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The Art of Bending and Forming PCBs

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Flexible circuits are designed to be bendable, but bending rigid PCBs is a little unusual. However, many applications that do not use flex circuit technology will also require bending and forming the circuit. Some of these applications use high-frequency circuit materials to create a circuit in a form that enables improved antenna functionality. Another application involves wrapping a circuit around a structure, which sometimes functions as an antenna as well.

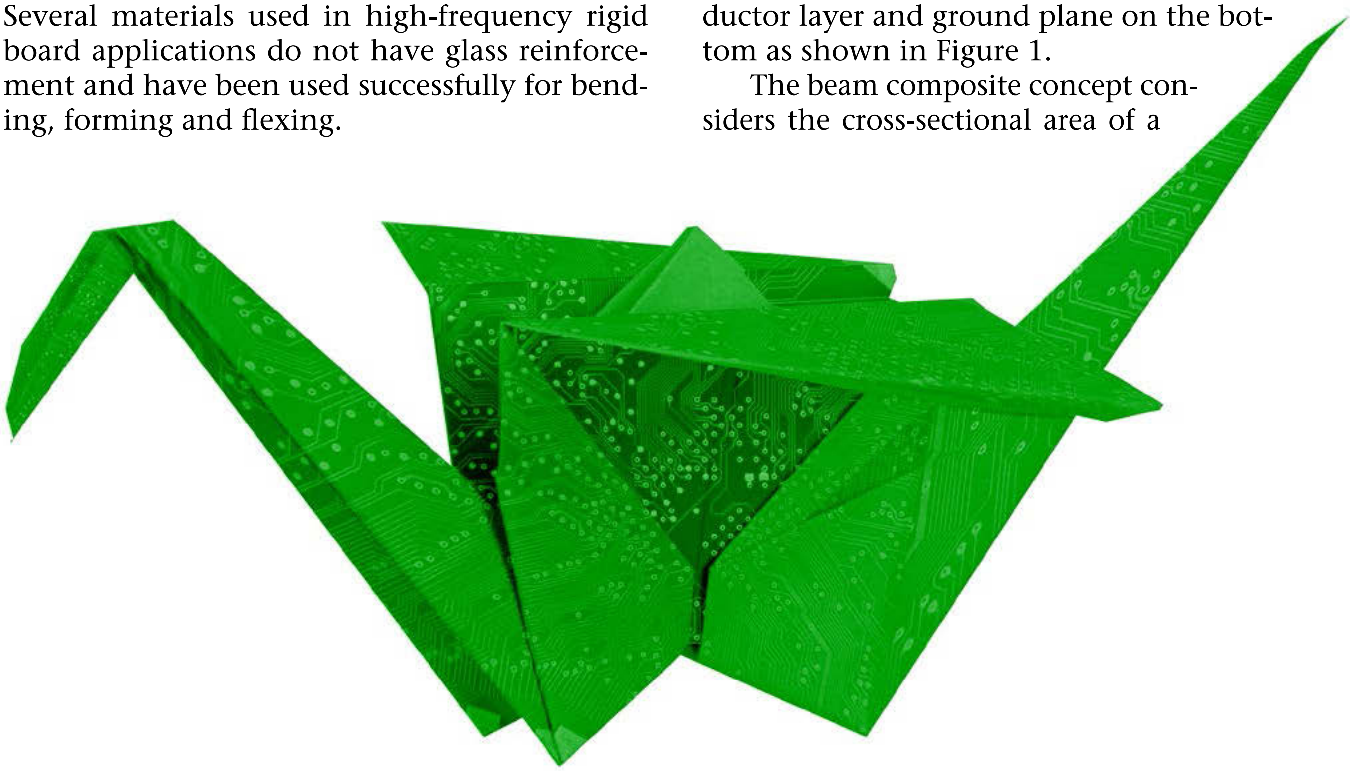
Bending and forming a circuit with dynamic flexing action will require understanding a few basic principles, regardless of the circuit material used. Of course, the circuit material used can make a huge difference in the success of forming circuits without causing conductor or material fracturing. As a general statement with a few exceptions, a circuit material used for bending, forming and flexing cannot have woven glass reinforcement. Because of this, typical FR-4 materials with woven glass are not recommended. Several materials used in high-frequency rigid board applications do not have glass reinforcement and have been used successfully for bending, forming and flexing.

LCP circuit materials are quite suitable for applications where bending, forming and flexing is necessary, and they offer very good high-frequency electrical performance as well. These materials are made as relatively thin laminates, typically less than 5 mils. This thinness aids in the successful bending of the circuits.

However, another set of high-frequency materials has been on the market for many years and used in forming applications: PTFE-based laminates, without glass reinforcement. These materials typically use fillers with the PTFE substrate to help lower the high CTE of PTFE, and this does not detract from the material's bending capabilities.

The basic idea of bending circuits is based on mechanical beam composite theory. As an example, a simple double-sided circuit will be used to demonstrate the concepts. This circuit will be considered a microstrip transmission line with a signal conductor on the top conductor layer and ground plane on the bottom as shown in Figure 1.

The beam composite concept considers the cross-sectional area of a



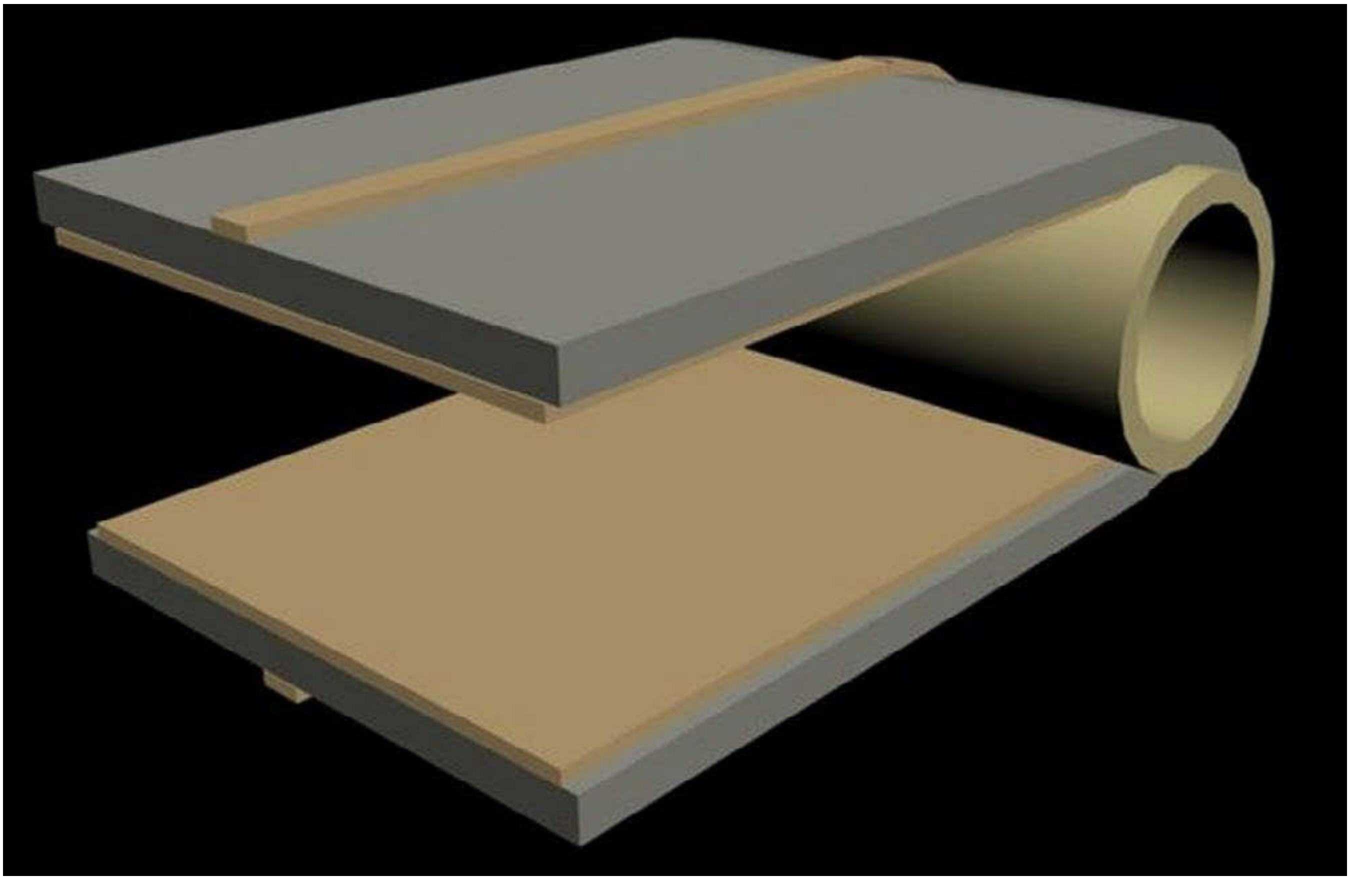


Figure 1: Double-sided PCB used to demonstrate mechanical beam composite theory.

circuit that is made from different layers of materials. One property critical to understanding bending is modulus; in this case, modulus is the measurement of how stiff the circuit is. A high modulus is stiff, and low modulus is soft. When bending a circuit, softer material will generate less stress within the circuit and when there is less stress, the different layers are less likely to fracture.

Bend radius is another very important issue. A simple way to think about this: If it is necessary to bend a metal sheet that is 1/8" thick without fracturing the metal, then having a large bend radius will be advantageous and, of course, a small, tight bend radius is more likely to cause metal fracturing. The small bend radius causes more internal stress on the metal and is prone to fracturing.

Another concept to consider is the neutral axis of the composite beam (or the circuit). The neutral axis is the plane within the circuit with no stress. Consider bending the 1/8" metal sheet again and try to imagine the stresses at different thicknesses within the metal sheet. First, the metal at the inside of the bend radius and those layers of the metal sheet will try to compress and will thus have stress due to compression. Then, consider the outside layers of the metal sheet; those layers of metal will try to rip apart or will suffer stress due to tension. Somewhere in the bend area, there is a transition in the metal, from stress as compression to stress as tension. That small transition area that has no stress is called the neutral axis. Ideally, when a circuit is formed, if there is a conductor on the neutral axis it would not fracture, even considering a circuit with a very tight bend radius, because there would be no stress within the conductor.

The neutral axis is usually considered while modeling bending, forming and flexing circuits; the idea is to keep the critical copper layers as close to the neutral axis as possible. In the case of the microstrip circuit shown in Figure 1, the neutral axis will be located somewhere between the ground plane and the signal plane. That means there will be stress as compression on the ground plane and stress as tension on the signal plane. If a different structure is considered, such as a three-layer stripline circuit with a copper layering scheme of ground-signal-ground, then the neutral axis can be very close to the signal conductor layer. The top and bottom ground layers will have stress as tension and compression respectively, but the signal layer in the geometric center of the cross-section may have very little or no stress. Due to this, the stripline circuit may be formed effectively without damage to the inner signal conductor; however, it is likely to cause some damage on the outer ground plane layers. A thin stripline circuit would minimize the stress on the outer layers and minimize the risk of fracturing.

There are many fabrication variables to consider as well. One is that nickel is very brittle and can easily initiate cracking of the conductor layers. Another issue is copper plating over the laminate copper, which has a potential to have a copper grain boundary difference and may be an issue for cracking when the circuit is bent. Plated through-holes in the bending area are problematic and the type of copper used on the laminate can be critical.

If more information on bending, forming and flexing of rigid circuits is required, it is best to discuss these issues with your material supplier, or contact a technologist familiar with flexible circuit technology. Many times, bending, forming and flexing a high-frequency circuit board will follow the same basic principles of flexible circuit technology. Even though the two technologies differ electrically, the mechanical aspects are similar. **PCBDESIGN**

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