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POWER MODULE HAVING A MULTI-LEVEL METALLIC FRAME WITH POWER TERMINALS

Abstract

A power module includes: a substrate having a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate. The multilevel metallic frame includes a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration.

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Background/Summary

BACKGROUND

[0001] Molded power semiconductor modules include power semiconductor dies embedded in a mold compound and electrically interconnected to form a power converter component of a power electronics device, e.g., such as a half bridge or full bridge converter. The signal and power terminals typically jut out from one or more side faces of the mold compound. The power terminals are connected to a busbar and the signal terminals are connected to a printed circuit board (PCB) that has the gate driver and/or controller IC (integrated circuit) used to drive and control the power module. Each power terminal is part of an inductance loop, e.g., such as a DC+ to AC inductance loop, an AC to DC− inductance loop, and a DC+ to DC− inductance loop. Long inductance loops result in high stray inductance, which leads to overvoltage conditions and slower switching frequencies at the power module. Shorter inductance loops are a key challenge in power module design. The power terminal design and signal/power routing on the module substrate are limiting factors. These same factors limit the circuit symmetry achievable by the module design.

[0002] Hence, there is a need for power modules and related power electronics assemblies with lower stray inductance.

SUMMARY

[0003] According to an embodiment of a power module, the power module comprises: a substrate comprising a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate, wherein the multilevel metallic frame comprises a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration. A power electronic assembly that includes a plurality of the power modules and a busbar attached to the power terminals of the power modules is also described, as are methods of producing the power module.

[0004] According to an embodiment of a power electronics assembly for power a multi-phase load, the power electronics assembly comprises: one or more power modules for each phase of the multi-phase load, each power module comprising: a substrate comprising a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate, wherein the multilevel metallic frame comprises a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration, wherein the power electronics assembly further comprises a busbar connected to the exposed part of the power terminals of the power modules.

[0005] Those skilled in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE FIGURES

[0006] The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts. The features of the various illustrated embodiments can be combined unless they exclude each other. Embodiments are depicted in the drawings and are detailed in the description which follows.

[0007] FIG. **1**A illustrates a side perspective view of an embodiment of a power module.

[0008] FIG. **1**B illustrates a top plan view of the power module.

[0009] FIG. **1**C illustrates a cross-sectional view of the power module along the line labelled A-A in FIG. **1**B.

[0010] FIG. **1**D illustrates a cross-sectional view of the power module along the line labelled B-B in FIG. **1**B.

[0011] FIGS. **2**A through **2**C each illustrate a top plan view (left side of the figures) and a side perspective view (right side of the figures) during different stages of producing the power module shown in FIGS. **1**A through **1**D.

[0012] FIG. **3**A illustrates a top plan view of the power module, FIG. **3**B illustrates a cross-sectional view of the power module along the line labelled A-A in FIG. **3**A, and FIG. **3**C illustrates a cross-sectional view of the power module along the line labelled B-B in FIG. **3**A, according to another embodiment.

[0013] FIG. **4** illustrates a side perspective view of the power module, according to another embodiment.

[0014] FIGS. **5**A through **5**C each illustrate a top plan view (left side of the figures) and a side perspective view (right side of the figures) during different stages of producing the power module shown in FIG. **4**.

[0015] FIGS. **6** through **9** illustrate a side perspective view of the power module, according to additional embodiments.

[0016] FIG. **10** illustrates a partial cross-sectional view of the power module in the region of a single screw type or bolt type power terminal connector.

[0017] FIG. **11** illustrates a partial cross-sectional view of the power module in the region of forming a laser welded busbar connection to the exposed part of a power terminal of the power module.

[0018] FIG. **12** illustrates a partial cross-sectional view of the power module in the region of forming a laser welded busbar connection to the exposed part of a power terminal of the power module, according to another embodiment.

[0019] FIG. **13** illustrates a top plan view of a power electronics assembly, according to an embodiment.

[0020] FIG. **14** illustrates a top plan view of the power electronics assembly, according to another embodiment.

DETAILED DESCRIPTION

[0021] The embodiments described herein provide a molded power module design having a low stray inductance, e.g., below 10 nH, below 5 nH, below 3 nH, or even below 2 nH. Such low stray inductance is realized by using a multilevel metallic frame to implement the power terminals of the molded module. The power terminals have a shorter length compared to conventional power module terminals that protrude from one or more side faces of the mold compound. Instead, the power terminals are exposed for connecting to at a side of the mold compound that faces away

from the die carrier (substrate) that is at least partly embedded in the mold compound. Such a configuration reduces the length of the power terminals, thus reducing the module stray inductance.
[0022] The power terminals transition between two or more different levels to electrically interconnect power semiconductor dies attached to the substrate in a half bridge or full bridge configuration. The multilevel metallic frame may be designed such that power terminals at different potentials have some degree of vertical overlap, further reducing the module stray inductance. The multilevel metallic frame together with a separate metallic frame used for the power module signal connections enable highly symmetric power, gate, and signal routing, which more evenly distributes the current amongst the power semiconductor dies included in the module and reduces deadtime requirements.
[0023] Described next, with reference to the figures, are exemplary embodiments of the power module design and corresponding methods of production. Any of the power module embodiments described herein may be used interchangeably unless otherwise expressly stated.
[0024] FIG. **1**A illustrates a side perspective view of an embodiment of a power module **100**. FIG. **1**B illustrates a top plan view of the power module **100**. FIG. **1**C illustrates a cross-sectional view of the power module **100** along the line labelled A-A in FIG. **1**B. FIG. **1**D illustrates a cross-sectional view of the power module **100** along the line labelled B-B in FIG. **1**B. The power module **100** may be part of a power electronics assembly for use in various power applications such as in a DC/AC inverter, a DC/DC converter, an AC/DC converter, a DC/AC converter, an AC/AC converter, a multi-phase inverter, an H-bridge, DC motor drive, etc.
[0025] The power module **100** includes a substrate **102** having a patterned first metallization **104** on an electrically insulative body **106**. The substrate **102** may also have a second metallization **108** on the opposite side of the electrically insulative body **106** as the patterned first metallization **104**. The substrate **102** may be a direct copper bonded (DCB) substrate, an active metal brazed (AMB) substrate, or an insulated metal (IMS) substrate, where in each case the electrically insulative body **106**, e.g., a ceramic body, separates the first and second metallizations **104**, **108** of the substrate **102** from one another.
[0026] The first metallization **104** of the substrate **102** is patterned to ensure proper isolation and signal routing for implementing a power electronics device implemented using the power module **100**. Exemplary electrical connections are described in more detail later in the context of a half bridge. However, a half bridge is just one example of a power electronics device that may be implemented using the power module **100**. The first metallization **104** of the substrate **102** may be patterned differently than what is illustrated in the figures, to facilitate electrical connections for any type of power electronics device implemented using the power module **100**.
[0027] The power module **100** also includes first power semiconductor dies **110** attached to a first metallic island **112** of the patterned first metallization **104**, and second power semiconductor dies **114** attached to a second metallic island **116** of the patterned first metallization **104**. In one embodiment, the power semiconductor dies **110**, **114** are vertical power transistor dies. For a vertical power transistor die, the primary current flow path is between the front and back sides of each die **110**, **114** (along the z direction in FIGS. **1**A through **1**D). The drain pad is typically disposed at the die backside, with gate and source pads (and optionally one or more sense pads) at the die frontside. Additional types of semiconductor dies may be included in the power module **100**, such as power diode dies, logic dies, controller dies, gate driver dies, etc.
[0028] In one embodiment, the power semiconductor dies **110**, **114** are SiC power MOSFET (metal-oxide-semiconductor field-effect transistor) dies. The power semiconductor dies **110**, **114** instead may be Si power MOSFET dies, HEMT (high-electron mobility transistor) dies, IGBT (insulated-gate bipolar transistor) dies, JFET (junction filed-effect transistor) dies, etc. The first power semiconductor dies **110** may be the same or different type of die as the second power semiconductor dies **114**.
[0029] A mold compound **118** at least partly embeds the substrate **102**, the first power

semiconductor dies **110**, and the second power semiconductor dies **114**. The mold compound **118** is a plastic encapsulant that may be formed from an organic resin such as an epoxy resin. The plastic encapsulant may include fillers such as non-melting inorganic materials. Catalysts may be used to accelerate the cure reaction of the organic resin. Other materials such as flame retardants, adhesion promoters, ion traps, stress relievers, colorants, etc. may be added to the plastic encapsulant, as appropriate. The mold compound **118** may be formed by injection molding, compression molding, film-assisted molding (FAM), reaction injection molding (RIM), resin transfer molding (RTM), blow molding, etc.

[0030] A multilevel metallic frame **120** is partly embedded in the mold compound **118** and disposed over the substrate **102**. In FIGS. **1**A through **1**D, the multilevel metallic frame **120** is disposed above the substrate **102** in the vertical (z) direction. The front (top) surface of the substrate **102** forms a baseline that defines the horizontal plane in FIGS. **1**A through **1**D. The vertical (z) direction is perpendicular to the horizontal plane, with the horizontal plane being defined by the x and y directions in FIGS. **1**A through **1**D.

[0031] The multilevel metallic frame **120** includes the module power terminals **122**, **124**, **126** which are exposed at the side of the mold compound **118** that faces away from the patterned first metallization **104** of the substrate **102**. The module power terminals **122**, **124**, **126** transition between two or more different levels L**1**, L**2**, L**3** to electrically interconnect the first power semiconductor dies **110** and the second power semiconductor dies **114** in a half bridge or full bridge configuration. The multilevel metallic frame **120** may be a multilevel lead frame. The levels, level transitions, and power terminal features of the multilevel metallic frame **120** may be produced by metal processing techniques such as stamping, punching, etching, coining, etc. The multilevel metallic frame **120** may comprise a core metal region with one or more layers or coatings, e.g., adhesion promotion layers, anticorrosion layers, etc.

[0032] In the case of a half bridge configuration, the first power semiconductor dies **110** may be electrically coupled in parallel to form a high-side switch device of the half bridge and the second power semiconductor dies **114** may be electrically coupled in parallel to form a low-side switch device of the half bridge. Continuing with the half bridge example, the multilevel metallic frame **120** may provide a high-side (DC+) power terminal **122** for providing a high-side DC current path to the high-side switch device, a low-side (DC−) terminal for providing a low-side DC current path to the low-side switch device, and a phase (AC) terminal **126** for providing a phase or quasi-AC current path to the switch node between the high-side switch device and the low-side switch device. The power terminal configuration of the multilevel metallic frame **120** may be designed for other types of power circuit configurations.

[0033] In each case, the power terminals **122**, **124**, **126** have a shorter length compared to conventional power module terminals that would otherwise protrude from one or more side faces of the mold compound **118** in the x and/or y direction in FIGS. **1**A through **1**D. Instead, the power terminals are exposed for connecting to at the front (top) side of the mold compound **118** in the z direction in FIGS. **1**A through **1**D. Such a configuration reduces the length of the power terminals **122**, **124**, **126**, thus reducing the module stray inductance. In one embodiment, the power module **100** has a stray inductance below 10 nH, below 5 nH, below 3 nH, or even below 2 nH by utilizing the multilevel metallic frame **120**.

[0034] As shown in FIG. **1**B, the multilevel metallic frame **120** may be laterally restricted to the footprint of the substrate **102**. That is, the multilevel metallic frame **120** may not extend laterally in the x direction or y direction beyond the outer edge or perimeter of the substrate **102**. Such a configuration further reduces the length of at least some of the power terminals **122**, **124**, **126**, correspondingly reducing the module stray inductance.

[0035] As shown in FIGS. **1**C and **1**D, the DC+ terminal **122** of the multilevel metallic frame **120** transitions from a first level L**1** to a second level L**2** in the vertical (z) direction. The DC− terminal **124** of the multilevel metallic frame **120** transitions from the first level L**1** to a third level L**3** that is between the first level L**1** and the second level L**2**. The phase (AC) terminal **126** of the multilevel metallic frame **120** transitions from the first level L**1** to the third level L**3** and to the second level L**2**. At the first level L**1**, the DC+ terminal **122**, the DC− terminal **124**, and the phase (AC) terminal **126** are each uncovered by the mold compound and therefore externally accessible at the front (top) side of the mold compound **118** in the z direction.

[0036] Further as shown in FIGS. **1**C and **1**D, at the second level L**2**, the DC+ terminal **122** of the multilevel metallic frame **120** is attached to the first metallic island **112** of the patterned substrate metallization **104** and the phase (AC) terminal **126** of the multilevel metallic frame **120** is attached to the second metallic island **116** of the patterned substrate metallization **104**. At the third level L**3**, the DC− terminal **124** of the multilevel metallic frame **120** is attached to a load pad **128** of the second power semiconductor dies **114** and the phase (AC) terminal **126** of the multilevel metallic frame **120** is attached to a load pad **130** of the first power semiconductor dies **110**.

[0037] In one embodiment, the first power semiconductor dies **110** and the second power semiconductor dies **114** are power MOSFET dies. According to this embodiment, a drain pad **132** of each first power semiconductor die **110** is attached to the first metallic island **112** of the patterned substrate metallization **104** at the back side of the first power semiconductor dies **110**. The first metallic island **112** of the patterned substrate metallization **104** provides an electrical connection between the drain pad **132** of each first power semiconductor die **110** and the DC+ terminal **122** of the multilevel metallic frame **120**. Each first power semiconductor die **110** also has at least a source pad **130** and a gate pad **134** at the front side of the die **110**.

[0038] Continuing with the power MOSFET example, a drain pad **136** of each second power semiconductor die **114** is attached to the second metallic island **116** of the patterned substrate metallization **104** at the back side of the second power semiconductor dies **114**. The second metallic island **116** of the patterned substrate metallization **104** provides an electrical connection between the drain pad **136** of each second power semiconductor die **114** and the phase (AC) terminal **126** of the multilevel metallic frame **120**. Each second power semiconductor die **110** also has at least a source pad **128** and a gate pad **138** at the front side of the die **114**. At the third level L**3**, the DC− terminal **124** of the multilevel metallic frame **120** is attached to the source pad **128** of the second power semiconductor dies **114** and the phase (AC) terminal of the multilevel metallic frame **120** is attached to the source pad **130** of the first power semiconductor dies **110**. Solder, diffusion solder, glue, adhesive, etc. may be used to make the respective attachments.

[0039] The signal connections to the power module **100** may be implemented using an additional metallic frame **140** that is separate and distinct from the multilevel metallic frame **120**. In FIGS. **1**A through **1**D, the additional metallic frame **140** is partly embedded in the mold compound **118** and includes a first gate terminal **142** protruding from a side face **144** of the mold compound **118** and running along a first edge **146** of the substrate **102**. The additional metallic frame **140** also includes a second gate terminal **148** protruding from the side face **144** of the mold compound **118** and running along a second edge **150** of the substrate **102** opposite the first edge **146**. The gate terminal configuration shown in FIGS. **1**A through **1**D provides better symmetry of the gate signals provided to the power semiconductor dies **110**, **114**. The configuration of the patterned substrate metallization **104** shown in FIGS. **1**A through **1**D similarly provides better power symmetry.

[0040] The first gate terminal **142** of the additional metallic frame **140** is electrically connected to a third metallic island **152** of the patterned substrate metallization **104**. The third metallic island **152** of the patterned substrate metallization **104** is electrically connected to the gate pad **134** of the first power semiconductor dies **110** by one or more electrical conductors **154** such as a wire ribbon, a metallic clip, bond wires, etc. The second gate terminal **148** of the additional metallic frame **140** is electrically connected to a fourth metallic island **156** of the patterned substrate metallization **104**. The fourth metallic island **156** is electrically connected to the gate pad **138** of the second power semiconductor dies **114** by one or more electrical conductors **158** such as a wire ribbon, a metallic clip, bond wires, etc.

[0041] In FIGS. **1**A through **1**D, the third metallic island **152** of the patterned substrate metallization **104** is laterally interposed between the first edge **146** of the substrate **102** and the first metallic island **112** of the patterned substrate metallization **104**. The fourth metallic island **156** of the patterned substrate metallization **104** is laterally interposed between the second edge **150** of the substrate **102** and the second metallic island **116** of the patterned substrate metallization **104**. According to this embodiment, the first gate terminal **142** and the second gate terminal **148** of the additional metallic frame **140** run lengthwise in a first lateral direction (y direction in FIGS. **1**A through **1**D) and the part of each power terminal **122**, **124**, **126** of the multilevel metallic frame **120** exposed at the top (front) side of the mold compound **118** also runs lengthwise in the first lateral direction.

[0042] The additional metallic frame **140** may include additional terminals. For example, a first drain sense terminal **160** may be electrically connected to the first metallic island **112** of the patterned substrate metallization **104** by an electrical conductor **162** such as a wire ribbon, a metallic clip, one or more bond wires, etc. A second drain sense terminal **164** may be electrically connected to the second metallic island **116** of the patterned substrate metallization **104** by an electrical conductor **166** such as a wire ribbon, a metallic clip, one or more bond wires, etc. A source sense terminal **168** may be electrically connected to the source pad **128** of the second power semiconductor dies **114** by an electrical conductor **170** such as a wire ribbon, a metallic clip, one or more bond wires, etc. Temperature sense terminals **172**, **174** may be electrically connected to fifth and sixth metallic islands **176**, **178**, respectively, of the patterned substrate metallization **104** by respective electrical conductors **180**, **182** such as a wire ribbon, a metallic clip, one or more bond wires, etc. to sense the voltage across a temperature sensor **184** such as an NTC (negative temperature coefficient) thermistor. The power module **100** may include additional terminals, components, etc.

[0043] FIGS. **2**A through **2**C each illustrate a top plan view (left side of the figures) and a side perspective view (right side of the figures) during different stages of producing the power module **100** shown in FIGS. **1**A through **1**D.

[0044] FIG. **2**A shows the substrate **102** with the first power semiconductor dies **110** attached to the first metallic island **112** of the patterned substrate metallization **104** and the second power semiconductor dies **114** attached to the second metallic island **116** of the patterned substrate metallization **104**. The dies **110**, **114** may be attached to the patterned first metallization **104** of the substrate **102** by soldering, diffusion soldering, brazing, welding, gluing, adhering, etc. The terminals **142**, **148**, **160**, **164**, **172**, **174** of the additional metallic frame **140** may be attached to the patterned first metallization **104** of the substrate **102** during this stage of the module production process.

[0045] FIG. **2**B shows the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** attached to the corresponding pads **128**, **130** of the respective dies **110**, **114** and to the respective metallic islands **112**, **116** of the patterned substrate metallization **104**. The power terminals **122**, **124**, **126** of the multilevel metallic frame **120** may be attached by soldering, diffusion soldering, brazing, welding, gluing, adhering, etc.

[0046] FIG. **2**C shows the power module **100** after the molding process. The mold compound **118** at least partly embeds the substrate **102**, the first power semiconductor dies **110**, and the second power semiconductor dies **114**. The multilevel metallic frame **120** is partly embedded in the mold compound **118** such that the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** are exposed for contact at the front (top) side of the mold compound **118** in the z direction in FIG. **2**C, which reduces the length of the power terminals **122**, **124**, **126** and thus the module stray inductance. The signal terminals **142**, **148**, **160**, **164**, **172**, **174** of the additional metallic frame **140** protrude from a side face **144** of the mold compound **118** so that the power terminals **122**, **124**, **126** and the signal terminals **142**, **148**, **160**, **164**, **172**, **174** are externally accessible at different sides of the power module **100**.

[0047] FIG. **3**A illustrates a top plan view of the power module **100**, FIG. **3**B illustrates a cross-sectional view of the power module **100** along the line labelled A-A in FIG. **3**A, and FIG. **3**C illustrates a cross-sectional view of the power module **100** along the line labelled B-B in FIG. **3**A, according to another embodiment. FIGS. **3**A, **3**B and **3**C are the same views as in FIGS. **1**B, **1**C and **1**D, respectively.
[0048] In FIGS. **3**A, **3**B and **3**C, the first (DC+) power terminal **122** of the multilevel metallic frame **120** vertically overlaps a part **141_1** of the second (DC−) power terminal **124** of the multilevel metallic frame **120** that is attached to the load pad **128** of the second power semiconductor dies **114**. Separately or in combination, the first (DC+) power terminal **122** of the multilevel metallic frame **120** may vertically overlap a part **1261** of the phase (AC) terminal of the multilevel metallic frame **120** that is attached to the second metallic island **116** of the patterned substrate metallization **104**. The overlap between the DC+ and DC− terminals **122**, **124** and/or the DC+ and AC terminals **122**, **126** of the multilevel metallic frame **120** further reduces the module stray inductance since these terminals are at different potentials.
[0049] FIG. **4** illustrates a side perspective view of the power module **100**, according to another embodiment. FIGS. **5**A through **5**C each illustrate a top plan view (left side of the figures) and a side perspective view (right side of the figures) during different stages of producing the power module **100** shown in FIG. **4**.
[0050] FIG. **5**A shows the substrate **102** with the first power semiconductor dies **110** attached to the first metallic island **112** of the patterned substrate metallization **104** and the second power semiconductor dies **114** attached to the second metallic island **116** of the patterned substrate metallization **104**. The dies **110**, **114** may be attached to the patterned first metallization **104** of the substrate **102** by soldering, diffusion soldering, brazing, welding, gluing, adhering, etc. The terminals **142**, **148**, **160**, **164**, **172**, **174** of the additional metallic frame **140** may be attached to the patterned first metallization **104** of the substrate **102** during this stage of the module production process.
[0051] In FIGS. **4** through **5**C, the third and fourth metallic islands **152**, **156** of the patterned substrate metallization **104** are laterally interposed between the first and second metallic islands **112**, **116** of the patterned substrate metallization **104**. According to this embodiment, the first and second gate terminals **142**, **148** of the additional metallic frame **140** run lengthwise in a first lateral direction (y direction in FIGS. **4** through **5**C) and the part of each power terminal **122**, **124**, **126** of the multilevel metallic frame **120** exposed at the side of the mold compound **118** that faces away from the patterned substrate metallization **104** runs lengthwise in a second lateral direction (x direction in FIGS. **4** through **5**C) that is transverse to the first lateral direction.
[0052] Also as shown in FIGS. **4** through **5**C, an intermediate part **152_1** of the third metallic island **152** of the patterned substrate metallization **104** is laterally interposed between the first metallic island **112** of the patterned substrate metallization **104** and an intermediate part **156_1** of the fourth metallic island **156** of the patterned substrate metallization **104**. The intermediate part **156_1** of the fourth metallic island **156** of the patterned substrate metallization **104** is laterally interposed between the second metallic island **116** of the patterned substrate metallization **104** and the intermediate part **152_1** of the third metallic island **152** of the patterned substrate metallization **104**.
[0053] FIG. **5**B shows the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** attached to the corresponding pads **128**, **130** of the respective dies **110**, **114** and to the respective metallic islands **112**, **116** of the patterned substrate metallization **104**. The power terminals **122**, **124**, **126** of the multilevel metallic frame **120** may be attached by soldering, diffusion soldering, brazing, welding, gluing, adhering, etc.
[0054] FIG. **5**C shows the power module **100** after the molding process. The mold compound **118** at least partly embeds the substrate **102**, the first power semiconductor dies **110**, and the second power semiconductor dies **114**. The multilevel metallic frame **120** is partly embedded in the mold

compound **118** such that the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** are exposed for contact at the front (top) side of the mold compound **118** in the z direction in FIG. **2**C, which reduces the length of the power terminals **122**, **124**, **126** and thus the module stray inductance. The signal terminals **142**, **148**, **160**, **164**, **172**, **174** of the additional metallic frame **140** protrude from a side face **144** of the mold compound **118** so that the power terminals **122**, **124**, **126** and the signal terminals **142**, **148**, **160**, **164**, **172**, **174** are externally accessible at different sides of the power module **100**.

[0055] As shown in FIGS. **4** though **5**C, the multilevel metallic frame **120** may be laterally restricted to the footprint of the mold compound **118**. That is, the multilevel metallic frame **120** may not extend laterally in the x direction or y direction beyond the outer edge or perimeter of the mold compound **118**. Such a configuration further reduces the length of at least some of the power terminals **122**, **124**, **126**, correspondingly reducing the module stray inductance.

[0056] In FIGS. **1**A through **5**C, the first DC terminal **122** of the multilevel metallic frame **120** may be interposed between the second DC terminal **124** and the phase terminal **126** of the multilevel metallic frame **120** at the first (exposed) level L**1**, e.g., as shown in FIGS. **1**A through **3**C. In another embodiment, the phase terminal **126** of the multilevel metallic frame **120** may be interposed between the first and second DC terminals **122**, **124** of the multilevel metallic frame **120** at the first (exposed) level L**1**, e.g., as shown in FIGS. **4** through **5**C. In yet another embodiment, the second DC terminal **124** of the multilevel metallic frame **120** may be interposed between the first DC terminal **122** and the phase terminal **126** of the multilevel metallic frame **120** at the first (exposed) level L**1**. In each of these embodiments, the exposed part of the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** may run lengthwise in the y lateral direction (e.g., as shown in FIG. **2**C) or the x lateral direction (e.g., as shown in FIG. **5**C).

[0057] In FIGS. **1**A through **5**C, the first DC terminal **122**, the second DC terminal **124**, and the phase terminal **126** of the multilevel metallic frame **120** each run exposed along the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. Such a terminal configuration allows for surface mounting of the power module **100** to a busbar. However, the power module **100** may have other power terminal connection configurations for interfacing with a busbar as described next in connection with FIGS. **6** through **9**.

[0058] FIG. **6** illustrates a side perspective view of the power module, according to an embodiment. In FIG. **6**, the first DC terminal **122**, the second DC terminal **124**, and the phase terminal **126** of the multilevel metallic frame **120** each protrude from the side of the mold compound **119** that faces away from the patterned substrate metallization **104**. The protruding part of the power terminals **122**, **124**, **126** form a tab-like interface for connecting to a busbar.

[0059] FIG. **7** illustrates a side perspective view of the power module, according to an embodiment. In FIG. **7**, the first DC terminal **122**, the second DC terminal **124**, and the phase terminal **126** of the multilevel metallic frame **120** form the same tab-like interface as in FIG. **6**, but the tabs may have different profiles and optional holes **200** for connecting to a busbar.

[0060] FIG. **8** illustrates a side perspective view of the power module, according to an embodiment. In FIG. **8**, the first DC terminal **122**, the second DC terminal **124**, and the phase terminal **126** of the multilevel metallic frame **120** each have an exposed screw type, bolt type, press-fit type, or rivet type connector **202** that protrudes from the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. That is, the protruding connector part **202** of the power terminals **122**, **124**, **126** may have the form of a screw, bolt, press-fit pin, or rivet and provide an interface for connecting to a busbar.

[0061] FIG. **9** illustrates a side perspective view of the power module, according to an embodiment. In FIG. **9**, the first DC terminal **122**, the second DC terminal **124**, and the phase terminal **126** of the multilevel metallic frame **120** each have an exposed screw type, bolt type, press-fit type, or rivet type surface connector **204** formed in the exposed part of the terminals **122**, **124**, **126** at the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. That is, the exposed surface connector **204** of the power terminals **122**, **124**, **126** may have the form of a hole for receiving a screw, bolt, press-fit pin, or rivet and provide an interface for connecting to a busbar.

[0062] FIG. **10** illustrates a partial cross-sectional view of the power module **100** in the region of a single screw type or bolt type power terminal connector **202** that protrudes from the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. The protruding screw type or bolt type power terminal connector **202** has the form of a screw or bolt and provides an interface for connecting to a busbar. The protruding screw type or bolt type power terminal connector **202** may be soldered, welded, brazed, screwed, or riveted to the corresponding power terminal of the multilevel metallic frame **120**.

[0063] In FIG. **10**, the protruding screw type or bolt type power terminal connector **202** is shown with a rivet or press-fit bolt type connection to the second DC terminal **124** of the multilevel metallic frame **120**. For example, a rivet connection may be implemented using a rivet nut **204** that is inserted and set entirely from one side of the second DC terminal **124** of the multilevel metallic frame **120**. The rivet nut **204** has an internal thread which provides a secure mounting for a threaded bolt **206**. Friction drilling instead may be used to make an opening in the second DC terminal **124** of the multilevel metallic frame **120** and thread or press-fit the bolt **206** into the opening. Still other techniques may be used to provide any of the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** with a screw type, bolt type, press-fit type, or rivet type connector.

[0064] The other power terminals **122**, **126** of the multilevel metallic frame **120** may also have the screw type or bolt type power terminal connector **202** shown in FIG. **10**, or a different type of connector for interfacing with a busbar. More generally, the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** may use the same or different busbar connector types.

[0065] FIG. **11** illustrates a partial cross-sectional view of the power module **100** in the region of forming a laser welded busbar connection to the second power terminal **124** of the multilevel metallic frame **120** at the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. The exposed part of the second power terminal **124** is laser welded **300** to a busbar which is not shown in FIG. **11**. In one embodiment, the mold compound **118** has an undercut **302** in each region where the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** are exposed at the side of the mold compound **118** that faces away from the patterned substrate metallization **104**. The undercut **302** allows for the laser welding **300** without damaging the mold compound **118**.

[0066] FIG. **12** illustrates a partial cross-sectional view of the power module **100** in the region of forming a laser welded busbar connection to the second power terminal **124** of the multilevel metallic frame **120** at the side of the mold compound **118** that faces away from the patterned substrate metallization **104**, according to another embodiment. A heat insulation foil/coating **400** may be provided on the underside of each power terminal **122**, **124**, **126** of the multilevel metallic frame **120** being laser welded **300**, to protect the adjoining mold compound **118** during the laser welding **300**. The heat insulation foil/coating **400** may be a standard thermal interface material such as thermal greases, polyimide film, etc. Another non-metallic material with good heat capacity could be attached to the underside to store/buffer heat energy generated during laser welding. The mold compound **118** may or may not have the undercut **302** in each region where the power terminals **122**, **124**, **126** of the multilevel metallic frame **120** are exposed and laser welded **300** at the side of the mold compound **118** that faces away from the patterned substrate metallization **104**.

[0067] The power module **100** illustrated in FIGS. **1**A through **12** may be included on a power electronics assembly. The power electronics assembly may include a plurality of the power modules **100**, e.g., to power two or more phases of a multi-phase load such as a motor drive system. The power modules **100** are connected to a busbar that carries power between the power modules **100** and the load.

[0068] FIG. **13** illustrates a top plan view of a power electronics assembly **500**, according to an embodiment. In the example illustrated, the power electronics assembly **500** drives a load (not shown) that has three phases, U, V, W, e.g., such as a motor drive system. In FIG. **13**, the power electronics assembly **500** includes a single power module **100** for each phase U, V, W of the load. The exposed part of the power terminals **122**, **124**, **126** of each power module **100** are connected to a busbar **502**. The busbar **502** includes a first metallic strip or bar **504** that provides DC+ potential to the exposed part of the first power terminal **122** of each power module **100**. The busbar **502** also includes a second metallic strip or bar **506** that provides DC− potential to the exposed part of the second power terminal **124** of each power module **100**. The busbar **502** further includes a separate metallic strip or bar **508**_*n* that forms the respective phase connection (U, V or W) to the exposed part of the phase (AC) terminal **126** of each power module **100**, where n corresponds to the individual phases supported by the power electronics assembly **500**. The power modules **100** may have any of the connector types previously described herein to facilitate connection to the busbar **502**.
[0069] The power electronics assembly **500** also includes a control board **110** that has the gate driver and control circuitry for driving and controlling the power semiconductor dies **110**, **114** included in the power modules **100**. The control board **110** is connected to the terminals of the power modules **100** provided by the additional metallic frame **140** included in the modules **100**. The control board **110** may be connected to the terminals of the power modules **100** by soldering, brazing, press-fitting, etc. The metallization **108** at the bottom side of the power modules **100** may be contacted by a heat exchanger **512** such as an actively or passively cooled heat sink, to extract heat dissipated by the power semiconductor dies **110**, **114** during operation. The busbar **502**, control board **510** and heat exchanger **512** are schematically illustrated in FIG. **13** as dashed rectangles to provide an unobstructed view of the interface between the power modules **100** and the busbar **502**, control board **510** and heat exchanger **512**.
[0070] FIG. **14** illustrates a top plan view of the power electronics assembly **500**, according to another embodiment. In FIG. **14**, the power electronics assembly **500** includes two power modules **100** for each phase U, V, W of the load. More generally, the power electronics assembly **500** may have one or more of the power modules **100** per phase U, V, W, where the number of modules per phase depends on the phase current requirement and the current rating of the power modules **100**.
[0071] Although the present disclosure is not so limited, the following numbered examples demonstrate one or more aspects of the disclosure.
[0072] Example 1. A power module, comprising: a substrate comprising a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate, wherein the multilevel metallic frame comprises a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration.
[0073] Example 2. The power module of example 1, wherein the power module has a stray inductance below 5 nH.
[0074] Example 3. The power module of example 1 or 2, wherein the multilevel metallic frame is laterally restricted to a footprint of the substrate.
[0075] Example 4. The power module of any of examples 1 through 3, wherein the plurality of power terminals of the multilevel metallic frame comprises a first DC terminal, a second DC terminal, and a phase terminal.
[0076] Example 5. The power module of example 4, wherein the first DC terminal transitions from

a first level to a second level, wherein the second DC terminal transitions from the first level to a third level that is between the first level and the second level, wherein the phase terminal transitions from the first level to the third level and to the second level, wherein at the first level, the first DC terminal, the second DC terminal, and the phase terminal are each uncovered by the mold compound.

[0077] Example 6. The power module of example 5, wherein at the second level, the first DC terminal is attached to the first metallic island of the patterned metallization and the phase terminal is attached to the second metallic island of the patterned metallization, wherein at the third level, the second DC terminal is attached to a load pad of the second power semiconductor dies and the phase terminal is attached to a load pad of the first power semiconductor dies.

[0078] Example 7. The power module of example 6, wherein the first power semiconductor dies are power MOSFET dies each having a drain pad attached to the first metallic island of the patterned metallization at a first side of the first power semiconductor dies and a source pad and a gate pad at a second side opposite the first side, wherein the second power semiconductor dies are power MOSFET dies each having a drain pad attached to the second metallic island of the patterned metallization at a first side of the second power semiconductor dies and a source pad and a gate pad at a second side opposite the first side, wherein at the third level, the second DC terminal is attached to the source pad of the second power semiconductor dies and the phase terminal is attached to the source pad of the first power semiconductor dies.

[0079] Example 8. The power module of example 6 or 7, wherein the first DC terminal vertically overlaps a part of the second DC terminal that is attached to the load pad of the second power semiconductor dies.

[0080] Example 9. The power module of any of examples 5 through 8, wherein at the first level, the first DC terminal is interposed between the second DC terminal and the phase terminal.

[0081] Example 10. The power module of any of examples 5 through 9, wherein at the first level, the second DC terminal is interposed between the first DC terminal and the phase terminal.

[0082] Example 11. The power module of any of examples 5 through 10, wherein at the first level, the phase terminal is interposed between the first DC terminal and the second DC terminal.

[0083] Example 12. The power module of any of examples 5 through 11, wherein the first metallic island and the second metallic island of the patterned metallization have a lengthwise extension in a first lateral direction, and wherein at the first level, the first DC terminal, the second DC terminal, and the phase terminal each have a lengthwise extension in the first lateral direction.

[0084] Example 13. The power module of any of examples 5 through 12, wherein the first DC terminal vertically overlaps a part of the phase terminal that is attached to the second metallic island of the patterned metallization.

[0085] Example 14. The power module of any of examples 4 through 13, wherein the first DC terminal, the second DC terminal, and the phase terminal each run exposed along the side of the mold compound that faces away from the patterned metallization.

[0086] Example 15. The power module of any of examples 4 through 13, wherein the first DC terminal, the second DC terminal, and the phase terminal each protrude from the side of the mold compound that faces away from the patterned metallization.

[0087] Example 16. The power module of examples 4 through 15, wherein the first DC terminal, the second DC terminal, and the phase terminal each have an exposed screw type, bolt type, press-fit type or rivet type connector at the side of the mold compound that faces away from the patterned metallization.

[0088] Example 17. The power module of any of examples 4 through 16, wherein the mold compound has an undercut in each region where the first DC terminal, the second DC terminal, and the phase terminal are exposed at the side of the mold compound that faces away from the patterned metallization.

[0089] Example 18. The power module of any of examples 1 through 17, further comprising: an additional metallic frame partly embedded in the mold compound and comprising: a first gate terminal protruding from a side face of the mold compound and running along a first edge of the substrate; and a second gate terminal protruding from the side face of the mold compound and running along a second edge of the substrate opposite the first edge, wherein the first gate terminal is electrically connected to a third metallic island of the patterned metallization and the third metallic island is electrically connected to a gate pad of the first power semiconductor dies, wherein the second gate terminal is electrically connected to a fourth metallic island of the patterned metallization and the fourth metallic island is electrically connected to a gate pad of the second power semiconductor dies.

[0090] Example 19. The power module of example 18, wherein the third metallic island of the patterned metallization is laterally interposed between the first edge of the substrate and the first metallic island of the patterned metallization, and wherein the fourth metallic island of the patterned metallization is laterally interposed between the second edge of the substrate and the second metallic island of the patterned metallization.

[0091] Example 20. The power module of example 18, wherein the third metallic island and the fourth metallic island of the patterned metallization are laterally interposed between the first metallic island and the second metallic island of the patterned metallization.

[0092] Example 21. The power module of example 20, wherein an intermediate part of the third metallic island of the patterned metallization is laterally interposed between the first metallic island of the patterned metallization and an intermediate part of the fourth metallic island of the patterned metallization, and wherein the intermediate part of the fourth metallic island of the patterned metallization is laterally interposed between the second metallic island of the patterned metallization and the intermediate part of the third metallic island of the patterned metallization.

[0093] Example 22. The power module of any of examples 18 through 21, wherein the first gate terminal and the second gate terminal run lengthwise in a first lateral direction, and wherein the part of each power terminal exposed at the side of the mold compound that faces away from the patterned metallization runs lengthwise in the first lateral direction.

[0094] Example 23. The power module of any of examples 18 through 21, wherein the first gate terminal and the second gate terminal run lengthwise in a first lateral direction, and wherein the part of each power terminal exposed at the side of the mold compound that faces away from the patterned metallization runs lengthwise in a second lateral direction that is transverse to the first lateral direction.

[0095] Example 24. The power module of any of examples 1 through 23, wherein the multilevel metallic frame is laterally restricted to a footprint of the mold compound.

[0096] Example 25. A power electronics assembly for power a multi-phase load, the power electronics assembly comprising: one or more power modules for each phase of the multi-phase load, each power module comprising: a substrate comprising a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate, wherein the multilevel metallic frame comprises a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration, wherein the power electronics assembly further comprises a busbar connected to the exposed part of the power terminals of the power modules.

[0097] Example 26. The power electronics assembly of example 25, wherein each power module further comprises an additional metallic frame partly embedded in the mold compound and

comprising: a first gate terminal protruding from a side face of the mold compound and running along a first edge of the substrate; and a second gate terminal protruding from the side face of the mold compound and running along a second edge of the substrate opposite the first edge, wherein the first gate terminal is electrically connected to a third metallic island of the patterned metallization and the third metallic island is electrically connected to a gate pad of the first power semiconductor dies, wherein the second gate terminal is electrically connected to a fourth metallic island of the patterned metallization and the fourth metallic island is electrically connected to a gate pad of the second power semiconductor dies, wherein the power electronics assembly further comprises a control board that has gate driver and control circuitry for driving and controlling the power semiconductor dies included in the power modules, and wherein the control board is connected to the terminals of the power modules provided by the additional metallic frame included in the power modules.
[0098] Terms such as “first”, “second”, and the like, are used to describe various elements, regions, sections, etc. and are also not intended to be limiting. Like terms refer to like elements throughout the description.
[0099] As used herein, the terms “having”, “containing”, “including”, “comprising” and the like are open ended terms that indicate the presence of stated elements or features, but do not preclude additional elements or features. The articles “a”, “an” and “the” are intended to include the plural as well as the singular, unless the context clearly indicates otherwise.
[0100] The expression “and/or” should be interpreted to cover all possible conjunctive and disjunctive combinations, unless expressly noted otherwise. For example, the expression “A and/or B” should be interpreted to mean only A, only B, or both A and B. The expression “at least one of” should be interpreted in the same manner as “and/or”, unless expressly noted otherwise. For example, the expression “at least one of A and B” should be interpreted to mean only A, only B, or both A and B.
[0101] It is to be understood that the features of the various embodiments described herein may be combined with each other, unless specifically noted otherwise.
[0102] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

Claims

1. A power module, comprising: a substrate comprising a patterned metallization on an electrically insulative body; a plurality of first power semiconductor dies attached to a first metallic island of the patterned metallization; a plurality of second power semiconductor dies attached to a second metallic island of the patterned metallization; a mold compound at least partly embedding the substrate, the first power semiconductor dies, and the second power semiconductor dies; and a multilevel metallic frame partly embedded in the mold compound and disposed over the substrate, wherein the multilevel metallic frame comprises a plurality of power terminals exposed at a side of the mold compound that faces away from the patterned metallization and that transition between two or more different levels to electrically interconnect the first power semiconductor dies and the second power semiconductor dies in a half bridge or full bridge configuration.
2. The power module of claim 1, wherein the power module has a stray inductance below 5 nH.
3. The power module of claim 1, wherein the multilevel metallic frame is laterally restricted to a footprint of the substrate.
4. The power module of claim 1, wherein the plurality of power terminals of the multilevel metallic

frame comprises a first DC terminal, a second DC terminal, and a phase terminal.
5. The power module of claim 4, wherein the first DC terminal transitions from a first level to a second level, wherein the second DC terminal transitions from the first level to a third level that is between the first level and the second level, wherein the phase terminal transitions from the first level to the third level and to the second level, wherein at the first level, the first DC terminal, the second DC terminal, and the phase terminal are each uncovered by the mold compound.
6. The power module of claim 5, wherein at the second level, the first DC terminal is attached to the first metallic island of the patterned metallization and the phase terminal is attached to the second metallic island of the patterned metallization, wherein at the third level, the second DC terminal is attached to a load pad of the second power semiconductor dies and the phase terminal is attached to a load pad of the first power semiconductor dies.
7. The power module of claim 6, wherein the first power semiconductor dies are power MOSFET dies each having a drain pad attached to the first metallic island of the patterned metallization at a first side of the first power semiconductor dies and a source pad and a gate pad at a second side opposite the first side, wherein the second power semiconductor dies are power MOSFET dies each having a drain pad attached to the second metallic island of the patterned metallization at a first side of the second power semiconductor dies and a source pad and a gate pad at a second side opposite the first side, wherein at the third level, the second DC terminal is attached to the source pad of the second power semiconductor dies and the phase terminal is attached to the source pad of the first power semiconductor dies.
8. The power module of claim 6, wherein the first DC terminal vertically overlaps a part of the second DC terminal that is attached to the load pad of the second power semiconductor dies.
9. The power module of claim 5, wherein at the first level, the first DC terminal is interposed between the second DC terminal and the phase terminal.
10. The power module of claim 5, wherein at the first level, the second DC terminal is interposed between the first DC terminal and the phase terminal.
11. The power module of claim 5, wherein at the first level, the phase terminal is interposed between the first DC terminal and the second DC terminal.
12. The power module of claim 5, wherein the first metallic island and the second metallic island of the patterned metallization have a lengthwise extension in a first lateral direction, and wherein at the first level, the first DC terminal, the second DC terminal, and the phase terminal each have a lengthwise extension in the first lateral direction.
13. The power module of claim 5, wherein the first DC terminal vertically overlaps a part of the phase terminal that is attached to the second metallic island of the patterned metallization.
14. The power module of claim 4, wherein the first DC terminal, the second DC terminal, and the phase terminal each run exposed along the side of the mold compound that faces away from the patterned metallization.
15. The power module of claim 4, wherein the first DC terminal, the second DC terminal, and the phase terminal each protrude from the side of the mold compound that faces away from the patterned metallization.
16. The power module of claim 4, wherein the first DC terminal, the second DC terminal, and the phase terminal each have an exposed screw type, bolt type, press-fit type or rivet type connector at the side of the mold compound that faces away from the patterned metallization.
17. The power module of claim 4, wherein the mold compound has an undercut in each region where the first DC terminal, the second DC terminal, and the phase terminal are exposed at the side of the mold compound that faces away from the patterned metallization.
18. The power module of claim 1, further comprising: an additional metallic frame partly embedded in the mold compound and comprising: a first gate terminal protruding from a side face of the mold compound and running along a first edge of the substrate; and a second gate terminal protruding from the side face of the mold compound and running along a second edge of the

substrate opposite the first edge, wherein the first gate terminal is electrically connected to a third metallic island of the patterned metallization and the third metallic island is electrically connected to a gate pad of the first power semiconductor dies, wherein the second gate terminal is electrically connected to a fourth metallic island of the patterned metallization and the fourth metallic island is electrically connected to a gate pad of the second power semiconductor dies.

19. The power module of claim 18, wherein the third metallic island of the patterned metallization is laterally interposed between the first edge of the substrate and the first metallic island of the patterned metallization, and wherein the fourth metallic island of the patterned metallization is laterally interposed between the second edge of the substrate and the second metallic island of the patterned metallization.

20. The power module of claim 18, wherein the third metallic island and the fourth metallic island of the patterned metallization are laterally interposed between the first metallic island and the second metallic island of the patterned metallization.

21. The power module of claim 20, wherein an intermediate part of the third metallic island of the patterned metallization is laterally interposed between the first metallic island of the patterned metallization and an intermediate part of the fourth metallic island of the patterned metallization, and wherein the intermediate part of the fourth metallic island of the patterned metallization is laterally interposed between the second metallic island of the patterned metallization and the intermediate part of the third metallic island of the patterned metallization.

22. The power module of claim 18, wherein the first gate terminal and the second gate terminal run lengthwise in a first lateral direction, and wherein the part of each power terminal exposed at the side of the mold compound that faces away from the patterned metallization runs lengthwise in the first lateral direction.

23. The power module of claim 18, wherein the first gate terminal and the second gate terminal run lengthwise in a first lateral direction, and wherein the part of each power terminal exposed at the side of the mold compound that faces away from the patterned metallization runs lengthwise in a second lateral direction that is transverse to the first lateral direction.

24. The power module of claim 1, wherein the multilevel metallic frame is laterally restricted to a footprint of the mold compound.
