SILATHERM®

创新的导热填料

Innovative thermally conductive filler concepts

Hidden inside – Performance outside!

HPF Minerals Ltd.

A SUBSIDIARY OF THE QUARZWERKE GROUP

HPF The Mineral Engineers 是 Quarzwerke 集团的一个部门，该部门着眼于未来，致力于在矿物学和合成基础上开发创新、功能性的高性能填料和添加剂。凭借数十年在矿物填料表面处理方面的经验，我们能够提供独特的系统解决方案。

HPF The Mineral Engineers is a division of Quarzwerke Group, which is looking toward the future with the development of innovative and functional high-performance fillers and additives on a mineralogical and synthetic basis. Decades of experience in surface treatment of mineral fillers have enabled us to supply unique system solutions.

Hidden Inside – Performance Outside

电气化的发展为母 粒 和化合物制造商开辟了新的业务领域。具有适当机械和物理性能的高质量塑料变得越来越受欢迎。

发热和有效散热不仅在汽车领域发挥着重要作用。它们在许多其他应用中也发挥着关键作用。例如，LED 被越来越多地用于现代照明技术。良好的热量管理直接关系到灯具的使用寿命。

导热塑料将在未来发挥越来越重要的作用，因为它们具有许多显著的优势。因此，SILATHERM® 产品系列被开发出来用于提高塑料的导热性。同时，这些矿物填料对电流具有绝缘作用，并可改善机械性能。

With increasing electrification, new fields of activity are opening for masterbatch and compound producers. Plastics with the appropriate mechanical and physical properties and high quality requirements are in demand.

Not only in automotive, the topic of heat generation and its effective dissipation plays an important role. A targeted heat dissipation is required for numerous other applications. For example, LEDs are increasingly being used in modern lighting technology, as good heat management is indispensable for the service life of the luminaires.

Heat-conductive plastics will therefore play an increasingly important role in the future, as their use creates a number of considerable advantages. Therefore the SILATHERM® product family was specially developed to improve the thermal conductivity of plastics. At the same time, these mineral fillers insulate against electric current and improve the mechanical properties.

塑料还是金属?

金属越来越多地被塑料取代，这不仅仅是因为塑料具有更高的成本效益。塑料还提供了设计复杂几何形状和系统集成的可能性。除了耐腐蚀和耐化学性外，在相同强度的情况下，它的重量也更轻。从长远来看，这些特性可以节省能源，最终对环境有利。

Plastic or metal?

Metals are increasingly being replaced by plastics, and not only because of their higher economic efficiency. Plastic production also offers the possibility of designing complex geometries and system integration. In addition to corrosion and chemical resistance, there is also a lower weight with partly comparable strength. In the long term, these properties can lead to energy savings, which is ultimately better for the environment.

碳足迹

我们用 SILATHERM® 制成的化合物与传统的铝产品进行了比较。温室效应结果为，每吨化合物产生了 2.8 吨的二氧化碳，而每吨铝产品则产生了 11 到 16 吨的二氧化碳*。这意味着，SILATHERM® 将塑料化合物在气候保护和温室效应方面的指数提高了4 到6倍*。如果对产品的几何形状（例如散热片）进行优化，指数可提高至8*倍，但具体取决于重量减轻的情况。

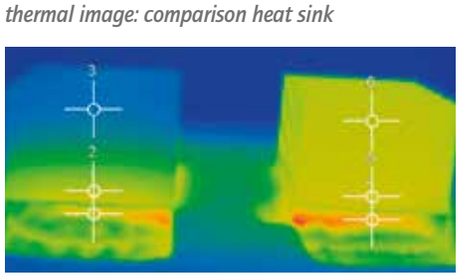
铝和 SILATHERM® 塑料散热片的比较（请参见下面的 IR 图像）表明，通过选择导热塑料和改变组件几何形状，可创建一种在技术和经济上可行的替代金属的解决方案。这项研究的细节可应要求提供。

Carbon Footprint

We compared a compound made with SILATHERM® with a conventional aluminium product. The greenhouse effect is 2.8 tonnes of CO_2 per tonne of compound while the comparable aluminium solution is 11 to 16 tonnes of CO_2 per tonne of product. This means that in a direct comparison, a plastic compound with SILATHERM® performs better by a factor of 4 to 6* in terms of climate protection and greenhouse effects.If the geometry of the product, e.g. of a heat sink, is optimised, the factor increases to up to 8* depending on the weight reduction.*

The comparison of the aluminium and plastic heat sinks with SILATHERM® (see IR image below) shows that the choice of a thermally conductive plastic in combination with a change in the geometry of the component offers a technically and economically sensible alternative to metal solutions. Details of this investigation are available upon request.

散热片的热图像比较
thermal image: comparison heat sink



复合材料 *composite*　　铝 *aluminium*

材料 | material	密度 | *density* [g/cm³]	导热率 | *thermal conductivity* [W/mK]
塑料 | *plastic*	1.13	0.22
铝 | *aluminium*	2.7	235
化合物 + 65m% SILATHERM®	1.9	1.3

*取决于重量和区域
**based on the weight and depending on the region*

选择的苦恼

- 塑料本身是绝缘体，导热率低，约为 0.2 W/mK。
- 为了增加它的导热率，必须向聚合物添加导热添加剂。
- 热传导是通过晶格振动（所谓的声子）进行。声子是弹性场的基本激发（量子）。
- 原子的运动从相邻原子传递到相邻原子。
- 电子牢固地结合在原子上，因此不能像导电固体那样额外地促进热传导。

The agony of choice

- *Polymers intrinsically have a low thermal conductivity of approx.0.2 W/mK.*
- *In order to increase this, thermally conductive additives must be added to the polymer.*
- *Heat conduction takes place through lattice oscillations, the so-called phonons. A phonon is the elementary excitation (quantum) of the elastic field.*
- *The movement of the atoms is transmitted from neighbour to neighbour.*
- *The electrons are firmly bound to the atom and therefore cannot additionally contribute to heat conduction, as is the case with electrically conductive solids.*

典型的添加剂是石墨、金属颗粒或陶瓷材料。选择合适的填料可以获得除导电外的其他金属材料所没有的特性。通过调整填料和填料量，通常可实现 1 到 20 W/mK 之间的导热率。

Typical additives are graphite, metallic particles or ceramic materials. When choosing the right filler, a combination of properties can be achieved that is not present in metallic materials because they also conduct the electric current. Depending on the filler and the quantity, the achievable thermal conductivity often ranges between 1 and 20 W/mK.

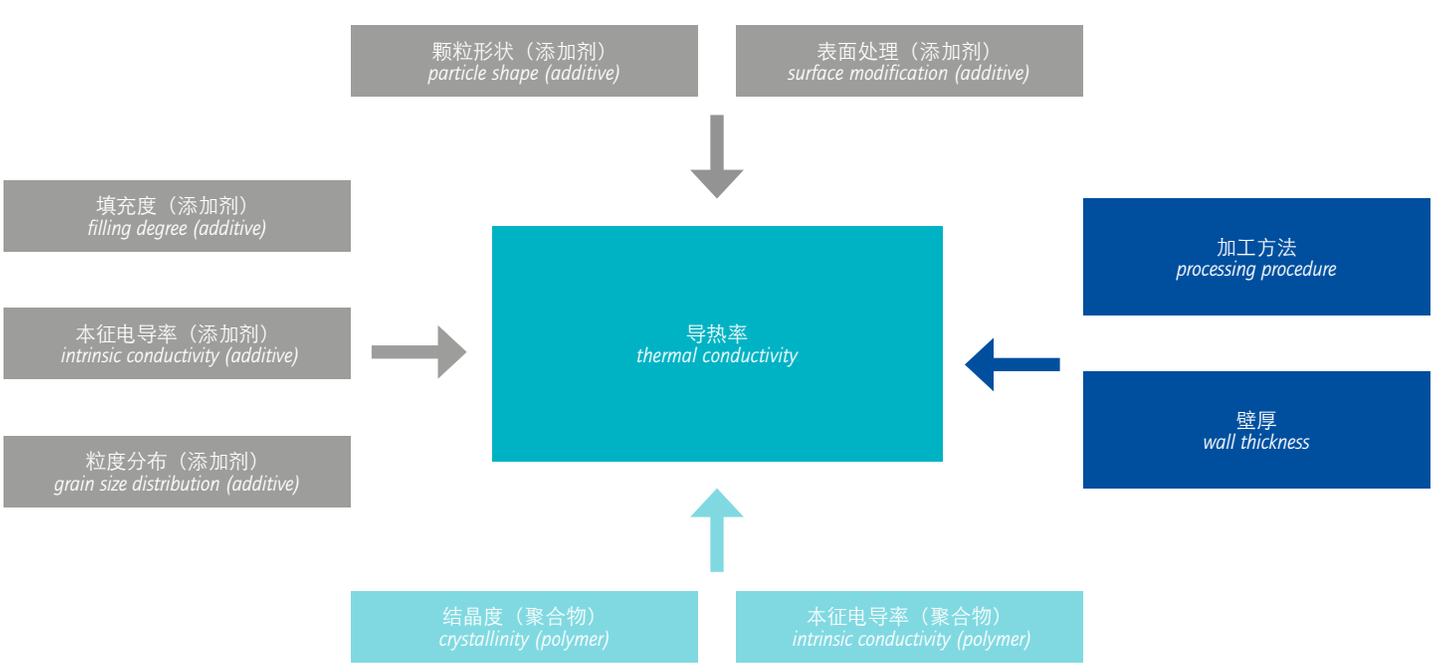
电导率和电阻 | *conductivity & resistance*

矿物 *mineral*		导热率 *thermal conductivity* / [W/mK]	电阻值 *electrical resistance* [Ω·m]
电绝缘 *electrically insulative*	氧化镁	*magnesium oxide*	30	10^{20}
	氧化铝	*aluminium oxide*	30	10^{12}
	氮化硼	*boron nitride*	30 ⊥; (400 ∥)	10^{13}
	氮化铝	*aluminium nitride*	180	10^{15}
	硅酸铝	*aluminium silicate*	14	10^{13}
	氧化锌	*zinc oxide*	30	10^{11}
	硫化锌	*zinc sulphide*	27	10^{11}
其他填料 *other fillers*		**导热率 *thermal conductivity* / [W/mK]**	**电阻值 *electrical resistance* [Ω·m]**
导电 *electrically conductive*	铜	*copper*	400	1.7×10^{-8}
	铝	*aluminium*	235	2.2×10^{-8}
	铁	*iron*	80	1.0×10^{-7}
	石墨	*graphite*	150	2.5×10^{-6}
	导电炭黑	*conductive carbon black*	15	5×10^{-5}
	银	*silver*	430	16×10^{-3}
	CNT（碳纳米管）		6000	10^{3}
	硅	*silicon*	150	10^{3}

填充度对导热率的影响

可实现的导热率取决于以下因素：

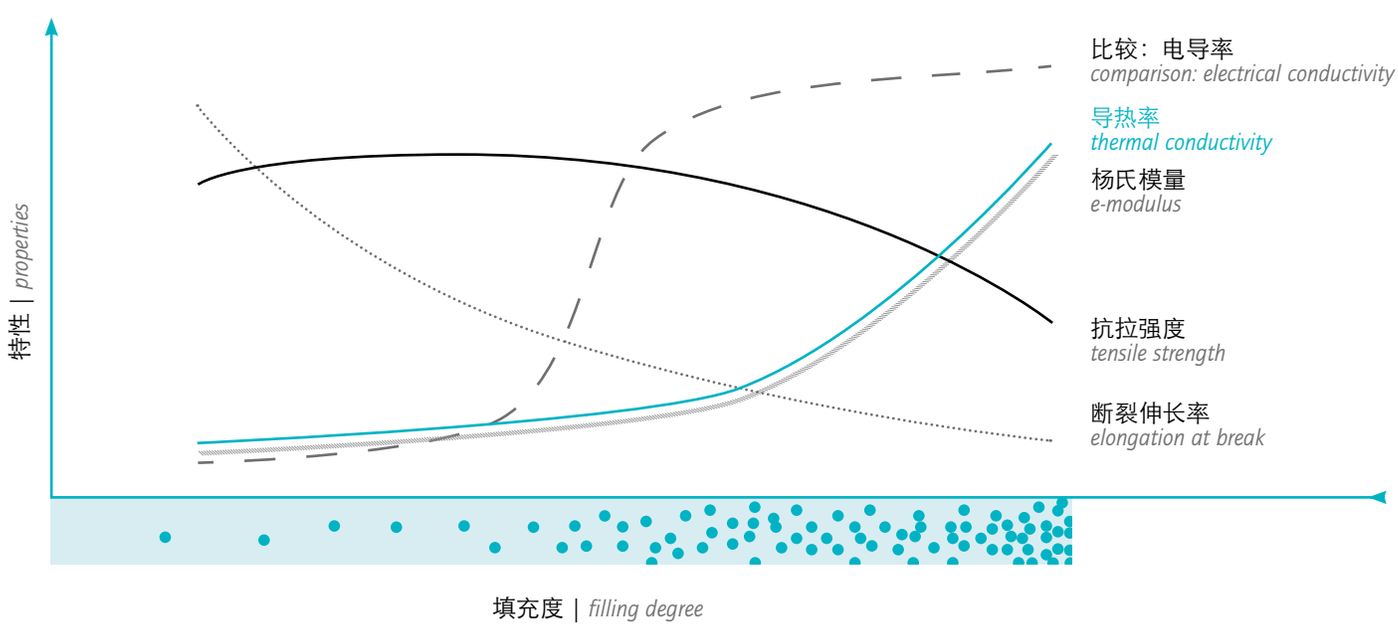
The achievable thermal conductivity depends on the following factors:



Influence of the filing degree on the heat conductivity

除导热性外，填料对其他特性也有很大影响。随着填料含量的增加，导热率成比例地增加。同时，导热塑料的可加工性降低。因此，在制造导热塑料时，必须在导热性、可加工性、机械性能和材料成本之间做出取舍。

In addition to thermal conductivity, fillers have a strong influence on other properties, too. With increasing filler content, the thermal conductivity increases proportionally. At the same time, the processability of the thermally conductive plastic decreases. Thus, when selecting a thermally conductive plastic, a compromise must always be made between thermal conductivity, processability, mechanical properties and material costs.



SILATHERM® 产品一览
Available SILATHERM® products at a glance

产品 product	SILATHERM®	SILATHERM® Lite	SILATHERM® Plus	SILATHERM® Ultra	SILATHERM® Next	SILATHERM® Extra
密度 *density* [g/cm³]	3.6	2.3	4	2.3	4	可定制 *customised*
中值粒径 *medium grain size* D_{50} [µm]	2 - 15	5 - 6	5 - 73	3 - 20	2.3	可定制 *customised*
莫氏硬度 *Mohs hardness*	5	6.5	9	1	9	可定制 *customised*
天然色 *intrinsic color*	浅灰至 浅棕色 *light greyish to light brownish*	白色 *white*	白色 *white*	白色 *white*	白色 *white*	浅色到白色 *light to white*
导热率 *thermal conductivity*	[W/mK]	[W/mK]	[W/mK]	[W/mK]	[W/mK]	[W/mK]
矿物 *mineral*	14	7	30	30⊥; (400∥)	30	可定制 *customised*
在热塑性塑料中 *in thermoplastics*	≤2.5	≤1.5	≤1.3	≤6.2	≤2.0	≤4.0
在热固性塑料中 *in thermosets*	>3.0	测量中 *in progress*	>4.0	测量中 *upon demand*	测量中 *upon demand*	>4.0
在胶粘剂中 *in adhesives*	>2.0	测量中 *in progress*	≤2.0	测量中 *upon demand*	测量中 *upon demand*	测量中 *upon demand*
在弹性体中 *in elastomers*	≤2.0	测量中 *in progress*	≤3.0	测量中 *upon demand*	测量中 *upon demand*	>4.0

所有列出的值都是参考值。系统的导热性主要取决于填充度、所用产品的纯度和颗粒形状。有关详细的技术数据， 请参阅应用说明。

All listed values are indicative. The thermal conductivity of a system depends mainly on the degree of filling, the fineness and the grain shape of the product used. Detailed technical information is available in form of technical application notes.

主要应用

- 导热热塑性化合物
- 导热环氧树脂材料
- 高能量密度的电气组件
- LED、传感器
- 微处理器、EMC、CCL
- TIM 材料

Key applications

- *thermally conductive thermoplastic compounds*
- *thermally conductive epoxy resin composites*
- *electrical components with high energy density*
- *light emitting diodes, sensors*
- *microprocessors, EMC, CCL*
- *TIM material*

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优势：

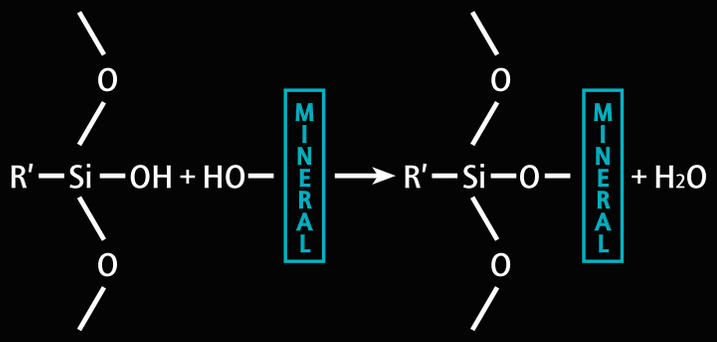
- 导热性显著增加
- 增强的抗热变形性、各向同性和抗翘曲性
- 与聚合物基质的良好融合
- 定制产品
- 高填充度下的出色可加工性
- 电绝缘
- 全球供应
- 高性价比

通过对聚合物体系进行特定的表面处理，甚至可以获得更好的性能。表面改性可以显著改善所有 SILATHERM® 产品的均质性。这可以实现更好的机械性能甚至更高的热导率。

Advantages:

- *significant increase in thermal conductivity*
- *increased heat distortion resistance, isotropy and warpage resistance*
- *excellent connection to the polymer matrix*
- *customised product adaptations*
- *excellent processability despite high filling levels*
- *electrical insulation*
- *worldwide availability*
- *good price/performance ratio*

Even better properties are achieved by surface treatment tailored to the polymer system. With all SILATHERM® grades, the surface modification can achieve significantly better homogenisation. This leads to better mechanics and even higher thermal conductivities.



矿物表面的硅烷化反应
Silan reaction at the surface of the mineral

硅烷化可获得更好的性能
Silanisation for even better properties

HPF Minerals Ltd.

09.2022

我们的一些产品根据欧洲 CLP 法规（EC/1272/2008）被划分为 STOT RE 1 类或 2 类。详情请参阅相应的材料安全数据表。
本应用报告中的数据在我们的认知范围内收集和编写。但是，我们要求大家理解，我们不为个别情况的结果以及建议的适用性和完整性承担责任，也不保证未侵犯任何第三方专利权。
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Some of our products are classified into the STOT RE cat.1 or 2 according to the European CLP Regulation (EC/1272/2008). More detailed information is available from the respective material safety data-sheet.
The figures documented in this application technique report were collected and shown to the best of our knowledge. However, we ask for understanding that we cannot take over liability for the results in individual cases and for the suitability and completeness of our recommendations, and cannot guarantee that no third-party patent rights are restricted.
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7F, Glaston Bldg.,
108 Bongeunsa-Ro,
Gangnam-Gu,
Seoul, Korea (06123)
Phone: +82-2-6490-9977
www.hpfminerals.kr

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A SUBSIDIARY OF THE QUARZWERKE GROUP