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[Continued on nextpage]

(54) Title: A POLYMERIC HEAT DISSIPATION DEVICE, METHODS OF MAKING AND OF USING THE SAME

(57) Abstract: In an embodiment, a heat dissipation device, comprises a baffle and an optional disk (2); wherein the heat dissipation device is defined by one or more of the baffle being a multi-layer baffle comprising an inner layer (20) and an outer layer (21), wherein the in-plane thermal conductivity of the inner layer is greater than the in-plane thermal conductivity of the outer layer, wherein the through-plane thermal conductivity of the inner layer is greater than the through-plane thermal conductivity of the outer layer; the disk (2) being present, wherein the disk (2) is a thermally conductive disk; and the baffle having a tapered wall thickness.

Fig. 2
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A POLYMERIC HEAT DISSIPATION DEVICE, 
METHODS OF MAKING AND OF USING THE SAME

TECHNICAL FIELD

[0001] Disclosed herein is a heat dissipation device and a method of making and using the same.

BACKGROUND

[0002] Light emitting diodes (LEDs) are currently used as replacements for incandescent light bulbs and fluorescent lamps. LEDs are semiconductor devices that emit incoherent narrow-spectrum light when electrically biased in the forward direction of their PN junctions, and are thus referred to as solid-state lighting devices. The high power LED light devices produce considerable amount of heat, which can cause performance degradation or even damage if the heat is not removed from the LED chips efficiently. In an LED light device, the core is an LED chip mounted on a substrate. A transparent top covering the LED chip serves as a lens for modifying the direction of the emitted light. Although there are many different designs, the major heat dissipation route for the heat produced by the LED chip is usually managed through the base to which the LED chip is mounted or through an additional metal heat dissipation device below the base and then to an outer heat dissipation device.

[0003] One approach for dissipating heat from LEDs is to include die cast material, such as aluminum, as a heat dissipation device material for LED applications. However, due to poor electrical insulation, poor processability, design constraints, and costs, alternative designs to heat dissipation devices employing die cast materials are being sought.

[0004] Another approach involves a hybrid metal/polymeric material heat dissipation device. However, metal insert hybrid designs can be limited by the compatibility between the inserted metal and overmolded plastics. Thus, poor compatibility can lead to cracking after molding or endurance testing (heat shock, hydro aging, and the like). In addition, poor compatibility and adhesion between the metal and the plastic can cause delamination and cavities between the layers, which may significantly decrease the efficiency of the heat dissipation device. Furthermore, aging tests for metal insert hybrid designs have resulted in yellowing and cracking. Also, due to the poor flowability of the heat conductive materials, it is difficult to produce thin parts and achieve the goal of meeting performance standards and cost-saving.
Accordingly, there is a need for simplified LED packages having one or more of reduced weight, better processability, greater design freedom, and compatible materials.

BRIEF DESCRIPTION

[0006] Disclosed, in various embodiments, are heat dissipation devices and methods for making and using the same.

[0007] In an embodiment, a heat dissipation device comprises an inner layer comprising a first polymeric material; an outer layer comprising a second polymeric material; and wherein the in-plane thermal conductivity of the first layer is greater than the in-plane thermal conductivity of the second layer, wherein the through-plane thermal conductivity of the first layer is greater than the through-plane thermal conductivity of the second layer. The heat dissipation device can optionally comprise a disk.

[0008] In an embodiment, a heat dissipation device, comprises a baffle and an optional disk, wherein the optional disk is concentrically located at a first end of the baffle; and wherein the heat dissipation device is defined by one or more of the baffle being a multi-layer baffle comprising an inner layer and an outer layer, wherein the inner layer comprises a first polymeric material having a through-plane thermal conductivity of at least 2 or at least 3.5 W/mK and an in-plane thermal conductivity of at least 10 or at least 15 W/mK; wherein the inner layer has a thickness of greater than or equal to 1.5 mm, wherein the outer layer comprising a second polymeric material having an in-plane thermal conductivity of at least 0.2 W/mK and a through-plane thermal conductivity of at least 0.2 W/mK, wherein the in-plane thermal conductivity of the first layer is greater than the in-plane thermal conductivity of the second layer, wherein the through-plane thermal conductivity of the first layer is greater than the through-plane thermal conductivity of the second layer; the disk being present, wherein the disk is a thermally conductive disk with a through-plane thermal conductivity of at least 2 W/mK or at least 3.5 W/mK and an in-plane thermal conductivity of at least 10 or at least 15 W/mK; and the baffle having a tapered wall thickness such that a first wall thickness at the first of the baffle has a thickness of 2 to 10 mm and a second wall thickness at a second end of the baffle has a thickness of 0.1 to less than 2 mm.

[0009] In an embodiment, an LED illuminating device comprises the heat dissipation device.

[0010] In an embodiment, a light emitting device comprises the heat dissipation device, an electrical connection configured to electrically connect with a light source, wiring
connected to the electrical connection and configured to provide electricity to the light source, and a lens.

[0011] In an embodiment, a method of manufacturing the heat dissipation device comprises disposing a first material comprising one of the first polymeric material and the second polymeric material into a mold; molding a second material comprising the other of the first polymeric material and the second polymeric material onto the first material to form the baffle; removing the baffle from the mold; and disposing the disk concentrically in the baffle.

[0012] In an embodiment, a method of manufacturing the heat dissipation device comprises injecting the first polymeric material and second polymeric material into a mold via two separate injection units; and removing the heat dissipation device from the mold.

[0013] The above described and other features are exemplified by the following figures and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The patent or application file contains at least one drawing executed in color. Copies of this patent or application publication with color drawings may be provided by the Office upon request and payment of the necessary fee.

[0015] Refer now to the figures, which are exemplary embodiments, and wherein the like elements are numbered alike and which are presented for the purposes of illustrating the exemplary embodiments disclosed herein and not for the purposes of limiting the same.

[0016] FIG. 1 is a cross-sectional front view of an embodiment of a heat dissipation device for an LED light of the prior art;

[0017] FIG. 2 is a cross-sectional front view of an embodiment of a heat dissipation device for an LED light;

[0018] FIG. 3 is a simulated temperature profile of a device of FIG. 1;

[0019] FIG. 4 is a simulated temperature profile of a device of FIG. 2;

[0020] FIG. 5 is an illustration of the heat dissipation device of Examples 61-72; and

[0021] FIG. 6 is a graphical illustration of the temperature profile through the baffle wall thickness of Examples 61-64.

DETAILED DESCRIPTION

[0022] FIG. 1 illustrates a typical aluminum/polymeric material hybrid heat dissipation device for an LED bulb. As shown in FIG. 1, the heat dissipation device includes inner layer 10 and outer layer 11. Inner layer 10 includes aluminum. Outer layer 21 includes
a polymeric material such as PX13322 and PX11313 available from SABIC’s Innovative Plastics business. The heat dissipation device of FIG. 1 can result in one or more of cracking after molding or endurance testing, poor compatibility or adhesion between the metal and the plastic causing delamination and cavities between the layers, yellowing, and an inability to utilize thin parts. One or more of these disadvantages was overcome by the present heat dissipation device, also referred to herein as heat sink and heat sink assembly comprising a polymeric dissipation baffle (also referred to herein as the baffle) and a polymeric disk, wherein the disk is concentrically located at a first end of the baffle. It is believed that the favorable results obtained herein, e.g., a low cost, production efficient heat dissipation devices with high heat dissipation efficiency, can be obtained through one or more of a baffle comprising a polymeric inner layer with a high thermal conductivity, overmolded with an outer layer with a lower thermal conductivity; a thermally conductive disk; and a wall taper. When the baffle includes two or more layers, the baffle can be formed through overmolding or 2K techniques. It is noted that other layers can be present and that the inner layer is not necessarily the inner-most layer and that the outer layer is not necessarily the outer-most layer.

[0023] For example, FIG. 2 illustrates a polymeric heat dissipation device comprising a baffle with inner layer 20 and outer layer 21. Inner layer 20 can include a high thermal conductive polymeric material. For example, inner layer 20 can include a polycarbonate base polymeric material (e.g., polycarbonate) with a conductive filler. Inner layer 20 can have a through-plane thermal conductivity of at least 3.5 Watts per meter-Kelvin (W/mK). Inner layer 20 can have a thickness of greater than or equal to 1.5 millimeters (mm). Outer layer 21 can comprise a polymeric material having an in-plane thermal conductivity of greater than or equal to 0.2 W/mK and can be overmolded onto inner layer 20. Outer layer 21 and inner layer 20 can be made through a 2K process or an overmolding process. Outer layer 21 can include the same base polymeric material as inner layer 20 (e.g., polycarbonate). The heat dissipation device can comprise disk 2 that can be a thermally conductive disk. One or more LED lights can be located on the disk.

[0024] The heat dissipation device can include a baffle with one or more layers. For example, the heat dissipation device can include an inner layer and an outer layer. The inner layer can include a first polymeric material and the outer layer can include a second polymeric material. The first polymeric material can comprise a thermally conductive filler. When the thermally conductive filler has a non-spherical shape, for example, with a long axis
and short axis, then the filler can be oriented in the layer and the layer can have an in-plane thermal conductivity and a through-plane thermal conductivity. As used herein the in-plane thermal conductivity refers to the thermal conductivity as measured parallel to a broad surface of a layer and the through-plane thermal conductivity refers to the thermal conductivity as measured perpendicular to a broad surface of a layer. For example, FIG. 5 illustrates a through-plane conductivity \( k_t \) and in-plane conductivities \( k_2 \) and \( k_3 \). The in-plane thermal conductivity and the through-plane thermal conductivity of the inner layer can be greater than the in-plane thermal conductivity and the through-plane thermal conductivity of the outer layer, respectively. The outer layer in-plane thermal conductivity and through-plane thermal conductivity can be within 1% of each other, e.g., they can be the same.

[0025] The inner layer can have a through-plane thermal conductivity of greater than or equal to 3.5 W/mK and an in-plane thermal conductivity of greater than or equal to 15 W/mK. The inner layer can have a through-plane thermal conductivity of greater than or equal to 5 W/mK and an in-plane thermal conductivity of at least 20 W/mK. The inner layer can have a through-plane thermal conductivity of greater than or equal to 7 W/mK and an in-plane thermal conductivity of at least 30 W/mK. The outer layer can have an in-plane thermal conductivity and a through-plane thermal conductivity of at least 0.2 W/mK. The outer layer can have through-plane thermal conductivity of at least 0.7 W/mK and an in-plane thermal conductivity of at least 1.2 W/mK. The outer layer can have a through-plane thermal conductivity of at least 1 W/mK and an in-plane thermal conductivity of at least 1.4 W/mK. The outer layer can have a through-plane thermal conductivity of at least 1.2 W/mK and an in-plane thermal conductivity of at least 1.8 W/mK. The outer layer can have a through-plane thermal conductivity of at least 1.4 W/mK and an in-plane thermal conductivity of at least 2 W/mK.

[0026] The through-plane thermal conductivity of the inner layer can be greater than the through-plane thermal conductivity of the outer layer. The in-plane thermal conductivity of the inner layer can be greater than the in-plane thermal conductivity of the outer layer. The outer layer can have a through-plane thermal conductivity of less than or equal to 3 W/mK. The outer layer can have a through-plane thermal conductivity of less than or equal to 2 W/mK. The outer layer can have an in-plane thermal conductivity of less than or equal to 10 W/mK. The outer layer can have an in-plane thermal conductivity of less than or equal to 5 W/mK. The inner layer can have a through-plane thermal conductivity and an in-plane thermal conductivity of less than or equal to 500 W/mK.
[0027] The wall thickness of the baffle can be constant from a first end proximal to the disk to a second end distal from, for example, the disk. For example, wall thickness can be 0.5 to 10 mm. If the baffle comprises both an inner layer and an outer layer, then each layer independently can have a wall thickness of 1 to 9.5 mm. The wall thickness of the baffle can change from a first end proximal to the disk to a second end distal, for example, from the disk, referred to herein as a tapered wall thickness. Even though the wall thickness of the baffle can vary, the wall thickness at any location can be 0.5 to 10 mm. The wall thickness of the baffle can decrease from a first end proximal to the disk to a second end distal, for example, from the disk. The wall thickness at the first end can be 10 to 2 mm. The wall thickness at the second end can be 0.1 to less than 2 mm. The wall thickness can change as a linear function with distance from the disk or as a non-linear function.

[0028] The inner layer can have a thickness that is greater than the thickness of the outer layer. For example, the inner layer can have a thickness that is greater than or equal to 150% of the thickness of the outer layer. The inner layer can have a thickness that is at least 200% greater than the thickness of the outer layer. The inner layer can have a thickness of less than or equal to 5 mm. The inner layer can have a thickness of less than or equal to 3 mm. The thickness of the inner layer can be 1.5 mm to 3 mm. The outer layer can have a thickness of greater than or equal to 1.5 mm. The outer layer can have a thickness of less than or equal to 1.5 mm. The outer layer can have a thickness of less than or equal to 1.2 mm.

[0029] The baffle can be cone-shaped, specifically, frustoconical. For example, the cone-shaped baffle can have one or both an inner and an outer diameter that increases linearly from a first end proximal to the disk to a second end distal, for example, from the disk. The baffle can be n-hedral-shaped, for example, having one or both an inner and an outer diameter that increases linearly, with a changing slope from a first end proximal to the disk to a second end distal, for example, from the disk. The baffle can have a curvilinear shape, for example, having one or both an inner and an outer diameter that increases with a curved portion and a linear portion from a first end proximal to the disk to a second end distal, for example, from the disk. The baffle can have a curved shape, for example, having one or both an inner and an outer diameter that increases with a curved shape from a first end proximal to the disk to a second end distal, for example, from the disk. The baffle can be cylindrically shaped, for example, having one or both of an inner and an outer diameter that is constant from a first end proximal to the disk to a second end distal, for example, from the disk.
The outer layer can be electrically insulating or conductive. As used herein, "electrically insulating" means having a dielectric strength greater than or equal to 4 kiloVolts per millimeter (kV/mm). The outer layer can have a dielectric strength of at least 8 kV/mm, for example, 8 to 50 kV/mm. The outer layer can have a dielectric strength of at least 14 kV/mm. The inner layer can be electrically conductive. As used herein "electrically conductive" means having a dielectric strength less than 4 kV/mm.

The outer layer can have an L* value of greater than or equal to 65, specifically, greater than or equal to 85 as determined in accordance with CIELAB color space. This color space uses three dimensions, L*, a*, and b*. L* is the lightness or L-value, and can be used as a measure of the amount of light transmission through the polycarbonate resin. The values for L* range from 0 (black) to 100 (diffuse white).

The heat dissipation device can comprise a thermally conductive disk. The thermally conductive disk can have a through-plane thermal conductivity of at least 2 W/mK, or at least 3.5 W/mK, or 2 to 500 W/mK; and an in-plane thermal conductivity of at least 10 W/mK, or at least 15 W/mK, or 10 to 500 W/mK. The thermally conductive disk can have a through-plane thermal conductivity of greater than or equal to 5 W/mK and an in-plane thermal conductivity of at least 20 W/mK. The thermally conductive disk can have a through-plane thermal conductivity of greater than or equal to 7 W/mK and an in-plane thermal conductivity of at least 30 W/mK. When the disk is a thermally conductive disk, the baffle can include the inner layer and optionally the outer layer. The thermally conductive disk can include a thermally conductive filler.

The thermally conductive disk can have a thickness that is greater than the wall thickness of the baffle. The thickness of the thermally conductive disk can be 0.1 to 10 mm, for example, 0.5 to 4 mm. The thickness of the thermally conductive disk can be 2 to 10 mm, for example, 4 to 8 mm.

The baffle and the disk can each independently include a polymeric material. If the baffle includes an inner layer and an outer layer, the inner layer and the outer layer can each independently include a polymeric material. For example, the inner layer can comprise a first polymeric material and the outer layer can comprise a second polymeric material, wherein the first polymeric material and the second polymeric material can be the same or different. At least one of the first and second polymeric materials can include a non-crystalline polymer. As used herein, "non-crystalline polymer" refers to a polymer with a degree of crystallization of less than 0.1 as measured by differential scanning calorimetry.
(DSC). According to this method, polymer crystallinity is determined by quantifying the heat associated with melting (fusion) of the polymer. This heat is reported as percent crystallinity by normalizing the observed heat of fusion to that of a 100% crystalline sample of the same polymer. Use of non-crystalline polymer, such as polycarbonate, can improve one or more of dimension stability, mechanical performance, weatherability, and colorability.

[0035] The polymeric materials can be selected from a wide variety of thermoplastic material resins, blends of thermoplastic material resins, thermosetting resins, or blends of thermoplastic material resins with thermosetting resins, as well as combinations comprising at least one of the foregoing. The polymeric materials can comprise a blend of polymers, copolymers, terpolymers, or combinations comprising at least one of the foregoing. The polymeric materials can comprise an oligomer, a homopolymer, a copolymer, a block copolymer, an alternating block copolymer, a random polymer, a random copolymer, a random block copolymer, a graft copolymer, a star block copolymer, a dendrimer, or the like, or a combination comprising at least one of the foregoing. The polymeric materials can include polyacetalts, polyolefins, polyacrylics, poly(arylene ether) polycarbonates, polystyrenes, polyester (e.g., cycloaliphatic polyester, high molecular weight polymeric glycol terephthalates or isophthalates, and so forth), polyamides (e.g., semi-aromatic polyamide (PA) such as PA6, PA66, PA12, PA46, PA4T, PA6T, PA9T, PA10T, and so forth), polyamideimides, polyarylates, polyarylsulfones, polyethersulfones, polyphenylene sulfides, polyvinyl chlorides, polysulfones, polyimides, polyetherimides, polytetrafluoroethylenes, polyetherketones, polyether etherketones, polyether ketone ketones, polybenzoxazoles, polyphthalides, polycetals, polyanhydrides, polyvinyl ethers, polyvinyl thioethers, polyvinyl alcohols, polyvinyl ketones, polyvinyl halides, polyvinyl nitriles, polyvinyl esters, polysulfonates, polysulfides, polythioesters, polysulfones, polysulfonamides, polyureas, polyphosphazenes, polysilazanes, styrene acrylonitrile, acrylonitrile-butadiene-styrene (ABS), polyethylene terephthalate, polybutylene terephthalate, polyurethane, ethylene propylene diene rubber (EPR), polytetrafluoroethylene, fluorinated ethylene propylene, perfluoroalkoxyethylene, polychlorotrifluoroethylene, polyvinylidene fluoride, or the like, or a combination comprising at least one of the foregoing polymers. Examples of polyolefins include polyethylene (PE), including high-density polyethylene (HDPE), linear low-density polyethylene (LLDPE), low-density polyethylene (LDPE), mid-density polyethylene (MDPE), glycidyl methacrylate modified polyethylene, maleic anhydride functionalized polyethylene, maleic anhydride functionalized elastomeric
ethylene copolymers (like EXXELOR VA1801 and VA1803 from ExxonMobil), ethylene-
butene copolymers, ethylene-octene copolymers, ethylene-acrylate copolymers, such as
ethylene-methyl acrylate, ethylene-ethyl acrylate, and ethylene butyl acrylate copolymers,
glycidyl methacrylate functionalized ethylene-acrylate terpolymers, anhydride functionalized
ethylene-acrylate polymers, anhydride functionalized ethylene-octene and anhydride
functionalized ethylene-butene copolymers, polypropylene (PP), maleic anhydride
functionalized polypropylene, glycidyl methacrylate modified polypropylene, and a
combination comprising at least one of the foregoing polymers. The polymeric material can
comprise a polyamide, a polyphenylene sulfide, a polycarbonate, or a combination
comprising at least one of the foregoing.

[0036] As used herein, a "semi-aromatic polyamide" is understood to be a polyamide homo-
or copolymer that contains aromatic or semi-aromatic units derived from an aromatic
dicarboxylic acid, an aromatic diamine or an aromatic aminocarboxylic acid, the content of
said units being at least 50 mole percent (mol%). In some cases these semi-aromatic
polyamides are blended with small amounts of aliphatic polyamides for better processability.
They are available commercially from DuPont, Wilmington, DE, USA under the tradename
ZYTEL™ HTN, Solvay Advanced Polymers under the tradename Amodel, or from DSM,
Sittard, The Netherlands under the tradename STANYL FORTH™.

[0037] Examples of blends of thermoplastic material resins include acrylonitrile-
butadiene-styrene/nylon, polycarbonate/acrylonitrile-butadiene-styrene, acrylonitrile
butadiene styrene/polyvinyl chloride, polyphenylene ether/polystyrene, polyphenylene
ether/nylon, polysulphone/acrylonitrile-butadiene-styrene, polycarbonate/thermoplastic
material urethane, polycarbonate/polyethylene terephthalate, polycarbonate/polybutylene
terephthalate, thermoplastic material elastomer alloys, nylon/elastomers,
polyester/elastomers, polyethylene terephthalate/polybutylene terephthalate, acetal/elastomer,
styrene-maleicanhydride/acrylonitrile-butadiene-styrene, polyether etherketone/polyethersulfone, polyether etherketone/polyetherimide polyethylene/nylon,
polyethylene/polycetal, or the like.

[0038] Examples of thermosetting resins include polyurethane, natural rubber,
synthetic rubber, epoxy, phenolic, polyesters, polyamides, silicones, or the like, or a
combination comprising at least one of the foregoing thermosetting resins. Blends of
thermoset resins and blends of thermoplastic material resins with thermosets can be utilized.
[0039] The baffle can comprise an inner layer that comprises a first polymeric material and an outer layer that comprises a second polymeric material. The first and second polymeric materials can each independently include a polyarylene ether. The term poly(arylene ether) polymer includes polyphenylene ether (PPE) and poly(arylene ether) copolymers; graft copolymers; poly(arylene ether) ionomers; and block copolymers of alkenyl aromatic compounds with poly(arylene ether)s, vinyl aromatic compounds, and poly(arylene ether), and the like; and combinations including at least one of the foregoing.

[0040] The first and second polymeric materials of the inner and outer layers can be the same, wherein the inner and outer layers can comprise a different filler. The first and second polymeric materials of the inner and outer layers can be the same, wherein the inner and outer layers can comprise the same filler, but in different concentrations. For example, the inner layer can comprise a greater concentration of the same thermally conductive filler than is present in the outer layer. It is noted that a discrete boundary may not be present between the inner layer and the outer layer. Instead, for example, a gradient in an amount of a thermally conductive surface could exist from a first surface of the inner layer to a second surface of the outer layer.

[0041] The baffle and the disk can each independently comprise a filler. When the baffle comprises an inner and an outer layer, the inner and outer layers can each independently comprise a filler. The filler can comprise one or both of a thermally conductive filler and a non-thermally conductive filler. For example, one or both of the disk and the inner layer can comprise a thermally conductive filler and optionally a non-thermally conductive filler; and the outer layer can comprise a non-thermally conductive filler. The outer layer can comprise a thermally conductive filler, for example, in a concentration such that the outer layer has one or both of a through-plane thermal conductivity of less than or equal to 3 W/mK. As used herein the non-thermally conductive filler has a thermal conductivity of less than 100 W/mK and the thermally conductive filler has a thermal conductivity of greater than 100 W/mK at 23 degrees Celsius (°C). The inner layer can include a thermally conductive filler. The disk can include a thermally conductive filler. The outer layer can be free of a thermally conductive filler. As used herein, "free of a thermally conductive filler" can mean that the polymeric material comprises less than or equal to 5 weight percent (wt%), specifically, less than or equal to 1 wt%, more specifically, less than or equal to 0.01 wt%, or 0 wt% of a filler based on the total weight of the polymeric material and filler.
[0042] The thermally conductive fillers can be in the shape of regular or irregular sphericals, nanotube, fibers, whiskers, flakes, or platelets. The thermally conductive fillers can be mono-layer or multiple layer flakes or platelets with an aspect ratio above 1 and below 200. Aspect ratio refers to the ratio of the longest side to the shortest side of the flat plane of the flake or platelet. The particles can have a longest dimension of 100 nanometers (nm) to 1500 micrometers (μm). The thickness of the particles can be 10 nm to 100 μm. Surface area of the particles can be 0.01 square meters per gram (m²/g) to 1000 m²/g.

[0043] The thermally conductive filler can have a thermal conductivity greater than or equal to 100 W/mK. The thermally conductive filler can have a thermal conductivity greater than or equal to 200 W/mK. The thermally conductive filler can have a thermal conductivity greater than or equal to 500 W/mK.

[0044] The filler can comprise, but is not limited to, graphite, expanded graphite, graphene, carbon fiber, carbon nanotubes (CNT), graphitized carbon black, AlN, Al₄C₃, Al₂O₃, BN, AlON, MgSiN₂, SiC, Si₃N₄, graphite, expanded graphite, graphene, carbon fiber, ZnS, CaO, MgO, ZnO, TiO₂, H₂Mg₃(SiO₃)₄, CaCO₃, Mg(OH)₂, mica, BaO, γ-AlO(OH), α-AlO(OH), Al(OH)₃, BaSO₄, CaSiO₃, ZrO₂, SiO₂, a glass bead, a glass fiber, MgOxAI₂O₃, CaMg(CO₃)₂, clay, or a combination comprising at least one of the foregoing.

[0045] The thermally conductive filler can comprise graphite, expanded graphite, graphene, carbon fiber, carbon nanotubes (CNT), graphitized carbon black, aluminum nitride, boron nitride, or a combination comprising one or more of the foregoing. One or both of the disk and the inner layer can comprise a thermally conductive filler, for example, graphite.

[0046] One or more of the inner and outer layers and the disk can comprise a filler comprising Al₂O₃, CaO, MgO, ZnO, TiO₂, H₂Mg₃(SiO₃)₄, CaCO₃, Mg(OH)₂, mica, BaO, γ-AlO(OH), α-AlO(OH), Al(OH)₃, BaSO₄, CaSiO₃, ZrO₂, SiO₂, a glass bead, a glass fiber, MgOxAI₂O₃, CaMg(CO₃)₂, clay, or a combination comprising at least one of the foregoing. One or both of the inner and outer layers can comprise a filler comprising magnesium dihydroxide, magnesium oxide, CaO, TiO₂ and mica or a combination comprising at least one of the foregoing.

[0047] One or both of the inner and outer layers can comprise a filler comprising magnesium dihydroxide, a glass fiber, or a combination comprising at least one of the foregoing. For example, one or both of the disk and the inner layer can comprise polyphenylene sulfide, graphite, and glass fibers; and the outer layer can comprise a polyamide, magnesium dihydroxide, and glass fibers.
The inner layer can include 10 to 90 wt% filler and 90 to 10 wt% first polymeric material. The inner layer can include 20 to 80 wt% filler and 80 to 20 wt% first polymeric material. The outer layer can include 0 to 50 wt% filler and 100 to 50 wt% second polymeric material. The outer layer can include 10 to 90 wt% filler and 90 to 10 wt% second polymeric material. The disk can include 0 to 50 wt% filler and 100 to 50 wt% second polymeric material. The disk can include 10 to 90 wt% filler and 90 to 10 wt% third polymeric material.

Additionally, the inner and outer layers and the disk can each independently optionally contain additives such as antioxidants, such as, for example, organophosphites, for example, tris(nonyl-phenyl)phosphate, tris(2,4-di-t-butylphenyl)phosphate, bis(2,4-di-t-butylphenyl)pentaerythritol diphosphate or distearyl pentaerythritol diphosphate, alkylated monophenols, polyphenols and alkylated reaction products of polyphenols with dienes, such as, for example, tetrakis[methylene(3,5-di-t-butyl-4-hydroxyhydrocinnamate)] methane, 3,5-di-tet-butyl-4-hydroxyhydrocinnamate, octadecyl 2,4-di-tet-butylphenyl phosphite, butylated reaction products of para-cresol and dicyclopentadiene, alkylated hydroquinones, hydroxylated thiophenyl ethers, alkylidene-bisphenols, benzyl compounds, esters of beta-(3,5-di-tet-butyl-4-hydroxyphenyl)-propionic acid with monohydric or polyhydric alcohols, esters of beta-(5-tet-butyl-4-hydroxy-3-methylphenyl)-propionic acid with monohydric or polyhydric alcohols; esters of thioalkyl or thioaryl compounds, such as, for example, distearyltiopropionate, dilauryltiopropionate, distearylthiodipropionate, amides of beta-(3,5-di-tet-butyl-4-hydroxyphenyl)-propionic acid; and other additives such as, for example, mold release agents, ultraviolet absorbers, stabilizers such as light stabilizers and others, lubricants, polymeric materializers, pigments, dyes, colorants, anti-static agents, blowing agents, flame retardants, impact modifiers, among others, as well as combinations comprising at least one of the foregoing additives.

An example of a polymeric material for use as the first polymeric material is KONDUr™ thermally conductive polymeric material commercially available from SABIC’s Innovative Plastics business, Pittsfield, MA, including, but not limited to, grades PX08321, PX08322, PX09322, PX10321, PX10322, PX10323, PX13322, PX11311(U), PX1 1313, and OX10324. An example of a polymeric material for use in the disk is KONDUr™ thermally conductive polymeric material commercially available from SABIC’s Innovative Plastics business, Pittsfield, MA, including, but not limited to, grades PX08321, PX08322, PX09322, PX10321, PX10322, PX10323, PX13322, PX11311(U),
PX11313, and OX10324. Non limiting examples of second polymeric materials are polycarbonate, polyester, and polyamide. The outer layer can contain a filler.

[0051] The baffle can be formed by molding. When the baffle comprises an inner layer and an outer layer, the inner and outer layers can be formed through an overmolding process. For example, the inner layer can be fabricated through a first molding process. During a second molding process the outer layer can be formed on the outer surface of the prefabricated inner layer. An outer surface of the inner layer (for example, outer surface 19 of inner layer 20 as illustrated in FIG. 2) that will be in contact with the outer layer and that is formed in the first molding process can be roughened prior to the second molding process. The outer surface of the inner layer can be rough due to one or more of the presence of a filler, controlling the molding process (e.g., using a low molding temperature), and a texturing in a mold surface. In the alternative, the outer layer can be fabricated through a first molding process. During a second molding process the inner layer can be formed on the inner surface of the prefabricated outer layer. An inner surface of the outer layer (for example, inner surface 22 of outer layer 21) that will be in contact with the inner layer and that is formed in the first molding process can be roughened prior to the second molding process. The inner surface of the outer layer can be rough due to one or more of the presence of a filler, controlling the molding process (e.g., using a low molding temperature), and a texturing in a mold surface.

[0052] The inner and outer layers can be formed through a 2K process. For example, the inner and outer layer can be formed through a two shot process wherein both the first material and the second material are injected into the same mold. 2K molding is a manufacturing process for producing two colors or two component injected molded parts from two different thermoplastic materials in one process that requires a machine with two independent injection units, each of which shoots different material. The first material is injected through a primary runner system, as in a normal injection molding cycle. During the injection, the mold volume to be occupied by the second material is shut off from the primary runner system. The mold is then opened and the core plate rotated 180 degrees. The mold is again closed and the secondary runner system is connected to the volume to be filled. After sufficient part cooling, the mold is opened and the part is ejected.

[0053] The inner layer and the outer layer can have a good adhesion to each other, where the good adhesion can be defined by conducting a tensile test on a tensile bar with a first bar half comprising the composition of the inner layer and a second bar half comprising
the composition of the outer layer according to ISO 527 and having an average knit line
strength of greater than or equal to 10 megapascal (MPa) averaged over five samples. The
adhesion between the inner layer and the outer layer can be increased by roughening at least
one of the surfaces of contact of the inner layer and the outer layer during forming of the heat
dissipation device. For example, a first of the inner layer and the outer layer can be molded,
a surface of contact of the first molded layer can be roughened and the second of the inner
layer and the outer layer can be molded.

[0054] The thermally conductive disk can be added to the baffle, for example, by an
overlocking method or by ultrasonic welding. In the overlocking method, one of the
thermally conductive disk and the baffle can be formed with a contact surface for contacting
the other of the thermally conductive disk and the baffle, the contact surface of the first
formed part can be optionally roughened, and the other of the thermally conductive disk and
the baffle can be formed onto the contact surface. The ultrasonic welding can include
forming the thermally conductive disk and the baffle and then welding the two parts together
using ultrasonic vibrations. The ultrasonic vibrations can have a frequency of greater than or
equal to 20 kilohertz (kHz), for example, 20 kHz to 10 gigahertz (GHz).

[0055] The following examples are provided to illustrate the heat dissipation device.
The examples are merely illustrative and are not intended to limit devices made in accordance
with the disclosure to the materials, conditions, or process parameters set forth therein.

EXAMPLES

Examples 1-2: Heat sink temperature profiles

[0056] A simulation was performed in FloEFD software based on the following:

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading condition</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
<tr>
<td>Boundary condition</td>
</tr>
</tbody>
</table>

[0057] FIG. 3 illustrates the results of a simulation under the conditions set forth in
Table 1 for an LED light utilizing the construction of FIG. 1. The simulation utilized a heat
dissipation device including an aluminum inner layer with a thickness of 1 mm and thermal
conductivity (through-plane/in-plane) of 200/200 W/mK and a polymeric outer layer with a
thickness of 1.2 mm and thermal conductivity (through-plane/in-plane) of 1.2/1.2 W/mK.

[0058] FIG. 4 illustrates the results of a simulation under the conditions set forth in
Table 1 for an LED light utilizing the construction of FIG. 2. The simulation utilized a heat
dissipation device including a polymeric inner layer with a thickness of 3 mm and thermal conductivity (through-plane/in-plane) of 7/30 W/mK and a polymeric outer layer with a thickness of 0.5 mm and thermal conductivity (through-plane/in-plane) of 1.2/1.8 W/mK.

[0059] As illustrated in FIGS. 3 and 4, the heat dissipation device incorporating aluminum displays a lower surface temperature than that of the fully polymeric heat dissipation device. However, the difference in surface temperature is insignificant. Thus, the polymeric heat dissipation device discussed above regarding FIG. 2 is comparable in heat dissipation to the aluminum insert construction of FIG. 1.

Examples 3-47: Temperature rise in multilayer heat dissipation devices

[0060] Table 2 illustrates the temperature rise for various constructions under the conditions set forth in Table 1. "Temperature rise" is defined as the difference between the maximum outer surface temperature and the ambient temperature. A lower temperature rise indicates a better heat dissipation performance. Examples 3 and 4 comprise an aluminum metal inner layer having a through-plane thermal conductivity and an in-plane thermal conductivity of 200 W/mK and a thickness of 0.8 to 1.2 mm overmolded with a non-filled polymeric material having a through-plane thermal conductivity and an in-plane thermal conductivity of 0.2 W/mK and a thickness of 0.5 to 1.2 mm resulting in a temperature rise of about 64°C. Examples 5 and 6 comprise an aluminum metal inner layer having a through-plane thermal conductivity and an in-plane thermal conductivity of 200 W/mK and a thickness of 1.0 mm overmolded with a thermal conductive polymeric material having through-plane thermal conductivity/in-plane thermal conductivity of 1.2/1.2 or 1.4/1.8 W/mK and a thickness of 1.2 mm resulting in a temperature rise (Temp. Rise) of 57 to 58°C. Examples 3-6, which are industrially used, are set as benchmarks. Examples 7-47 are examples of a heat dissipation device with a multilayer layer polymeric baffle comprising first and second polymeric materials with properties as shown in Table 2. For samples with both first and second polymeric materials (i.e., no aluminum), Table 2 shows that temperature rises can be within or near the ranges of the comparative examples (e.g., 57 to 64°C) when the inner layer has an in-plane/through-plane thermal conductivity of at least 3.5/15 and with layer thickness of at least 1.5 mm. In such cases, the second polymeric material can be selected from a wide range of thermal conductivity and thickness (e.g., as illustrated in Examples 7, 8, 14-17, 19, 20, 22-24, 26, and 30-47). As used herein, "TC" stands for thermal conductivity, "Thr. Plane" stands for through-plane.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Inner layer</th>
<th>Outer layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC (w/mK)</td>
<td>Thickness</td>
</tr>
<tr>
<td></td>
<td>Thr. Plane</td>
<td>In-plane mm</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>0.8</td>
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<tr>
<td>5</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>3</td>
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<tr>
<td>8</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>0.2</td>
</tr>
<tr>
<td>14</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>2</td>
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<tr>
<td>16</td>
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<td>2</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>7</td>
<td>0.8</td>
</tr>
<tr>
<td>19</td>
<td>7</td>
<td>0.2</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
<td>2</td>
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<tr>
<td>21</td>
<td>7</td>
<td>1.2</td>
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<tr>
<td>22</td>
<td>7</td>
<td>1.8</td>
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<tr>
<td>23</td>
<td>7</td>
<td>1.8</td>
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<td>24</td>
<td>7</td>
<td>1.8</td>
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<td>25</td>
<td>5</td>
<td>1.2</td>
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<tr>
<td>26</td>
<td>3.5</td>
<td>1.8</td>
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<td>27</td>
<td>3.5</td>
<td>1.2</td>
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<td>28</td>
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<td>29</td>
<td>3.5</td>
<td>0.8</td>
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<tr>
<td>30</td>
<td>3.5</td>
<td>0.5</td>
</tr>
<tr>
<td>31</td>
<td>3.5</td>
<td>1.5</td>
</tr>
<tr>
<td>32</td>
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<td>33</td>
<td>3.5</td>
<td>2.5</td>
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<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>41</td>
<td>3.5</td>
<td>5</td>
</tr>
<tr>
<td>42</td>
<td>3.5</td>
<td>3</td>
</tr>
<tr>
<td>Sample</td>
<td>Inner layer</td>
<td>Outer layer</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>TC (w/mK)</td>
<td>Thickness</td>
</tr>
<tr>
<td>Thr.</td>
<td>mm</td>
<td>In-plane</td>
</tr>
<tr>
<td>Plane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>3.5</td>
<td>15</td>
</tr>
<tr>
<td>44</td>
<td>3.5</td>
<td>15</td>
</tr>
<tr>
<td>45</td>
<td>3.5</td>
<td>15</td>
</tr>
<tr>
<td>46</td>
<td>3.5</td>
<td>15</td>
</tr>
<tr>
<td>47</td>
<td>3.5</td>
<td>15</td>
</tr>
</tbody>
</table>

Example 48: Adhesion strength

[0061] The adhesion strength between an inner layer and an outer layer was tested by determining the knit line strength of a tensile bar prepared by overmolding first material of PXI 10323-B-KNAT with a second material of PXI 1311U-WHG327. Specifically, the tensile bar was prepared by placing half of a pre-heated tensile bar of the first material, pre-heated to a temperature of 150°C, in a mold at 90°C, and overmolding the second material onto the first material. It is noted that the tensile bar, prepared in the manner, comprises a left half comprising the second material and the right half is the first material, where each half consists of one of the broad grips and half of the narrow testing part from the broad grip to the center of the bar.

[0062] A tensile test was performed on the tensile bar according to ISO 527 showed an average knit line strength of 16.1 ± 2 per 1 megapascal (MPa) averaged over five samples, indicating good adhesion. It is understood that the adhesion values in practice can be greatly enhanced, for example, by surface roughening prior to overmolding.

[0063] The following examples, Examples 49-73, are provided to illustrate the effect varying the thermal conductivities of the disk and baffle as well as their respective thicknesses on the temperatures the heat dissipation devices will experience. These examples are finite element analyses that were performed using a basic baffle and disk shape as illustrated in FIG. 5. In FIG. 5 inner layer 20 and outer layer 21 form the baffle, where the directionality of the coefficients of thermal conductivity $k_i$ (through the plane of the baffle), $k_2$ (in the plane of the baffle in the length direction), and $k_3$ (in the plane of the baffle in the radial direction) are illustrated by arrows. In the model, the material of the inner and outer layers was the same and $k_i$ and $k_2$ were set to be equal. The ambient temperature was set at 23°C and the heat transfer coefficient was set at 15 Watts per meter squared-degree Celsius (W/m²°C). The max temperature rise is determined at the x location in the center of disk 2.
Unless otherwise stated, inner layer 20 has a thickness of 1 mm, outer layer 21 has a thickness of 1 mm, the length L of the baffle is 60 mm, and the thickness t of disk 2 is 2 mm. Table 3 lists the materials used, where the through-plane and in-plane thermal conductivity for the filled PA and PPS were measured using the Hotdisk TPS2500 tester according to ISO 22007-2 on injection molded disks (85 mm diameter and 3 mm thickness) and the through-plane and in-plane thermal conductivity for the PA-6 was measured using the Nanoflash in accordance with ASTM E1461 on injection molded samples with a thickness of 2 mm and a diameter of 12.7 mm.

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>$k_1$ (W/mK)</th>
<th>$k_2$ (W/mK)</th>
<th>$k_3$ (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA-6</td>
<td>Polyamide 6</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>Filled PA</td>
<td>Polyamide 6 comprising magnesium dihydroxide and glass fibers</td>
<td>0.85</td>
<td>1.45</td>
<td>1.45</td>
</tr>
<tr>
<td>PPS</td>
<td>Polyphenylene sulfide comprising graphite and glass fibers</td>
<td>1.5</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Low TC</td>
<td>-</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>High TC</td>
<td>-</td>
<td>4</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Examples 49-60: Peak temperature of the disk center

[0064] The peak temperature at location x of various heat dissipation devices was determined varying the material of both the baffle and the disk and with varied heat input as shown in Table 4.

<table>
<thead>
<tr>
<th>Example</th>
<th>Baffle</th>
<th>Disk</th>
<th>Heat input (W)</th>
<th>Peak Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>Filled PA</td>
<td>Filled PA</td>
<td>1</td>
<td>75.5</td>
</tr>
<tr>
<td>50</td>
<td>Filled PA</td>
<td>Filled PA</td>
<td>3</td>
<td>180.6</td>
</tr>
<tr>
<td>51</td>
<td>Filled PA</td>
<td>Filled PA</td>
<td>5</td>
<td>285.6</td>
</tr>
<tr>
<td>52</td>
<td>PPS</td>
<td>PPS</td>
<td>1</td>
<td>37.0</td>
</tr>
<tr>
<td>53</td>
<td>PPS</td>
<td>PPS</td>
<td>3</td>
<td>65.1</td>
</tr>
<tr>
<td>54</td>
<td>PPS</td>
<td>PPS</td>
<td>5</td>
<td>93.1</td>
</tr>
<tr>
<td>55</td>
<td>Filled PA</td>
<td>PPS</td>
<td>1</td>
<td>50.0</td>
</tr>
<tr>
<td>56</td>
<td>Filled PA</td>
<td>PPS</td>
<td>3</td>
<td>104.1</td>
</tr>
<tr>
<td>57</td>
<td>Filled PA</td>
<td>PPS</td>
<td>5</td>
<td>158.2</td>
</tr>
<tr>
<td>58</td>
<td>PA-6</td>
<td>PPS</td>
<td>1</td>
<td>61.0</td>
</tr>
<tr>
<td>59</td>
<td>PA-6</td>
<td>PPS</td>
<td>3</td>
<td>136.9</td>
</tr>
<tr>
<td>60</td>
<td>PA-6</td>
<td>PPS</td>
<td>5</td>
<td>212.8</td>
</tr>
</tbody>
</table>
Table 4 shows that the peak temperature is increased with increasing heat input in each material system. Table 4 shows that by using a disk material with a high thermal conductivity, the peak temperature is reduced. For example, the peak temperature using a Filled PA disk with a through-plane conductivity of 0.85 W/mK and an in-plane conductivity of 1.45 W/mK at each heat input is greater than the peak temperature using a PPS disk with a through-plane conductivity of 1.5 W/mK and an in-plane conductivity of 18 W/mK. For example, comparing Examples 49 and 55, the peak temperature at a heat input of 1 Watts (W) is reduced from 75.5°C to 50.0°C; comparing Examples 50 and 56, the peak temperature at a heat input of 3 W is reduced from 180.6°C to 104.1°C; and comparing Examples 51 and 57, the peak temperature at a heat input of 5 W is reduced from 285.6°C to 158.2°C.

Table 4 further shows that increasing the thermal conductivity of the baffle further results in a decrease in the peak temperature. For example, comparing Examples 58, 55, and 52, at a heat input of 1 W, as the in-plane thermal conductivity increases from 0.36 to 1.45 to 18 W/mK, the peak temperature decreases from 61.0 to 50.0 to 37.0°C, respectively. The same holds true for heat inputs of 3 W and 5 W.

These results illustrate that utilizing a baffle and/or a disk with an increased thermal conductivity also results in a reduced peak temperature. These results illustrate that the heat dissipation device can be operated at a higher thermal input to yield more lumens of light output while maintaining a reduced peak temperature.

Examples 61-64: Temperature gradient through the base of the baffle

A finite element analysis was performed using Abaqus software to determine the temperature gradient through the wall of the baffle that is in contact with the disk starting from the inner surface at \( x_i \) through to the outer surface at \( x_o \) as illustrated in FIG. 5. Here, the heat input was 1 W, the ambient temperature was set at 23°C and the heat transfer coefficient was set at 15 W/m²°C. The results are shown in Table 5 and in FIG. 6.

<table>
<thead>
<tr>
<th>Example</th>
<th>61</th>
<th>62</th>
<th>63</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baffle</td>
<td>Filled PA</td>
<td>PPS</td>
<td>Filled PA</td>
<td>PA-6</td>
</tr>
<tr>
<td>Disk</td>
<td>Filled PA</td>
<td>PPS</td>
<td>PPS</td>
<td>PPS</td>
</tr>
<tr>
<td>Temperature at ( x_i ) (°C)</td>
<td>43.7</td>
<td>32.7</td>
<td>46.0</td>
<td>57.2</td>
</tr>
<tr>
<td>Temperature at ( x_o ) (°C)</td>
<td>40.8</td>
<td>31.2</td>
<td>43.0</td>
<td>50.7</td>
</tr>
</tbody>
</table>

Examples 62-64 illustrate that baffles with increasing thermal conductivity result in a decreased temperature through the walls of the baffle.
Examples 65-72: Effect of disk thickness on peak temperature

[0070] The effect of disk thickness, t, on peak temperature at location x in the center of the disk was determined using finite element analysis. In Examples 65-72, the baffle material was the Low TC material for the inner and outer layers, and the heat input was 1 W.

<table>
<thead>
<tr>
<th>Example</th>
<th>65</th>
<th>66</th>
<th>67</th>
<th>68</th>
<th>69</th>
<th>70</th>
<th>71</th>
<th>72</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc Material</td>
<td>Low TC</td>
<td>High TC</td>
<td>Low TC</td>
<td>High TC</td>
<td>Low TC</td>
<td>High TC</td>
<td>Low TC</td>
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<td>89.8</td>
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<td>-</td>
<td>73.3</td>
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[0071] Table 6 illustrates that increasing the thickness of the disc results in a reduction of the peak temperature.

Example 73: Effect of a changing wall thickness on peak temperature

[0072] The effect of a changing wall thickness on peak temperature at location x in the center of the disk was determined using finite element analysis. Here, the finite element analysis of Examples 69 and 70 were repeated except that the wall thickness of the baffle (m+n) where the disk and the baffle mean was 2 mm and the wall thickness (m+n) decreased to 1 mm at the distal edge of the baffle, for example, that is away from the disk. The peak temperature was determined and is shown in Table 6. Table 6 shows that using a tapered wall thickness results in a decrease in the peak temperature of the disk.

[0073] Set forth below are some embodiments of the heat dissipation device and methods of making and of using the heat dissipation device as disclosed herein.

[0074] Embodiment 1: A heat dissipation device comprising: an inner layer comprising a first polymeric material; an outer layer comprising a second polymeric material; and wherein the in-plane thermal conductivity of the first layer is greater than the in-plane thermal conductivity of the second layer, wherein the through-plane thermal conductivity of the first layer is greater than the through-plane thermal conductivity of the second layer. The heat dissipation device can optionally comprise a disk.

[0075] Embodiment 2: A heat dissipation device, comprising: an inner layer comprising a first polymeric material having a through-plane thermal conductivity of at least 3.5 W/mK and an in-plane thermal conductivity of at least 15 W/mK; wherein the inner layer
has a thickness of greater than or equal to 1.5 mm; an outer layer comprising a second polymeric material having an in-plane thermal conductivity of at least 0.2 W/mK and a through-plane thermal conductivity of at least 0.2 W/mK; and wherein the in-plane thermal conductivity of the first layer is greater than the in-plane thermal conductivity of the second layer, wherein the through-plane thermal conductivity of the first layer is greater than the through-plane thermal conductivity of the second layer, wherein at least one of the first polymeric material and second polymeric material comprises a non-crystalline polymer. The heat dissipation device can optionally comprise a disk.

[0076] Embodiment 3: A heat dissipation device, comprising: a baffle and an optional disk, wherein the optional disk is concentrically located at a first end of the baffle; and wherein the heat dissipation device is defined by one or more of the baffle being a multi-layer baffle comprising an inner layer and an outer layer, wherein the inner layer comprises a first polymeric material having a through-plane thermal conductivity of at least 2 or at least 3.5 W/mK and an in-plane thermal conductivity of at least 10 or at least 15 W/mK; wherein the inner layer has a thickness of greater than or equal to 1.5 mm, wherein the outer layer comprises a second polymeric material having an in-plane thermal conductivity of at least 0.2 W/mK and a through-plane thermal conductivity of at least 0.2 W/mK, wherein the in-plane thermal conductivity of the first layer is greater than the in-plane thermal conductivity of the second layer, wherein the through-plane thermal conductivity of the first layer is greater than the through-plane thermal conductivity of the second layer; the disk being present, wherein the disk is a thermally conductive disk with a through-plane thermal conductivity of at least 2 W/mK or at least 3.5 W/mK and an in-plane thermal conductivity of at least 10 or at least 15 W/mK; and the baffle having a tapered wall thickness such that a first wall thickness at the first of the baffle has a thickness of 2 to 10 mm and a second wall thickness at a second end of the baffle has a thickness of 0.1 to less than 2 mm.

[0077] Embodiment 4: The heat dissipation device of Embodiment 3, wherein the baffle is the multi-layer baffle.

[0078] Embodiment 5: The heat dissipation device of any of Embodiments 3-4, wherein the disk is present, specifically, the disk that is present in the thermally conductive disk.

[0079] Embodiment 6: The heat dissipation device of any of Embodiments 3-5, wherein the baffle has the tapered wall thickness.
[0080] Embodiment 7: The heat dissipation device of Embodiment 6, wherein the baffle is a single layer baffle and wherein the single layer baffle comprises the first polymeric material. The single layer baffle can comprise a coating.

[0081] Embodiment 8: The heat dissipation device of any of the preceding embodiments, wherein one or both of the disk and the inner layer comprises a thermally conductive filler, specifically, wherein the inner layer comprises the thermally conductive filler.

[0082] Embodiment 9: The heat dissipation device of any of the preceding embodiments, wherein the outer layer comprises no thermally conductive filler, for example, 0 to 0.01 wt%, specifically, 0 wt% of the thermally conductive filler based on the total weight of the outer layer.

[0083] Embodiment 10: The heat dissipation device of any of Embodiments 1-8, wherein the outer layer comprises a thermally conductive filler.

[0084] Embodiment 11: The heat dissipation device of any of Embodiments 8-10, wherein the thermally conductive filler comprises graphite, expanded graphite, graphene, carbon fiber, carbon nanotubes, graphitized carbon black, aluminum nitride, boron nitride, or a combination comprising one or more of the foregoing, for example, the outer layer can comprise graphite.

[0085] Embodiment 12: The heat dissipation device of any of Embodiments 8-11, wherein the inner layer comprises a greater concentration of the thermally conductive filler than the outer layer.

[0086] Embodiment 13: The heat dissipation device of any of the preceding embodiments, wherein one or both of the disk and the inner layer comprises graphite, expanded graphite, graphene, carbon fiber, carbon nanotubes (CNT), graphitized carbon black, aluminum nitride, boron nitride, or a combination comprising one or more of the foregoing.

[0087] Embodiment 14: The heat dissipation device of any of the preceding embodiments, wherein at least one of the baffle and the disk comprises a non-crystalline polymer.

[0088] Embodiment 15: The heat dissipation device of any of the preceding embodiments, wherein one or more of the disk, the inner layer, and the outer layer comprises $\text{Al}_2\text{O}_3$, CaO, MgO, ZnO, TiO$_2$, $\text{H}_2\text{Mg}_3(\text{SiO}_3)_4$, CaCO$_3$, Mg(OH)$_2$, mica, BaO, $\gamma$-AlO(OH), $\alpha$-
AIO(OH), Al(OH)₃, BaSO₄, CaSiO₃, ZrO₂, SiO₂, a glass bead, a glass fiber, MgOxAl₂O₃, CaMg(CO₃)₂, clay, or a combination comprising at least one of the foregoing.

[0089] Embodiment 16: The heat dissipation device of any of the preceding embodiments, wherein the inner layer is electrically conductive and has a dielectric strength of less than 4 kV/mm.

[0090] Embodiment 17: The heat dissipation device of any of the preceding embodiments, wherein the outer layer is an electrical insulator and has a dielectric strength of greater than or equal to 4 kV/mm.

[0091] Embodiment 18: The heat dissipation device of any of the preceding embodiments, wherein the inner layer is thicker than the outer layer.

[0092] Embodiment 19: The heat dissipation device of any of the preceding embodiments, wherein a thickness of the inner layer is less than or equal to 3 mm, specifically, 1.5 to 3 mm.

[0093] Embodiment 20: The heat dissipation device of any of the preceding embodiments, wherein a thickness of the outer layer is less than or equal to 1.5 mm.

[0094] Embodiment 21: The heat dissipation device of any of the preceding embodiments, further comprising a plurality of fins extending radially from the outer layer.

[0095] Embodiment 22: The heat dissipation device of any of the preceding embodiments, wherein one or both of the through-plane thermal conductivity of the inner layer is greater than the through-plane thermal conductivity of the outer layer and the in-plane thermal conductivity of the inner layer is greater than the in-plane thermal conductivity of the outer layer.

[0096] Embodiment 23: The heat dissipation device of any of the preceding embodiments, wherein the through-plane thermal conductivity of the outer layer is less than or equal to 3 W/mK, or 0.01 to 3 W/mK.

[0097] Embodiment 24: The heat dissipation device of any of the preceding embodiments, wherein the in-plane thermal conductivity of the outer layer is less than or equal to 10 W/mK, or 3 to 10 W/mK.

[0098] Embodiment 25: The heat dissipation device of any of the preceding embodiments, wherein first and second polymeric materials each independently comprise a thermoplastic material.

[0099] Embodiment 26: The heat dissipation device of Embodiment 25, wherein the first and second polymeric materials comprise the same thermoplastic material.
[0100] Embodiment 27: The heat dissipation device of any of Embodiments 25-26, wherein the inner layer and the outer layer comprise the same thermoplastic material and the same filler.

[0101] Embodiment 28: The heat dissipation device of any of Embodiments 25-27, wherein the inner layer and the outer layer comprise the same thermoplastic material and a different filler.

[0102] Embodiment 29: The heat dissipation device of any of the preceding embodiments, wherein a concentration of the filler changes from a first surface of the inner layer to a second surface of the outer layer.

[0103] Embodiment 30: The heat dissipation device of any of the preceding embodiments, wherein a discrete boundary is not present between the inner layer and the outer layer.

[0104] Embodiment 31: An LED illuminating device comprising the heat dissipation device of any of the preceding embodiments and an LED.

[0105] Embodiment 32: A light emitting device comprising the heat dissipation device of any of the preceding embodiments, an electrical connection configured to electrically connect with a light source, wiring connected to the electrical connection, and configured to provide electricity to the light source, and a lens.

[0106] Embodiment 33: The device of Embodiment 32, wherein the light source is an LED.

[0107] Embodiment 34: A method of manufacturing the heat dissipation device of any of Embodiments 1-6 and 8-33 comprising: disposing a first material comprising one of the first polymeric material and the second polymeric material into a mold; molding a second material comprising the other of the first polymeric material and the second polymeric material onto the first material to form the baffle; removing the baffle from the mold; and disposing the disk concentrically in the baffle.

[0108] Embodiment 35: The method of Embodiment 34, wherein the second polymeric material is disposed into the mold and the first polymeric material is molded onto the second polymeric material to form the heat dissipation device.

[0109] Embodiment 36: The method of any of Embodiments 34-25, wherein if the first material comprises the first polymeric material, then the method further comprises roughening an outer surface of the inner layer prior to molding the second material; and wherein if the first material comprises the second polymeric material, then the method further
comprises roughening an inner surface of the outer layer prior to molding the second material.

[0110] Embodiment 37: A method of manufacturing the heat dissipation device of any of Embodiment 1-6 and 8-33 comprising: injecting the first polymeric material and second polymeric material into a mold via two separate injection units; and removing the heat dissipation device from the mold.

[0111] Embodiment 38: The method of Embodiment 37, wherein the injecting comprises injecting the first polymeric material prior to injecting the second polymeric material or wherein the injecting comprises injecting the second polymeric material prior to injecting the first polymeric material.

[0112] As used herein, the thermal conductivity is determined in accordance with ASTM E1461 using a laser flash method with a Nanoflash LFA 447 xenon flash apparatus available from Netzsch. For the through-plane thermal conductivity, test specimens were cut into 10x10x3 mm square samples from an injection molded 80x10x3 mm IZOD bar. The thermal conductivity (k(T)) is calculated in units of W/mK. The thermal diffusivity (oc(T)) is measured in units of centimeters squared per second (cm²/s), and can be determined by measurement of time needed for the rear face of a thin-disc specimen to achieve maximum temperature rise after a short energy pulse input on the front face. The pulse is emitted by the xenon flash lamp with the fixed parameters setting on power, filter, pulse width, pre-amp and main amp. The thermal diffusivity, a, can be calculated as shown in formula (1)

\[ a = 0.1388 \times d \times \frac{2}{t_{50}} \]  

(1)

where \( d \) is the thickness of the sample measured in micrometers and \( t_{50} \) is half of the time for the rear face to achieve the highest temperature rise. The specific heat (Cp) is measured in Joules per gram-Kelvin (J/gK) and the density (p) is measured in grams per centimeter cubed (g/cm³). The specific heat is measured by comparison between the testing sample and a standard sample of known specific heat. The density is determined using a water immersion method (ASTM D792). The thermal conductivity is calculated as shown in formula (2)

\[ k(T) = \frac{cc(T) + C_p(T) \times p(T)}{2} \]  

(2)

wherein \( k(T) \) refers to thermal conductivity; \( oc(T) \) refers to thermal diffusivity; \( C_p(T) \) refers to specific heat at a temperature, \( T \), and \( p(T) \) refers to the density of the specimen at a temperature, \( T \).

[0113] In-plane thermal conductivity is calculated by formula (2), using a 2.5 mm diameter circular sample with a thickness of 0.4 mm cut from 0.4 mm thick sheet produced
by injection molding. The thermal diffusivity (\(\alpha(T)\)) can be determined by measurement of
the average temperature rise of 4 testing spots at the rear face of the specimen produced by a
short energy pulse on the front face, as set forth in ASTM E1461.

[0114] In general, the compositions, methods, and articles can alternatively comprise,
consist of, or consist essentially of, any ingredients, components, or steps herein disclosed.
The compositions, methods, and articles can additionally, or alternatively, be formulated,
conducted, or manufactured so as to be devoid, or substantially free, of any ingredients, steps,
or components, not necessary to the achievement of the function or objectives of the present
claims.

[0115] The endpoints of all ranges directed to the same component or property are
inclusive of the endpoints, are independently combinable, and include all intermediate points
and ranged (e.g., ranges of "up to 25 wt\%, or, more specifically, 5 to 20 wt\%," is inclusive of
the endpoints and all intermediate values of the ranges of "5 to 25 wt\%," such as 10 to 23
wt\%, etc.). "Combination" is inclusive of blends, mixtures, alloys, reaction products, and the
like. Furthermore, the terms "first," "second," and the like, herein do not denote any order,
quantity, or importance, but rather are used to denote one element from another. The terms
"a" and "an" and "the" herein do not denote a limitation of quantity, and are to be construed
to cover both the singular and the plural, unless otherwise indicated herein or clearly
contradicted by context. "Or" means "and/or." Reference throughout the specification to
"one embodiment," "another embodiment," "an embodiment," and so forth, means that a
particular element (e.g., feature, structure, and/or characteristic) described in connection with
the embodiment is included in at least one embodiment described herein, and may or may not
be present in other embodiments. In addition, it is to be understood that the described
elements may be combined in any suitable manner in the various embodiments. "Optional" or
"optionally" means that the subsequently described event or circumstance can or cannot
occur, and that the description includes instances where the event occurs and instances where
it does not. Unless defined otherwise, technical and scientific terms used herein have the
same meaning as is commonly understood by one of skill in the art to which this disclosure
belongs.

[0116] While particular embodiments have been described, alternatives,
modifications, variations, improvements, and substantial equivalents that are or may be
presently unforeseen may arise to Applicants or others skilled in the art. Accordingly, the
appended claims as filed and as they may be amended are intended to embrace all such
alternatives, modifications variations, improvements, and substantial equivalents.

[0117] All cited patents, patent applications, and other references are incorporated
herein by reference in their entirety. However, if a term in the present application contradicts
or conflicts with a term in the incorporated reference, the term from the present application
takes precedence over the conflicting term from the incorporated reference.

[0118] In addition, it is to be understood that the described elements can be combined
in any suitable manner in the various embodiments.

[0119] Unless specified to the contrary herein, all test standards are the most recent
standard in effect as of the date of filing this application, or, if priority is claimed, the date of
filing of the earliest priority application in which the test standard appears.

[0120] This application claims the benefit of U.S. Provisional Patent Application
Serial No. 62/097,678 filed December 30, 2014 and U.S. Provisional Patent Application
Serial No. 62/215,471 filed September 8, 2015. The related applications are incorporated
herein in their entirety by reference.

[0121] I/we claim:
CLAIMS

1. A heat dissipation device, comprising:
   a baffle and an optional disk, wherein the optional disk is concentrically located at a first end of the baffle; and wherein the heat dissipation device is defined by one or more of the baffle being a multi-layer baffle comprising an inner layer and an outer layer wherein the inner layer comprises a first polymeric material having a first through-plane thermal conductivity of at least 2 or at least 3.5 W/mK and a first in-plane thermal conductivity of at least 10 or at least 15 W/mK, wherein the inner layer has a thickness of greater than or equal to 1.5 mm; wherein the outer layer comprises a second polymeric material having a second in-plane thermal conductivity of at least 0.2 W/mK and a second through-plane thermal conductivity of at least 0.2 W/mK, wherein the first in-plane thermal conductivity of the first layer is greater than the second in-plane thermal conductivity of the second layer, wherein the first through-plane thermal conductivity of the first layer is greater than the second through-plane thermal conductivity of the second layer;

   the disk being present, wherein the disk is a thermally conductive disk with a disk through-plane thermal conductivity of at least 2 W/mK or at least 3.5 W/mK and a disk in-plane thermal conductivity of at least 10 or at least 15 W/mK; and

   the baffle having a tapered wall thickness such that a first wall thickness at the first end of the baffle has a thickness of 2 to 10 mm and a second wall thickness at a second end of the baffle has a thickness of 0.1 to less than 2 mm.

2. The heat dissipation device of Claim 1, wherein one or both of the disk and the inner layer comprises a thermally conductive filler.

3. The heat dissipation device of any of the preceding claims, wherein at least one of the baffle and the disk comprises a non-crystalline polymer.

4. The heat dissipation device of any of the preceding claims, wherein the outer layer comprises no thermally conductive filler.

5. The heat dissipation device of any of the preceding claims, wherein one or both of the disk and the inner layer comprises graphite, expanded graphite, graphene, carbon fiber, carbon nanotubes (CNT), graphitized carbon black, aluminum nitride, boron nitride, or a combination comprising one or more of the foregoing.

6. The heat dissipation device of any of the preceding claims, wherein one or more of the disk, the inner layer, and the outer layer comprises Al₂O₃, CaO, MgO, ZnO, TiO₂, H₂Mg₃(SiO₃)₄, CaCO₃, Mg(OH)₂, mica, BaO, γ-Al₂O₃(OH), α-Al₂O₃(OH), Al₃(OH)₃,
BaSO₄, CaSiO₃, ZrO₂, SiO₂, a glass bead, a glass fiber, MgOₓAl₂O₃, CaMg(CO₃)₂, clay, or a combination comprising at least one of the foregoing.

7. The heat dissipation device of any of the preceding claims, wherein the inner layer is electrically conductive and has a dielectric strength of less than 4 kV/mm.

8. The heat dissipation device of any of the preceding claims, wherein the outer layer is an electrical insulator and has a dielectric strength of greater than or equal to 4 kV/mm.

9. The heat dissipation device of any of the preceding claims, wherein the inner layer is thicker than the outer layer.

10. The heat dissipation device of any of the preceding claims, wherein a thickness of the inner layer is less than or equal to 3 mm.

11. The heat dissipation device of any of the preceding claims, wherein a thickness of the outer layer is less than or equal to 1.5 mm.

12. The heat dissipation device of any of the preceding claims, wherein one or both of the through-plane thermal conductivity of the inner layer is greater than the through-plane thermal conductivity of the outer layer and the in-plane thermal conductivity of the inner layer is greater than the in-plane thermal conductivity of the outer layer.

13. The heat dissipation device of any of the preceding claims, wherein the through-plane thermal conductivity of the outer layer is less than or equal to 3 W/mK.

14. The heat dissipation device of any of the preceding claims, wherein the in-plane thermal conductivity of the outer layer is less than or equal to 10 W/mK.

15. An LED illuminating device comprising the heat dissipation device of any of the preceding claims and an LED.

16. A method of manufacturing the heat dissipation device of any of Claims 1-14 comprising:

   disposing a first material comprising one of the first polymeric material and the second polymeric material into a mold;
   molding a second material comprising the other of the first polymeric material and the second polymeric material onto the first material to form the baffle;
   removing the baffle from the mold; and
   optionally, disposing the disk concentrically in the baffle.
17. The method of Claim 16, wherein the second polymeric material is disposed into the mold and the first polymeric material is molded onto the second polymeric material to form the baffle.

18. The method of any of Claims 16 to 17, wherein if the first material comprises the first polymeric material, then the method further comprises roughening an outer surface of the inner layer prior to molding the second material; and

wherein if the first material comprises the second polymeric material, then the method further comprises roughening an inner surface of the outer layer prior to molding the second material.

19. The method of any of Claims 16-18, comprising disposing the disk, wherein the disposing the disk occurs by an overlocking method or by ultrasonic welding, specifically, by the overlocking method.

20. A method of manufacturing the heat dissipation device of any of Claims 1-14 comprising:

injecting the first polymeric material and second polymeric material into a mold via two separate injection units; and

removing the heat dissipation device from the mold.
## INTERNATIONAL SEARCH REPORT

### A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or both national classification and IPC:

- F21V29/71
- F21V29/87
- F21K9/232
- F21Y115/10

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols):

- F21V
- F21K
- F21Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched:

- EPO-Internal, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document(s) which may throw doubts on priority claim(s) or which may affect the novelty of the claimed invention
- "O" document referring to an oral disclosure, use, exhibition or other special reason
- "P" document published prior to the international filing date but later than the priority date claimed

**"X"** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

**"Y"** document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

**"N"** document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

**"A"** document member of the same patent family

**"T"** document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

### Date of the actual completion of the international search

4 March 2016

### Date of mailing of the international search report

11/03/2016

Name and mailing address of the ISA:

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NL - 2280 HV RIJWIJK
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Authorized officer:

Soto Salvador, Jesus
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