THE MISSING PIECE TO SOLVE THERMAL CHALLENGES

WHY DO YOU NEED THERMAL RESISTANCE VALUES (K/W) FROM METALLIZED SUBSTRATES?

THE MISSING PIECE TO SOLVE THERMAL CHALLENGES

INDEX

WHY DO WE NEED MORE THERMAL DATA?

WITH GREAT POWER COMES GREAT HEAT

From high performance computing data centers and AI applications to ultra-compact electric vehicle (EV) batteries, the demand for next-generation power conversion technologies is relentless.

Chip fabs are in the race to deliver the latest node using wide bandgap semiconductors like Silicon Carbide (SiC) and Gallium Nitride(GaN) for higher output, faster speed, and less energy consumption.

The results are some extremely hot chips, from a temperature standpoint.

If you want to increase revenue this year by:

- Improving quality in both chip and system
- Shortening time-to-market
- Reducing scrap
- Lowering production and testing costs

Make thermal management a top priority!

TEST YOUR THERMAL DATA, DON'T GUESS

Choosing the right metallized substrates to efficiently manage and dissipate heat generated during use is crucial to the overall performance and reliability of advanced power modules.

This document provides a detailed overview of the materials used as metallized substrates, current methods for evaluating their thermal performance, and the limitations of these methods.

We then take a look at a new ISO thermal characteristics assessment method for metallized substrates and power modules in mounted form.

Incorporating accurate thermal data of metallized substrates, particularly thermal resistance under real operating conditions, is essential for effective thermal budgeting.

This ensures that your design is both robust and reliable.

Ask us for more tips on evaluating thermal properties in substrate materials

1. APPLICATION: ELECTRIC VEHICLE BATTERIES

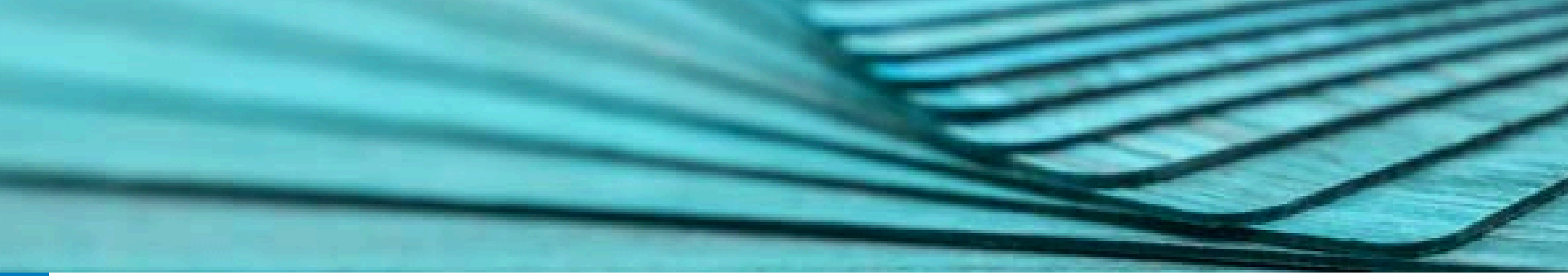
Heat dissipation is a top priority for the ultra-compact EV batteries.

2. APPLICATION: SERVER BANKS

Improve quality in both chip and system with accurate thermal resistance value for metallized substrates.

3. APPLICATION: AI

Compare thermal resistance (K/W) between different metallized substrates and geometries to lower your overall production cost and shorten time-to-market for high performance computing (HPC) applications.



CERAMICS 101

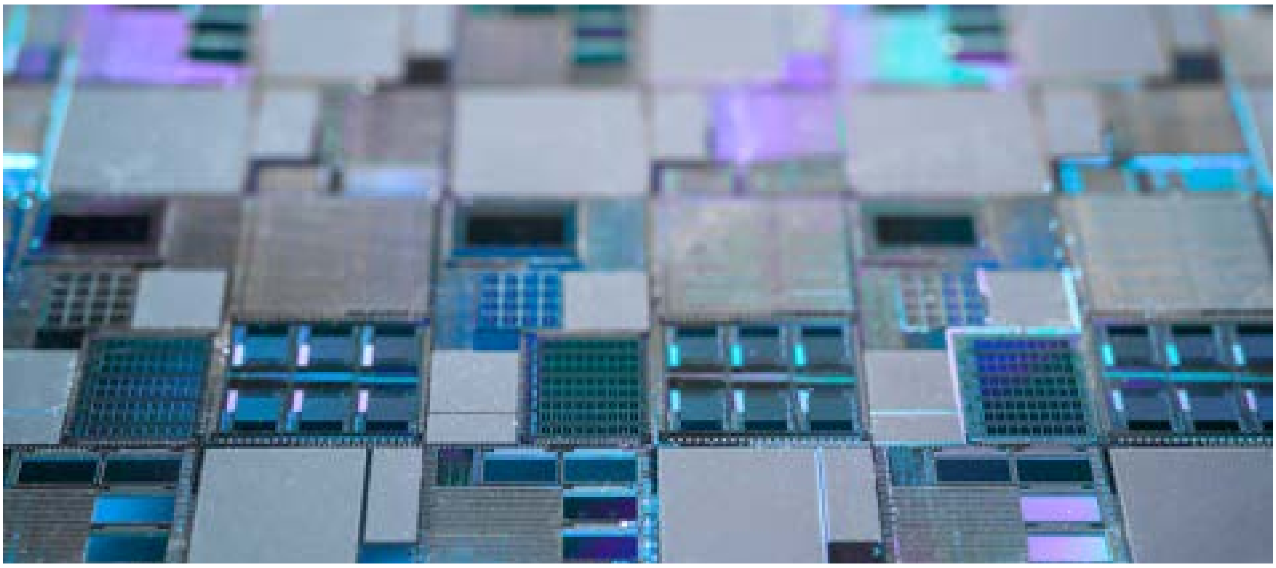
TECHNICAL CERAMIC, DCB CERAMIC, METALLIZED CERAMIC, AND HOW ARE THEY DIFFERENT FROM YOUR COFFEE CUP?

WHY DO WE USE CERAMICS AS METALLIZED SUBSTRATES?

In power electronics, just like printed circuit boards, metallized substrates need to electrically connect components and help dissipate their heat. These metallized substrates must be capable of handling high currents and providing strong voltage isolation sometimes up to several thousand volts. They also need to endure a wide temperature range, often up to 150 or 200°C.

Ceramics are preferred over metals and polymers for substrates because of their superior hardness, compressive strength, and resistance to wear, abrasion, chemicals, and electricity.

They also match well in terms of thermal expansion with other components of power modules.



Semiconductor substrates require meticulous machining and modifications to meet the exact specifications needed for high performance power module applications.

WHAT ARE TECHNICAL CERAMICS?

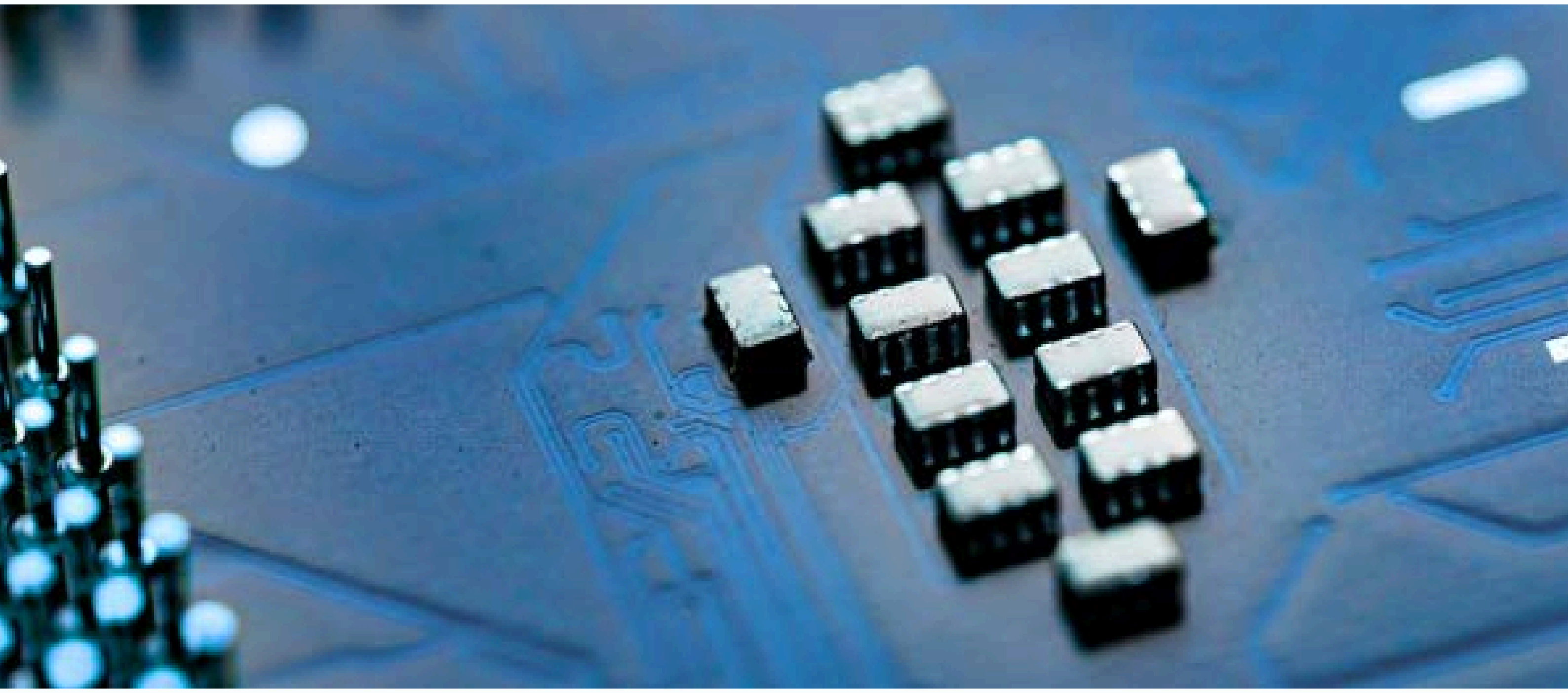
Technical ceramics, also known as engineered or advanced ceramics, are a step up from the traditional ceramics, like your coffee mug, which is made from natural clays.

These high-performance ceramics are made from highly purified materials, refined to control particle size and shape, and then mixed with other materials to get the right properties. Once shaped, they're fired under strict conditions sometimes in a vacuum or controlled atmospheres to nail the specific qualities needed.

Often, they require a bit of extra machining after firing to meet the exact specifications needed for high-tech uses.

The choice between oxides (alumina), non-oxides (aluminum nitride and silicon nitride), or ceramic composites often comes down to the individual thermal conductivity and the cost of each material.

Ask us for more tips on evaluating thermal properties in substrate materials



Considerations for choosing insulating substrates include the material's hardness, compressive strength, and resistance to wear, abrasion, chemicals, and electricity.

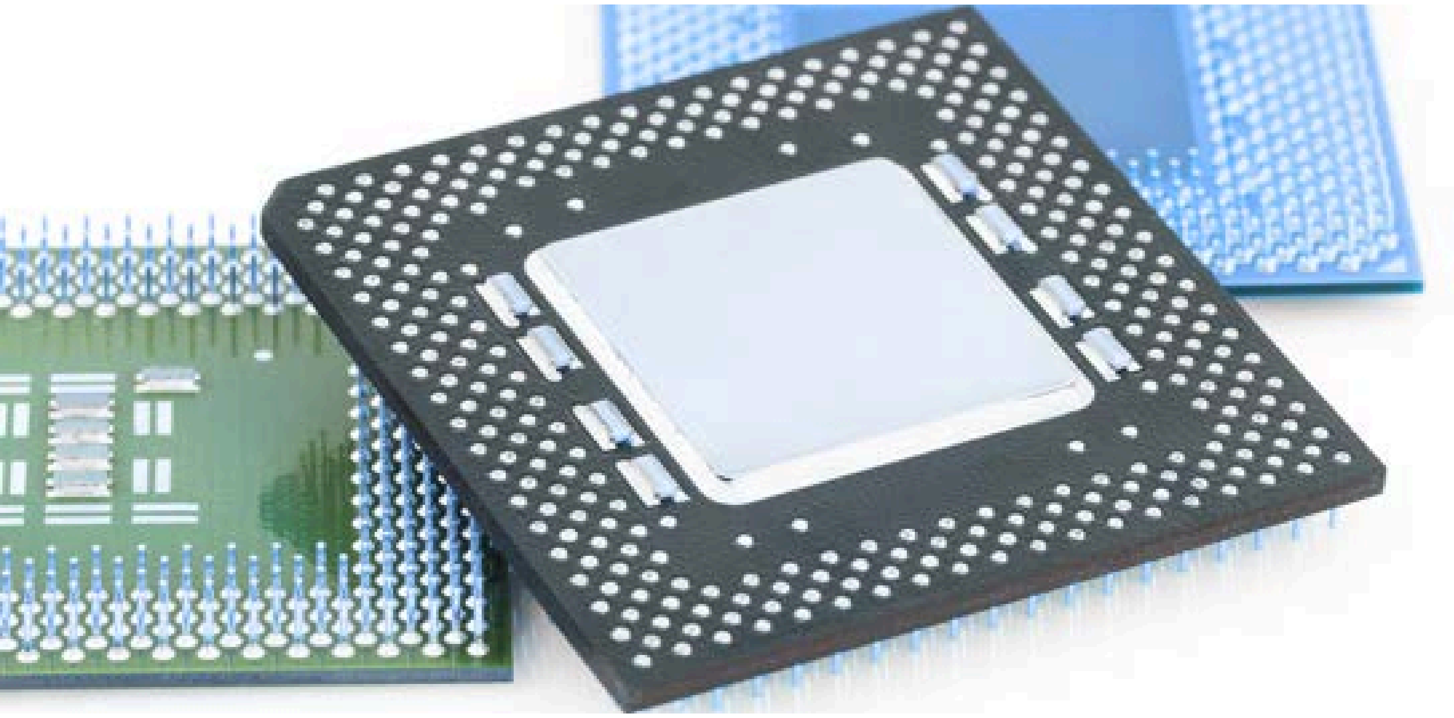
FROM CLAY TO SUPER HEAT SPREADERS

To bolster their roles as both electrical and thermal insulators in power modules, copper or aluminum are often added to technical ceramic to enhance their heat spreading capabilities. Ceramics with direct copper bonding (DCB) are particularly popular in power modules for their superb electrical insulation and robust heat spreading abilities.

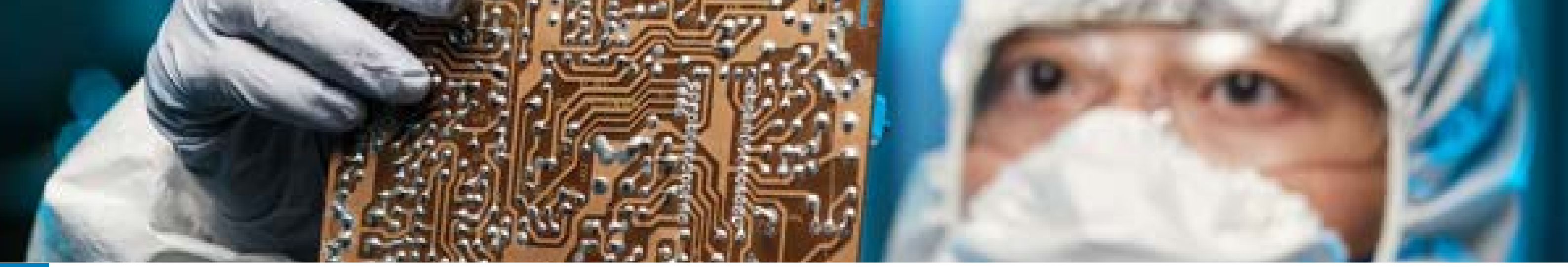
Common ceramic materials used in DCB include:

- Alumina (Al_2O_3): Low thermal conductivity, but popular for its cost-effectiveness.
- Aluminum nitride (AlN): Chosen for its superior thermal conductivity.
- Silicon nitride (SiN): Provides moderate thermal conductivity.
- HPS (Alumina with 9% ZrO_2): Utilized for enhanced properties.
- Beryllium oxide (BeO): Noted for its high thermal conductivity, though its use is limited due to toxicity concerns.

Ask us for more tips on evaluating thermal properties in substrate materials



Metallized ceramics with direct copper bonding (DCB) are used in power modules for their superb electrical insulation and robust heat spreading abilities.



OUTDATED THERMAL DATA FOR ADVANCED SUBSTRATES

WHAT DATA IS AVAILABLE NOW FOR THERMAL BUDGETING?

When manufacturers select substrate materials for a new design, they consider data on several thermal properties that are commonly available: maximum heat capacity, thermal shock resistance, and thermal conductivity.

Here's what each of these properties implies and why they don't provide enough information to pick the right material:

Heat capacity measures a material's stability across temperature ranges. Yet, the maximum use temperature of a material really depends on how it's used. For example, a metallized substrate under compressive stress will tolerate a lower maximum temperature than one without any load. Importantly, standard tests for thermal stability typically do not involve actual loads on the samples.

The **thermal shock resistance** test determines how materials react to abrupt temperature changes. Materials that perform well in these tests are ideal for environments with rapid temperature fluctuations, such as in aerospace applications, which differ significantly from the gradual heat increases seen in electronic device operations.

Thermal conductivity refers to the material's ability to transfer heat efficiently. Although materials with high thermal conductivity are excellent for use as heat sinks and spreaders, they don't prevent localized overheating, known as hot spots.

Application-base thermal resistance value on insulating substrates helps to optimize design for high performance computing applications.

Ask us for more tips on evaluating thermal properties in substrate materials

LIMITATION ON ESTABLISHED TEST METHODS

The most common methods to measure thermal properties are the ASTM C518 heat testing, which quantify the heat flow through materials to determine thermal conductivity.

The GHP method is considered the gold standard for testing insulator materials, but it comes with some limitations:

While we can measure the thermal conductivity of individual materials in metallized (direct copper bonding) ceramic substrates, there's no comprehensive methods to assess the substrate's overall thermal characteristics.

There are also no established test methods for evaluating the static thermal properties of semiconductor components in mounted form.

Typically, thermal tests are done during manufacturing on sample pieces crafted into a standardized geometry, not on the final product. Geometric differences and varied processing techniques (like machining or pressing) mean that the actual property values of a finished part might differ from those measured in a test sample.

Thermal performance can be significantly affected by the conditions under which ceramic is used, such as under heavy compression loads.

Lowering overall production and testing costs by including thermal resistance measurement for each individual substrate in power module design.

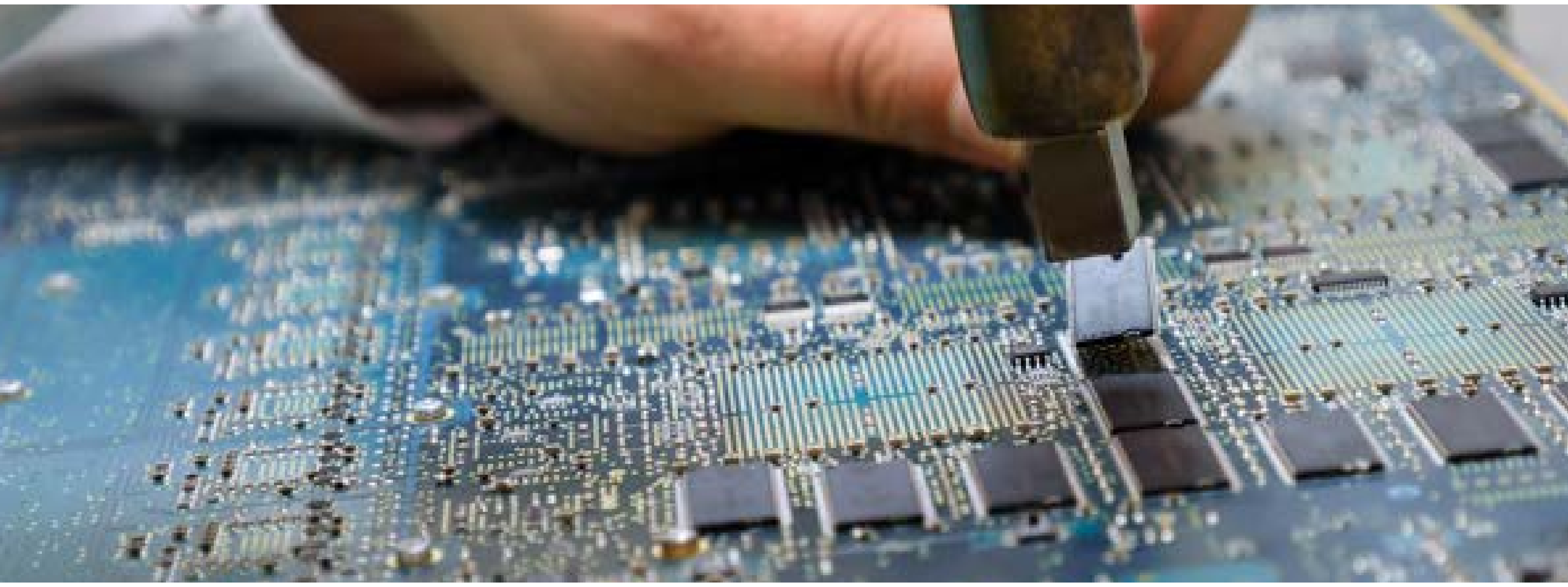
[Ask us for more tips on evaluating thermal properties in substrate materials]

MODELING INEFFICIENCY

In most production processes, material testing won't happen until much later. With just the 3 data sets above, designers have to rely on theoretical models for their thermal budgeting.

This could lead to several issues:

- Large margin to compensate for practical thermal values under real workload, which can compromise performance;
- A lengthy signoff process might be needed to retest and possibly change materials during later production stages;
- Or, the device could fail due to unresolved thermal issues.



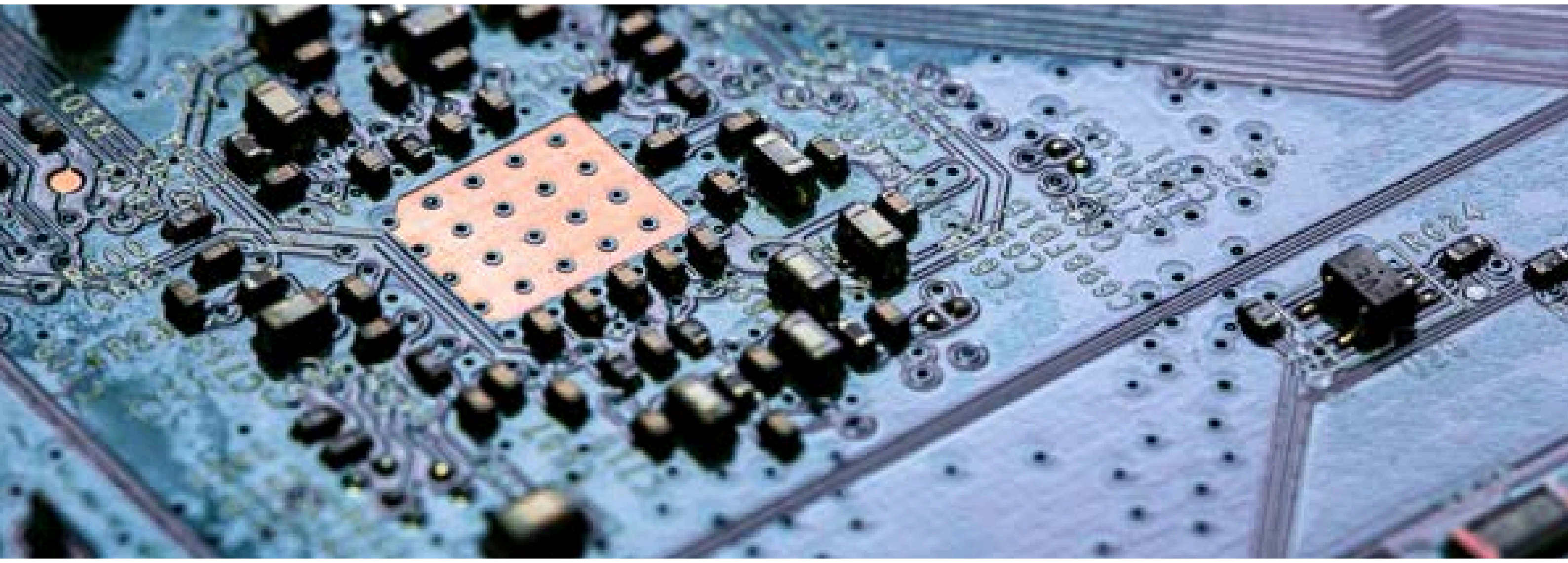
Thermal resistance measurements improve thermal planning, which helps to reduce production scrap and lower the risk of product recall.

What you should ask when choosing a semiconductor substrate are:

1. Can this material distribute and manage heat across its surface?
2. How well can the material resist the flow of heat through it?
3. If the substrate is a metal bonded ceramic, e.g. DCB Alumina, is there any way to test its overall thermal conductivity?

Ask us for more tips on evaluating thermal properties in substrate materials

THERMAL RESISTANCE - THE MISSING PIECE OF THERMAL DATA



To determine whether the material is right for a specific application, as a thermal insulator for instance, you need the thermal resistance value.

While thermal conductivity deals with how quickly and efficiently a material can transport heat, thermal resistance is about how well the material resists the flow of heat through it. This distinction is crucial in preventing localized overheating, which can lead to device failure.

Here’s a deeper look into how thermal resistance impacts the metallized substrate's function and why this data is vital:

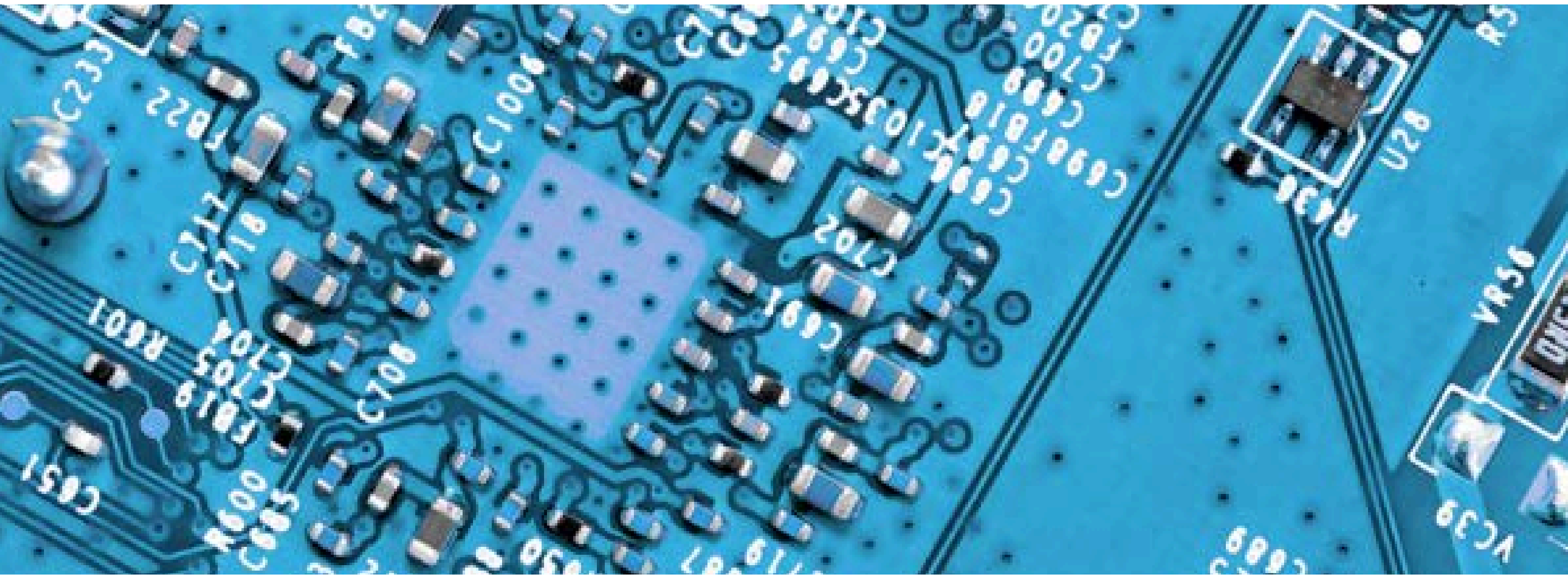
1.**Heat Distribution**: Effective heat management requires that the metallized substrate not only conduct heat away from the sources (like power transistors) but also distribute it across its surface. This distribution helps to avoid hot spots, which are localized areas of high temperature that can damage electronic components.

2. **Substrate Thickness:** The thickness of the substrate plays a significant role in its thermal resistance. Thicker substrates can increase thermal resistance potentially interfering with the electrical performance of the device. Finding the right balance in substrate thickness is crucial for optimizing both thermal and electrical performance.

3. **Design Configuration:** The overall design of the metallized substrate, including its shape and the materials used in conjunction with it, affects its thermal resistance. For instance, substrates may be metallized with pathways or channels that enhance heat flow or with integrated heat sinks that aid in heat dissipation. The physical layout of components on the metallized substrate can also be optimized to spread heat production more evenly, reducing the likelihood of hot spots.

4. **Material Composition:** The choice of material and different bonding techniques have an influence on the intrinsic thermal conductivity. Other factors such as the presence of impurities, grain boundaries, and internal structures can modify this property.

5. **Environmental Interaction:** Finally, the metallized substrate's interaction with its environment influences its thermal resistance. Is there a compress load in the application? The method of heat removal whether by natural convection, forced air, or liquid cooling plays into how effectively the metallized substrate can maintain acceptable temperatures.



Thermal resistance data is essential effective semiconductor lifecycle management

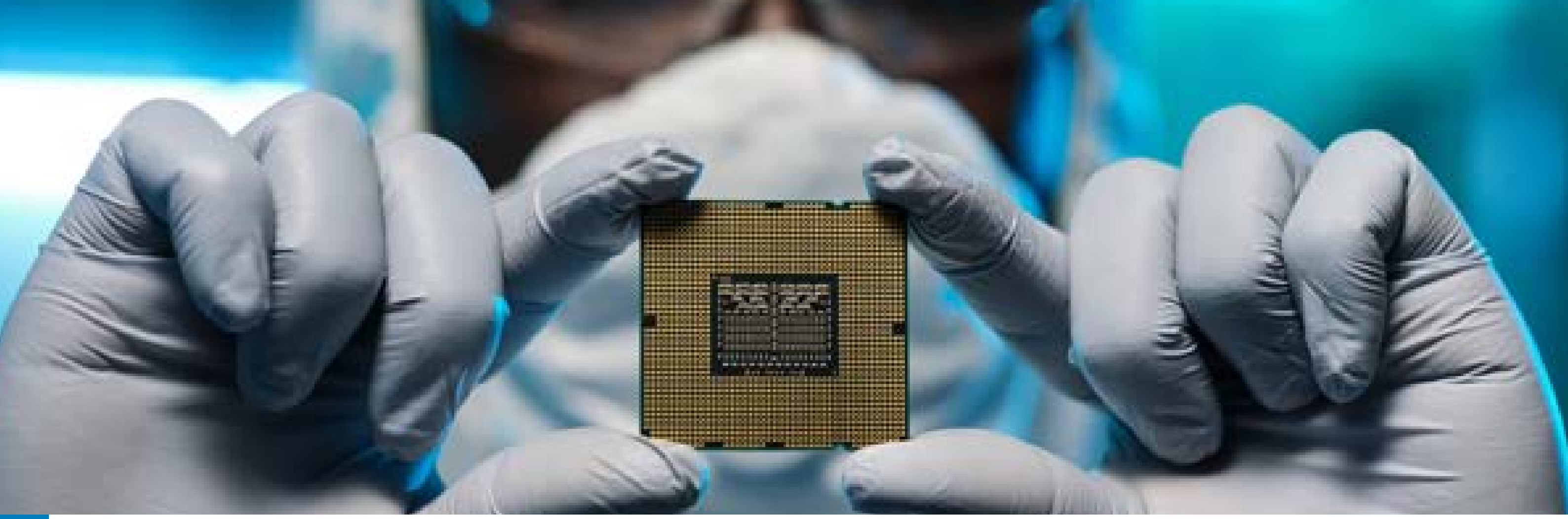
Accurate metallized substrate thermal resistance data is essential to material selection, physical design, and integration strategies, all aimed at efficiently managing and dissipating heat.

You don't have to over-margin your design.

You don't have to wait until packaging to find out about thermal issues.

You have precise data for thermal budgeting right from the start.

[Find out how thermal properties in substrate materials affects to your application.]



FAST & ACCURATE SUBSTRATE THERMAL EVALUATION

THERMAL RESISTANCE UNDER REAL WORKLOAD

Thermal resistance is a property that measures the resistance to heat flow from a hotter area to a cooler area within a structure. It is quantified by the temperature difference across the material's thickness per unit of heat energy that flows through it per unit time. The standard unit for thermal resistance is Kelvin per Watt (K/W).

This data is essential for designing power modules that effectively manage heat.

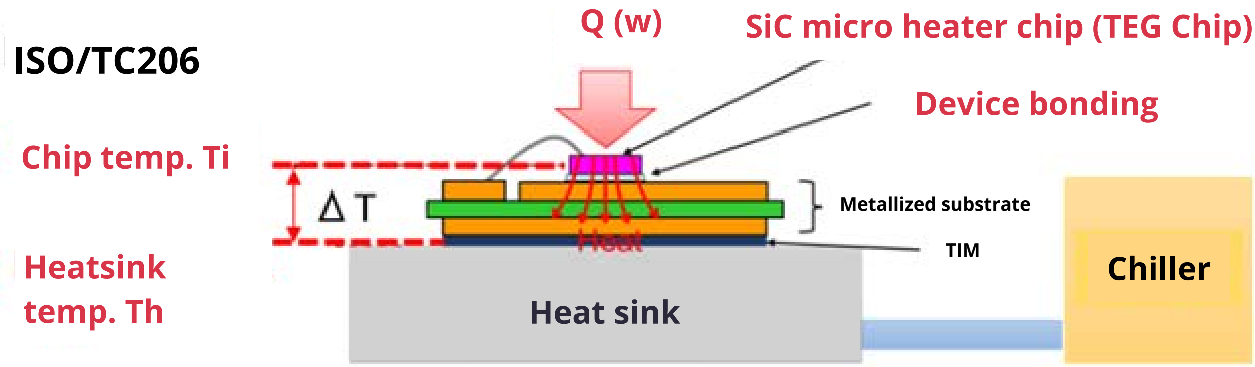
Manufacturers of ceramic and metallized ceramic components can apply these standards to actively assess and optimize the heat dissipation properties of their products in typical operational scenarios.

Accurate thermal resistance data for thermal budgeting right from the start of the design.

EVALUATING METALLIZED SUBSTRATES

Assessment Process: A TEG chip (SiC micro heater chip) heats one surface of the substrate sample, while the opposite surface is cooled using a heat sink. The temperature difference between the two surfaces and the power input for TEG chip (SiC micro heater chip) are used to calculate the thermal resistance.

Thermal assessment illustrated:



Define effective thermal resistance as Rth

$$Rth = (Tj - Th) / Q$$

$$Rth = \Delta T / Q$$

The ISO 4825-1:2023 thermal assessment for metallized substrate in mounted form.

This assessment protocol simulates the actual operating conditions of an advanced power module with the following specifications:

1. This test is designed to evaluate the thermal characteristics of metallized substrate sample components in which metallic circuit layers are joined to a ceramic substrate.

2. A TEG chip (SiC micro heater chip), capable of generating at least 200W of thermal energy, is attached to the substrate sample to simulate an advanced power module. This TEG chip is made of silicon carbide (SiC) and has a thermal resistance of more than 250°C. Platinum thin films are bonded to the TEG chip to measure temperature during thermal assessment.

3. Since ceramic has a lower maximum use temperature when placed under a compressive load compared to when it is not, a 10kg weight is placed on top of the metallized substrate during measurement. This is to mimic the actual operating condition of a metallized substrate in practical applications.

4. A predetermined quantity and type of Thermal Interface Material (TIM) is used to fill the small gaps and irregular surfaces between components, enabling efficient heat transfer from a device to a heat-dissipating component.

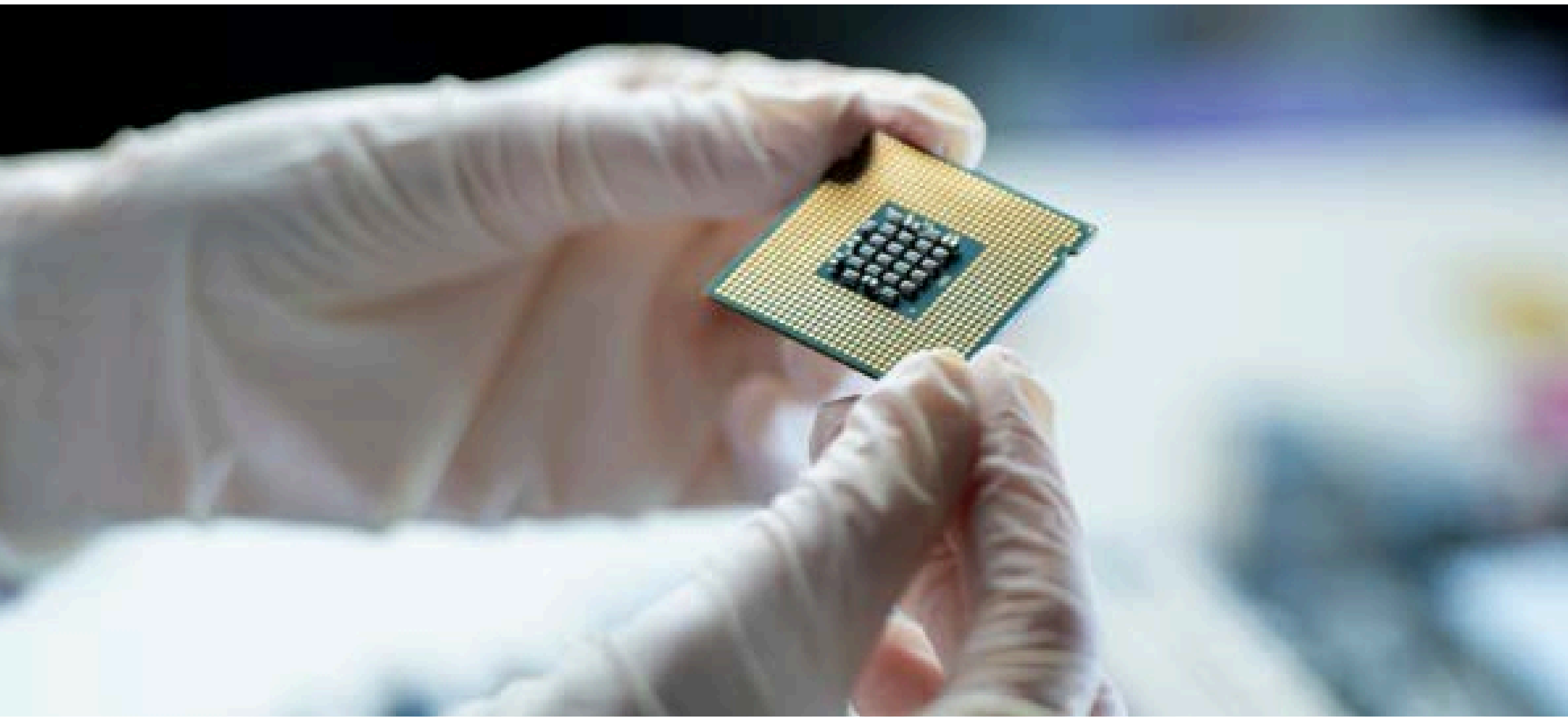
5. A water-cooled chiller is connected to the heat sink to provide constant temperature during measurement.

6. Thermocouple type K, specified in IEC 60584-1, is used to measure temperature on the heat sink and is as thin as possible.

7. A stabilized DC power source is used to supply electrical power for heating the heater chip is.

8. A controller turns on or off the electrical power for heating.

9. A recorder to simultaneously record the electrical power that heats the heater chip, the heater chip temperature, and the heat sink temperature and electric power.



Select the best suited substrate material to improve heat management and dissipation.

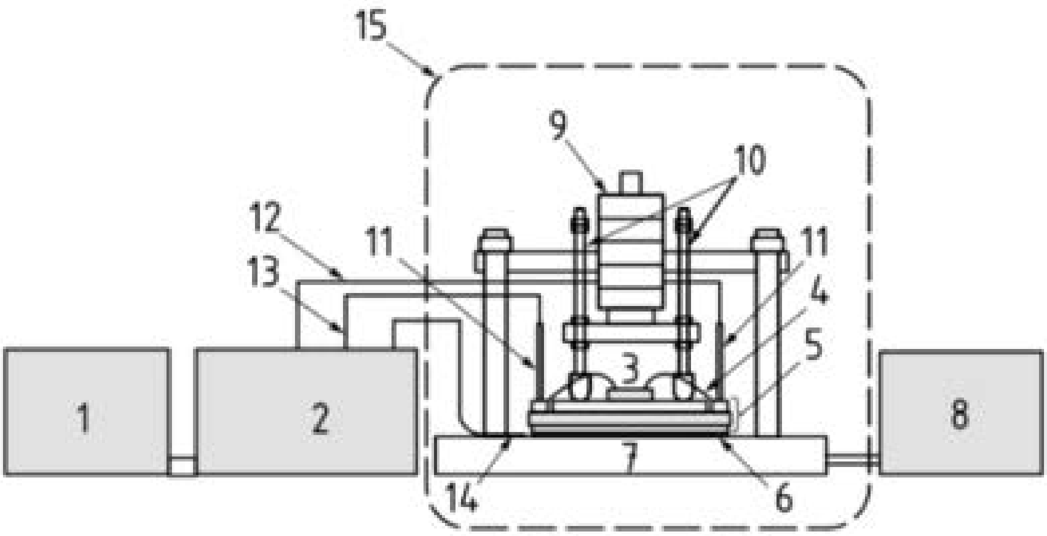
[Find out how thermal properties in substrate materials affects to your application.]

INSIDE THE YAMATO TE100 THERMAL CHARACTERISTICS EVALUATION ANALYSIS EQUIPMENT

The Yamato TE100 is purpose-built to provide test environment for metallized substrates as well as other component materials such as silver-sintered materials, solders, and thermal interface material (TIM): greases.

The apparatus set includes a controller and recording unit, a measurement unit, and an external chiller.

What it looks like inside the TE100 measurement unit



KEY

1. DC power supply	**9. weight (10kg)**
2. TE100 Control Unit (Controller)	10. load applying supporting rod
3. TEG heater chip	11. contact pin
4. wire bonding	12. temperature sensor line
5. TEST SUBJECT - substrate sample	13. power supplying line
6. thermal interface material (TIM)	14. thermocouple K
7. heat sink	15. draft shield box
8. chiller	

The TE100 thermal characteristics evaluation analysis equipment simulates the real operating condition in advanced power modules to test the thermal resistance of ceramic substrates.

In this sample set-up, the TE100 thermal characteristics evaluation analysis equipment produced accurate and reproducible results across different metallized substrate materials and thicknesses.

CALCULATE ACTUAL THERMAL RESISTANCE

STEP 1:

Heat one surface of the metallized substrate sample with a TEG heater chip.

STEP 2:

Cool the opposite surface of the same substrate sample with a heat sink.

STEP 3:

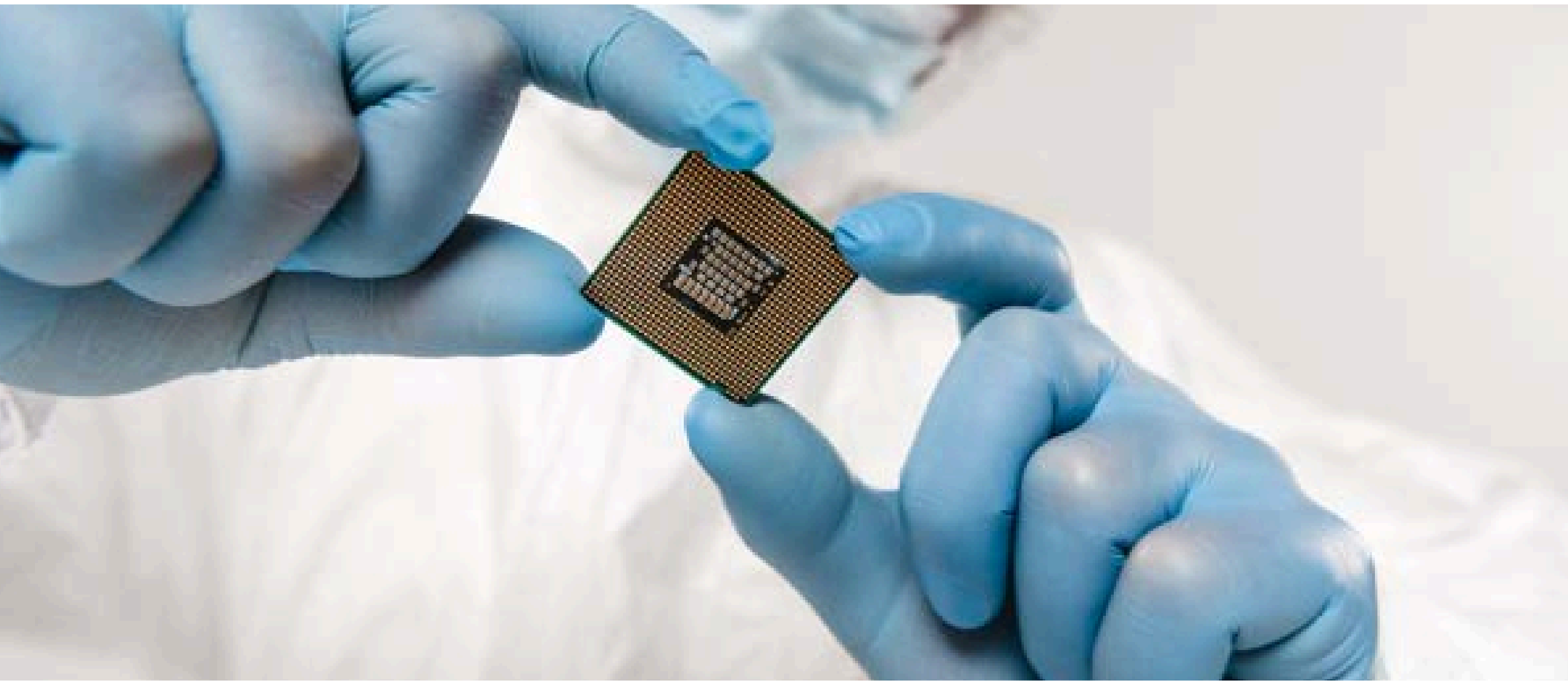
Calculate thermal resistance of the substrate sample by finding the temperature difference between the two surfaces and electric power.

THERMAL RESISTANCE FORMULA:

Thermal resistance (Rth) = Temperature difference (K) between TEG chip and heat sink / divided by electric power (W)

For more details of the test standard and equipment requirements, see ISO 4825-1:2023.

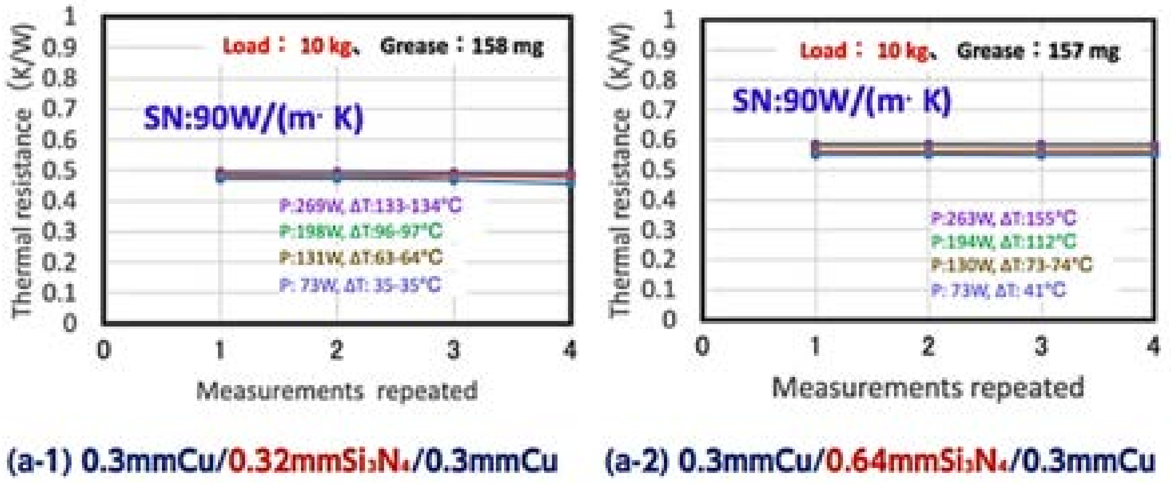
Find out how thermal properties in substrate materials affect your application.



VALIDATED THERMAL DATA

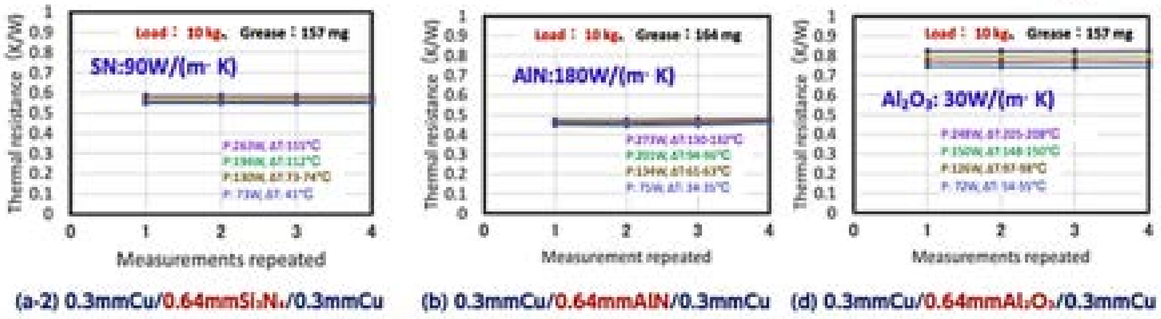
The TE100 method for evaluating metallized ceramic thermal data has been tested by 6 independent laboratories. The results are validated as accurate and reproducible.

Result Screen 1 and 2: Data comparison between 2 different thicknesses of the same substrate material (Si3N4). When input is 260W electric power for heater, thermal resistance for 0.32mm thickness is 0.5K/W, for 0.64mm is 0.59K/W.



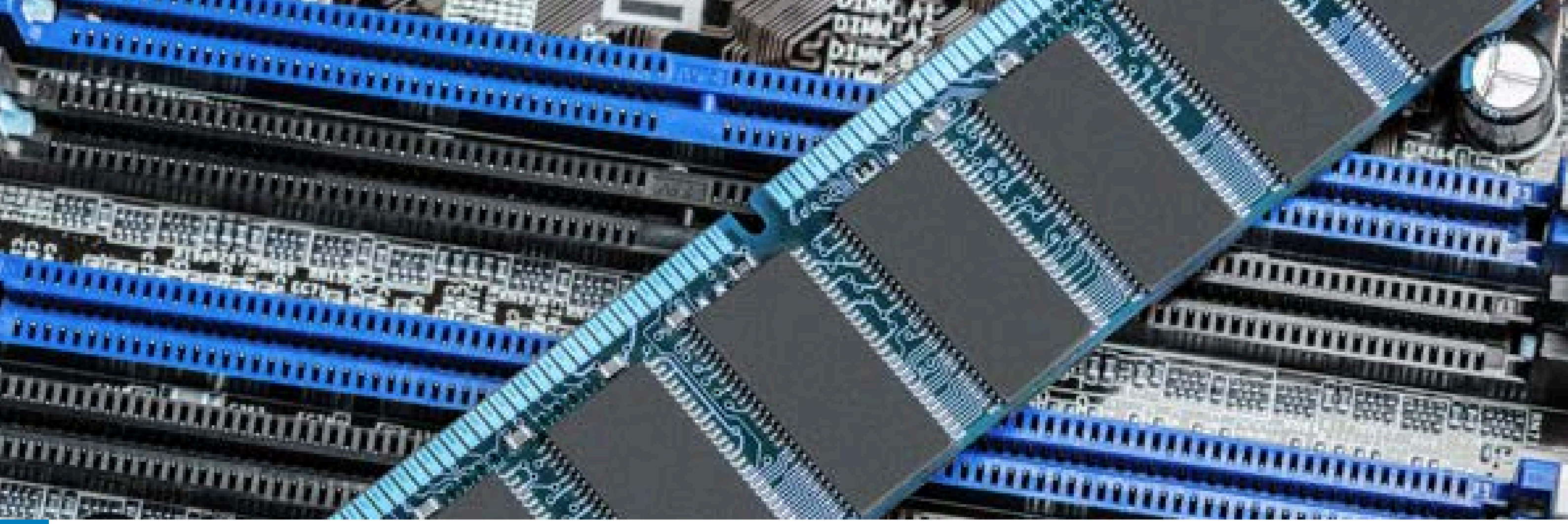
The variation in thermal resistance is directly related to the substrate's thickness.

Result Screen 3, 4, and 5: Data comparison between 3 different substrates – Silicon Nitride (Si3N4), Aluminum Nitride (AIN), Aluminum Oxide (Al2O3).



Leverage data to select the right substrate material for your design.

[Interested to see a demo? Chat with us now.]



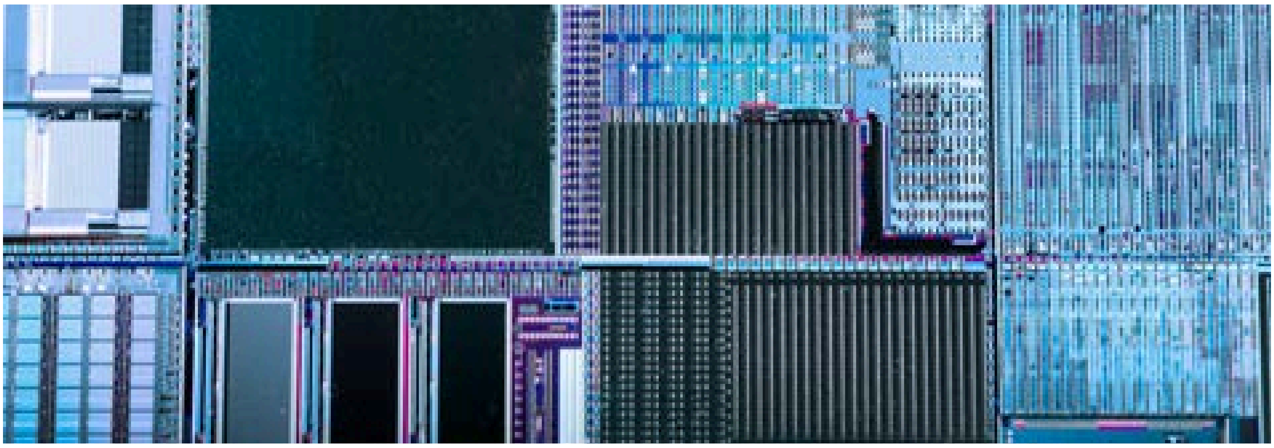
EASE YOUR TIME-TO-MARKET PRESSURE WITH ACTUAL THERMAL RESISTANCE DATA

TEST MORE METALLIZED SUBSTRATE MATERIALS

As power devices become more advanced, the variety of substrate materials available also broadens to meet increasing demands. This flexible testing method allows you to examine a wide array of materials, including oxide and non-oxide ceramics, ceramic composites, technical ceramics with direct copper bonding, and other metallized substrates under real operating conditions.

Instead of sticking with conservative options, designers can test different materials to find substrates most suited to their specific applications.

This targeted assessment helps pinpoint the best materials for optimizing device functionality and durability.



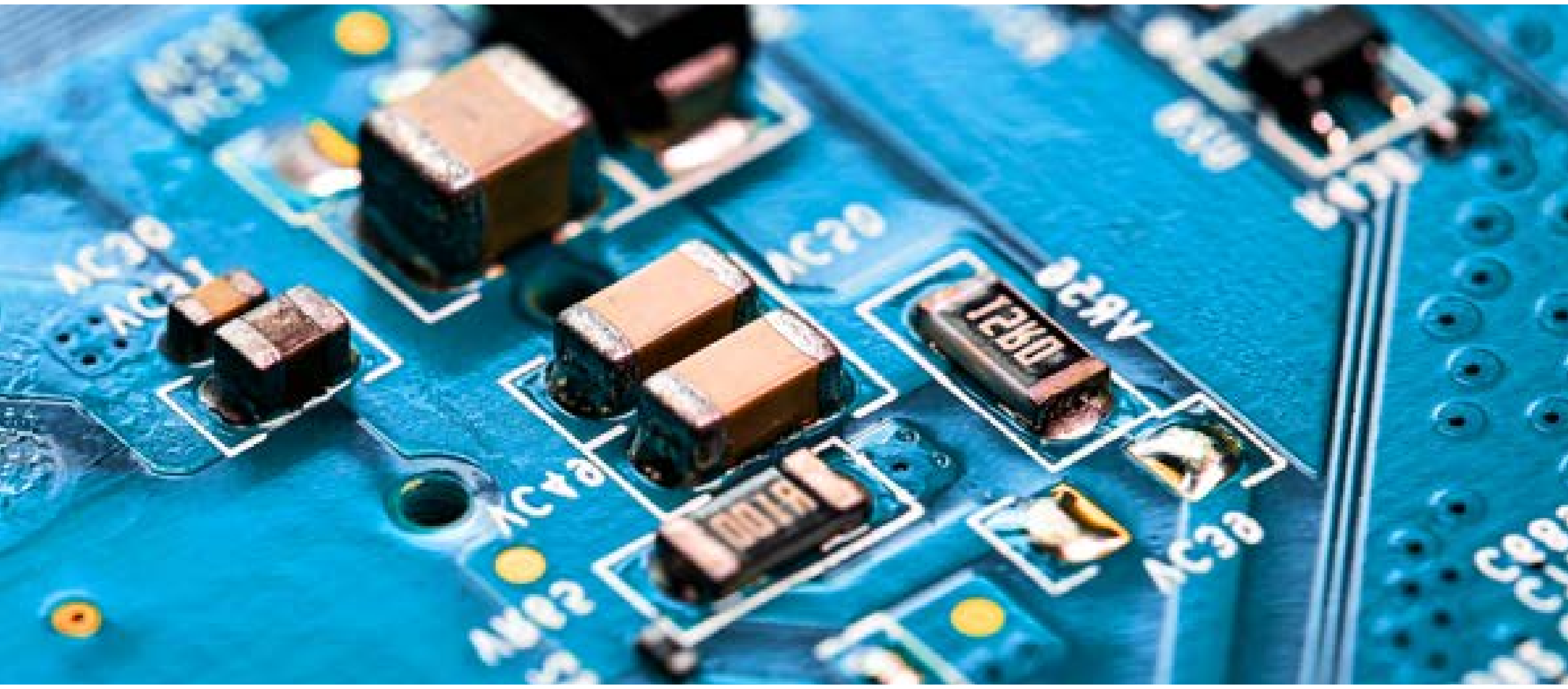
Test different materials to find substrates most suited to their specific applications.

EXPLORE METALLIZATION OPTIONS

If you work with metallized substrates, this standard method to get validated thermal data on metallized substrates will set you miles apart from competition.

With the purpose-built analyzer for metallized substrates, you can try all the different metallization techniques and materials like copper, aluminum, or silver.

Optimizing metallization improves the connection between the substrate and components like semiconductor chips, enhancing heat transfer and reducing thermal resistance. This approach boosts device reliability and performance by tailoring metallization to the specific needs of each application.



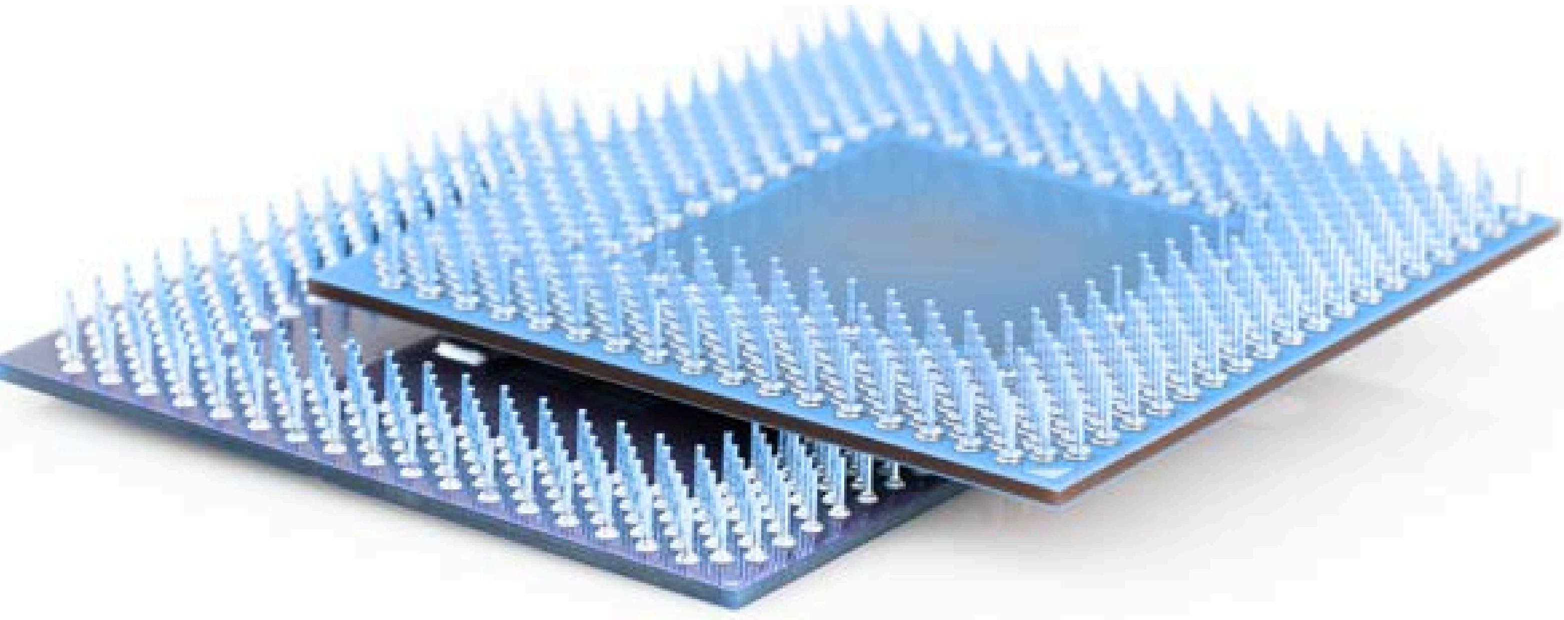
Targeted substrate thermal assessment helps pinpoint the best materials for optimizing device functionality and durability.

[Interested to see a demo? Chat with us now.]

OPTIMIZE METALLIZED SUBSTRATE THICKNESS FOR THERMAL PERFORMANCE

The thickness of a metallized substrate significantly influences its thermal performance. Instead of depending on standard thermal data from pre-manufactured materials for thermal budgeting, you can now test various metallized substrate thicknesses to find the perfect balance between thermal resistance and mechanical stability.

For metallized substrate manufacturers, this capability means you can offer more tailored options suited to specific applications. For chip engineers, it provides a more objective method to establish a reliable thermal budget for new designs.



Test various metallized substrate thicknesses to find the perfect balance between thermal resistance and mechanical stability.

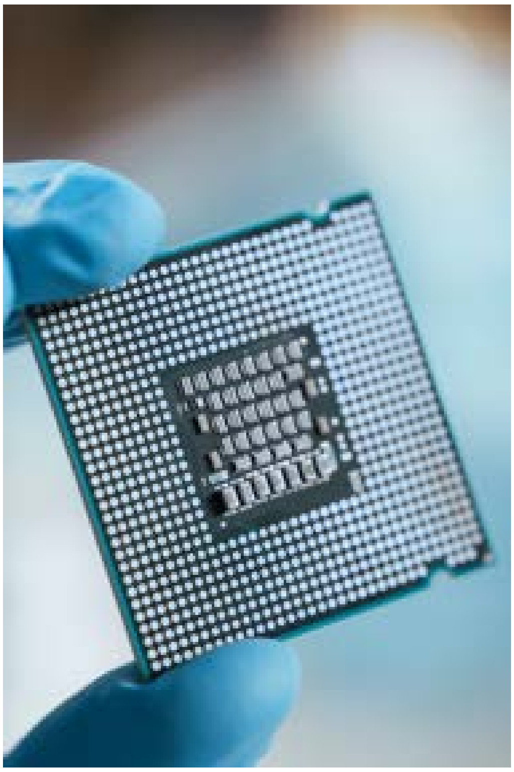
[Ask our application engineer how thermal resistance data help you improve your yield.]

WHO BENEFITS MOST FROM SUBSTRATE THERMAL RESISTANCE DATA UNDER REAL WORKLOAD?

Access to metallized substrate thermal resistance data under actual operational conditions is pivotal across various sectors in the electronics industry.

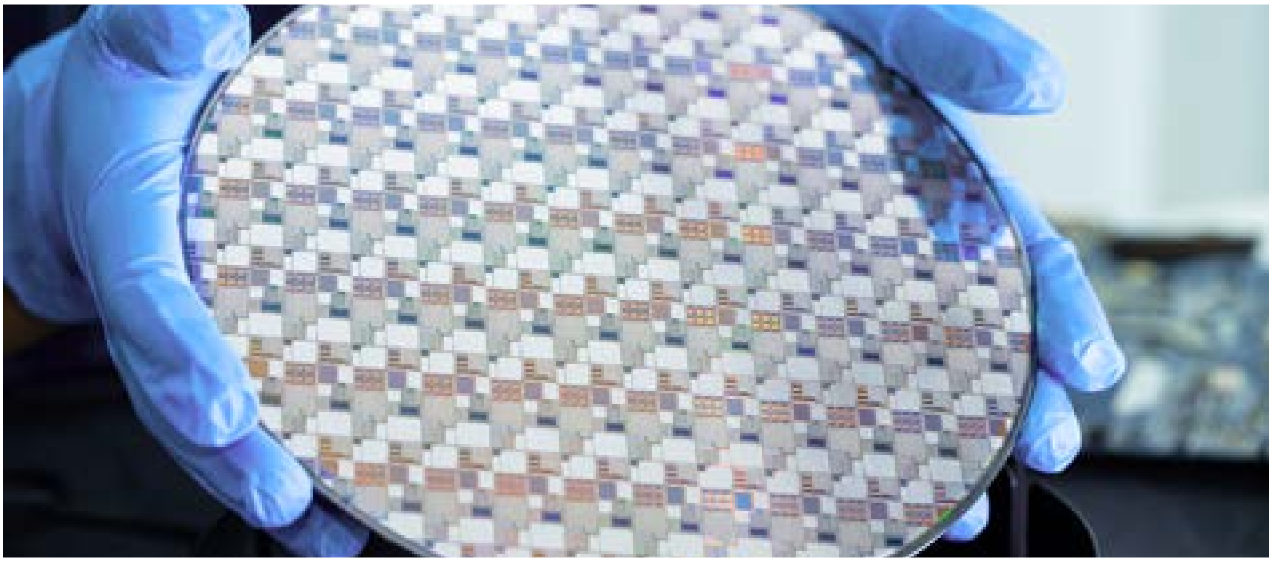
POWER SEMICONDUCTOR MANUFACTURERS

This data helps in selecting materials that balance thermal performance with cost, ultimately keeping production timeline and testing expenses manageable. This leads to more efficient products that meet the demands of high-performance applications, such as electric vehicles and renewable energy systems, without escalating costs and delay in deployment.



METALLIZED SUBSTRATE MANUFACTURERS

Detailed thermal resistance data under real workload conditions allows you to demonstrate the superiority and suitability of your products for specific applications. By providing data that shows your substrates can effectively dissipate heat, you increase customer confidence and satisfaction, which can lead to higher sales volumes and expanded market share. Moreover, this data aids in product development, enabling chip manufacturers to innovate substrates that address specific thermal challenges in electronics design.



THERMAL INTERFACE MATERIALS MANUFACTURERS

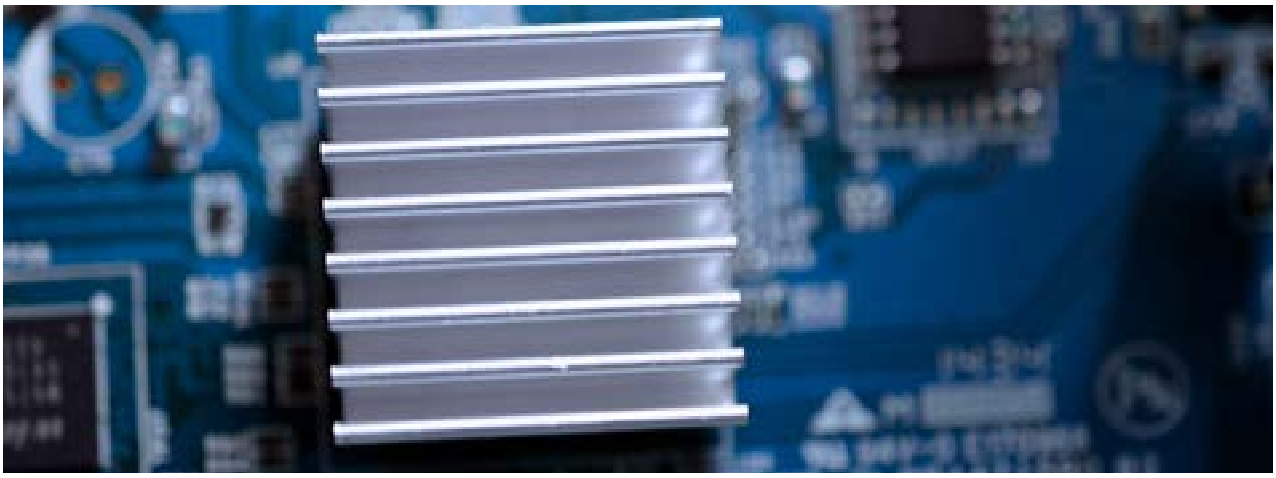
To keep pace with evolving industry requirements, particularly as devices become faster and smaller, raising the stakes for effective heat management. Access to accurate thermal resistance data helps you develop interface materials that are precisely formulated to manage heat in newly emerging device architectures. This proactive approach to product development can place you ahead in delivering solutions that meet or exceed the thermal management needs of the latest technologies.

DIE ATTACH BONDING MATERIAL MANUFACTURERS

You are in a unique niche and are keen on leading the market by providing materials that offer exceptional thermal management. Die attach materials are used in situations where superior thermal conductivity is needed to manage the heat generated by high-power devices. By leveraging substrate thermal resistance data, you can fine-tune your materials to optimize performance, thereby reinforcing your leadership and innovation in high-performance thermal solutions.

HEAT SINK MANUFACTURERS

Heat sinks are crucial for dissipating heat in electronic devices. With metallized substrate thermal resistance data, you can now design customized solutions for emerging applications like EV batteries and data center processors. Custom-built products not only meet the precise requirements of your clients but also distinguish you in the market, enhancing your reputation as an innovative leader in thermal solutions.



Metallized substrate thermal resistance data is a cornerstone for innovation and optimization across the electronics manufacturing industry. Uses the data to refine their products, tailor their solutions, and ensure that their offerings are aligned with the cutting-edge demands of modern electronics, thereby securing a competitive edge in their respective markets.

[Interested to see a demo? Chat with us now.]

ARE YOU MAXIMIZING YOUR TESTING CAPABILITIES?

Are you ready to fully leverage the substrate thermal resistance analysis to improve defect escape rates, lower costs, increase throughput, and enhance performance?

We are in a period of rapid evolution in the semiconductor industry, all under increasing cost pressures due to tighter defect tolerances.

This complexity demands precise and effective testing strategies.

IMPLEMENT A ROBUST TESTING AND ANALYTICS FLOW

To keep improving quality and yield while cutting down on production costs, it's essential for chipmakers and their suppliers to rethink their approach to substrate testing.

This includes integrating the fast and accurate method for thermal resistance testing under operating conditions. You need a flexible and versatile testing protocols tailored for incoming wafer lots and pave the way for potential real-time adjustments at the device level.

Thermal resistance measurements under a real workload is essential for designing power modules that effectively manage heat.

The upcoming advancements in power modules, particularly with the introduction of backside power, underscore the need for efficient thermal management. Backside power increases chip power density, which can exacerbate thermal challenges. By applying the substrate thermal resistance testing early in the design phase, you can accurately evaluate the thermal coefficients of different materials, ensuring that thermal management considerations are seamlessly integrated into chip design.

Ask us for more tips on evaluating thermal properties in substrate materials

DISCOVER HOW THE TE100 METHOD CAN TRANSFORM YOUR OPERATIONS

We're eager to demonstrate how the TE100 thermal characteristics evaluation analysis equipment can streamline your processes and significantly boost your revenue. Spending just half an hour with us could revolutionize how you manage thermal challenges in your designs.

World's first

Associated ISO testing method

Shorten time-to-market

Reduce scraps & minimize risk for recalls

Improve quality in both chip and system

Increase revenue

CONTACT US TODAY TO SEE HOW OUR TAILORED SOLUTIONS CAN ENHANCE YOUR APPLICATIONS USING THE TE100 METHOD.

Call us on: 1-800-292-6286 or email: customerservice@yamato-usa.com.