FOCUS ON

MULTILAYER CIRCUITS

CIRCUITS MULTICOUCHES

MEHRLAGENSCHALTUNGEN

CIRCUITI MULTISTRATO

FLEXIBLE MULTILAYER FORMULATIONS

By Brian Shorrock and Keith Netting, Teknoflex Limited, UK

The technology of flexible and flex-rigid multilayer circuits and all related technologies is well understood by many designers involved in electronic equipment in many diverse and wide ranging applications.

As is often the case, the technology of flexible circuitry has its origins in the aerospace and defence industries where the necessity for weight reduction, increased reliability and tighter packaging densities has driven changes.

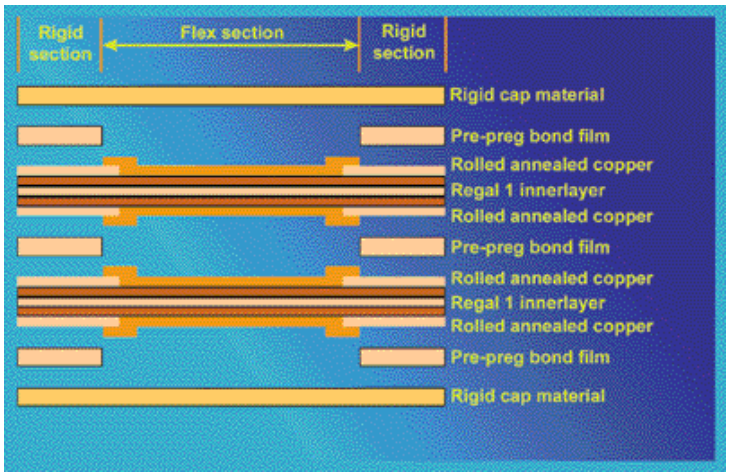

Fig. 1 - Schematic of Regal™ 1 flex construction

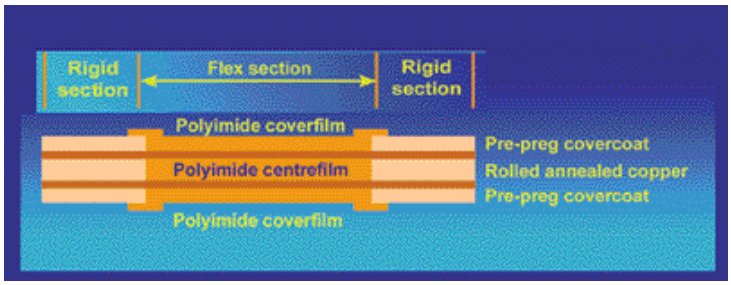

Fig. 2 - Schematic of Regal™ 5 flex construction

Regal ™ flex

This technology was developed in the late 1980s by Teledyne Electronic Technologies as a solution to the problems associated with barrel cracking in high layer count FRMLs.

Whilst the processes involved in manufacturing high layer count Regal™ flex circuits are similar to those used in the manufacture of FRMLs, the technology differs in that the multilayer area contains no polyimide or acrylic materials, whose higher coefficients of expansion and moisture absorption give rise to barrel cracking. The two Regal™ flex constructions are shown in figs. 1 and 2.

Regal 1 is a lower cost construction utilising specially formulated thin epoxy glass pre-preg to replace the flexible laminate, normally polyimide, for the inner layers.

Regal 5 circuits are constructed with inner layers of a hybrid construction in which some areas of the panel comprise epoxy glass pre-preg whilst other areas, the final flexible sections, utilise polyimide.

Both Regal 1 and Regal 5 circuits have flexible "hinges" for connection between rigidised or multilayered areas and "limbs" or "flying tail" sections that can accommodate through hole or surface mount components or pins/connectors for onward connection in the third dimension to other associated circuitry. The selection of Regal 1 or Regal 5 constructions is a function of the radius through which the flexible section needs to be formed and/or whether any flexible sections are dynamic in the application or simply flex to install. Both constructions offer a performance capability comfortably in excess of the demanding requirements of MIL spec and automotive testing regimes covering parameters such as thermal stress for 10 seconds at 288°C, thermal cycling -55°C to +125°C, flexural endurance and tear strength.

Whilst the technology of Regal™ flex circuits was developed initially for high cost, high reliability low volume products this technology and its associated manufacturing processes have been developed to the point where they have been adopted in some high volume, cost competitive applications where high reliability is still a requirement.

PinFlex© circuits

Teknoflex' Pinflex© circuitry was specifically designed for space, avionic and other applications where a cost effective, highly reliable interconnection solution was required. The technology has proven to be advantageous in applications where circuits must be interconnected and where it is important to avoid the use of expensive connectors without in any way compromising the system's integrity.

This technology has also gained favour in many applications for reasons associated with redesign and "in service" repairability. The technology involves the use of proprietary pins which are fitted into the flexible circuits using silver-based pre-formed brazing alloys which are reflowed using parallel gap or inline resistance welding techniques. The high temperature generated in this process to reflow the silver based alloys enables the joints to withstand many solder/desolder operations utilising regular 60/40 tin/lead and lead free alloys without any degradation whatsoever.

Epoxy "stand-off" features can be added when necessary if conformance with MIL-STD-2000A is required.

Typical design guideline dimensions when using Pinflex© technology are: hole diameters of 0.625mm and pad diameters of 1.625mm.

Pinflex© technology can be used on both single and double-sided circuits and can be fitted into a plated through hole. The minimum copper thickness for non-plated through circuits is 70 microns (2 oz).

Modular flex

This is a technique which involves the use of all the above technologies, perhaps together with multilayer rigid circuits, to produce an interconnection system which can be fully assembled when delivered to the customer or which can be supplied as individual piece parts for assembly by the customer or the chosen sub-contractor.

This approach is more than just an alternative to a single complex flex-rigid multilayer in that its flexibility and adaptability allows the user to consider the benefits provided by all of the different technologies. The most significant of these are:

- Use of thin substrates and the most appropriate and ductile copper to achieve maximum flexibility and highest density of conductor geometry
- Use of Sculptured™ circuits for robust interconnection points, unsupported features and maximum current carrying capability
- Use of flex-rigid multilayer or Regal™ flex technology to achieve the most desirable interconnection routing and component mounting
- Use of Pinflex© technology for reliable, robust and replaceable interconnections
- Infinite scope for redesign and "in service" repair, etc.

Hybridised interconnections

All the above technologies have their applications and offer their unique benefits. There are, however, occasions where a particular interconnection and packaging problem demands the design and construction of a unique circuit in which a combination of the above technologies are brought together in a fully bonded, hybridised construction. Examples of this are where circuits are required to carry both signal and heavy current capability, or instances where the number of soldered or mechanical interconnections must be minimised for reasons of reliability or packaging density or where there is perhaps a need for a high level of robustness or rigidity in one or more of the "flying tails" extending from a multilayered area.

These constructions can therefore be a combination of flex-rigid multilayer technology with Pinflex© circuits and Sculptured™ circuits bonded as inner layers into the package and fully plated through (see fig. 3).

The design of these products is highly specialised, and requires careful consideration not only of the finished product's mechanical and electrical performance, but also of the complexities involved in the manufacture of the circuit itself.

It is not uncommon for products at this level of sophistication to be utilised only in the most stringent and complex applications often associated with the aero-space and defence industries, although Teknoflex has also built such constructions for applications in lower profile markets.

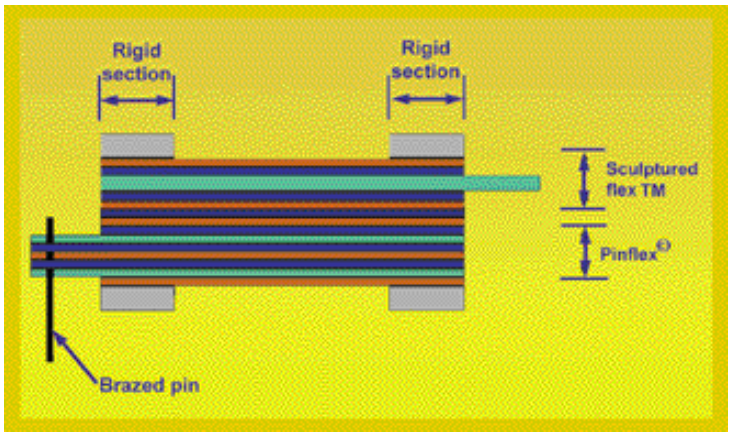

Fig. 3 - Hybrid flex schematic

Markets and applications

Markets which are extensively utilising flexible and flex-rigid multilayer circuits and their many derivatives in the 21st century include aerospace, defence, automotive, computers, medical, telecommunications, cellular communications, instrumentation, etc. In fact it is difficult to identify any market sector which is not utilising this technology in one form or another as a means to reduce cost and weight and increase reliability, among others.

Whilst the world market for flexible circuits and their derivatives may only be 10% of that for multilayer rigid boards, it is nonetheless a high growth technology. This is because, superimposed on the overall growth of the electronics industry in general, demand for flex is being driven by the substitution wires by flexible circuits, and flex circuitry is also being understood more comprehensively by design engineers. ✓

Information request no. 2622

ABOUT THE AUTHOR

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The following survey introduces the latest developments in technologies, base materials, processes and equipment at the leading edge of multilayer circuit production. Products are listed in alphabetic order by supplier name. Edited by Amanda Gronau with the kind co-operation of the companies mentioned. Refer to the Productronica review in this issue for details of other materials and equipment for advanced PCB production.

ARLON

NEW THERMOUNT®

Arlon's new 55ST Thermount provides copper peel strengths of 10 lb/in, double those of previous generation epoxy/Thermount laminates.
This development comes with all of the established benefits of the nonwoven aramid substrate, including a smoother surface for fine line circuits, low in-plane CTE for reduced solder joint stress, excellent layer-to-layer registration, ease of laser drilling for cleaner, more reliable microvias, and resistance to resin cracking. This makes 55ST Thermount ideal for HDI applications, particularly those subject to the mechanical shock of being dropped, such as cell phones, PDAs and lap tops, where the improved copper adhesion resists device pull-off.

Thermount is a registered trademark of the DuPont Company.

Information request no. 2623

DUPONT

FINE-LINE, HIGH YIELD IMAGING

The YieldMaster® 2000 system developed by DuPont is a high performance, high productivity process technology that delivers optimum yields on fine feature, inner layer product. The system consists of a specially developed YieldMaster® photoimageable resist and lamination system, which has been developed applying a six-sigma approach to equipment design and defect reduction.
This system provides increased capability to produce the finest features at high yield. With over 60 YieldMaster® installations worldwide, the technology is becoming well established, both in terms of process yield and productivity.
YieldMaster® 2000 provides greatest benefit on sub-125 micron lines and spaces; on surface types where conformation is a potential issue; where opens and nicks are key defects in the inner layer process, and where yield improvement on inner layer processing is required.
The YieldMaster® system consists of specially formulated Riston, dry film photoresist providing excellent fine-line resolution capabilities with clean developing and stripping; equipment which can be attached to an existing dry film laminator and which ensures consistent, high yield results in fine line inner layer processing, and process technology.
DuPont's process knowledge and experience offers the potential for ongoing yield improvements through process optimisation. Resolution, exposure latitude, conformation, uniform coverage, low process running cost, ease of handling and process yield stability are the main factors to consider when evaluating inner layer imaging process technology. Conventional dry film resists perform well in all these areas, however, resist conformation to standard base material becomes more critical as the level of technology increases. Liquid resist systems can offer the potential for good conformation, but uniform coverage, panel handling and overall process yield stability are major areas of vulnerability. YieldMaster® 2000 offers high reliability processing with excellent conformation and stable, improved yields on fine feature technology.

Information request no. 2624

PRINTED CIRCUIT EUROPE - 4TH QUARTER 2001

Simple single and double-sided flexible circuits are now utilised in all walks of life from sophisticated avionic systems to toothbrushes.

The demand for higher levels of interconnect and packaging densities has driven the technology into increasingly complex sequentially laminated flex-rigid multilayers, microvias and an associated reduction in track and gap geometry.

In addition to the mainstream flex and flex-rigid multilayer technologies, a number of peripheral but nonetheless important technologies have emerged over the years including Sculptured™ and Regal™ flex circuits, multi chip modules and all the associated developments in through hole and surface mount assembly.

Whilst every one of these technologies has its own market position and applications there are instances where the solution to a complex interconnection and packaging requirement can only be satisfied by combining them into what can best be described as a highly customised hybridised interconnection system.

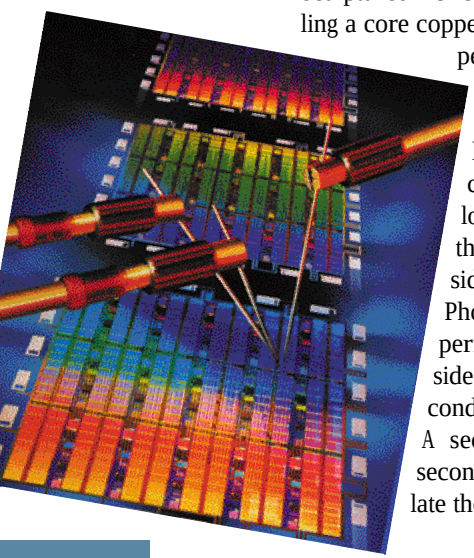
Circuit technologies

Flexible circuits

These products are normally single or double-sided circuits comprising a dielectric film, typically polyimide or polyester, containing copper on one or both sides which is configured through a photo imaging and etching process to derive the necessary conductor geometry for a given application. Double-sided circuits normally have plated through holes and both single and double-sided circuits usually have conductors protected by a printed covercoat or bonded coverlay and may also have rigidised sections for component mounting, etc.

Sculptured ™ circuits

Sculptured™ circuits are produced by chemically milling a core copper foil usually of rolled annealed copper which is typically between 140 and 250 microns thick.



The first stage of this chemical milling process partially etches the circuit pattern into the copper foil following which a dielectric cover film is then bonded to the foil on the etched side.

Photo imaging and etching are then performed from the as yet un-etched side developing the spaces between the conductors.

A second cover film is bonded to the second etched copper surface to encapsulate the conductors to complete the circuit.

Sculptured™ circuits therefore differ from flexible circuits by having variable copper thicknesses, so conductors can be 250 microns thick, satisfying the need for robustness, rigidity, unsupported fingers or high current carrying capacity.

The heavy copper employed enables the manufacture of power circuits capable of carrying 100 amps and more. Termination pads can be left at full thickness enabling raised contact points to be produced which can be gold plated and used as points of interconnection with other circuits using novel, low profile clamping connector technology. This has been widely utilised in many demanding applications.

For reasons associated with the manufacturing process, Sculptured™ circuits have previously been restricted to single layer constructions which has in some instances proved to limit the design process.

Teknoflex has, however, developed the capability of producing double sided plated through hole Sculptured™ circuits and a technique combining Sculptured™ circuits with flexible circuits by the use of welded links.

Flex-rigid multilayer (FRML)

As the name implies FRMLs are a combination of layers of flexible and rigid circuitry bonded together in the manufacturing process to produce what are often complex products with many levels of interconnection and high packaging densities. The circuits often have a number of multilayered areas with the flexible inner layers providing the means to connect between these areas in a foldable, three dimensional configuration. The multiple layers of circuitry are often laminated using a combination of pre-preg bond films and rigid caps, with circuit layer counts frequently exceeding 10. Blind and through vias can be created at the inner or sub multilayer stages and plated through to increase the connection density, provide screening layers or power or thermal planes.

Many construction options are available for FRMLs which utilise both FR4 and polyimide/glass rigid laminates in conjunction with adhesive or adhesiveless flexible laminates. The most common structure used today is based upon a polyimide/adhesive/copper foil flexible base laminate. Typical adhesives are acrylics, epoxies or phenolic butyrals and for higher performance applications, adhesiveless sputtered or cast-on flex circuit materials can be used.

It is common to find rolled annealed copper foil with the adhesive based laminates whilst electro-deposited foil is more commonly with adhesiveless laminates.

The processes involved in the production of FRMLs are similar to those used in the manufacture of regular flexible circuits.