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Highly Filled Polymers

Thermal Conductivity for LED Systems and 3D-MID Technology

Barcode zu Ansprech- partner und Infomaterialien

Motivation

Due to the limited mechanical, thermal and electrical properties of pure polymers, different types of fillers are used to tailor them to specific uses. In addition to the type of filler, the filler concentration also has a major influence on the properties of the plastics (Fig. 1). In the case of modern electronics, the removal of resulting heat loss is becoming more and more important. Particularly thermo-sensitive semiconductor devices, such as light-emitting diodes (LED), require efficient thermal management. Currently, light-emitting electronics with high performance LEDs are usually integrated into modular assemblies. Manual assembly processes are cost-intensive and the mostly poor thermal transitions result in thermally hot spots which may lead to thermal caused degradation and therefore failure of the component.

Application

New high performance LED systems based on thermal conductive polymers are planned to replace classical modular assemblies with hybrid material combinations in course of a lean approach. Therefore, solderable and thermally conductive thermoplastics are required, which work as both interconnecting device and simultaneously heat sink (e.g. Polyamid 66 (PA66), Polyphthalamide (PPA), Liquid Crystal Polymer (LCP)) (Fig.2).
In addition to the reduction of labour-intensive assembly processes, the plastic-based approach offers improved thermal management. Furthermore polymers can achieve weight savings and corrosion resistance.
Processing of thermally conductive polymers via injection molding allows for a high cost efficiency and the possibility of innovative design and shape, especially for high unit volumes. Also, centerings, fasteners or plugs can be easily integrated into the part. Moreover, thermally conductive polymers can be used for the housing of the parts, enabling further thermal improvements of the device.

Conductive Polymers

In order to achieve sufficient thermal conductivity, the polymer has to be functionalized using fillers (Fig. 3). If an electric insulation is required simultaneously, ceramic fillers such as boron nitiride or aluminum oxide can be used. However, the achievable thermal conductivity with these materials is low compared to metals or carbon derivates fillers.

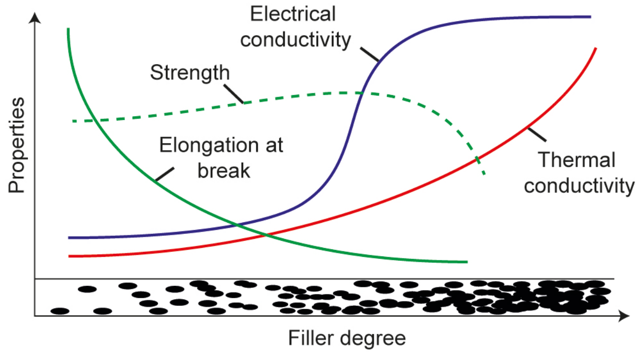

Fig. 1: Influence of filler degree on the properties of a plastic material

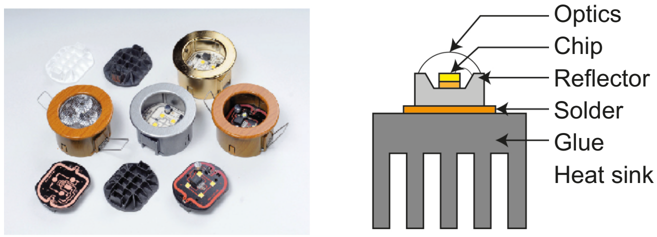

Fig. 2: High performance LED system based on thermally conductive plastics consisting of Molded Interconnect Device, housing and optics [Courtesy of RF Plast GmbH and Dommel GmbH]

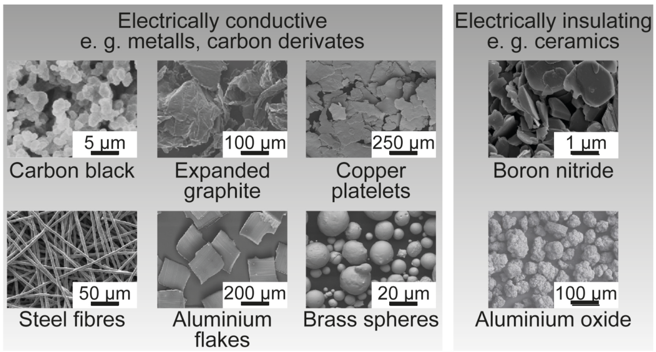

Fig. 3: Overview of common thermally conductive fillers, differentiated by their electrical conductivity

If no electrical insulation is required, electrically conductive fillers can be used, which are significantly cheaper and far less abrasive during processing. Electrically conductive plastics are commonly used in anti statics, electromagnetic shielding or conductive adhesives.

The thermal conductivity inside plastic parts is decisively influenced by the properties of the polymer and content, type and geometry of the fillers. Anisometric fillers (e. g. fibers or platelets) are oriented during processing procedures such as injection molding. This generates different thermal conductivities in the different spatial directions (Fig. 4). With spherical particles, however, the thermal conductivity of the spacial directions is not affected by the generation process. The maximum attainable thermal conductivity in flow direction is approximately up to 5 W/(mK) for hexagonal boron nitride and up to 20 W/(mK) for graphite.

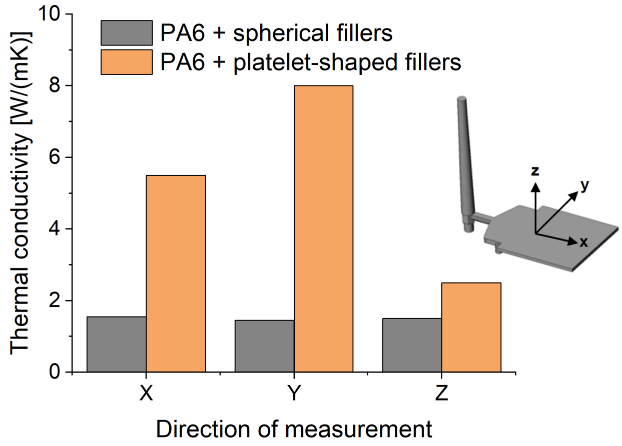

Fig. 4: Influence of the filler shape on the thermal conductivity ininjection-molded samples of Pa6

Manufacturing Processes (3D-MID)

In addition to increasing heat dissipation in LED systems, thermally conductive plastics also support a constructive use as three-dimensional molded interconnect devices (3D MID). Various production methods to apply conductive paths onto polymer substrates each with different technological and economical advantages are readily available and can be chosen depending on the application (Fig. 5). Thermally conductive polymers with electrically insulating fillers can be processed in two component injection molding, hot embossing, laser structuring, plasma structuring and printing. Using multi-layer setups, plastics with and without electrically conductive fillers can be combined to optimize thermal management while maintaining electrical insulation where contact to circuits is given.

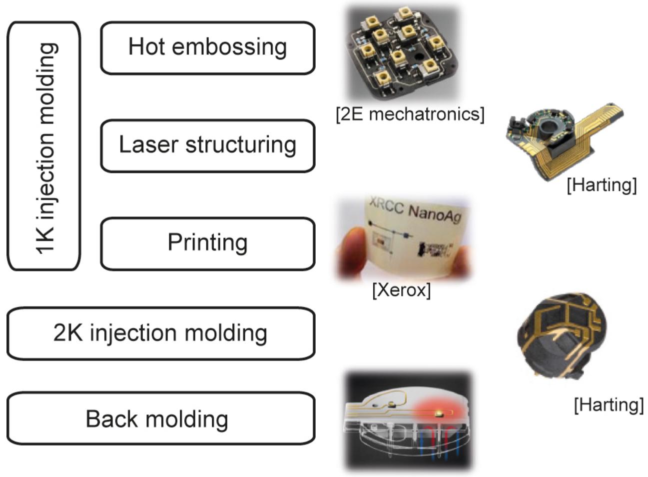

Fig. 5: Overview of 3D-MID metallization technologies

Design for X

Based on the requirements of the application, such as the optical target function (e.g. luminous flux per area) as well as the predominant thermal and geometric conditions at the installation point (e.g. ambient temperature), it is necessary to formulate design and technology guidelines for every step of the product design. Moreover, it is essential to merge these guidelines into a design ckecklist, if necessary as an iterative approach. This checklist consists, among others, of the thermal design, the assembly, the deflection of thermally conducting paths and heat sink structures, the curcuit design, adapted to the metallization process, as well as the product design. The structure of a high performance LED system based on thermally conductive polymers is shown in Fig. 6.

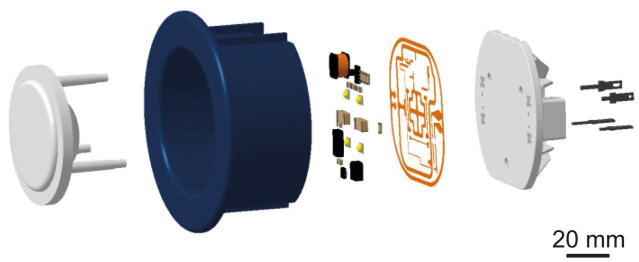

Fig. 6: Structure of a high performance LED system based on thermally conductive polymers

Thermal Management

Previous studies carried out at the LKT on the heat dissipation of high performance LEDs by thermally conductive polymers show that small to medium dissipation losses, assuming free convection at room temperature, can be transferred into the environment. However, successful implementation is based on the exact knowledge of material and process-specific influences.

Research Objects and Service for Industry

- Injection molding of highly filled plastics
- Devolopment of thermal conductive plastics
- Microscopic analysis of filler distribution and orientation
- Thermal analysis (e.g. heat capacity, thermal conductivity)
- 3D MID technology
- Failure analysis

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