CIPOS™ IPMs and MMs

Oxidized Copper Layer on CIPOS™ IPMs and MMs Products

About this document

Scope and purpose

This application note provides a detailed look at the oxidized copper layer that forms on Direct Copper Bonded (DCB) substrates used in Infineon's Control Integrated POwer System (CIPOS™) Intelligent Power Modules (IPMs) and Molded Modules (MMs). It covers the natural oxidation process of the copper layer, how it affects thermal and electrical performance, and why it doesn't significantly impact overall module functionality. The goal of this document is to explain that while oxidation is a normal process, it doesn't affect the performance of the modules in a meaningful way. Engineers and designers can use this information to better understand how the oxidized copper layer works with the materials in the module, helping ensure that the modules perform reliably.

Intended audience

This application note is for engineers, product designers, and technical professionals working with power semiconductor modules. It is especially helpful for those working with Infineon's CIPOS™ IPMs and MMs in applications like motor control, power supplies, and energy conversion. The content is also useful for anyone interested in how copper oxidation can affect power module performance, including those focused on reliability, thermal management, and electrical performance. A basic understanding of power modules and their thermal and electrical behavior will help in making the most of the information in this document.

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1.1 Introduction

Infineon's CIPOS™ IPMs and MMs utilize DCB substrates to ensure efficient thermal performance and reliable operation in demanding power applications. These substrates are designed with a copper layer that is directly exposed to air, leading to a natural oxidation process. When the copper layer contacts air, it forms a thin, non-uniform oxide layer primarily composed of copper oxides (Cu_2O/CuO). This oxidation is an inherent characteristic of copper when exposed to oxygen and does not affect the electrical or thermal performance of the module in any significant way. The oxidized copper layer appears in different colors (typically brown or silver) depending on its thickness, though it remains very thin, often in the nanometer range (typically less than 100 nm). Despite the presence of this oxidized layer, Infineon's IPMs and molded modules continue to operate efficiently, with no significant degradation in their electrical or thermal performance.

1.2 Thermal performance of CIPOS™ IPMs and MMs

Infineon's CIPOS™ IPMs and MMs are designed for efficient thermal management during normal operation. The backside of the DCB substrate, which consists of the copper layer, is exposed to cooling mechanisms such as heat sinks. Thermal grease is often used between the module and heat sink to ensure good thermal contact. Typical thermal greases have a thermal conductivity of approximately 1 W/mK, and the grease layer is usually about 100 µm thickness.

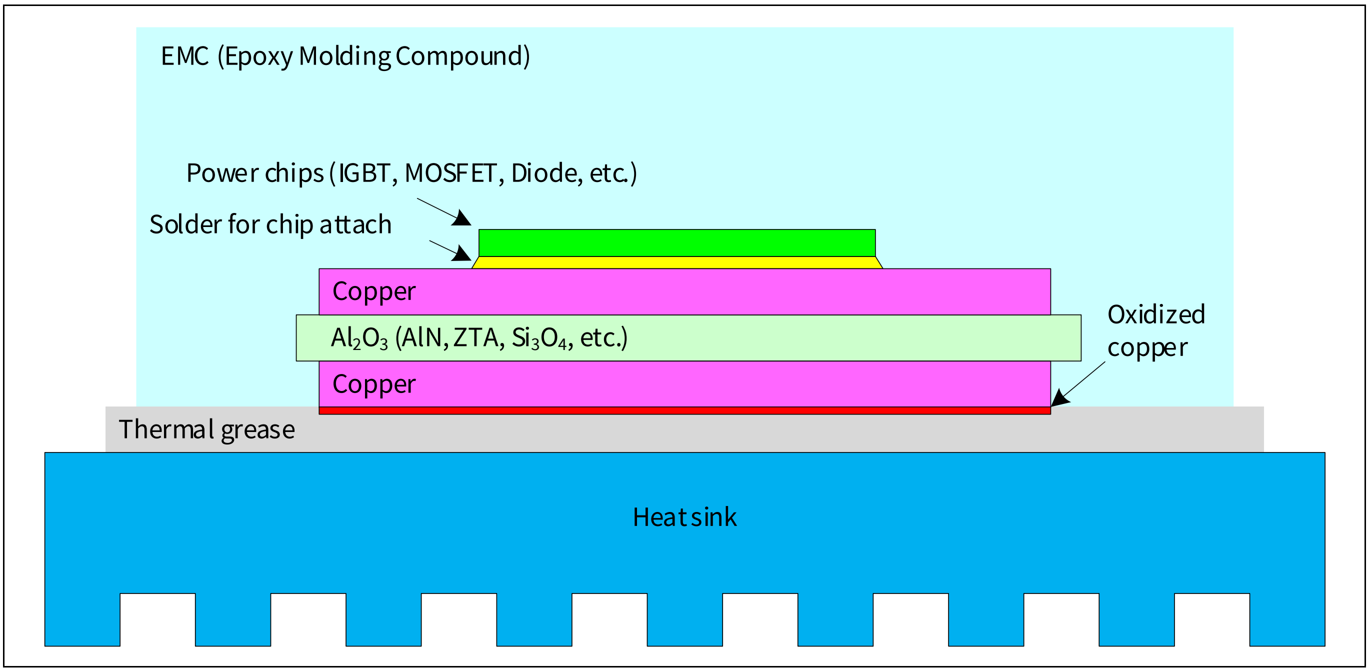

Figure 1 Simplified cross-section through the DCB of a CIPOS™ IPMs and MMs

When the system is properly cooled, one of the main factors determining its thermal impedance is the thermal grease. Characteristic of such a layer of thermal grease is the property $R_{th,\,grease} \cdot A = 100 \mu K/W \cdot m^2$ being much higher than the one of other layers (see Table 1).

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Table 1 Rth*A of different layers

Layer	Thickness [mm]	Thermal conductivity @ 100°C [W/mK]	Rth*A [W/K*m²]
Copper	0.3	385	7.79E-07
Al_2O_3	0.38	23	1.65E-05
Thermal grease	0.1	1	1.00E-04
Oxidized copper	0.0001	10	1.00E-08

Oxidized copper layers are typically very thin (the thickness hardly reaches 100 nm). The thermal conductivity of copper oxides ranges approximately from 10 W/mK to 40 W/mK. This yields at worst $R_{th,\,ox.Cu} \cdot A = 0.01\ \mu K/W \cdot m^2$. As heat spreading is negligible in such a thin layer, the heat flow through these layers covers the same area. Hence, the thermal resistance of the thermal grease will be approximately 10000 times higher than the thermal resistance of the oxidized copper:

$$R_{th,grease} \geq 10000 \cdot R_{\mathrm{th,ox.Cu}}$$

Even if one could provide an ideal thermal contact between module and heat sink, the thermal resistance of the DCB is much larger than that of the oxidized copper. Thus, the oxidized copper does not affect the thermal performance of the module.

1.3 Experimental results on oxidized CIPOS™ product

Figure 3 shows experimental setup used to evaluate ther thermal performance of oxidized CIOPS™ Mini IPM product. The setup includes a Micro Controller Unit (MCU), a three phase R-L load, an AC power supply, an oscilloscope, a digital temperature recoder and a low-voltage DC power supply. Fresh sample and heavily oxidized sample were tested to compare their thermal characteristics. The key parameters measured during the test were ambient temperature (T_A), case temperature (T_C) and the Negative Temperature Coefficient (NTC) thermisotor temperature (T_{NTC}) of each sample.

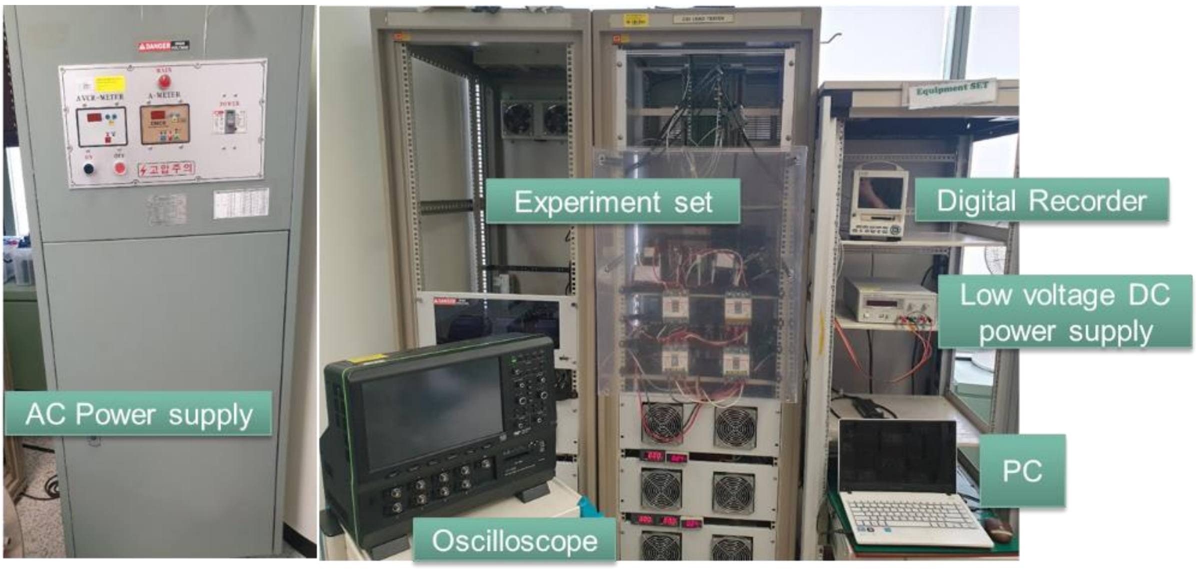

Figure 2 Experiment setup

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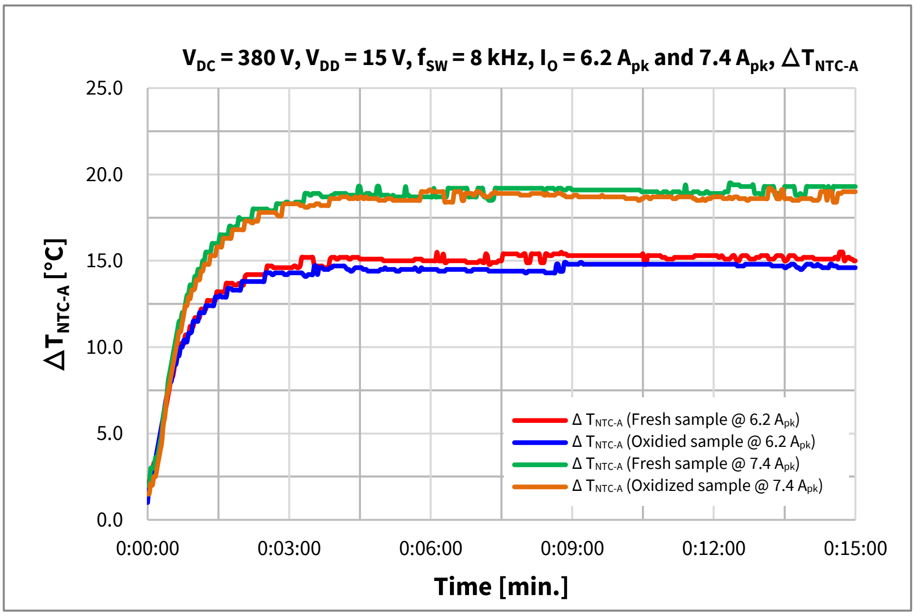
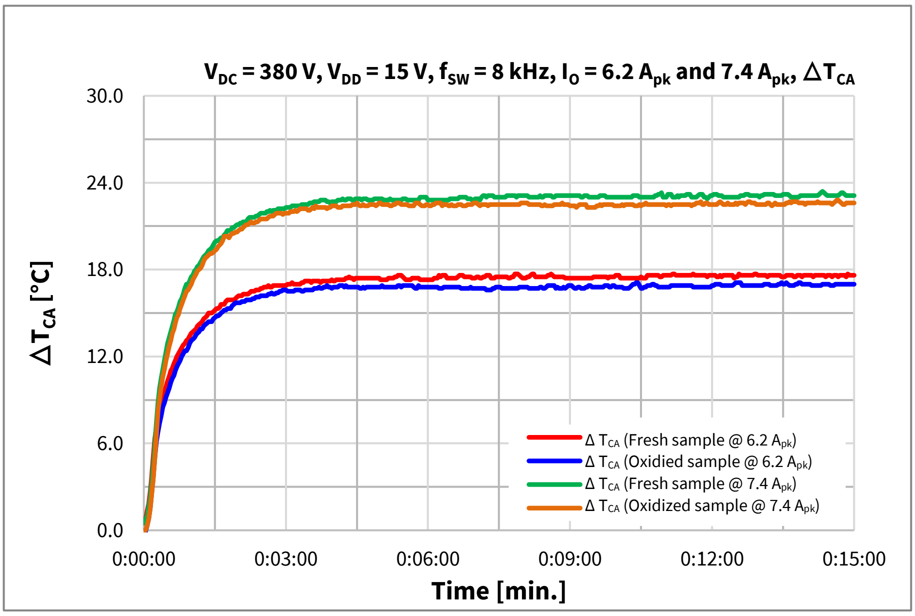
Figure 3 shows the thermal performance test results, indicating that the temperatures of the two samples are almost identical. For case temperature, the difference is approximately 0.6°C at 6.2 A_{pk} and 0.5°C at 7.4 A_{pk}, For the NTC thermistor temperature, the difference is about 0.4°C at 6.2 A_{pk} and 0.3°C at 7.4 A_{pk}. These differences are minimal and fall within the range of potential measurement errors.

Therefore, it can be concluded that the oxidized copper layer does not have a significant impact on the thermal performance of the module.



(a) Thermistor temperature measurement



(b) Case temperature measurement

Figure 3 Thermal performance test results

1.4 Example of oxidized CIPOS™ IPMs and MMs

Figure 4 to 6 provide examples of oxidized DCBs from various CIPOS™ IPMs and MMs, covering a range of product categories. These images illustrate typical surface conditions observed in both fresh and naturally

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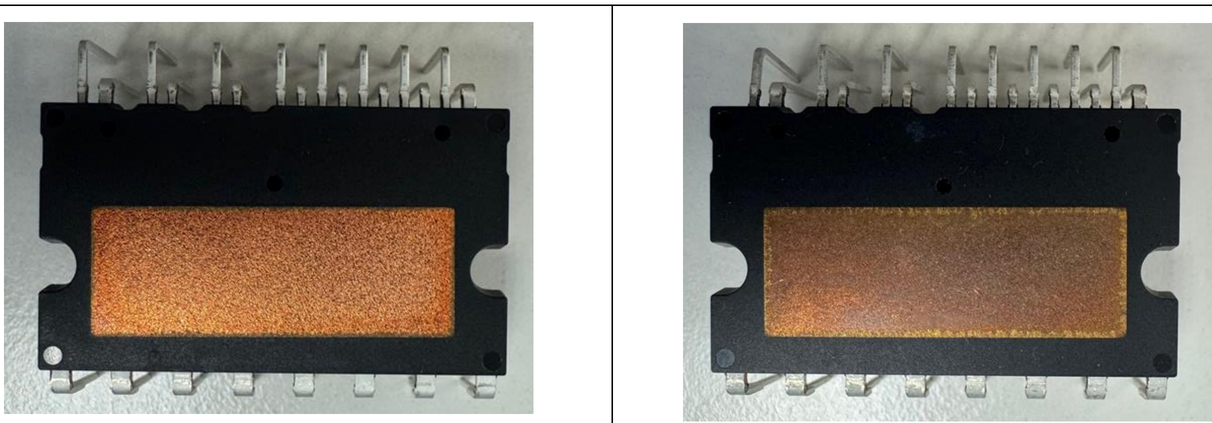
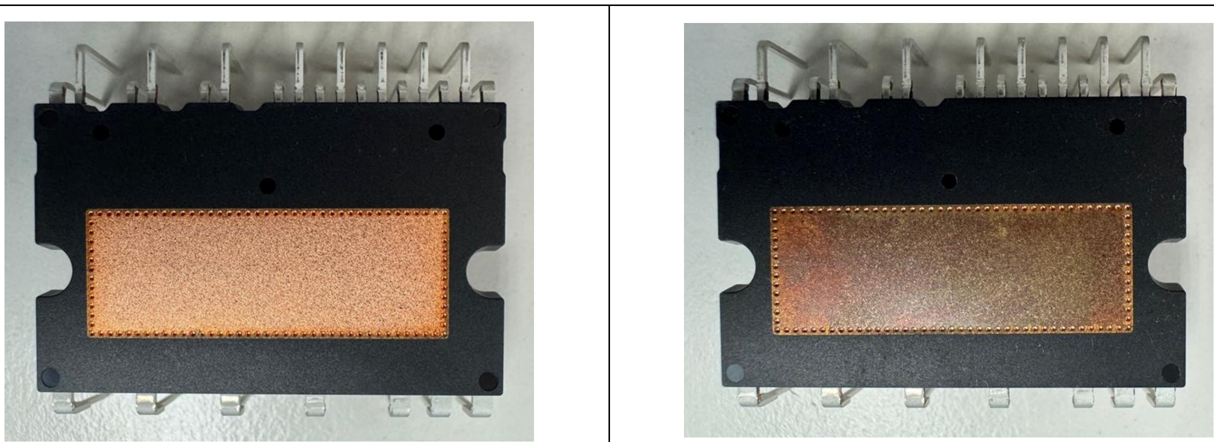
oxidized samples across different module types. The examples are intended to represent CIPOS™ module broadly, demonstrating that copper surface oxidation is a common phenomenon that does not affect the thermal performance of the product family.



(a) Fresh sample

(b) Oxidized sample

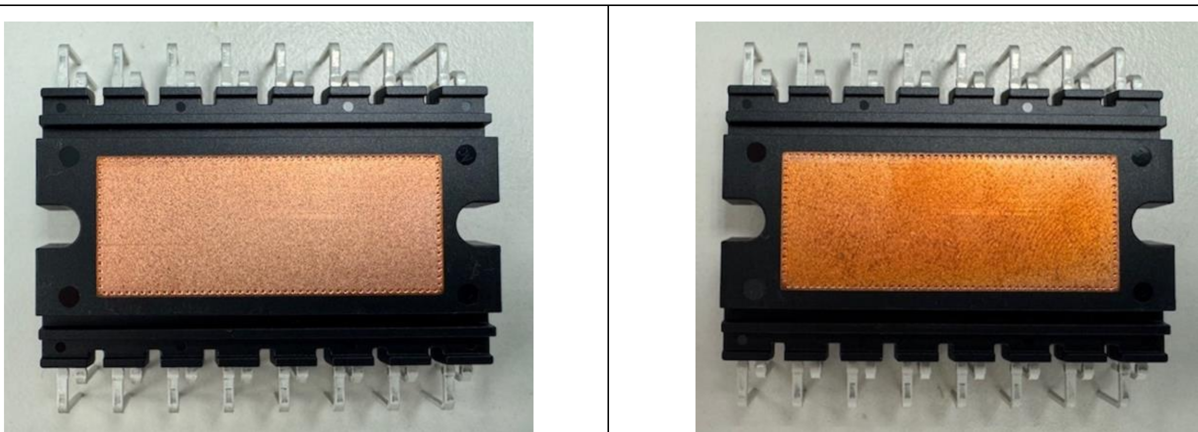
Figure 4 Example of CIPOS™ Mini IPM's oxidized DCB



(a) Fresh sample

(b) Oxidized sample

Figure 5 Example of CIPOS™ Maxi IPM's oxidized DCB



(c) Fresh sample

(d) Oxidized sample

Figure 6 Example of CIPOS™ Prime MM's oxidized DCB

Figure 7

1.5 Conclusion

The assessment of the thickness and thermal conductivity of different layers in CIPOS™ IPMs and MMs confirms that oxidized copper layers have no impact on the thermal performance of the modules. Therefore, oxidized copper does not affect the overall thermal behavior of these modules.

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Revision history

Major changes since the last revision

Version Number	Revision date	Revision description
1.00	2025-01-17	Initial release

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