 Deg. F) whereas the Tg of the bonding material used in rigid boards,



epoxy pre-preg is 125 to 180 Deg. C. A material with a low Tg and a high CTE, such as the acrylic adhesive



polyimide film combination used in many rigid flex constructions, can cause a board to delaminate during a soldering or reflow operation. The chart in Figure 5 shows a comparison of the Glass Transition Temperature (Tg) for various printed wiring board materials.

Figure 5: A Comparison of Glass transition Temperature for Various PWB Materials

An alternate manufacturing technique to using these conventional flexible circuitry materials has been developed by Teledyne Electronic Technologies of Hudson, NH. This construction technique, known as Regal Flex, targets the rigid board industry and provides



a unique solution to integrating the flexible circuitry into the rigidized sections using rigid laminates. With this method of manufacturing the fabricator starts with a basestock consisting of epoxy pre-preg clad with rolled annealed copper. This effectively removes all of the polyimide film and acrylic adhesive from the base substrate as show in Figure 6.



Figure 6: Regal 1 Double-Sided Base Stock Blank

This basestock substrate is then processed using conventional methods to define the conductive circuitry pattern. The next operation requires the placement of a flexible dielectric material covercoat to be bonded to encapsulate the conductive pattern in the flexible section only. Figure 7 shows a cross sectional view of a Regal Flex innerlayer for a rigid flex.

Figure 7: cross Sectional View of a Regal Flex Innerlayer for a Rigid/Flex

Note that the flexible dielectrics are only used in the flexible sections where they are need to provide flexibility. By fully encapsulating the basestock epoxy pre-preg with the flexible dielectric film circuit is allowed to bend and flex without damage to this material.

The covercoated individual layers are then selectively bonded using an epoxy pre-preg that has been machined to remove the epoxy material form the intended flexible regions. Figure 8 shows a cross-sectional view of a six layer rigid flex board constructed using the Regal Flex process. this allows for portions to become rigidized to allow for through hole processing for vias or component holes. the laminated board is then drilled and processed using all the same processes as any other printed wiring board.



Figure 8: Six-Layer Rigid/Flex Using Regal Flex

This technique yields a board that has all epoxy glass materials in the rigidized sections and a combination of epoxy pre-preg and polyimide film/acrylic adhesive materials in the flexible sections. Boards manufactured using this technique are normally used for applications requiring flexing during installation only due to the use of the pre-preg in the flexible section. Sample product has exceeded 700 bending cycles without electrical failure or mechanical failure.

To address applications requiring very tight bend radii or continuous flexing Teledyne has developed an enhanced version of the Regal Flex product. In this version, called Regal 5, the basestock material is pre-tooled to allow the removal of the epoxy pre-preg from the intended flex section. A polyimide film patch is registered and bonded to this window. A cross-sectional view, as shown in Figure 9, reveals all polyimide film/acrylic dielectric materials in the flex section for maximum flexibility.

Figure 9: Pre-Tooled Base Stock for Maximum Flexibility of Rigid/Flex

The rigidized sections remain as all epoxy materials for dimensional and thermal stability. Figure 10 is a cross-sectional view of a multi-layer rigid flex using Teledyne's Regal 5 construction technique.


Regal Flex allows for maximum thermal and dimensional stability by removing from the rigidized sections those materials that are not suited for this type of use. The resultant product is a printed wiring board that has all the benefits of conventional rigid-flex such as lower weight, less volume and the capability of

conforming to unique folded configurations, without the compromises of using traditional flexible circuit materials.

Teledyne Electronic Technologies has used this construction technique on many military and high reliability aerospace applications as all of the materials and processes are mil-spec qualified. It was through the success in these applications that Teledyne pursued the commercialization of Regal Flex. The technology has been used in many commercial products from portable computers to high memory disc drivers. Regal Flex has successfully passed automotive thermal cycling tests and has been used in several developmental programs with a major automotive producer. The thermal stability of the circuit board allows an end user the ability to wave solder or IR reflow the board multiple times without worry of

creating failures. It can be expected that in a high temperature soldering operation a rigid flex incorporating an acrylic adhesive construction will exhibit high losses at the assembly stage due to delamination and barrel cracks.

Designers are starting to realize the advantages of using rigid flex circuitry as today's applications for circuitry are becoming more and more compact. It is important not to compromise reliability when using a new technology. For packaging designs requiring double sided surface mount complexity with high circuitry density Regal Flex offers the ability of conformity found in traditional rigid flex with the proven reliability of standard rigid multilayer printed wiring board materials.

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