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Compounding WORLD

US COMPOUNDERS GATHER IN CLEVELAND

THERMALLY CONDUCTIVE DEVELOPMENTS

PPS COMPOUNDS ● MATERIALS TESTING

AMI
Bringing the plastics industry together

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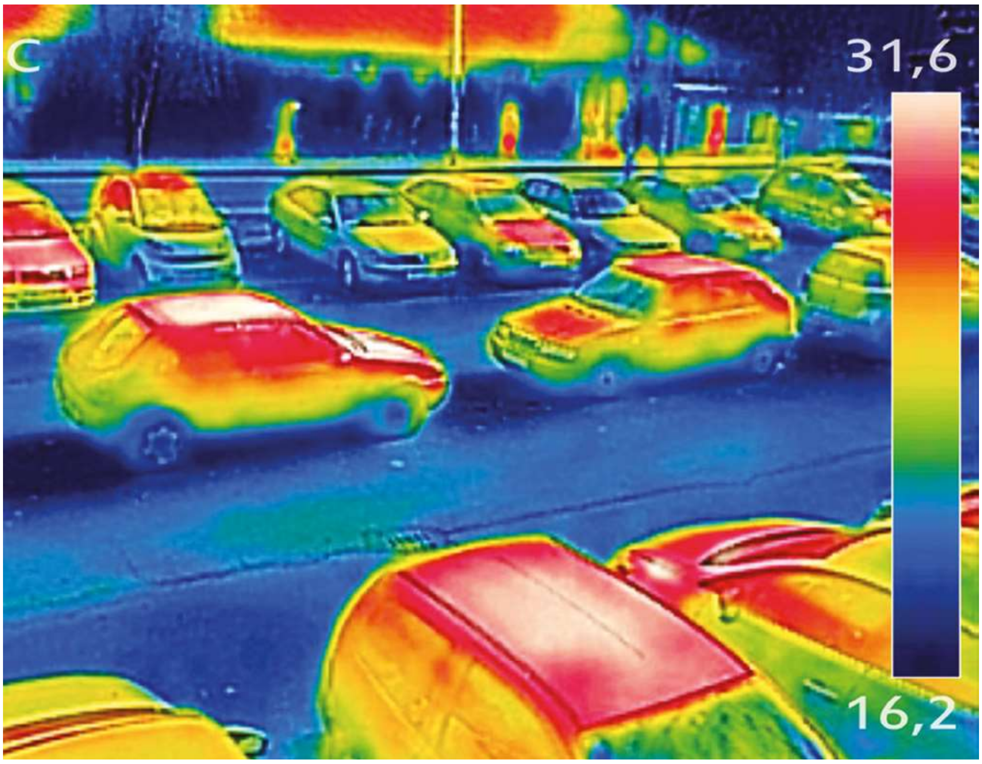

Applications for thermally conductive compounds are developing as their practical use becomes more extensively developed and understood. ***Mark Holmes*** *finds out more*

Keeping heat on the move

Plastics are not known for their thermal conductivity. However, interest in polymer compounds that offer enhanced thermal conductivity is developing as new applications emerge in areas ranging from automotive and electrical and electronics to medical devices and lighting. The move to reduced weight and the ongoing shift away from metals in many applications is also promoting their use. There are now a broad selection of additives available to improve thermal conductivity, but particular attention must be paid during compounding to ensure other important properties are not compromised.

The message from German company **Georg H Luh** is that while thermally conductive compounds have not yet reached mass market status, there are many interesting developmental projects currently going on in different industries. These projects will provide a boost to the thermally conductive compounds market and support further developments in the field.

Thermal management in the automotive industry is one area that is becoming increasingly important. "LED lights are getting more popular and have different requirements concerning heat management, which support the use of heat conductive compounds. In addition, battery systems in electric and hybrid vehicles create more heat than conventional battery systems, so there is a need for new concepts concerning heat management," says Klaus Rathberger, General Manager at Georg H Luh.

"Thermal management in the passenger cabin also becomes more important in electric vehicles because their use requires efficient usage of electrical battery energy. This provides great potential for intelligent solutions based on thermally conductive compounds. Similarly, the advantages of moulding, lightweight and corrosion-resistance will also support new applications in the chemical industry, for example," he says.

Rathberger believes that new thermally conductive compound solutions are going to require new additive developments. "Current additive solutions for thermal management are either efficient but costly, cheap but not efficient enough, or have other disadvantages like a major negative impact on the mechanical or corrosion properties of the compound," he says. "Some optimised additive solutions would be highly efficient, cheap and show only a small impact on the properties of the compound. There are unlikely

Main image: Automotive is expected to be a key market for thermally conductive plastics in the future

Right: LED lighting was one of the first high volume target markets for thermally conductive plastics


PHOTO: GEORG H LUH

to be many solutions covering all of these aspects, but there is a lot of potential to create optimally customised solutions for specific applications."

The company has developed a number of heat conducting mineral additive products to meet some of these challenging applications, according to Angelina Schöffel, Customer Support & Marketing. These include modified graphite grades – marketed as GraphTHERM and GraphCOND – which can improve thermal and electrical properties in plastics and coatings applications. GraphTHERM is optimised for the highest level of thermal conductivity, while GraphCOND is designed for good thermal conductive performance at low filling rates.

Graphene nanoplatelets have been developed as a high-end material for specific applications. These materials enhance high thermal and electrical conductivity in combination, while mechanical properties such as strength and surface resilience can also be improved. And MagTHERM is a white mineral additive that improves thermal conductivity while maintaining electrical insulation.

Ready-to-use solutions

According to HPF The Mineral Engineers, a division of **Quarzwerke**, there have been ongoing material developments in the thermally conductive compounds arena for more than a decade. However, these ready-to-use solutions did not make an appearance on the market. "The reason was quite simple. There were no reasonable applications to use a thermally conductive material, except for those that were electrically conductive at the same time," says Péter Sebö, Head of Marketing & Market Development.

"End-users and OEMs now realise the value of such compounds and are engaged in looking at and considering thermally conductive materials in more detail, in terms of changing the design or construction of a part that needs replacing or completely re-developed," he says. "Over the past two years, the market has moved noticeably towards thermally conductive compounds for a number of reasons. These include an increasing number of applications, while the fear of using thermally conductive plastics instead of metals is now decreasing. In addition, a wide range of grades is now available worldwide, and the know-how of different companies within the supply chain is increasing, which gives much needed security and guarantees."

Below: Georg H Luh offers a number of thermally conductive modified graphites


PHOTO: GEORG H LUH

E-mobility demands

E-mobility is currently one of the big driving forces in the development of thermally conductive compounds. "In electromobility, the objectives and achievements of future applications are closely linked to the use of new and innovative plastic materials and thermally conductive compounds will play an increasingly important role," says Sebö.

"The number of E&E applications in terms of automation, communication and security components is steadily increasing in the car of the future, particularly in e-mobility. The issue of heat generation and its effective conduction is a major challenge in many of these applications. In addition, in alternative power drives, battery technology has potential for heat conductive plastics, for example in battery housings and other components, as well as in the still costly and complex battery cooling systems. At the same time, a good choice and combination of plastics and fillers may offer a technical and economic alternative to metal. The resulting weight reduction can help to improve the reach of electrical cars," Sebö says.

"In addition, new developments in E&E, such as electrical tools, medical devices, lighting applications and tribology, are expanding the role of thermally conductive plastics. The increasing desire for higher levels of integration and downsizing of functional components requires the use of novel plastics for the realisation of highly functional system solutions. Thermally conductive plastics allow the possibility of achieving the required mechanical properties, heat dissipation function and electrical insulation in one automated production step. Design freedom and the good integration potential of plastics can be combined with effective heat dissipation and homogeneous temperature distribution," he explains.

According to Sebö, there are many new potential application areas that use high energy density electrical components – such as processors, light emitting diodes, electric motors, batteries and electronics – where efficient heat dissipation is required while maintaining electrical insulation. Integration of heat management/heat sinks into housings or enclosures, for example.

Processing considerations

"In addition, other considerations include processing or the targeted thermal conductivity of different additives and inorganic fillers, depending on the mechanical requirements," he says. "Independent of what kind of filler or additive is used to increase the thermal conductivity of the polymer, the main function must be adhered to. This means the higher the fill; the better the thermal conductivity. However, this will influence other material properties, such as mechanical. Processing is also influenced with an increased degree of filling. Furthermore, filler properties have to be considered in terms of density, hardness, grain size, colour, morphology and obviously price."

HPF The Mineral Engineers introduced its Silatherm product range in 2013. The company says that the fillers provide well balanced properties in a variety of polymer systems, including thermoplastics, thermosets and elastomers. The range can provide colourable solutions that offer good electrical insulation. Grain size can be optimised with bi- or tri-modular grain size distribution while surface treatment technology


PHOTO: SHUTTERSTOCK

Above: Thermal management is a key requirement in batteries for electric vehicles

is used to expand possible applications and various filler blends. Ready-to-use solutions are available and higher thermal conductivity products offering isotropic properties have been developed that are said to offer a good mechanical property/ price balance.

The latest product introductions include Silatherm 1466, which is based on alumosilicate. The company says that the 1466 grade is chemically similar to its standard Silatherm 1360 product but is much brighter in colour and offers better mechanical properties in compounds. A low grain size distribution of around an average 1.5 microns is offered. The Silatherm 1466-506 grade features a bi-modular grain size distribution.

The Silatherm Plus 1443 range is based on aluminium oxide and is said to provide a special morphology and tri-modular grain size distribution. This grade is particularly recommended for thermoset applications requiring higher fill densities, where it can achieve thermal conductivities of between 4–6 W/mK. The company says that a new Silatherm range and a number of experimental grades will be released at the upcoming K2019 trade show in Germany in October, where it will also show some new application examples.

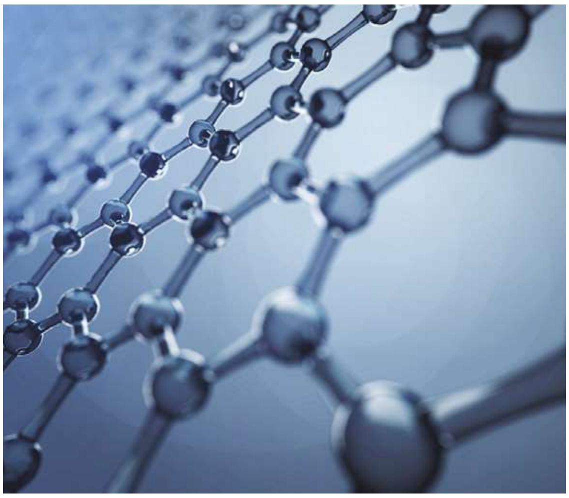

PHOTO: SHUTTERSTOCK

Right: Graphene is seen as a promising option for enhancing thermal conductivity

Polyamide options

Huber Martinswerk, part of the Huber Engineered Materials division of J M Huber, has developed its series of Martoxid alumina-based thermally conductive powders for modification of a range of polymers. It says that the Martoxid TM-4000 series products are specially designed for polyamides. The latest addition to the series is Martoxid TM-4250, which is said to increase orientation independent (isotropic) thermal conductivity in PA6 and PA66 to 2.5 W/mK (in-plane and through plane). Addition levels of up to 75 wt% are said to combine with low viscosity and good flowability, allowing higher throughputs during extrusion at lower energy consumption.

PHOTO: WITCOM ENGINEERING PLASTICS

Below: An LED heat sink produced in a halogen free, flame retardant, thermally conductive PA6 compound from Witcom

According to Huber, tests conducted at Fraunhofer LBF in Germany on PA6 compounds confirm that the abrasion level of Martoxid TM-4250 is low (the company says it is much less abrasive than fillers with a lower Mohs hardness such as aluminosilicate and glass fibre). The morphology and surface treatment of Martoxid TM-4250 is claimed to enable formulators to achieve good elongation at break and Charpy impact results.

Huber says that the optimised rheological behaviour of the Martoxid TM-4000 series means they can be successfully employed in compounds for injection moulding of sub-millimetre wall thicknesses using standard moulding techniques. In addition, injection moulding production processes show a reduced cycle time of up to 50% compared to standard polyamide parts as a result of the faster cooling times possible from the higher thermal conductivity.

Developing applications

While there are currently only a limited number of applications, thermal conductive plastic is an area seeing increased interest and more applications should develop in the near future, agrees Christine Van Bellingen, Business Development Manager at **Witcom Engineering Plastics**. "The demand is primarily driven by metal replacement for weight reduction and the need for heat dissipation in more confined spaces. However, there are probably still some technological and commercial barriers preventing quicker market development, and the thermally conductive additive producers still have some room for innovation," she says.

"The original demand for thermally conductive plastics for LED lamps has become a commodity market, where high levels - above 50 wt% - of the

PHOTO: SHUTTERSTOCK

Above: Many electronic applications will require thermal conductivity, electrical insulation and flame retardance

cheapest thermally conductive additives are used, or alternatively a thin metal layer is applied on virgin plastics," Van Bellingen says.

The combination of the known benefits of plastics with a better understanding of thermal system design is likely to help polymer-based application development. "Plastics solutions are ideal for overcoming the drawbacks of metal and offer corrosion resistance, lightweighting opportunities and a high degree of design freedom. It is now better accepted by industry that high metal thermal conductivity is not necessary to get outstanding heat dissipation from filled plastics; values below 5 W/mK and even between 1-2 W/mK through-plane can be enough to dissipate heat efficiently. While high levels of thermally conductive additives are still necessary to get the required performance, this may result in some brittleness especially when dispersibility or 'adhesion' with the plastics matrix is not optimal. When lower additive loadings can do the job, for example with expanded graphite, then higher viscosity will occur," Van Bellingen explains.

Formulation experts

"This is where a speciality plastics compounder can play the role of a formulation expert to overcome these drawbacks and deliver a correct, workable, solution," she says. "At Witcom, we develop customised compound solutions. For example, we have developed polyamide grades, all reinforced, that are thermally and electrically conductive, or thermally and electrically insulative, with some with halogen-free flame retardancy. As a customised engineering plastics compounder, we can develop any thermally conductive formulations based on various plastics, such as PA, PBT, PPS, PC and PEI."

Van Bellingen adds that graphene is increasingly being talked about as promising high tech theoretical solution. "As a compounder, the major technical criteria for thermally conductive additive selection include easy feedability, good dispersion that also influences mechanical strength, and impact on the rheology. Using lower additive levels – in the 10-20% range – is welcome, providing other properties can be maintained," she says.

Witcom says existing and potential applications for thermally conductive compounds include computer heat sinks, outdoor light housings, back parts of industrial cameras, and cooling parts for automotive batteries and engines. The materials can also find applications in parts that require a metal-like cool touch (thermal conductivity is a key factor in the surface haptic).

Future applications will, however, require a combination of material characteristics. "There will be increased needs for electrical conductivity, thermal conductivity, flame retardancy and EMI shielding, as related to e-mobility – electric and hybrid cars, autonomous driving, lightweighting and metal replacement, and higher safety concerns. Higher battery power, wider use of heat sensitive electronics and sensors, and the trend for smaller parts will call for more speciality plastics compounds with the combined properties of thermal conductivity and EMI, thermal conductivity, with EMI and flame retardance, and with electrical conductivity and flame retardance," Van Bellingen predicts.

Functionality matters

With increasing functionalisation of plastics in applications such as electronics and transportation, in particular, there is certainly a notable market demand for thermally conductive compounds, according to Sebastian Heitkamp, Global Marketing Segment Manager at **Cabot Corporation**. "The main trends are electrification of cars and increasing requirements with automotive and electronics 'merging' these two major plastic applications," he says.

Thermal management in the car is becoming more important as the batteries provide a new source of heat, Heitkamp explains. And as batteries are integrated into the structure of the vehicle, designers and plastic engineers will have to solve the heat transfer through plastic materials.

"Traditional and new additive solutions must not only perform in their thermally conductive behaviour, but must also function properly with additional levels of other additives such as stabilisers or flame retardants. With the growing need for functional plastics in demanding applications, the interaction between different filler types and additives must be understood to optimise the performance. There is also the additional need to consider how all these additives may impact the end products' mechanical properties, as well as how these raw materials interact with each other," Heitkamp says. "In addition, with the growing use of recycled grades, there is a need to analyse how thermal conductive additives will work with impurities."

Cabot has developed a range of thermally conductive compounds based on engineering thermoplastics with different formulations and specific additives. The most prominent recent development is a partial replacement of boron nitride, one of the more established thermally conductive additives. "With recent advances in nanomaterials we are addressing the need to develop solutions that have less impact on mechanical properties and at the same time are optimal in their conductive performance. A combination of traditional materials with the newly developed additives looks the most promising option," he says.

Lighting innovation

Italian compounder **LATI** recently provided a thermally conductive compound for use in a new LED lighting system produced by Romanian manufacturer Electromagnetica. Rapid evolution of LED lighting systems has led to development of increasingly powerful devices suitable for replacing conventional light sources even in the most challenging applications, for example lights for public and industrial use. The typical devices used in this sector are COB (Chip On Board) LEDs, where numerous diodes are joined together and mounted on the substrate to form a single large source.

LATI says the advantages of COB LED solutions include a reduction in the number of components, fewer welded joints, absence of lenses and higher light density. Management of the heat generated by such a structured system is vital for long service life and aluminium heat sinks have been considered as the only option for the maximum junction temperatures close to 150°C.

Below: The heat sink on Electromagnetica's industrial COB LED projector lamp is moulded in thermally conductive PA6 from Lati


PHOTO: LATI

Electromagnetica, however, decided to use a thermally conductive plastic compound to develop its latest COB LED industrial projector, completing rigorous simulations and experiments to evaluate cooling performance and emitted light quality. The result is the Castor 2M, an industrial projector that houses two COB modules for a total power close to 70W. Technical simulation showed that a thermally conductive polymer heat sink would handle the large amount of heat generated in operation provided that the geometry of the radiating elements and the interface between the PCB substrate and the thermoplastic compound was suitably configured.

Electromagnetica selected LATI's Laticonther 62 GR/70, which is a PA6-based compound with 70% graphite filler. The average thermal conductivity of this material is close to 10 W/mK, even at high ambient temperatures and regardless of the orientation of the graphitic flakes. The thermal conductivity of alloys normally used to manufacture heat sinks is close to 150 W/mK, while that for pure aluminium is 237 W/mK.

The key to the performance of the heat sink is in the optimisation of the design; the thickness of the heat sink base as well as the shape and spacing of the fins have been carefully calculated for the most effective performance. In particular, an understanding of the thermal phenomena at the base was fundamental as radiation contributes in a similar way to convection in cooling. The higher heat capacity of plastics over alloy alternatives is also a valuable advantage as it reduces the thermal load to be transferred due to the increased heat storage capability of the sink. Laticonther advantages include low mould shrinkage and good dimensional stability required for assembly, and reduced weight due to its density, which is close to half that of aluminium. As a result of this optimised design process, the Castor 2M is able to provide a minimum luminous flux of 8000 lm without the junction exceeding a temperature of 80°C.

CLICK ON THE LINKS FOR MORE INFORMATION:

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