USER GUIDE

UG012 | Phase Change Material – WE-PCM

Sebastian Mirasol-Menacho

1. INTRODUCTION TO WE-PCM

The phase change material WE-PCM poses an alternative to thermal pastes and greases that is easier to handle and can guarantee electrical insulation between contact surfaces. Due to its waxy nature, it remains a malleable solid at room temperature; however, when it reaches its softening temperature of 45-60 °C, the pad enters its liquid phase. After the transition, it can fill microscopic irregularities in the contact surfaces and achieve a thin bond line thickness comparable to that of a thermal paste.

One of the key benefits of WE-PCM is its ability to provide consistent thermal performance over a wide range of operating conditions.

Unlike traditional thermal grease, which can dry out or pump out over time, WE-PCM maintains its integrity and effectiveness throughout its lifecycle as it changes between phases along with the device's power cycles. This stability ensures reliable thermal management, which is critical to the longevity and performance of electronic components.

In addition, WE-PCM offers a clean and straightforward installation process. As a solid at room temperature, it is easy to handle and apply without the mess associated with liquid thermal pastes. Once in place, the material's phase-change properties allow it to conform perfectly to surface irregularities, ensuring optimal thermal contact and minimal thermal resistance.

2. MATERIAL SPECIFICATIONS

The phase change material has four main components, as shown in Figure 1.

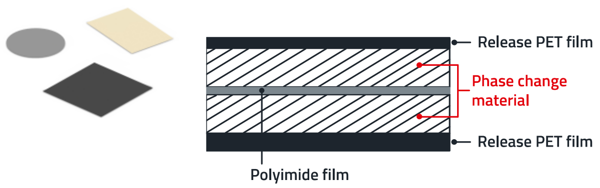


Figure 1: WE-PCM cross-section.

- **Release PET film:**
  Top protective and carrier film to ensure that foreign particles do not adhere to the sticky surface of the phase change material. It should be removed after applying the pad.
- **Phase change material:**
  Main component of the product. Ensures a low thermal contact resistance interface.
- **Polyimide film:**
  Present in the 1.6 W/m·K and 5 W/m·K standard parts, it provides electrical isolation between contact surfaces.

The properties of the WE-PCM phase change material pads can be grouped into three categories: material, thermal and electrical as can be seen in Table 1, Table 2 and Table 3.

Material Properties			
Bulk Thermal Conductivity	1.6 W/m·K	3 W/m·K	5 W/m·K
Color	Yellow	Gray	Blue
Thickness	0.2 mm		
Specific Gravity	1.8 g/cm^3	2.7 g/cm^3	2.3 g/cm^3
Operating Temperature	-40 up to 130 °C	-40 up to 130 °C	-40 up to 130 °C
Change Phase Temperature	55 °C		

Table 1: Material properties of WE-PCM.

Thermal Properties (34.5 N/cm² Compression)			
Bulk Thermal Conductivity	1.6 W/m·K	3 W/m·K	5 W/m·K
Thermal Impedance	2.91 K·cm²/W	1.03 K·cm²/W	0.77 K·cm²/W

Table 2: Thermal properties of WE-PCM.

Electrical Properties			
Bulk Thermal Conductivity	1.6 W/m·K	3 W/m·K	5 W/m·K
Breakdown Voltage	5 kV	-*	3 kV
Volume Resistivity	10^{12} Ω·cm	10^{14} Ω·cm	10^{7} Ω·cm
* As the 3 W/m·K comes without polyimide layer electrical insulation is not guaranteed between contact surfaces.			

Table 3: Electrical properties of WE-PCM.

3. DESIGN CONSIDERATIONS

Phase change materials are designed in the same way as any other gap filler, using the thermal resistance formula to validate our concept:

$$R = \frac{L}{\lambda \cdot A} \tag{1}$$

Where:

L is the bond line thickness; thickness of the phase change material

λ is the thermal conductivity of material

A is the area of contact surface

The main benefits of phase change materials as an alternative to thermal pastes are the handling characteristics and the reliability:

Ease of use: The phase change material at room temperature can be applied to any surface just like any other thermal pad without the need for dispensing equipment.

Guarantee electrical insulation: Thermal paste is also non-conductive, however, there is no physical barrier between the contact surfaces. If uneven pressure is applied to the cooling assembly, the paste can be pushed out and electrical contact can occur. The WE-PCM, on the other hand, offers a physical barrier by including the thin polyimide film.

Long-term stability: Phase change materials are more resilient to the pump-out effect than pastes. The main advantage of the phase change effect is that the PCM transitions between solid and liquid states are in sync with the device's power cycles, avoiding the creation of airgaps within the interface. When it becomes liquid, any gaps that may appear are filled by capillary action.

Regarding the shape of the pad, it is recommended to leave 2 mm clearance from the heat source profile to accommodate for expansion during phase change. This will prevent the phase change material from spilling outside the interface.

3.1 How to design in the WE-PCM

Let's consider the following scenario: We would like to cool an FPGA (Field Programmable Gate Array). We do not know exactly how much power needs to be dissipated, but we do know that we need to remove the power as fast as possible. We also know that a heat sink will be used, hence the thinnest bond line is required.

There are several tools available from FPGA manufacturers to accurately estimate how much power our design will dissipate in the form of thermal energy. For our design, we assume the following characteristics from the datasheets of the FPGA, the heat sink and our defined design parameters:

Parameter	Value
Power	20 W
Contact area	4 cm²
Max. ambiant temperature (T_A)	50 °C
Min. junction temperature (T_J)	85 °C
Air flow rate	400 LFM
Thermal resistance of the heat sink R_{HS}	1.35 °C/W
Thermal resistance junction-to-case R_{JC}	0.13 °C/W
Thermal resistance junction-to-PCB R_{JPCB}	7.4 °C/W

Table 4: Characteristics from the FPGA datasheet.

We can see from the FPGA datasheet that the thermal resistance from the die (silicon core of the IC) to the case (R_{JC}) is nearly two orders of magnitude lower than from the die to the PCB (R_{JPCB}), so we can assume that most of the heat will be dissipated from the FPGA to the environment through the heat sink connected to the case of our heat source.

The following images represent the whole thermal system:

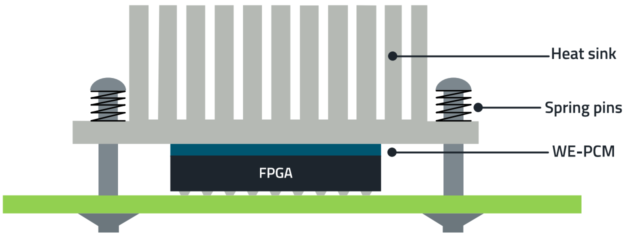
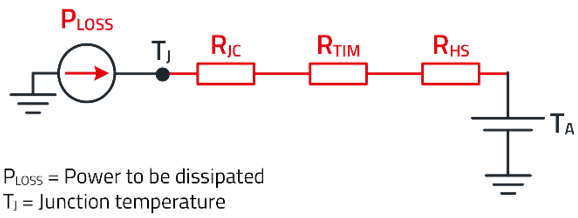


Figure 2: FPGA with thermal interface material (WE-PCM) and heat sink



P_{LOSS} = Power to be dissipated
T_J = Junction temperature
R_{JC} = Thermal resistance of junction-to-case
R_{TIM} = Thermal resistance of thermal interface material (WE-PCM)
R_{HS} = Thermal resistance of heat sink
T_A = Ambient temperature

Figure 3: Equivalent circuit model of heat dissipation

$$T_J = T_A + P_{LOSS} \cdot (R_{JC} + R_{TIM} + R_{HS}) \qquad (2)$$

Once we have determined the maximum ambient temperature (T_A) at which our design will operate and a target temperature for the chip (T_J), we can calculate R_{TIM} to determine the maximum thermal resistance our interface material will allow to achieve our design goal.

$$85\ °C = 50\ °C + 20\ W \left(0.13\ \frac{°C}{W} + R_{TIM} + 1.35\ \frac{°C}{W}\right) \qquad (3)$$

$$R_{TIM} = 0.27\ \frac{°C}{W}$$

Now that we have a target thermal resistance for the interface material, we can compare it with the thermal impedance values from the thermal properties table in chapter 2. The thermal impedance and thermal conductivity of the WE-PCM are shown again in Table 5.

Thermal Conductivity	Thermal Impedance
1.6 W/m·K	2.91 K·cm^2/W
3 W/m·K	1.03 K·cm^2/W
5 W/m·K	0.77 K·cm^2/W

Table 5: Thermal conductivity and impedance of WE-PCM.

Considering we have a contact area of 4 cm^2, we can calculate the thermal resistance for the WE-PCM with 3 W/m·K as:

$$\frac{1.03\ \frac{°C \cdot cm^2}{W}}{4\ cm^2} = 0.26\ \frac{°C}{W} \qquad (4)$$

According to these values, the WE-PCM 3 W/m·K at an applied pressure of 34.5 N/cm^2 will provide the interfacial thermal resistance we need to achieve our thermal targets. If we wanted to give more buffer to the maximum die temperature, we could evaluate how the phase change material performs at higher compressive forces, and if that is not enough, we could move to a higher performing material such as the WE-PCM 5 W/m·K.

4. THERMAL PERFORMANCE

Phase change materials are used in applications that need to dissipate a lot of heat energy in a very short time. In its liquid phase, the WE-PCM can fill even the smallest microscopic gaps to ensure as much contact area as possible between surfaces. It also ensures that the phase change material displays its thinnest bond line thickness.

Figure 4 shows the thermal impedance of the WE-PCM in relation to the compression force.

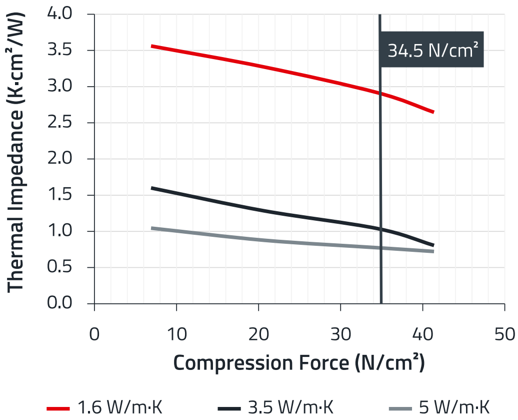


Figure 4: Thermal performance of WE-PCM.

5. THERMAL MEASUREMENT SETUP

All thermal parameters mentioned in this guideline have been performed in-house following ASTM D5470-Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials.

The standard focuses on steady-state heat transfer conditions.

During testing, a constant heat source is applied to one side of the thermal interface material (TIM) specimen, while a cooling assembly ensures a temperature difference to create a heat flow through the material under test. This setup allows for the measurement of thermal conductivity and impedance under different temperature and mechanical conditions.

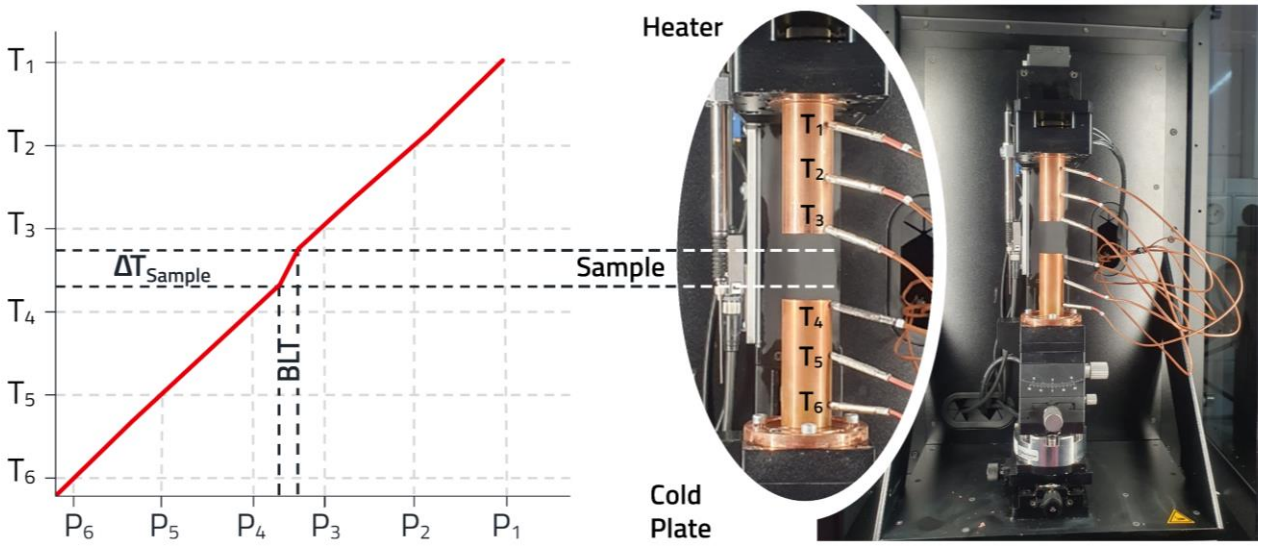


Figure 5: ASTM D5470 testing setup

6. INSTALLATION AND HANDLING

The correct installation of the phase changing pad is crucial for ensuring optimal thermal performance and long-term reliability of electronic devices. It is essential that the cooling assembly is fixed to the heat source with springs, clips or any other mechanical fixing method that applies constant pressure. This will ensure that an effective thermal interface is created when the pad changes phase for the first time.

In order to ensure correct application, the following steps are recommended:

1. The surface of the component and cooling assemblies must be clean and dry. It is recommended to use isopropyl alcohol applied with a lint-free wipe or swab to remove any particles on contact surfaces.
2. Pick the pad from the carrier and without removing the release film place the pad on one of the contact surfaces. It will remain in place during assembly due to its tacky nature.
3. When the cooling assembly is ready to be assembled, remove the release film and secure the cooling solution with a constant pressure mounting method.
4. Ensure that the device reaches phase changing temperature and that the pad has transitioned and is subject to constant pressure.

Cutting

The WE-PCM can be cut into shape with any sharp object. Laser cutting is discouraged because it can melt the edges and potentially fuse it with the carrier films.

Reworking

Phase change materials are a non-reworkable solution once it has transitioned to liquid phase. Removing the cooling assembly from the heat source will result in destruction of the interface and will require surface cleaning and application of a new pad.

Removing the WE-PCM

Removing the phase change material of a surface is a delicate process. In order to avoid damage to contact surfaces or electronic components use a heat gun to soften the material and a lint-free cloth with isopropyl alcohol to clean the surface.

If scraping is required, carefully use a wood or plastic tool to gently scrape any material left on the contact surfaces.

IMPORTANT NOTICE

USEFUL LINKS

Application Notes
www.we-online.com/appnotes

REDEXPERT Design Platform
www.we-online.com/redexpert

Toolbox
www.we-online.com/toolbox

Product Catalog
www.we-online.com/products

CONTACT INFORMATION

appnotes@we-online.com
Tel. +49 7942 945 - 0

Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1 74638 Waldenburg Germany
www.we-online.com