Compression Characteristics of Thermal Interface Gap Filler Materials

Introduction

Compression characteristics are a key function of gap fillers. Unlike thermal greases, the applications for gap fillers are quite different. Being mindful of compression characteristics and the factors that impact stress is important during the design phase to avoid over-stressing the printed circuit board (PCB).

What are Gap Fillers?

Gap fillers are a very specific type of thermal interface material (TIM). They are designed to deform various gaps when dealing with compliancy or flatness issues, providing a thermal heat transfer in the gaps — not just within one assembly, but as variations occur from one assembly to the next. There should not be one pad fine-tuned to the exact application of an assembly. One gap is chosen, and that gap filler should basically absorb the entire tolerance range for a design.

Gap fillers are very different from grease. The purpose of a grease interface change is solely to reduce contact resistance between two surfaces that are in contact. Deflection of grease and phase change is not a critical factor. Most greases and face change are put on top of a heat source. The heat sink is clamped down with a certain amount of force, and there is intimate contact; the only thing that greasing the phase changer does is to break down the contact resistance. As a result, compression isn't critical for those materials. On the other hand, for gap fillers, it is very critical. You will need to understand how a material deforms under pressure — what will it do, and how will it flow?

So why are there gaps to begin with? The less mass you're moving through, the lower the temperature gradient, and the better that heat can be pulled out of the heat source. But why not put a heat sink on the heat source directly in contact with grease or phase change? The closer you can get a heat sink to a component, the more efficient the heat transfer, but in many applications, that's just not realistic. You cannot mate all those different surfaces — that's where the gap filler comes in.

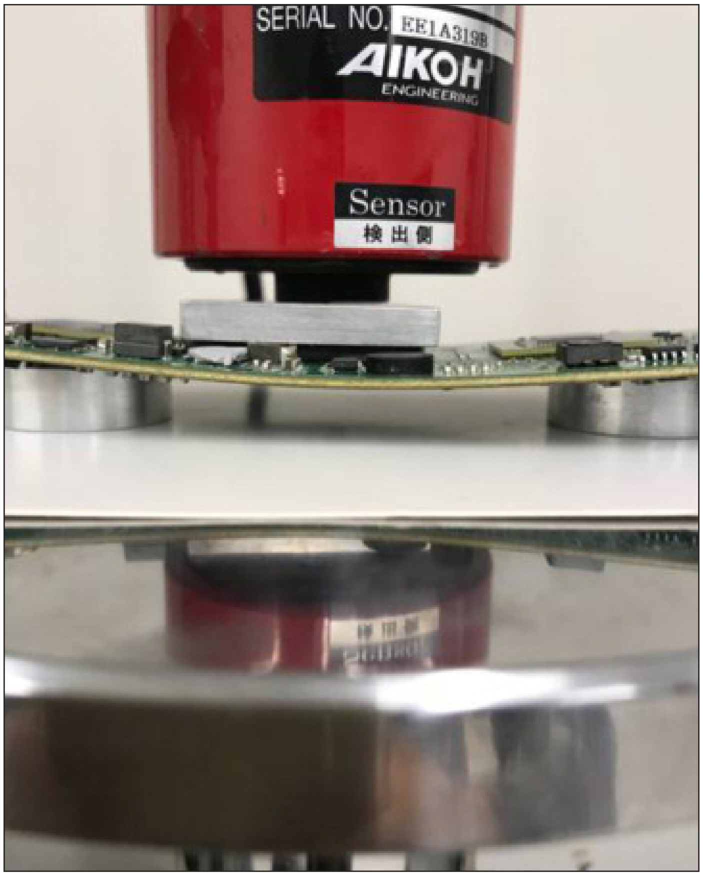

Figure 1. Understanding the variation in a gap means understanding the forces the assembly can withstand during the assembly process and the life of the product.

The gap filler pad acts as a buffer between the heat source and the sink. It will absorb the variations, but still be a very good heat transfer medium between the heat source and the sink. It absorbs varying gaps without producing an enormous amount of stress.

Why do gaps vary? The tolerance variation is primarily due to the components, and soldering them down — they don't always solder down in the same manner. There are many other factors that can throw off the nominal gap and extend that tolerance. The gap filler will allow you to work within those tolerances.

Basic Design Considerations

What do these varying gaps mean to your application? Basically, varying gaps equal varying stress — in some

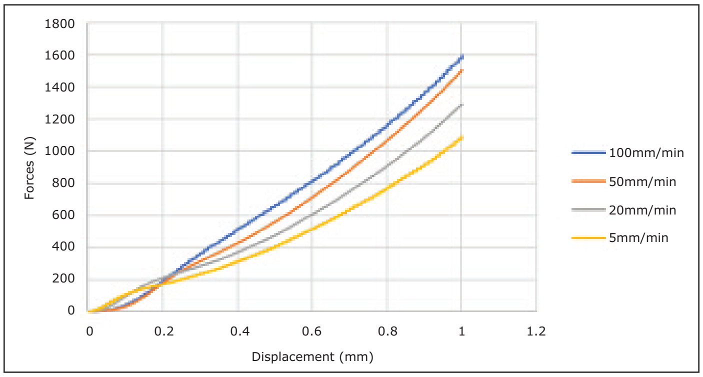

Figure 2. Compression speed dictates the maximum stress the assembly can handle. At five millimeters per minute, there is slightly more than 1,000 newtons of force. When increasing displacement to 100 millimeters per minute, force increases to 16,000 newtons.

cases, too much stress in the assembly on the board. Figure 1 shows a test run on a PCB in a situation where there is quite a bit of bending on the board, which is not uncommon. In this case, the PCB didn't break, but the stress could have been significant enough to result in broken solder joints. By understanding the variation in the gap, you will understand what the stress will be on that component.

There are some things to be mindful of when choosing a gap filler at the start of the design process. The first thing is that gap fillers require some compression. They are a thermal interface material, and like many such materials, they require some compression to overcome contact resistance.

Gap fillers also are designed to have very little contact resistance at very low pressure. Generally, manufacturers will specify a minimum compression percentage — Fujipoly recommends at least a 10% compression. The reason is that you don't have much control over the force to be applied on the pad, but you do have control over the gap. If you can ensure that the maximum gap will at least give you 10% compression, you will have a reliable contact.

Also, never use a gap filler that is the same thickness as the actual gap, or you will not get that compression. There will be a certain point where the stress produced by the gap filler is going to be fairly high, and it will be unable to compress variations without causing damage.

An important thing to remember is that the relationship between deflection and compression is not linear.

When starting the design process, identify the nominal gap and know the tolerances. Then, determine if the gap can be adjusted. If the gap can change, it will be helpful when the gap must be opened up to reduce stress. It's counterintuitive from a thermal standpoint, but from a mechanical standpoint, sometimes it's the only option.

The other design consideration is tolerances. Unfortunately, the gap is going to vary quite a bit, so, when identifying tolerances, know what gave you that tolerance, and find out if that tolerance can be improved.

Ideally, the softer the gap filler material, the better. When working with materials that have a higher conductivity and lower thermal resistance, the deflection force must be higher. That is due to the fact that some of the higher-performing materials have a higher concentration of thermal fillers or particles that make them thermally conductive, but the material is going to harden.

The starting point for evaluating a material is the data sheet, which provides characteristics of the material to help in making a decision during the selection process. Often, however, hardness is categorized in many different ways. The most commonly used method for measuring hardness is the Shore scale, but it adds limited value from a design standpoint, especially for gap fillers.

Fujipoly lists compression characteristics explicitly on its data sheets. Compression ratio from 10 to 50 is provided, as well as loads or pressure required to get to that gap.

Dynamic and Static Characteristics

As gap filler materials begin compressing, they will resist deformation; in turn, that will provide stress. A gap filler can be broken into two parts — one of which is this dynamic state. The other part — the static state — happens when these materials are held at a specific gap. There is some residual stress, but the peak loads happen during this dynamic state when the material is deforming.

This is why much of the focus is on compression of the pad in the dynamic state, as opposed to the static state of the material. One of the biggest factors when dealing with compression of the pad is compression speed. In a lab environment, compression speed is very slow, but in a manufacturing setting, compression speed will definitely increase. This means that the pad can undergo some very fast compression, creating more stress than anticipated.

The gap illustrated in Figure 2 indicates displacement in millimeters. At five millimeters per minute, there is slightly more than 1,000 newtons of force. When increasing displacement to 100 millimeters per minute, force increases to 16,000 newtons — a 50% increase in compression force.

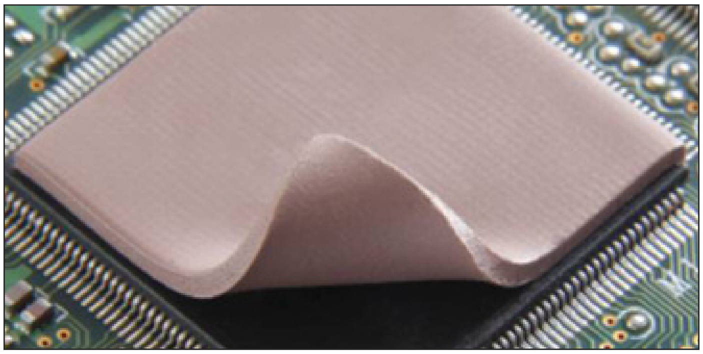

Figure 3. Unlike standard gap pads, putty pads have almost no tensile strength — they can be pulled apart very easily and are applied in the same manner as a gap filler pad.

Gap Filler Pads

Standard gap filler pad materials have tensile strength, but little elasticity. There are other forms of gap fillers, but they have pluses and minuses. One of the more common types is putty pads (Figure 3). Unlike standard gap pads, they have almost no tensile strength — they can be pulled apart very easily, and are applied in the same manner as a gap filler pad.

The downside is that because the putty pad does not have great tensile strength and no elasticity, the compression is 100% — they do not bounce back. If there is any further deformation — for instance, if the assembly is squeezed a bit more and the sheet metal bounces back — the putty materials are not going to bounce back. It's important to ensure two good surfaces that will not move if using putty pads.

A plus with putty pads is that they can compress down significantly — much farther than viscoelastic pads. They require a minimum amount of compression; at least 10%. They also relax over time. Standard gap fillers and putty gap filler pads have essentially the same performance for a given gap. They are soft, and eventually they will bottom out past 80% — what's referred to as densification. The material is no longer flowing, and is being crushed.

Make sure not to exceed a certain amount of force when using these materials. It's very common for gap fillers to form in place. Form-in-place materials (Figure 4) create almost no stress. They are viscous materials, so they are different from a gap filler pad. They have almost a toothpaste consistency, and some will actually cure in place.

Form-in-place materials are not thermal grease — they are very much a gap filler. They are designed to fill in gaps in the 1-mm or 0.5-mm range. These types of gap fillers are very popular, but keep in mind that because they are viscous, there may be a limit on the size of the gap they will fill.

Shape Factor

The shape factor is a ratio of loaded area to free bulging area. The larger the surface area and the thinner the material, the higher the stress. The thicker the material and the smaller the loaded area, the softer the material will appear. If you begin with a very small area, the pressure is quite small. As you creep up to a larger surface area, the amount of free bulging area decreases, and you end up with a larger surface area. When choosing a family of materials, the thinnest version of the material requires more pressure than a very thick material. Shape factor plays a big part in that.

Systems and Test Equipment

If working with elastomers such as gap filler pads or seals, there are tools that may be good investments; for example, a compression tester. A compression tester, or force test system, measures displacement and actually compresses the material.

Pressure mapping systems are computerized systems that create a heat map indicating pressure distribution location. This system is used when dealing with very large gaps. A low-cost alternative to a pressure mapping system is pressure sensitive films. They are placed between the gap filler pad and the heat sink, and are

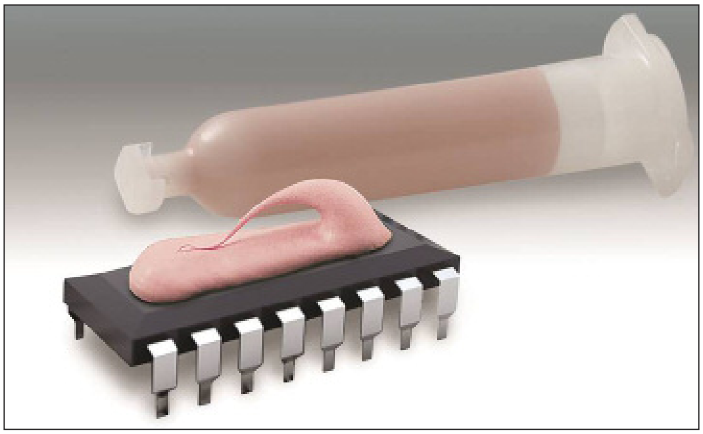

Figure 4. Form-in-place materials are viscous, and have almost a toothpaste consistency; some will actually cure in place.

compressed. The film is removed, and a mark indicates where there is pressure.

Summary

As mentioned earlier, the first step before choosing a gap filler is to identify if there is a need for a gap filler. Determine if a gap filler or grease is required by identifying the gap fill application as well as nominal gaps and tolerances. As a general rule, variation should be 30 to 40% of the gap. If using putty or form-in-place materials, that variation can be higher. It is important to investigate whether tolerances can be improved, and what stressors the PCB can tolerate.

Assume data sheet forces are on the low end of the spectrum for your application. There are many factors, especially boundaries, that will affect how the material flows.

As far as data sheets are concerned, they are not conclusive, and values should be used for comparison only. Having compression data for the size of the pad under specific compression conditions is helpful. Also consider heat stress that happens during the dynamic loading of the pad. The gap may be highly dependent on speed, so increasing the speed will increase the force dramatically.

Basically, keep in mind that if you are extrapolating data to learn how a large pad would perform, you need to understand that the forces will deviate significantly from the data sheet.

While many of these considerations are based on common sense, it helps to be mindful of these steps as you start the process of design, implementation, and manufacturing.

Author/Presenter

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