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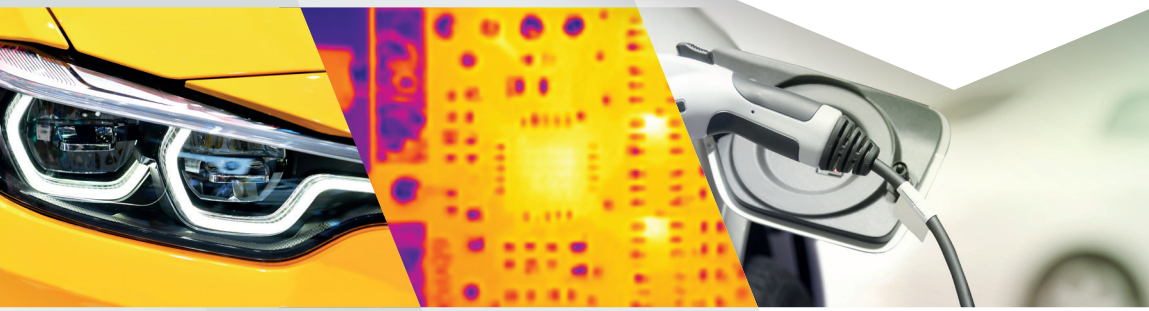

Thermal Management Material Selection

Key Factors to Consider

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takes you, Ventec delivers

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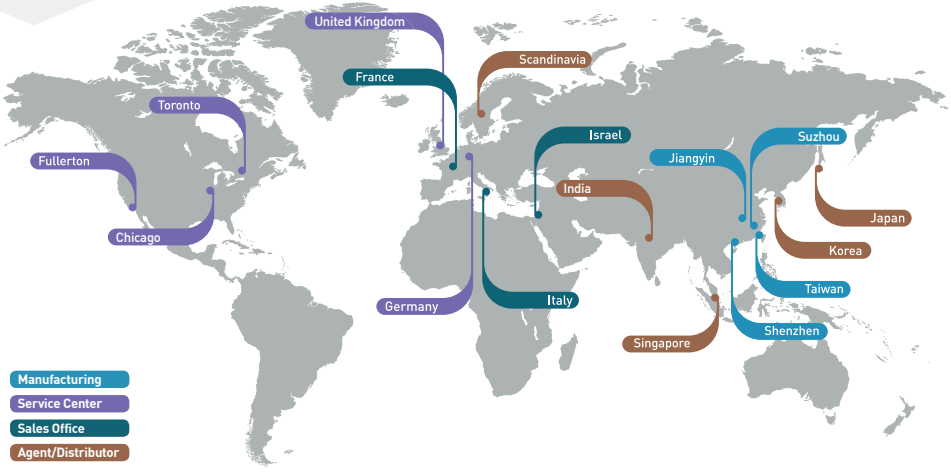
Ventec International Group is a world leader in polyimide & high-reliability epoxy laminates and prepregs and a specialist provider of high-speed hydrocarbon- and high-frequency PTFE materials. Founded in 2000 and listed on the Taiwan Stock Exchange since 2018, Ventec employs over 1100 people. The company maintains a global network of warehousing, sales and technical support offices in Europe, USA and Asia.

Our focus on innovation, quality, and value starts with strong R&D, and powered by the world's leading materials and applications specialists.

We support you from materials selection and design-in to production and beyond, working with OEM's, PCB fabricators and EMS companies to create the complete solution.

All Ventec products are manufactured at our quality-approved factories in China and Taiwan: your assurance of ultimate performance and service.

Global Reach... Local Service



Thermal Management Material Selection: Key Factors to Consider

Insulated metal substrate (IMS)technology provides an elegant and economical solution for managing component temperatures in electronic applications such as computing, lighting, and power supplies for a wide range of markets and environments. Identifying a suitable IMS to maintain components at a desired operating temperature enables engineers to design products that enjoy several advantages in the marketplace:

- Superior reliability
- Smaller size
- Attractive appearance
- Competitive price

This Thermal Management Material Selection guide describes the popular applications, IMS products and selection criteria, and engineering support services that can help engineers understand and overcome thermal-management challenges.

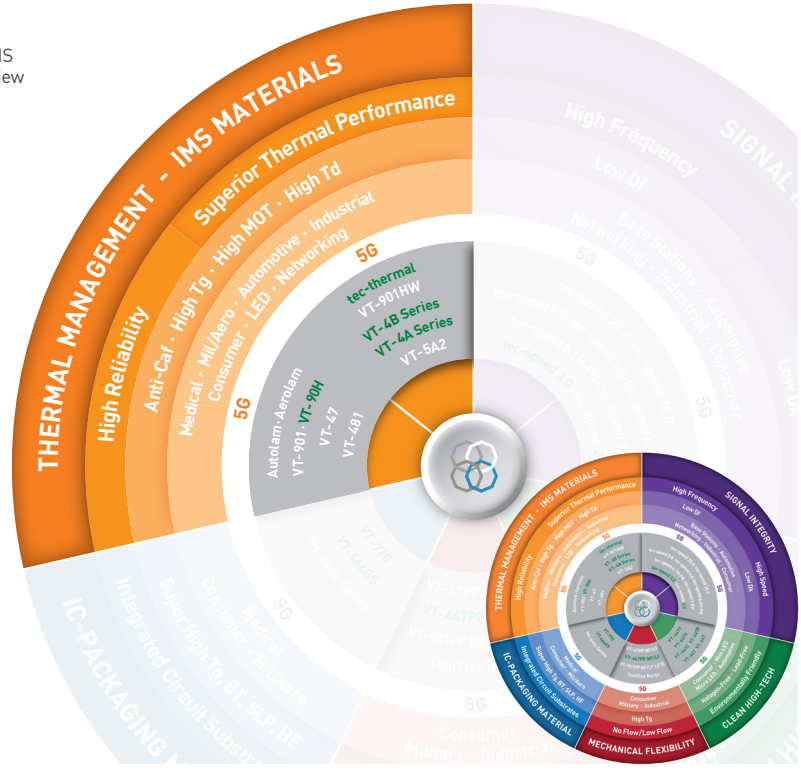


Figure 1:
Ventec Thermal Management IMS Materials Overview

Why Thermal Management?

Proper thermal management is critical in applications such as power conversion, lighting, and all sorts of computing applications from embedded modules and smartphones to desktops, network infrastructure, and cloud servers. Thermal management has a critical role in determining reliability and, in lighting applications, is needed to maintain consistent lumen output and chromaticity.

Reducing the operating temperature by 10°C effectively doubles an electronic component's lifetime. Hence designing to achieve a target temperature gives control over reliability. Various techniques can be employed, such as applying a heatsink, thermoelectric pump, cooling fan, heat pipe, or cooling plate. Alternatively, or in addition, heat can be extracted through a component package into the substrate. This can be achieved by customizing basic FR4 board with specially positioned thermal vias or a heat slug, by specifying special substrate material such as alumina, or using a die-attach technique such as direct-boned copper (DBC).

Identifying a suitable strategy at an early stage of development gives the greatest freedom to engineer a solution that best satisfies important targets such as the cost, size, and appearance of the end product.

A thermally enhanced substrate from a range such as Ventec's tec-thermal portfolio offers several potential advantages including simplified engineering, lower cost, and smaller size. Designed to extract heat directly from attached components into the substrate and ultimately away from the application, and so stabilize the operating temperature, tec-thermal materials cover a broad performance spectrum, giving designers many choices of key parameters such as thermal conductivity, operating temperature range, and electrical properties.

You can use a tec-thermal substrate as the sole thermal management in your application. On the other hand, you can combine tec-thermal with other techniques if needed, to achieve a desired operating temperature.

This guide is a companion to Ventec's two ebooks that cover the principles and practice of thermal management, published in 2019 and 2022 in conjunction with iConnect007. The first of these ebooks provides in-depth analysis of cooling and thermal management in electronics and describes how IMS is typically used in major applications such as automotive control modules and LED lighting.

The second book provides guidance on enhancements to IMS, such as high-emissivity coating and multi-layer IMS. This book also describes how solder cracks can impair thermal dissipation and explains the development of various industry-standard test methodologies that enable substrate manufacturers to publish the key characteristics of their products. Differences between these test methodologies can complicate the

engineer's task when comparing products, giving the potential for unexpected results in practice. Caution is advised when reading datasheets, and hands-on experience is usually recommended before making a final decision.

Popular IMS Applications

Major trends in the world today – including e-mobility, cloud computing, AI, digital money, smart everything, renewable energy – are driving up demand for high-performing electronic systems: more intensive computing, more pervasive power conversion, more energy-intensive applications.

While they certainly bring many advantages to the way we live, thermal management in these applications is a critical challenge. Factors such as size and weight, particularly in small embedded systems and automotive, the appearance of consumer products and appliances (which can be impaired by large bulky heatsinks, for example), must also be considered, as well as the engineering costs and reliability implications if active cooling such as forced-air (fan) or liquid cooling is used.

Ventec's tec-thermal portfolio of thermal substrates can offer a cost-effective, compact passive cooling solution suitable for applications such as:

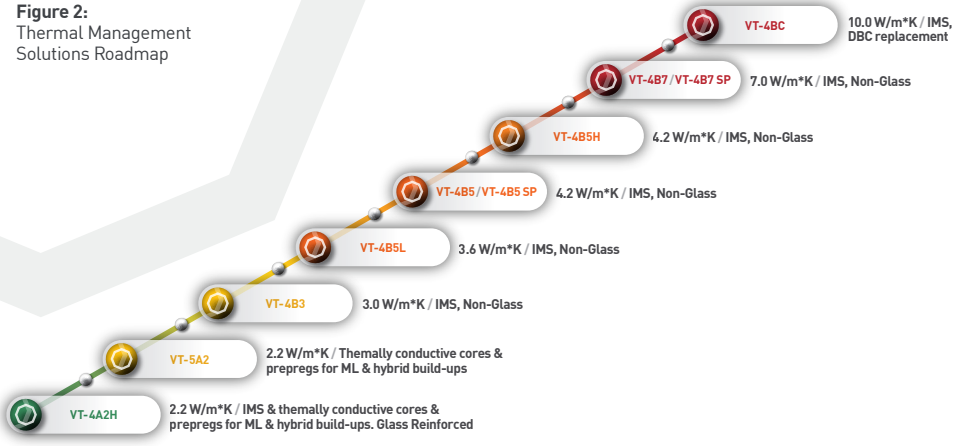
- Power supplies including inverters and DC/DC converters in renewable power generation
- Automotive control modules including electric power steering (EPS), engine management, motor drives for pumps, fans, and blowers
- Traction inverters for electric-vehicle powertrain
- Heatsink replacement in power applications containing wide-bandgap silicon carbide (SiC) and gallium nitride (GaN) power semiconductors. The high efficiency of these next-generation power components enables designers to replace large, expensively finned heatsinks with IMS. This enables a slimmer, neater appearance,which is important in applications such as external power adapters for home electronics
- Domestic LED lighting. Typical surface-mount LED packages are designed to conduct heat from the emitter through the bottom-side and into the substrate, allowing the topside area to be designed for maximum light emission. IMS excels in this situation
- In automotive lighting, the compact dimensions and freedom to create imaginative shapes is a key attraction drawing designers towards the use of LEDs

IMS delivers important advantages, including small size, mechanical flexibility, and the ability to form complex shapes. Reliability and longevity are further key benefits of LED lighting in the automotive context, which can last for the intended life of the vehicle with proper construction and temperature control.

Choosing the Right Thermal Substrate

Ventec's tec-thermal portfolio contains materials that offer various values for thermal resistance (Rth) and other properties such as maximum operating temperature (MOT). While most are based on IMS technology, the range begins with non-IMS products that allow the broadest possible choice when seeking optimal overall performance.

Figure 2:
Thermal Management Solutions Roadmap



Note that Ventec VT-5A2 non-IMS substrate provides thermal performance eight times better than FR4 and can be used in applications where an IMS may be uneconomic.

A typical single-layer IMS substrate is composed as shown.

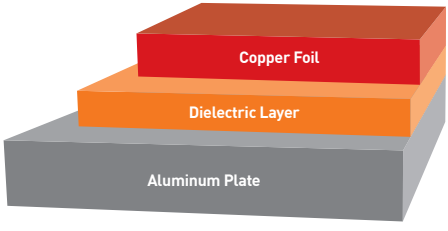


Figure 3:
Composition of a typical single-layer IMS substrate

The circuit foil and plate are metallic objects and hence have relatively low Rth compared to the dielectric layer. As a result, the Rth of this layer dominates the overall thermal resistance of the stack. The dielectric Rth can be managed by adjusting the thickness of the layer as well as the formulation. In particular, increasing the proportion of ceramic filler reduces the Rth. Optimizing the contact surfaces between each layer and adjusting the size and thickness of the baseplate also influences the overall Rth and thermal capacity of the substrate.

In addition, a choice can be made between a copper or aluminum baseplate. The main effect is to eliminate stresses that can result from mismatches between the coefficient of thermal expansion (CTE) of the circuit foil and baseplate. A copper baseplate can provide ideal CTE matching, where this is needed. The trade-off is found in the increased cost and weight of a copper baseplate versus aluminum. Alternatively, a low-CTE aluminum baseplate, or low-modulus dielectric material, can help mitigate CTE stresses. These are particularly valuable in applications that are deployed in harsh environments.

The IMS Performance/Applications Spectrum

Figure 4 describes the Ventec tec-thermal portfolio of high thermal performance substrates, which covers a wide range of properties and values of thermal resistance from standard to ultra-low.

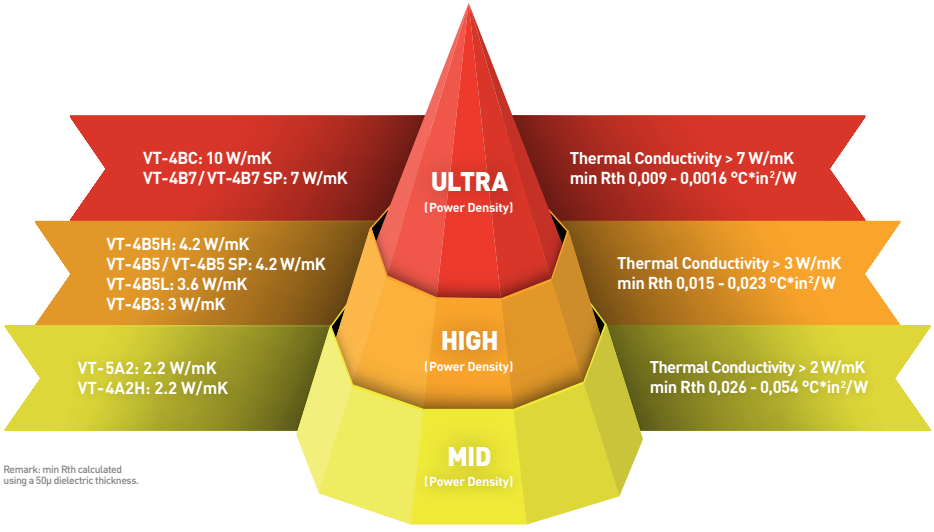


Figure 4:
Thermal Management
Product Positioning Pyramid

At the mid Rth range level, Ventec offers IMS-based substrates with thermal conductivity of about 2.0 W/mK. These are ideal for applications such as automotive taillights and 3D lighting, and offer properties such as flexibility that can assist installation in tight spaces.

At the opposite end of the spectrum, VT-4B7 SP has thermal conductivity greater than 7.0 W/mK for applications such as high-power matrix lighting, projector LEDs, and demanding automotive modules such as electric power steering drives. Our ER1 high-emissivity coating adds a further special option, which can b

e applied to further enhance the thermal performance of the chosen substrate. With ER1, the emissivity of a standard IMS brushed aluminum finish is more than an order of magnitude greater, giving additional freedom to replace a bulky heatsink with IMS of a suitable size to meet a specific device (junction) temperature.

If the desired substrate Rth for a given application is known, selecting candidate materials from the available choices is relatively easy using this graphic. This can provide a starting point for practical evaluation.

Alternatively, the desired thermal conductivity of the IMS can be calculated taking into account the quantity of heat to be handled, the ambient temperature, and desired component temperature.

On the other hand, the shape of the above graphic, as a pyramid, allows a more intuitive approach to selecting an IMS that offers adequate thermal performance. Note, however, that an over-specified solution will likely incur extra cost, while under-specifying risks reduced reliability. To avoid either of these situations, expert support is recommended. (See the section on Engineering Support).

tec-thermal Material Specifications

Product	Thermal Conductivity (W/mK)	Thermal Impedance (°C*in²/W)	Dielectric Breakdown (Volt)	Tg (DSC) (°C)	Td (TGA) (°C)	Dk (@1MHz)	Df (@1MHz)	MOT (°C)	Flammability (UL 94)	Peel Strength - 1oz LB/in (N/mm)
Without Glass Reinforcement										
VT-4BC	10.0	0.016	8000	180	400	5.5	0.014	155	V-0	6 (1.05)
VT-4B7SP	7.0	0.009	3000	100	380	4.8	0.016	130	V-0	7 (1.23)
VT-4B7	7.0	0.017	7000	100	380	4.8	0.016	130	V-0	4.5 (0.79)
VT-4B5SP	4.2	0.015	3000	120	380	4.8	0.016	130	V-0	7 (1.23)
VT-4B5H	4.2	0.029	7000	180	400	4.8	0.016	155	V-0	4.5 (0.79)
VT-4B5L	3.6	0.034	7000	100	380	4.8	0.016	155	V-0	5 (0.88)
VT-4B5	4.2	0.029	7000	120	380	4.8	0.016	130	V-0	7 (1.23)
VT-4B3	3.0	0.040	7000	130	380	4.8	0.016	130	V-0	11 (1.93)
Glass Reinforced										
VT-4A2H	2.2	0.054	6000	130	380	5.1	0.014	105	V-0	12 (2.1)

- Values provided are typical values for 3 mil (75 micron) dielectrics (except SP) but not intended to be specification values
- Thermal Conductivity according to ISO 22007-2 (Transient Method – Hot Disk)

Product	Thermal Conductivity (W/m*K)		Tg (DSC) (°C)	Td (TGA) (°C)	Dk (@1 MHz)	Df (@1 MHz)	MOT (°C)	Flammability (UL 94)
	Z axis	X, Y axis						
VT-5A2	2.2	3.4	190	375	4.3	0.008	150	V-0
VT-4A2H	2.2	3.4	130	380	5.1	0.014	105	V-0

Item	Availability
Copper Foil	Hoz, 1oz, 2oz, 3oz
Dielectric	.003" (80μm), .004" (100μm), .006" (150μm)
Standard Size	37"*49", 41"*49", 43"*49" and panels could be cut from above sizes

- VT-5A2 is a CCL & PP material designed for manufacturing thermally conductive ML and ML hybrid PCB
- VT-4A2H material is optimized for laminating copper foil or a hybrid construction to an aluminum or copper heatsink plate

Engineering Support

Ventec's tec-thermal substrates offer many choices for designers to select a formula to deliver the desired performance within the prevailing constraints. Thermal management is a complex subject that involves evaluating many variables; some inter-related, some independent. High-quality technical support is a critical aspect of any material vendor's value proposition.

Our product specialists and engineers provide help to choose and use products from the portfolio to achieve the desired performance in the target application.

Moreover, Ventec engineers participate in industry bodies, such as the IPC, to help develop high-quality standards and test specifications. These are needed to enable customer engineers to compare the various choices on offer and make properly informed decisions.

For reliability & quality, Ventec's commitment is underlined by strict and thorough material testing processes that ensure the stringent requirements of industry standards are met for both the materials and the seamless global supply chain that customers rely on.

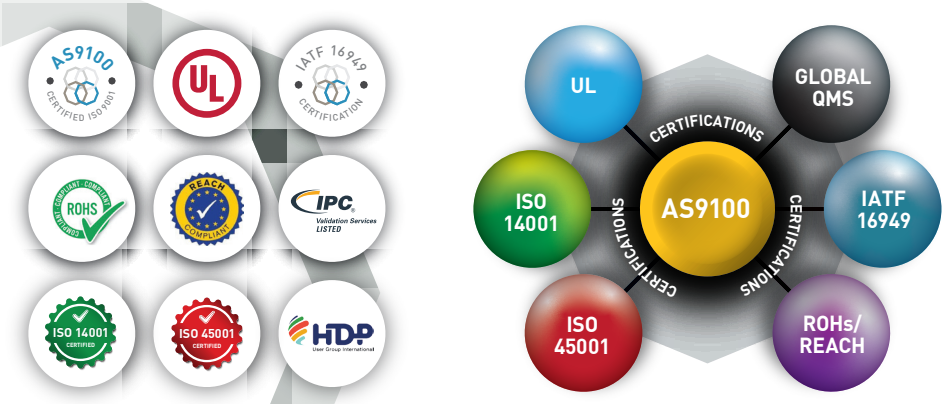


Figure 5:
Ventec is committed to meet the strictest industry requirements

Summary – A Brief Guide to Thermal Substrate and Vendor Selection

Read Datasheets

Read datasheets carefully to ensure that suitable test methodologies have been applied and that the latest specifications are referenced. Recent changes to specifications such as lifetime testing according to UL 746 can mean chosen materials fail to deliver the expected performance in the field.

Request Samples

Acquire samples and characterize any candidate materials to be sure of the expected performance in your application. Datasheets from different manufacturers may be more, or less, accurate and may not be directly comparable. They may reference different standards and test methodologies – such as ASTM D5470 and ISO 22007-2, for example. Ultimately, the material's performance in the real world is critical and cannot be anticipated entirely through desk research.

Carefully Select Your Vendors

Look for a vendor that can provide a differentiated product range that gives flexibility to get the performance best suited to your application requirements at a suitable price.

Assess More Specifications

As well as thermal conductivity/resistance values, consider other relevant parameters, including maximum operating temperature, CTE and the options available to help mitigate the effects of any mismatches.

Delve Even Deeper!

Also consider electrical characteristics, such as dielectric breakdown voltage: is the performance adequate, especially in a high-voltage application?

Don't forget the Supply Chain

Be sure that your chosen vendor has a robust supply chain. Ventec's ownership of the complete supply chain, from end to end, protects customers against shortages and fluctuations that can affect prices and deliveries.

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