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FLEXIBLE DESIGNS

High-Frequency Flexible Circuits

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Flexible circuits, as a family of products, come in many variations. There are the more traditional flex circuits that are low layer-count, very flexible, used in dynamic motion applications and static scenarios. The static case is generally an application of a one-time bend, where the circuit is formed to a shape in the assembly and then it never has to flex again. In dynamic applications, the circuit must continually flex during the product's lifecycle, such as a read-write flex circuit inside of a hard disk drive.

Rigid-flex circuits have the ability to join multilayer rigid PCB technology with flexible circuits. Think of this concept as having flex circuit layers built into a multilayer PCB. The rigid areas are typically a FR-4 type material and the flex layers are polyimide-based materials. Rigid-flex offers the best of both worlds but can be problematic for manufacturing and reliability issues. Over the years, manufacturers of rigid-flex have fine-tuned the technology to where the manufacturing and reliability issues are well understood. Now, rigid-flex can be made effectively and with very good reliability.

Flexible circuit materials offer great properties for the typical end-use application. However, they do have natural limits, as all materials do. A few potentially limiting properties, at least for some applications: relatively high moisture absorption, poor thermal conductivity, high CTE (coefficient of thermal expansion), low T_g, and poor dissipation factor. But with a wide range of polyimide films and adhesives now available, many of these issues can be addressed through a thoughtful combination of materials for the flex circuit construction.

Even with the most innovative selection of customary flexible circuit materials, one issue stands alone and that is poor performance with high-frequency applications. There are applications where flex circuit technology could offer a major advantage if the circuit had good electrical performance at high frequencies. What is meant by high frequencies? Well, the answer to that question is a bit subjective depending on your reference frame, but at 2.5 GHz, 5.8 GHz, 18 GHz, 24 GHz, 60 GHz and 77 GHz, flex circuits could be beneficial. Traditional flex materials have been used in the frequency range of hundreds of megahertz and even stretching beyond one gigahertz. Typically, traditional flex circuits struggle to have good electrical performance above 1 or 2 GHz due to high dissipation factor and the associated losses. There are some exceptions that may allow flex circuits to extend to the 2.5 or possibly 5.8 GHz, but there is no hope for 24 GHz using traditional flex materials.

Some materials are formulated for high-frequency applications, where the frequencies mentioned are not a concern and some of these materials have flexible properties. In general,

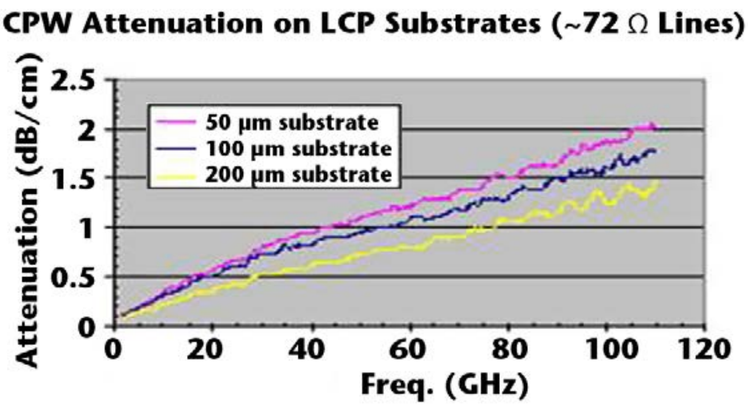

Figure 1: LCP loss performance over an extremely wide range of frequencies from a study[1] done by the Georgia Institute of Technology.

a material can be used for flexible circuit applications when the material is thin, modulus is relatively low, there is no woven glass reinforcement and the copper type used has good flexibility. Some of the thin PTFE-based circuit materials can and have been used in flexible high-frequency circuit applications.

One application was the 5 mil thick RT/duroid 5880® laminate used in a positioning arm, with high-frequency circuitry at the end of the arm. This was a dynamic application, and given the large bend radius, there was less strain on the circuit during the flexing motion, which allowed better flex life. The RT/duroid 5880 substrate is a nearly pure PTFE laminate with a small percentage of filler, which helps to reduce the CTE and there are no woven glass layers. The rolled annealed copper has been proven in innumerable flex circuit applications to be the copper type of choice for flexibility. An additional benefit of the rolled copper is the very smooth surface that helps to minimize conductor loss. This type of loss will be a major contributing factor for overall insertion loss, given a thin circuit that is operating at high frequency.

There are other materials to consider as well. Liquid crystalline polymer (LCP) has been known for decades to be an extremely good material at the highest RF frequencies and it is flexible. The ULTRALAM 3850® laminate is based on thin film technology, with no woven glass, and low modulus. This is available with a copper that is very flexible. This material is being used in many high-frequency applications and the graph shown in Figure 1 demonstrates very low loss (low attenuation) at high frequencies.

There have been rigid-flex circuits made using LCP flexible circuit layers combined with rigid high-frequency laminate layers. This is an excellent combination for a circuit with high utility, excellent high-frequency performance, flexibility and the ability to minimize the electrical transitions from the rigid circuit to the flex. If the rigid-flex was made as a separate rigid board and flex circuit, the connectors between these circuits can alter the electrical performance significantly. Rigid-flex design has more freedom to adjust the electrical transition from the rigid portion of the circuit to the flex portion, and this allows a better signal propagation, less EMI issues and overall improved performance.

When considering a flexible circuit application which needs good high-frequency performance, there are many more material choices than the traditional flexible circuit material. These other materials are often not considered for flex applications because of a mindset and not necessarily due to flexible performance issues. It is always recommended that the circuit designer consult their materials supplier when considering a new application and explore many options that may not be apparent. **PCBDESIGN**

References

1. Thompson, Kirby, Papapolymerou, Tentzeris, "W-Band Characterization of Finite Ground Coplanar Transmission Line on Liquid Crystal (LCP) Substrates", IEEE Polytronic Conference 2003.

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