THE MINI-HANDBOOK OF FLEXIBLE CIRCUITS

Industrial trade magazines contain extensive references to flexible circuits and their use in commercial products. Much information on the latest developments, marketing trends and technical progress is available through this source. The design guidelines for flex have been written many times. There are textbooks that describe the unique nature of the product and the processes involved in development and manufacturing. With a wealth of trade magazines specifically devoted to flexible circuits available, many resources are now being utilized more efficiently.

There has been tremendous growth in the flex market and interest continues to grow. This is due to the adaptable nature of flexible circuit used in electronic packages. The latest news in this area is the renewed interest in rigid-flex technology. Primarily developed for the military, this technology has some highly attractive features. There has also been rapid progress in materials and processing technology.

We believe that we can make a good contribution in this area by providing a dynamic document containing a glossary of manufacturing and material terms used and the specifications governing the materials.

Note: We will be updating the information over time. Please call us so we can place you on a mailing list for the future updates.

GLOSSARY OF TERMS

Unlike the rigid PWB sector, the terms in the flex manufacturing have not matured to a point of universal acceptance. Some companies may have different expressions for the same material or process.

Kapton ™: This is a non-reinforced flexible polyimide film made by Du Pont and under their trademark. Since Du Pont was the pioneer in this field, this material is synonymous with any flexible polyimide film. The material is currently made by multiple manufacturers. Generic name for the film is PI (polyimide) film.

Adhesives: The Kapton ™ is not bondable by itself unless a very high temperature and pressure is used. A layer of flexible adhesive is coated on the Kapton. The copper is bonded over this film to make a clad material.
Acrylic - This is an adhesive of choice due to its flexible nature. Typical acrylic adhesive does not meet UL 94 V-0 requirement.
FR - Acrylic - This modified acrylic formulation meets the UL 94 V-0 requirements.
Epoxy - Typical epoxy resin is too brittle to be used in flexible applications. The base epoxy is heavily modified to make it more flexible.
Polyester - This formulation is an enhanced version of the polyester which can withstand higher temperatures.
Butyral Phenolics - This is a special adhesive that has application in some selected areas.

ED copper: Rigid PWBs use Electro-deposited (ED) copper. Typically, this copper is not flexible enough for flex applications. However, there have been some recent developments in making ED copper as flexible as the RA copper. The clad material with flex base is available with various types of ED copper.

RA copper: Rolled annealed (RA) copper is the material of choice for flex applications. The copper is rolled from raw stock and then annealed to give it the desired flexibility.

Adhesiveless: Since the adhesive layer is the area of lowest temperature performance, a thermal failure will occur at that plane. In order to increase the film's performance, this new class of materials has emerged. There are three major types.
Sputtered: Raw Kapton film is treated and processed through a chamber where copper is deposited directly over the film or over a seed layer. The copper layer is only a few Angstroms thick. This layer is conductive enough to build up copper layer in a typical plating line.
Direct Cast: The polyimide adhesive is coated directly over copper.
Adhesive over film: The polyimide adhesive is cast over Kapton film.

Flexibility: IPC test method TM - 650 - 2.4.3.1 defines a standard for flexibility performance. There are three major categories of flex application. Each has their own set of requirements for flexibility.
Flex to Fit: The circuit is used to bridge electronic modules including rigid PWBs in an enclosure. Once installed, the flex does not have any movement. As long as the material does not crack during bending, it can be used for this application. This is also called FPO- For Positioning Only.

Hinge Flex: When the flex is used in a hinge for a lap top computer, or other similar application, it is subjected to 180 degree turn open / close cycles. A standard flexibility test is not sufficient. In this case, the actual parts are subjected to simulated cycles to measure the performance. Typical requirement is 50 K- 100 K cycles.

Dynamic: In case of applications such as a read-write flex in a hard disk assembly (HDA), the circuit has to withstand millions of cycles.

Autoclave: Typical rigid PWBs are laminated in a hydraulic press with or without vacuum assist. The pressure in such a press is unidirectional. The non-reinforced base in flex tends to get distorted due to this force. An autoclave is basically a pressure chamber filled with nitrogen gas. As the gas is heated, it expands and builds up pressure. The flex material is sealed under the vacuum in a flexible plastic bag and placed inside the chamber. The vacuum is attached to the bag while in the chamber. This process creates ‘isostatic’ pressure which will reduce the distortion in the flex material.

Electro-less silver: This is an option for surface finish. The process applies a thin layer of silver over exposed copper. During assembly, the solder paste is screened over and the silver becomes part of the solder.

ENIG (Electroless nickel gold): This is another option for surface finish. The process applies a thin layer of gold over base nickel on exposed copper. During assembly, the solder paste is screened over and the gold becomes part of the solder alloy.

PSA: Pressure Sensitive Adhesive (PSA) is used extensively in flex circuits. The adhesive material (typically 5 mils) comes in rolls with release liners on both sides. This material is first fabricated (drilled, die cut etc.) and then the primary release is removed. The PSA is attached to the circuit by hand pressure. During the final assembly, the secondary release is removed from the circuit for final positioning.

Base: Equivalent to the 'core' in the rigid boards. It is loosely used for both the copper clad and the adhesive coated Kapton (prior to lamination).

Cover lay: The outer layers on rigid boards are typically covered with a solder mask (SMOBC). This mask is too brittle to be used on a flex circuit. Some new masks have been developed specifically for flex but their use is very limited. The material of choice is adhesive-coated PI film that is drilled/die cut and then laminated over the circuit layer. This cover coat application yields final circuits that can withstand many bending cycles. The exposed copper in the relieved area of the cover coat is treated with surface finishes such as gold, solder, silver, etc.

Stiffener: Since the flex circuits are very thin, it is necessary to rigidize certain area. For connector area stiffening, 5-10 mil Kapton is used. For mounting and other applications, a thin or thick FR-4 or a metal piece is used.

Free Film: The same adhesive that is coated over Kapton is also available on release sheet. It is used for stiffener lamination or to make customized clad material.

Pull Tab: Quite often, the flex is inserted into a connector mounted on a substrate (e.g. a back plane or a PWB). During field repair, it is necessary to pull the flex out. In this case, the flex stiffener is designed with a partially bonded tab. The technician can use this free end to remove the flex.

ZIF / LIF: Zero / low insertion force connectors. These are standardized connectors with typical 1 mm or 0.5 mm pitch. The distance of the outline edge of the flex to the first contact tip is very important because the connector aligns with the flex using the edges as guides. This requires special care during fabrication of the flex circuits.

Tear stop: If there is a slit in the flex to fold the two segments in opposite directions, the end of the slit will be subjected to a twisting force that can cause tearing. To prevent this, a small hole is drilled at the end of the slit and a small half moon shape of copper is placed around the circular area.

SRD: Steel rule die - This is the most commonly used means of final fabrication. A narrow channel is cut in a laminated piece of wood and a steel blade is inserted in the channel. The blade follows the contour of the channel and completes the desired outline. When the panel is registered over the blade with tooling pins, the individual circuits can be cut using clicker presses.

Milled Die: A solid block of steel is engraved by NC milling process. It is used in the same manner as the SRD.

Chem-Milled Die: A thin sheet of metal is engraved by chemical milling process. It is used in the same manner as the SRD.

Hard Die: For high volume and tight tolerance cutting, a male / female die is made from steel and hardened for long life. These dies take a long time to make and are very expensive. The die can be used to cut millions of pieces.

Laser cut: The use of laser for cutting has been picking up in Flex industry because of flexibility in low volume high mix and for tight tolerance. Typical CO2 laser cuts flex very well but due to the IR band for these lasers, the edges have carbon deposit that need to be cleaned up. 1064 nm and 535 nm lasers are better. 355 nm UV laser is best because it makes a cut without creating carbon particles.

Shielding: When RF/EMI shielding is required, the traces are covered by shield layers separated by dielectric material . The typical shield layer is either a continuous (or cross hatched pattern) copper or screened silver epoxy paste.