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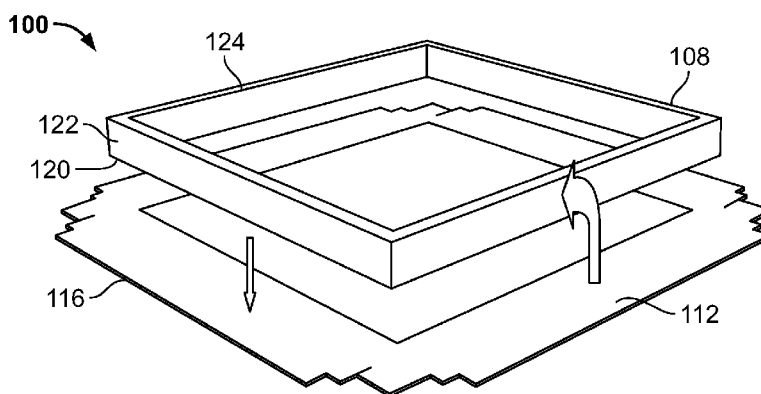


FIG. 1

(57) **Abstract:** According to various aspects, exemplary embodiments are disclosed of soft and/or flexible EMI shields. An exemplary embodiment includes a shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate. The shield generally includes one or more sidewalls and a cover coupled to the one or more sidewalls. The one or more sidewalls may be dielectric, soft, and/or flexible.

SOFT AND/OR FLEXIBLE BOARD LEVEL SHIELDS AND RELATED METHODS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 62/159,189 filed May 8, 2015. The entire disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure generally relates to soft and/or flexible board level shields and related methods.

BACKGROUND

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] A common problem in the operation of electronic devices is the generation of electromagnetic radiation within the electronic circuitry of the equipment. Such radiation may result in electromagnetic interference (EMI) or radio frequency interference (RFI), which can interfere with the operation of other electronic devices within a certain proximity. Without adequate shielding, EMI/RFI interference may cause degradation or complete loss of important signals, thereby rendering the electronic equipment inefficient or inoperable.

[0005] A common solution to ameliorate the effects of EMI/RFI is through the use of shields capable of absorbing and/or reflecting and/or redirecting EMI energy. These shields are typically employed to localize EMI/RFI within its source, and to insulate other devices proximal to the EMI/RFI source.

[0006] The term “EMI” as used herein should be considered to generally include and refer to EMI emissions and RFI emissions, and the term “electromagnetic” should be considered to generally include and refer to electromagnetic and radio frequency from external sources and internal sources. Accordingly, the term shielding (as used herein) broadly includes and refers to mitigating (or limiting) EMI and/or RFI, such as by absorbing, reflecting, blocking, and/or redirecting the energy or some combination thereof so that it no longer interferes, for example, for government compliance and/or for internal functionality of the electronic component system.

SUMMARY

[0007] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0008] According to various aspects, exemplary embodiments are disclosed of soft and/or flexible board level shields. An exemplary embodiment includes a shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate. The shield generally includes one or more sidewalls and a cover coupled to the one or more sidewalls. The one or more sidewalls may be dielectric, soft, and/or flexible.

[0009] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0010] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0011] FIG. 1 is an exploded perspective underside view of a board level shield according to an exemplary embodiment;

[0012] FIG. 2 is an exploded perspective underside view of a board level shield according to another exemplary embodiment;

[0013] FIG. 3 is an exploded perspective topside view of a board level shield according to another exemplary embodiment;

[0014] FIG. 4 shows a board level shield according to another exemplary embodiment;

[0015] FIG. 5 shows a board level shield according to another exemplary embodiment;

[0016] FIG. 6 shows a board level shield according to another exemplary embodiment;

[0017] FIGS. 7, 8, and 9 are process flow diagrams of exemplary methods of making board level shields according to exemplary embodiments;

[0018] FIGS. 10, 11, and 12 illustrate exemplary processes of combining a cover with a fence or frame by wrapping or folding the cover about the sidewalls of the fence or frame according to exemplary embodiments;

[0019] FIG. 13 illustrates three steps or phases of an exemplary assembly process using a fixture according to exemplary embodiments;

[0020] FIG. 14 is a process flow diagram of an exemplary production process using automation equipment for making board level shields according to exemplary embodiments; and

[0021] FIGS. 15 through 18 are exemplary line graphs of shielding effectiveness in decibels versus frequency from 30 Megahertz (MHz) to 18 Gigahertz (18GHz) for several exemplary embodiments of EMI shields and a conventional metal board level shield for comparison purposes.

DETAILED DESCRIPTION

[0022] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0023] Disclosed herein are exemplary embodiments of electromagnetic (EMI) shields, shielding apparatus or assemblies. In some exemplary embodiments, an EMI shield includes one or more sidewalls, internal walls, fences, frames, *etc.*, and a cover (broadly, a top or upper surface). In an exemplary embodiment, the walls are dielectric, soft, and/or flexible. A cover may include electrically-conductive materials such as metal foil, electrically-conductive fabric, tin-containing polyimide film, or other shielding film, *etc.* By way of example, an exemplary embodiment of an EMI shield may be capable of being bent or curved around a curved surface having a diameter of about 50.8 millimeters. As another example, another exemplary embodiment of an EMI shield may be capable of being bent or curved around a curved surface having a diameter of about 37.45 millimeters.

[0024] With reference to the figures, FIG. 1 illustrates an exemplary embodiment of an EMI shield 100 according to aspects of the present disclosure. The EMI shield 100 includes soft and/or flexible sidewalls 108 and a cover 112. The shield 100 is operable for shielding one or more components that may be provided on a substrate (not shown) within an interior or shielding enclosure cooperatively defined by the sidewalls 108 and the cover 112.

[0025] In various exemplary embodiments, the sidewalls 108 are dielectric, soft, and flexible. In such exemplary embodiments, the sidewalls 108 may be formed from rubber, non-conductive plastic, foam, other dielectric, soft, and flexible materials, *etc.* In an exemplary embodiment, the sidewalls 108 are formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the sidewalls. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the sidewalls may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection molding, rubber and molding, rubber and die cutting, *etc.*

[0026] The cover 112 may be made from an electrically-conductive fabric (*e.g.*, metal plated cloth, *etc.*), electrically-conductive film, *etc.* The cover 112 is attached to the sidewalls 108 by folding edges 116 of the cover 112 around portions of the sidewalls 108. For example, the edges 116 of the cover 112 may be folded around the first, upper, or top edges 120 of the sidewalls 108. The cover 112 may be sized relative to the sidewalls 108 such that the cover's edges 116 also extend at least partially or entirely along an exterior or outer surface of the middle portions 122 of the sidewalls 108. The middle portions 122 are between the first edges 120 and the second, lower, or bottom edges 124 of the sidewalls 108. The cover 112 may also be sufficiently large enough so that the cover's edges 116 may also be folded (*e.g.*, wrapped, *etc.*) around the second or lower edges 124 of the sidewalls 108. In which case, the cover's edges 116 may also extend at least partially or entirely along an interior or inner surface of the middle portions 122 of the sidewalls 108.

[0027] The cover's edges 116 may be secured to the sidewalls 108 by an adhesive, *e.g.*, a pressure-sensitive adhesive (PSA), hot melt adhesive, epoxy, *etc.* In example embodiments, an adhesive (*e.g.*, an electrically-conductive pressure sensitive adhesive (CPSA), electrically non-conductive or dielectric PSA, *etc.*) is used to attach the folded edges 116 of the cover 112 to the sidewalls 108. For example, an acrylic CPSA may be used to attach the folded

edges 116 of the cover 112 to the sidewalls 108. The acrylic CPSA may be disposed between the cover's folded edges 116 and the top edges 120, bottom edges 124 and/or middle portions 122 of the sidewalls 108 in embodiments in which the cover's folded edges 116 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 124 of the sidewalls 108. Other or additional adhesives and/or methods could be used to attach the cover 112 to the sidewalls 108.

[0028] After the cover 112 has been attached to the sidewalls 108, the shield 100 may be attached to a PCB or other substrate using an electrically-conductive pressure-sensitive adhesive (CPSA) (*e.g.*, nickel/copper acrylic-based CPSA, *etc.*), an electrically-conductive hotmelt adhesive, *etc.* The shield 100 may be attached to the PCB such that the shield 100 is positioned over one or more components mounted (*e.g.*, previously soldered, *etc.*) on the PCB. For example, a CPSA may be laminated onto the bottom edges 124 of the sidewalls 108 in embodiments in which the cover's edges 116 are not folded around the bottom edges 124 of the sidewalls 108. Or for example, a CPSA may be laminated onto the folded or wrapped portions of the cover's edges 116 that are disposed along the bottom edges 124 of the sidewalls 108 in embodiments in which the cover's edges 116 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 124 of the sidewalls 108.

[0029] The shield 100 may be pressed onto the PCB or other substrate. The shield 100 may be attached to the PCB or other substrate using an electrically-conductive pressure sensitive adhesive (CPSA) composed of electrically-conductive material powder, glues, and substrate. Or, for example, the shield 100 may be attached to the PCB or other substrate using an electrically-conductive double-sided tape where the substrate is electrically-conductive fabric (*e.g.*, taffeta, *etc.*) having CPSA on both sides. As a further example, the shield 100 may be attached to the PCB or other substrate using a double sided tape in which the composition includes viscose and fiber-reinforced materials. Advantageously, some exemplary embodiments use reworkable tape which may be used to stick to an object and be fixed in place, but the tape may also be easy to remove and can be repeated. Other adhesives and/or methods may also be used to attach the shield 100 to a substrate.

[0030] FIG. 2 illustrates an exemplary embodiment of an EMI shield 200 according to aspects of the present disclosure. The shield 200 may be made of materials capable of withstanding the high temperatures of solder reflow processes (*e.g.*, temperatures up to about 245 degrees Celsius or higher, temperatures up to at least about 280 degrees Celsius, *etc.*), such that

the shield 200 is solderable onto a PCB or other substrate (not shown). The EMI shield 200 includes soft and/or flexible sidewalls 208 and a cover 212. The shield 200 is operable for shielding one or more components that may be provided on the substrate within an interior or shielding enclosure cooperatively defined by the walls 208 and the cover 212.

[0031] In various exemplary embodiments, the sidewalls 208 are dielectric, soft, and flexible. In such exemplary embodiments, the sidewalls 208 may be formed from high-temperature rubber, plastic, foam, surface-mount device (SMD) high-density (90 kg) foam, *etc.* In an exemplary embodiment, the sidewalls 208 are formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the sidewalls. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the sidewalls may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection molding, rubber and molding, rubber and die cutting, *etc.*

[0032] The cover 212 may be made from an electrically-conductive fabric and/or electrically-conductive film. The cover 212 is attached to the sidewalls 208 by folding edges 216 of the cover 212 around edges 220 of the sidewalls 208. The cover 212 is attached to the sidewalls 208 by folding edges 216 of the cover 212 around portions of the sidewalls 208. For example, the edges 216 of the cover 212 may be folded around the first, upper, or top edges 220 of the sidewalls 208. The cover 212 may be sized relative to the sidewalls 208 such that the cover's edges 216 also extend at least partially or entirely along an exterior surface of the middle portions 222 of the sidewalls 208. The middle portions 222 are between the first edges 220 and the second, lower, or bottom edges 224 of the sidewalls 208. The cover 212 may also be sufficiently large enough so that the cover's edges 216 may also be folded (*e.g.*, wrapped, *etc.*) around the second or lower edges 224 of the sidewalls 208. In which case, the cover's edges 216 may also extend at least partially or entirely along an interior surface of the middle portions 222 of the sidewalls 208.

[0033] The cover edges 216 may be secured to the sidewalls 208 by an adhesive, *e.g.*, a high-temperature adhesive, epoxy, *etc.* In example embodiments, an adhesive (*e.g.*, an electrically-conductive PSA, electrically non-conductive or dielectric PSA, *etc.*) is used to attach the folded edges 216 of the cover 212 to the sidewalls 208. For example, an acrylic CPSA may be used to attach the folded edges 216 of the cover 212 to the sidewalls 208. The acrylic CPSA may be disposed between the cover's folded edges 216 and the top edges 220, bottom edges 224 and/or middle portions 222 of the sidewalls 208 in embodiments in which the cover's folded edges 216 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 224 of the sidewalls 208. Other or additional adhesives and/or methods could be used to attach the cover 212 to the sidewalls 208.

[0034] In some exemplary embodiments that are solderable, the cover 212 may be made from a solderable film (*e.g.*, tin/copper-plated polyimide film, other metal plated films, other solderable electrically-conductive films, *etc.*). In such exemplary embodiments, the solderable film may be soldered to the sidewalls 208. For example, the solderable film may be folded (*e.g.*, wrapped, *etc.*) around at least the top edges 220 of the sidewalls 208 and then soldered to the sidewalls 208. The solderable film may also be folded around and/or soldered to the middle portions 222 and/or bottom edges 224 of the sidewalls 208 in some exemplary embodiments.

[0035] After the cover 212 has been attached to the sidewalls 208, solder reflow may be used to join bottom edges of the shield 200 with a PCB or other substrate. In one example embodiment in which the sidewalls 208 are made of SMD high-density foam (90kg) and solderable film is used to make the cover 212, the shield 200 may be soldered as a surface-mount device to a PCB or other substrate. In exemplary embodiments in which the solderable film is also wrapped around the bottom edges 224 of the sidewalls 208, the portions of the solderable film that are along the bottom edges 224 of the sidewalls 208 may be soldered to a PCB or other substrate. Other or additional methods (*e.g.*, adhesives, *etc.*) could be used to attach the shield 200 to a substrate.

[0036] FIG. 3 illustrates an exemplary embodiment of an EMI shield 300 according to aspects of the present disclosure. The EMI shield 300 includes dielectric, soft, and/or flexible sidewalls 308 to which a cover 312 is attachable. The shield 300 is operable for shielding one or

more components that may be provided on a substrate (not shown) within an interior or shielding enclosure cooperatively defined by the walls 308 and the cover 312.

[0037] In various exemplary embodiments, the sidewalls 308 are dielectric, soft, and flexible. In such exemplary embodiment, the sidewalls 308 may be formed from high-temperature rubber, plastic, foam, surface-mount device (SMD) high-density (90 kg) foam, *etc.* In an exemplary embodiment, the sidewalls 308 are formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the sidewalls. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the sidewalls may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection, rubber and molding, rubber and die cutting, *etc.*

[0038] The cover 312 may be made from an electrically-conductive fabric and/or electrically-conductive film. The cover 312 may be cut to a size that matches the outside dimensions of the sidewalls 308, such that the cover 312 does not need to be folded about any portions (*e.g.*, top edges 320, middle portions 322, bottom edges 324, *etc.*) of the sidewalls 308. The cover 312 is attached to first, upper, or top edges 320 of the sidewalls 308 by adhesive or by soldering, depending on the materials used to make the shield 300. In some embodiments, the cover's edges 316 may be secured to edges 320 of the sidewalls 308 by an adhesive, *e.g.*, a high-temperature adhesive, epoxy, CPSA, conductive hot melt, *etc.* Other or additional adhesives and/or methods could be used to attach the cover 312 to the sidewalls 308. In some exemplary embodiments that are solderable, the cover 312 may be made from a solderable film (*e.g.*, tin/copper-plated polyimide film, other metal plated films, other solderable electrically-conductive films, *etc.*) and soldered onto the top edges 320 of sidewalls 308.

[0039] After the cover 312 has been attached to the sidewalls 308, solder reflow may be used to join bottom edges 324 of the sidewalls 308 with a PCB or other substrate. Alternatively, solder reflow may be used to join bottom edges 324 of the sidewalls 308 with a

PCB or other substrate before the cover 312 is attached to the sidewalls 308. In which case, the cover 312 may not be attached until after the sidewalls 308 have been attached to the substrate with one or more components on the substrate within a perimeter defined by the sidewalls 308. In one example embodiment, the sidewalls 308 are made of SMD high-density foam (90kg), tin-containing polyimide film is used to make the cover 312, and the shield 300 is solderable as a surface-mount device to a PCB or other substrate. Other or additional methods (*e.g.*, adhesives, *etc.*) could be used to attach the shield 300 to a substrate.

[0040] FIG. 4 illustrates an exemplary embodiment of an EMI shield 400 according to aspects of the present disclosure. The EMI shield 400 includes a soft and/or flexible fence or sidewalls 408 and a cover 412. Also shown in FIG. 4 is an attachment 432 for attaching the shielding layer (fence 408 and cover 412) to a PCB or other substrate (not shown), whereby the shield 400 is operable for shielding one or more components within an interior or shielding enclosure cooperatively defined by the fence 408 and the cover 412.

[0041] In various exemplary embodiments, the fence 408 is dielectric, soft, and flexible. In such exemplary embodiments, the fence 408 may be formed from rubber, non-conductive plastic, foam, *etc.* In an exemplary embodiment, the fence 408 is formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the sidewalls. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the fence may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection, rubber and molding, rubber and die cutting, *etc.*

[0042] The cover 412 may be made from an electrically-conductive fabric (*e.g.*, metal plated cloth, *etc.*), electrically-conductive film, *etc.* The cover 412 may be attached to the fence 408 by folding edges of the cover 412 around portions of the fence 408. For example, the edges 416 of the cover 412 may be folded around the first, upper, or top edges 420 of the fence 408. The cover 412 may be sized relative to the fence 408 such that the cover's edges 416 also extend

at least partially or entirely along an exterior or outer surface of the middle portions 422 of the fence 408. The middle portions 422 are between the first edges 420 and the second, lower, or bottom edges 424 of the fence 408. The cover 412 may also be sufficiently large enough so that the cover's edges 416 may also be folded (*e.g.*, wrapped, *etc.*) around the second or lower edges 424 of the fence 408. In which case, the cover's edges 416 may also extend at least partially or entirely along an interior or inner surface of the middle portions 422 of the fence 408.

[0043] The cover's edges 416 may be secured to the fence 408 by a connection layer, *e.g.*, a pressure-sensitive adhesive (PSA), hot melt adhesive, epoxy, other adhesive disclosed herein, *etc.* In example embodiments, an adhesive (*e.g.*, an electrically-conductive pressure sensitive adhesive (CPSA), electrically non-conductive or dielectric PSA, *etc.*) is used to attach the folded edges 416 of the cover 412 to the fence 408. For example, an acrylic CPSA may be used to attach the folded edges 416 of the cover 408 to the fence 408. The acrylic CPSA may be disposed between the cover's folded edges 416 and the top edges 420, bottom edges 424 and/or middle portions 422 of the fence 408 in embodiments in which the cover's folded edges 416 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 424 of the fence 408. Other or additional adhesives and/or methods could be used to attach the cover 412 to the fence 408.

[0044] After the cover 412 has been attached to the fence 408, the shield 400 may be attached to a PCB or other substrate using the attachment 432, *e.g.*, an electrically-conductive pressure-sensitive adhesive (CPSA) (*e.g.*, nickel/copper acrylic-based CPSA, *etc.*), an electrically-conductive hotmelt adhesive, other adhesives disclosed herein, *etc.* The shield 400 may be attached to the PCB such that the shield 100 is positioned over one or more components mounted (*e.g.*, previously soldered, *etc.*) on the PCB. For example, a CPSA may be laminated onto the bottom edges 424 of the fence 408 in embodiments in which the cover's edges 416 are not folded around the bottom edges 424 of the fence 408. Or, for example, a CPSA may be laminated onto the folded or wrapped portions of the cover's edges 416 that are disposed along the bottom edges 424 of the sidewalls 408 in embodiments in which the cover's edges 416 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 424 of the fence 408.

[0045] FIG. 5 illustrates an exemplary embodiment of an EMI shield 500 according to aspects of the present disclosure. The shield 500 may be made of materials capable of withstanding the high temperatures (*e.g.*, up to about 245 degrees Celsius or higher, up to about 280 degrees Celsius or higher, *etc.*) of solder reflow processes, such that the shield 500 is

solderable onto a PCB or other substrate (not shown). The EMI shield 500 includes a soft and/or flexible fence or sidewalls 508 and a cover 512. The shield 500 is operable for shielding one or more components that are within an interior or shielding enclosure cooperatively defined by the walls 508 and the cover 512.

[0046] In various exemplary embodiments, the fence 508 is dielectric, soft, and flexible. In such exemplary embodiments, the fence 508 may be formed from high-temperature rubber, plastic, foam, surface-mount device (SMD) high-density (90 kg) foam, *etc.* In an exemplary embodiment, the fence 508 is formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the fence 508. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the sidewalls may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection, rubber and molding, rubber and die cutting, *etc.*

[0047] The cover 512 may be made from an electrically-conductive fabric and/or electrically-conductive film (*e.g.*, electrically-conductive polyimide film, *etc.*). The cover 512 may be attached to the fence 508 by folding edges of the cover 512 around portions of the fence 508. For example, the edges 516 of the cover 512 may be folded around the first, upper, or top edges 520 of the fence 508. The cover 512 may be sized relative to the fence 508 such that the cover's edges 516 also extend at least partially or entirely along an exterior or outer surface of the middle portions 522 of the fence 508. The middle portions 522 are between the first edges 520 and the second, lower, or bottom edges 524 of the fence 508. The cover 512 may also be sufficiently large enough so that the cover's edges 516 may also be folded (*e.g.*, wrapped, *etc.*) around the second or lower edges 524 of the fence 508. In which case, the cover's edges 516 may also extend at least partially or entirely along an interior or inner surface of the middle portions 522 of the fence 508.

[0048] The cover's edges 516 may be secured to the fence 508 by a connection layer, *e.g.*, a high-temperature adhesive, epoxy, other adhesive disclosed herein, *etc.* In example embodiments, a hotmelt adhesive or epoxy is used to attach folded edges 516 of the cover 512 to the fence 508. For example, a hotmelt adhesive or epoxy may be used to attach the folded edges 516 of the cover 508 to the fence 508. The hotmelt adhesive or epoxy may be disposed between the cover's folded edges 516 and the top edges 520, bottom edges 524 and/or middle portions 522 of the fence 508 in embodiments in which the cover's folded edges 516 are also folded (*e.g.*, wrapped, *etc.*) around the bottom edges 524 of the sidewalls 508. Other or additional adhesives and/or methods could be used to attach the cover 512 to the fence 508.

[0049] In some exemplary embodiments that are solderable, the cover 512 may be made from a solderable film (*e.g.*, tin/copper-plated polyimide film, other metal plated films, other solderable electrically-conductive films, *etc.*). In such exemplary embodiments, the solderable film may be soldered to the fence 508. For example, the solderable film may be folded (*e.g.*, wrapped, *etc.*) around at least the top edges 520 of the fence 508 and then soldered to the fence 508. The solderable film may also be folded around and/or soldered to the middle portions 522 and/or bottom edges 524 of the fence 508 in some exemplary embodiments.

[0050] After the cover 512 has been attached to the fence 508, solder reflow may be used to join bottom edges of the shield 500 with a PCB or other substrate. For example, the shield 500 may be soldered as a surface-mount device to a PCB or other substrate. In one example embodiment, the fence 508 is made of SMD high-density foam (90kg), and a solderable film is used to make the cover 512. In this example, the solderable film may be wrapped around the fence's top edges 520, middle portions 522, and bottom edges 224. The portions of the solderable film that are along the bottom edges 524 of the fence 508 may be soldered to a PCB or other substrate. Other or additional methods (*e.g.*, adhesives, *etc.*) could be used to attach the shield 500 to a substrate.

[0051] FIG. 6 illustrates an exemplary embodiment of an EMI shield 600 according to aspects of the present disclosure. The EMI shield 600 includes soft and/or flexible sidewalls or fence 608 to which a cover 612 is attachable. The shield 600 is operable for shielding one or more components within an interior or shielding enclosure cooperatively defined by the fence 608 and the cover 612.

[0052] In various exemplary embodiments, the fence 608 is formed from a material capable of withstanding the high temperatures (*e.g.*, up to about 245 degrees Celsius or higher, up to about 280 degrees Celsius or higher, *etc.*) of solder reflow processes, such that the shield 600 is solderable onto a PCB or other substrate (not shown). By way of example, the fence 608 may be formed from high-temperature rubber, plastic, foam, surface-mount device (SMD) high-density (90 kg) foam, *etc.* Or, for example, the fence 608 may be formed from an electrically-conductive weldable material, such as a metal used for a fence in a conventional metal BLS. In one exemplary embodiment, the fence 608 is formed from dielectric or electrically non-conductive urethane foam that is die cut into a desired shape for the sidewalls. By way of example only, the urethane foam may comprise PORON[®] 4701-60 urethane foam from Rogers Corporation. Or, for example, the urethane foam may comprise a different urethane foam having properties similar to PORON[®] 4701-60 urethane foam, *e.g.*, a hardness, durometer, Shore A value within a range from 30 to 53 (*e.g.*, 30, 42, and 53, *etc.*) and/or Shore O value within a range from 42 to 63 (*e.g.*, 42, 55, 63, *etc.*). The particular material and material hardness selected for the sidewalls may vary according to user preferences so long as it has the ability to support a desired height and can be processed. Different materials and different processes for making a wall may be used besides urethane foam and die cutting, such as plastic and injection, rubber and molding, rubber and die cutting, *etc.*

[0053] The cover 612 may be made from an electrically-conductive fabric, electrically-conductive film (*e.g.*, tin/copper plated polyimide (PI) film, *etc.*), or other suitable material capable of providing an EMI shielding function. The cover 612 may be cut to a size that matches or corresponds with the outside dimensions of the fence 608, such that the cover 612 does not need to be folded about any portions or edges of the fence 608. The cover 612 may be attached to the fence 608 by a connection layer, *e.g.*, adhesive, soldering, *etc.* In some embodiments, the cover 612 may be secured to the fence 608 by an adhesive, *e.g.*, a high-temperature adhesive, epoxy, CPSA, electrically-conductive hot melt, *etc.* Other or additional adhesives and/or methods (*e.g.*, solder, *etc.*) could be used to attach the cover 612 to the fence 608.

[0054] Various exemplary embodiments of EMI shields as disclosed herein are capable of providing useful levels of shielding effectiveness (SE). Several exemplary embodiments of EMI shields were tested under modified MIL-DTL-83528C-Radiated Shielding

Effectiveness standards. The test frequencies were between 30 megahertz (MHz) and 18 gigahertz (GHz). FIGS. 15 through 18 include line graphs of the shielding effectiveness test results for the EMI shields and for a conventional metal board level shield (BLS) for comparison purposes. These test results are provided for illustration purposes only as other exemplary embodiments of EMI shields disclosed herein may have different shielding effectiveness.

EXAMPLES

[0055] The following examples are merely illustrative, and are not limiting to the disclosure in any way. Twelve samples were configured as example embodiments, *e.g.*, as discussed above with reference to shields 100 and 200. The samples are described in Table 1 and were tested for shielding effectiveness along with a metal board-level shield (BLS) for comparative purposes as described below. The test results are shown in FIGS. 15 through 18. Generally, the test results shown in FIGS. 15 through 18 indicated that when electrically-conductive fabric is used as a cover for a soft and/or flexible board-level shield, the shielding effectiveness (SE) is comparable or competitive with that of a metal BLS. The test results also indicated that most leakage came from the adhesive used to attach the shields to the board. Because the shield height was small, *i.e.*, about 1mm in these examples, leakage from wrapping/overlapping of cover film/fabric was small. High shielding effectiveness (SE) was shown by a shield having a tin/copper PI film cover attached to the board by solder reflow.

[0056] The sidewalls, fences, or frames were made from PORON[®] urethane foam 4701-60 in these samples. The covers were made of metal-plated cloth (Fabric726) for the first eleven samples 1-1 to 5-1 and tin/copper-plated polyimide (PI) film for the twelfth sample 5-2. The adhesive used to attached the cover to the fence was an acrylic electrically-conductive pressure sensitive adhesive (LT350) for the first ten samples 1-1 to 4-3 and an electrically non-conductive hotmelt polyethylene vinyl acetate (PEVA) adhesive film (V799-1) for the eleventh sample 5-1. Regarding the adhesives used to attach the shield to the board, TT250 is an electrically-conductive pressure sensitive adhesive (CPSA) composed of electrically-conductive material powder, glues, and substrate. DT16A is an electrically-conductive double-sided tape where the substrate is electrically-conductive fabric having CPSA on both sides. 3M9485 is a double sided tape in which the composition includes viscose and fiber-reinforced materials.

Table 1

Sample	Fence	Cover	Cover Adhesive	Board Adhesive	Corners Side	Overlap Bottom
1-1	PORON	Fabric726	LT350	TT250(0.06mm)		
1-2	PORON	Fabric726	LT350	DT16A(0.155mm)		
1-3	PORON	Fabric726	LT350	3M9485(0.127mm)		
1-4	PORON	Fabric726	LT350	None (attached by clip)		
2-1	PORON	Fabric726	LT350	TT250 (0.06mm)	Overlap inside	
2-2	PORON	Fabric726	LT350	TT250 (0.06mm)	No overlap	
3-1	PORON	Fabric726 w/ holes	LT350	TT250 (0.06mm)		
4-1	PORON	Fabric726	LT350	TT250 (0.06mm)		No overlap 1
4-2	PORON	Fabric726	LT350	TT250 (0.06mm)		No overlap 2
4-3	PORON	Fabric726	LT350	TT250 (0.06mm)		No overlap 3
5-1	PORON	Fabric726	V799-1	TT250 (0.06mm)		
5-2	PORON	Sn/Cu PI		Soldering		

[0057] Samples 1-1, 1-2, 1-3, and 1-4 were tested to compare shielding effectiveness leakage relative to different adhesives used to connect the shield to a board, which test results are shown in FIG. 9. For the test samples, adhesives were applied at a width of 0.8mm along the bottom edges of the fence or sidewalls. As shown by FIG. 15, the best performance was by sample 1-4, which was clipped to the board without using adhesive. Sample 1-4 also performed better than a metal board-level shield (BLS). The poorest performance was by sample 1-3, which was attached to a board using a non-conductive PSA. Samples 1-1 and 1-2 were attached to a board using different CPSAs, and sample 1-2 performed better than sample 1-1.

[0058] Samples 1-1, 2-1, and 2-2 were tested to compare shielding effectiveness relative to different ways of wrapping cover edges over sidewalls, which test results are shown in FIG. 16. Not much difference was shown, although the metal shield showed better shielding effectiveness than samples 1-1, 2-1, and 2-2 as shown by FIG. 10.

[0059] The electrically-conductive fabric of sample 3-1 was punched with vias or holes having 1mm diameters and was tested with sample 1-1, which shielding effective test results are shown in FIG. 17. No significant difference in shielding effectiveness was detected,

although the metal board level shield performed better than samples 1-1 and 3-1 as shown by FIG. 11.

[0060] Sample 5-2 had a tin/copper-plated polyimide film (Sn/Cu PI film) cover that was spot-soldered for surface mount device (SMD) contacts. Sample 5-2 was attached to the board by solder reflow. FIG. 18 shows the shielding effectiveness test results for sample 5-2, sample 1-1, and the metal board level shield. As shown by FIG. 12, sample 5-2 performed better than the metal board level shield.

[0061] In various embodiments, a total height of the shields (*e.g.*, 100, 200, 300, 400, 500, 600, *etc.*) may be less than 1.0 millimeter and exhibit the same or similar shielding effectiveness as conventional metal board-level shields. In some embodiments, the sidewalls or fence (*e.g.*, 108, 208, 308, 408, 508, 608, *etc.*) may have a thickness of 0.6 or less (*e.g.*, 0.5 millimeters, 0.4 millimeters, 0.3 millimeters, less than 0.3 millimeters, *etc.*). The materials and dimensions provided herein are for purposes of illustration only, as the shields (*e.g.*, 100, 200, 300, 400, 500, 600, *etc.*) may be made from different materials and/or have different dimensions depending, for example, on the particular application, such as the electrical components to be shielded, space considerations within the overall electronic device, EMI shielding and heat dissipation needs, and other factors.

[0062] In the illustrated embodiments, FIGS. 1 through 6 respectively show the EMI shields 100, 200, 300, 400, 500, 600 without any interior walls, dividers, or partitions such that the sidewalls and cover generally define a single interior space or compartment. In other exemplary embodiments, an EMI shield may include different EMI shielding compartments defined by interior walls and outer sidewalls. Components may be positioned in the different EMI shielding compartments such that the components are provided with EMI shielding by virtue of the EMI shielding compartments inhibiting the ingress and/or egress of EMI into and/or out of each EMI shielding compartment.

[0063] FIGS. 1 through 6 respectively show the EMI shields 100, 200, 300, 400, 500, 600 having generally rectangular shapes. Other exemplary embodiments may include shields having different configurations (*e.g.*, circular, curved, triangular, irregular, other non-rectangular shapes, *etc.*). The external overall height of a shield may be less than about one millimeter (mm). The dimensions and shapes provided in this application are for purpose of illustration only as

other exemplary embodiments may have a different configuration, such as a different size (*e.g.*, larger or smaller) and/or a different shape (*e.g.*, non-rectangular, *etc.*), *etc.*

[0064] Also disclosed are exemplary embodiments of methods relating to making EMI shields. In an exemplary embodiment, a method generally includes making one or more soft and/or flexible sidewalls, and making a cover for attachment to the one or more soft and/or flexible sidewalls. The method may further include attaching the cover to the one or more soft and/or flexible sidewalls. Attaching the cover to the sidewalls may be accomplished using adhesive or by soldering.

[0065] FIG. 7 is a process flow diagram of exemplary methods of making board level shields, such as the shield 400, shield 500, *etc.* As shown, an electrically-conductive fabric/film and an adhesive are laminated and then die cut. The fence material is also die cut. The die cut fence and cover materials are then combined. The die cut fence and cover materials may be combined in different ways depending on the type of shield and materials thereof.

[0066] For example, for a reflow type of shield (*e.g.*, shield 500, *etc.*), the die cut fence and cover materials may be correctly positioned on a substrate. And, then the fence is attached to the cover during the same reflow process by which the fence is soldered to the substrate.

[0067] Or, for example, for a non-reflow type of shield (*e.g.*, shield 400, *etc.*), the die cut fence and cover materials may be combined by using an additional material (*e.g.*, adhesive, *etc.*). As shown in FIG. 7, an attachment material may be die cut and then combined with the cover and fence materials, which attachment material may be used for attaching the cover and fence to a substrate.

[0068] FIG. 8 is a process flow diagram of exemplary methods of making board level shields, such as the shield 600, *etc.* As shown, method A includes laminating an electrically-conductive film with an adhesive, which are then die cut. The fence material is also die cut. The die cut components are then combined by correctly positioning the die cut fence and cover materials on a substrate. And, then the fence is attached to the cover during the same reflow process by which the fence is soldered to the substrate.

[0069] Method B includes molding, stamping, or otherwise forming a fence from an electrically-conductive weldable material, such as a metal used for a fence in a conventional metal BLS, *etc.* The fence is attached to a substrate by a solder reflow process. Method B also

includes die cutting an electrically-conductive fabric/film and an adhesive. The adhesive is used to attach the electrically-conductive fabric/film to the fence, which was previously attached to the substrate.

[0070] FIG. 9 is a process flow diagram of exemplary methods of making board level shields. As shown, an electrically-conductive fabric/film (cover material) may be die cut, formed (*e.g.*, folded, *etc.*) into a fixed shape, and positioned or placed in a mold. The support material (fence material) may be added (*e.g.*, injected, infused, *etc.*) to the mold at a specified location. The method may further include shaping the fence and cover material.

[0071] For a non-reflow type of shield, the fence and cover materials may be combined by using an additional material (*e.g.*, adhesive, *etc.*). As shown in FIG. 9, an attachment material may be die cut and then combined with the cover and fence materials, which attachment material may be used for attaching the cover and fence to a substrate.

[0072] FIGS. 10, 11, and 12 illustrate exemplary processes of combining a cover with a fence or frame. As shown, portions of the cover may be wrapped or folded about the sidewalls of the fence or frame according to exemplary embodiments.

[0073] FIG. 13 illustrates three steps or phases of an exemplary assembly process using a fixture according to exemplary embodiments. The first phase or step 1 generally includes folding portions of the cover (*e.g.*, generally perpendicularly upward, *etc.*) along creases to facilitate the subsequent combination with the fence or frame. The second phase or step 2 generally includes assembling and shaping the cover and fence. For example, the fence may be positioned within the cover and then the folded portions of the cover may be further folded about the sidewalls of the fence. The second phase may also include heating. The third phase or step 3 generally includes early curing, *e.g.*, heating the opposite or reverse side and allowing the adhesive or glue to cure.

[0074] FIG. 14 is a process flow diagram of an exemplary production process using automation equipment for making board level shields according to exemplary embodiments. As shown, the cover and fence materials may be die cut. Then, the die cut cover and fence materials may undergo the three steps or phases shown in FIG. 13 and described above. After the early curing (stage 3 in FIG. 13), the products are finished, which finished products may then be sent to end users, installed to a printed circuit board, *etc.*

[0075] An exemplary embodiment of a shield includes one or more soft and/or flexible sidewalls and a cover coupled to the one or more soft and/or flexible sidewalls. The shield is operable or suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate. In this exemplary embodiment, the one or more soft and/or flexible sidewalls are dielectric, and the cover is electrically-conductive. The cover is wrapped about the one or more soft and/or flexible sidewalls such that outer and/or exposed surfaces of the shield are defined by the cover and electrically-conductive. The one or more soft and/or flexible sidewalls are made of dielectric material. The cover is made of electrically-conductive material. The electrically-conductive material of the cover is wrapped about the dielectric material of the one or more soft and/or flexible sidewalls such that the electrically-conductive material is disposed over and covers the dielectric material. The one or more soft and/or flexible sidewalls may be made of rubber, plastic, foam, and/or surface-mount device high-density foam. The cover may include one or more of electrically-conductive fabric, shielding film, metal foil, and/or tin-containing polyimide film. The cover may be attached to the one or more soft and/or flexible sidewalls by one or more of pressure-sensitive adhesive, hot melt adhesive, high-temperature adhesive, epoxy, electrically-conductive pressure-sensitive adhesive, electrically-conductive hot melt adhesive, and/or solder.

[0076] Continuing with this example, the one or more soft and/or flexible sidewalls comprise urethane foam. The cover may comprise metal plated polyimide film attached to the urethane foam by solder, metal plated cloth attached to the urethane foam by an electrically-conductive pressure sensitive adhesive and/or an electrically non-conductive hotmelt adhesive, or metal plated cloth attached to the urethane foam by an acrylic electrically-conductive pressure sensitive adhesive or an electrically non-conductive hotmelt polyethylene vinyl acetate adhesive film. The one or more soft and/or flexible sidewalls may comprise urethane foam having a Shore A hardness value within a range from 30 to 53 or a Shore O hardness value within a range from 42 to 63. The shield may be able to withstand solder reflow conditions and temperatures up to at least about 280 degrees Celsius and maintain operational structural integrity following a solder reflow operation.

[0077] The one or more soft and/or flexible sidewalls may include top edges, bottom edges, and middle portions between the top and bottom edges. The cover may include edges

folded or wrapped around the top edges, the middle portions, and the bottom edges of the one or more soft and/or flexible sidewalls.

[0078] An exemplary embodiment of an electronic device may include a printed circuit board and the shield including the cover and the one or more soft and/or flexible sidewalls. The shield may be attached to the printed circuit board such that shield is operable for providing EMI shielding for one or more components on the printed circuit board that are within an interior cooperatively defined by the cover and the one or more soft and/or flexible sidewalls. The shield may be attached to the printed circuit board using an electrically-conductive pressure sensitive adhesive, a double sided tape, solder, or a clip without using any adhesive.

[0079] In another exemplary embodiment, a shield includes one or more dielectric sidewalls and an electrically-conductive cover coupled to the one or more dielectric sidewalls. The electrically-conductive cover is wrapped about the one or more dielectric sidewalls. In this exemplary embodiment, the one or more dielectric sidewalls are soft and/or flexible. The electrically-conductive cover is disposed over and covers the one or more dielectric sidewalls such that outer and/or exposed surfaces of the shield are defined by the electrically-conductive cover. The one or more dielectric sidewalls may be made of rubber, plastic, foam, and/or surface-mount device high-density foam. The electrically-conductive cover may include one or more of electrically-conductive fabric, shielding film, metal foil, and/or tin-containing polyimide film. The electrically-conductive cover may be attached to the one or more dielectric sidewalls by one or more of pressure-sensitive adhesive, hot melt adhesive, high-temperature adhesive, epoxy, electrically-conductive pressure-sensitive adhesive, electrically-conductive hot melt adhesive, and/or solder.

[0080] Continuing with this example, the one or more dielectric sidewalls may comprise urethane foam. The electrically-conductive cover may comprise metal plated polyimide film attached to the urethane foam by solder, metal plated cloth attached to the urethane foam by an electrically-conductive pressure sensitive adhesive and/or an electrically non-conductive hotmelt adhesive, or metal plated cloth attached to the urethane foam by an acrylic electrically-conductive pressure sensitive adhesive or an electrically non-conductive hotmelt polyethylene vinyl acetate adhesive film. The one or more dielectric sidewalls may comprise urethane foam having a Shore A hardness value within a range from 30 to 53 or a Shore O hardness value within a range from 42 to 63. The shield may be able to withstand solder reflow conditions and

temperatures up to at least about 280 degrees Celsius and maintain operational structural integrity following a solder reflow operation.

[0081] The one or more dielectric sidewalls may include top edges, bottom edges, and middle portions between the top and bottom edges. The electrically-conductive cover may include edges wrapped around the top edges, the middle portions, and the bottom edges of the one or more dielectric sidewalls.

[0082] An exemplary embodiment of an electronic device may include a printed circuit board and the shield including the cover and the one or more dielectric sidewalls. The shield may be attached to the printed circuit board such that the shield is operable for providing EMI shielding for one or more components on the printed circuit board that are within an interior cooperatively defined by the electrically-conductive cover and the one or more dielectric sidewalls. Portions of the electrically-conductive cover may be attached to the printed circuit board using an electrically-conductive pressure sensitive adhesive, a double sided tape, solder, or a clip without using any adhesive.

[0083] In another exemplary embodiment, a method includes attaching a cover to one or more soft and/or flexible sidewalls to thereby provide an electromagnetic interference (EMI) shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate. The one or more soft and/or flexible sidewalls may be dielectric. The cover may be electrically-conductive. The method may further include wrapping the cover about the one or more soft and/or flexible sidewalls such that outer and/or exposed surfaces of the shield are defined by the cover and electrically-conductive.

[0084] Continuing with this example, the one or more soft and/or flexible sidewalls may be made of dielectric material. The cover may be made of electrically-conductive material. The method may include wrapping the electrically-conductive material of the cover about the dielectric material of the one or more soft and/or flexible sidewalls such that the electrically-conductive material is disposed over and covers the dielectric material. Attaching the cover may comprise soldering the cover to the one or more soft and/or flexible sidewalls or adhesively attaching the cover to the one or more soft and/or flexible sidewalls.

[0085] The one or more soft and/or flexible sidewalls may include top edges, bottom edges, and middle portions between the top and bottom edges. The method may include folding edges of the cover around the top edges, the middle portions, and the bottom edges of the one or

more soft and/or flexible sidewalls. The method may further include adhesively attaching or soldering portions of the cover's folded edges that are folded around the bottom edges of the one or more soft and/or flexible sidewalls to a substrate such that one or more components on the substrate are within an interior defined by the cover and the one or more soft and/or flexible sidewalls.

[0086] The method may include using solder reflow to attach the cover to the one or more soft and/or flexible sidewalls and to attach the shield to a substrate such that one or more components on the substrate are within an interior defined by the cover and the one or more soft and/or flexible sidewalls. The method may include die cutting urethane foam to thereby make the one or more soft and/or flexible sidewalls and die cutting an electrically-conductive fabric, film, or cloth to thereby make the cover.

[0087] In another exemplary embodiment, a method includes attaching an electrically-conductive cover to one or more dielectric sidewalls such that the electrically-conductive cover is wrapped about the one or more dielectric sidewalls, to thereby provide an electromagnetic interference (EMI) shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate. The one or more dielectric sidewalls may be soft and/or flexible. The method may include wrapping the electrically-conductive cover about the one or more dielectric sidewalls such that the electrically-conductive cover is disposed over and covers the one or more dielectric sidewalls and such that outer and/or exposed surfaces of the shield are defined by the electrically-conductive cover. Attaching the electrically-conductive cover may include soldering the electrically-conductive cover to the one or more dielectric sidewalls or adhesively attaching the electrically-conductive cover to the one or more dielectric sidewalls.

[0088] Continuing with this example, the one or more dielectric sidewalls may include top edges, bottom edges, and middle portions between the top and bottom edges. The method may include folding edges of the electrically-conductive cover around the top edges, the middle portions, and the bottom edges of the one or more dielectric sidewalls. The method may also include adhesively attaching or soldering portions of the electrically-conductive cover's folded edges that are folded around the bottom edges of the one or more dielectric sidewalls to a substrate such that one or more components on the substrate are within an interior defined by the electrically-conductive cover and the one or more dielectric sidewalls.

[0089] The method may include using solder reflow to attach the electrically-conductive cover to the one or more dielectric sidewalls and to attach the shield to a substrate such that one or more components on the substrate are within an interior defined by the electrically-conductive cover and the one or more dielectric sidewalls. The method may die cutting urethane foam to thereby make the one or more dielectric sidewalls and die cutting an electrically-conductive fabric, film, or cloth to thereby make the electrically-conductive cover.

[0090] In exemplary embodiments, the EMI shield includes one or more sidewalls or fence and a cover, top, or upper surface. The one or more sidewalls may be dielectric, soft, and/or flexible. The one or more sidewalls may comprise a single sidewall, may comprise a plurality of sidewalls that are separate or discrete from each other, or may comprise a plurality of sidewalls that are integral parts of a single-piece EMI shield, *etc.*

[0091] In exemplary embodiments, the EMI shield's cover or upper surface may be made separately and not integrally with the sidewalls. In some embodiments, the EMI shield may comprise a two-piece shield in which the shield's cover or lid is removable from and reattachable to the sidewalls. In some exemplary embodiments, the EMI shield may include one or more interior walls, dividers, or partitions that are attached to and/or integrally formed with the EMI shield. In such embodiments, the shield's cover, sidewalls, and interior walls may cooperatively define a plurality of individual EMI shielding compartments.

[0092] In some exemplary embodiments, the EMI shield's cover or upper surface may include one or more apertures or holes, which may facilitate solder reflow heating interiorly of the shield and/or enable cooling of the components under the shield and/or permit visual inspection of the components beneath the shield. In some of these exemplary embodiments, the holes may be sufficiently small to inhibit passage of interfering EMI. The particular number, size, shape, orientation, *etc.* of the holes may vary depending, for example, on the particular application (*e.g.*, sensitivity of the electronics where more sensitive circuitry may necessitate the use of smaller diameter holes, *etc.*). In still other exemplary embodiments, the shield may include a cover or upper surface that does not have any such holes.

[0093] Exemplary embodiments disclosed herein may provide one or more (but not necessarily any or all) of the following advantages over some existing board level EMI shields. For example, exemplary embodiments disclosed herein may be flexible and/or soft compared to conventional shielding made of rigid materials, such as metal. Exemplary embodiments may

have shielding effectiveness performance about the same as a conventional metal board level shield (BLS). Exemplary embodiments may be able to withstand solder reflow conditions, *e.g.*, withstand the high temperatures (*e.g.*, up to about 245 degrees Celsius or higher, up to about 280 degrees Celsius or higher, *etc.*) associated with solder reflow processes, *etc.* For example, an exemplary embodiment of a shield may be able to withstand solder reflow conditions and temperatures up to at least about 280 degrees Celsius and maintain operational structural integrity following a solder reflow operation.

[0094] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms, and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail. In addition, advantages and improvements that may be achieved with one or more exemplary embodiments of the present disclosure are provided for purpose of illustration only and do not limit the scope of the present disclosure, as exemplary embodiments disclosed herein may provide all or none of the above mentioned advantages and improvements and still fall within the scope of the present disclosure.

[0095] Specific dimensions, specific materials, and/or specific shapes disclosed herein are example in nature and do not limit the scope of the present disclosure. The disclosure herein of particular values and particular ranges of values for given parameters are not exclusive of other values and ranges of values that may be useful in one or more of the examples disclosed herein. Moreover, it is envisioned that any two particular values for a specific parameter stated herein may define the endpoints of a range of values that may be suitable for the given parameter (*i.e.*, the disclosure of a first value and a second value for a given parameter can be interpreted as disclosing that any value between the first and second values could also be employed for the given parameter). For example, if Parameter X is exemplified herein to have value A and also exemplified to have value Z, it is envisioned that parameter X may have a range of values from about A to about Z. Similarly, it is envisioned that disclosure of two or more ranges of values for a parameter (whether such ranges are nested, overlapping or distinct) subsume all possible

combination of ranges for the value that might be claimed using endpoints of the disclosed ranges. For example, if parameter X is exemplified herein to have values in the range of 1 – 10, or 2 – 9, or 3 – 8, it is also envisioned that Parameter X may have other ranges of values including 1 – 9, 1 – 8, 1 – 3, 1 – 2, 2 – 10, 2 – 8, 2 – 3, 3 – 10, and 3 – 9.

[0096] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0097] When an element or layer is referred to as being “on”, “engaged to”, “connected to” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to”, “directly connected to” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (*e.g.*, “between” versus “directly between,” “adjacent” versus “directly adjacent,” *etc.*). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0098] The term “about” when applied to values indicates that the calculation or the measurement allows some slight imprecision in the value (with some approach to exactness in the value; approximately or reasonably close to the value; nearly). If, for some reason, the imprecision provided by “about” is not otherwise understood in the art with this ordinary meaning, then “about” as used herein indicates at least variations that may arise from ordinary methods of measuring or using such parameters. For example, the terms “generally”, “about”,

and “substantially” may be used herein to mean within manufacturing tolerances. Whether or not modified by the term “about”, the claims include equivalents to the quantities.

[0099] Although the terms first, second, third, *etc.* may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[00100] Spatially relative terms, such as “inner,” “outer,” “beneath”, “below”, “lower”, “above”, “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[00101] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements, intended or stated uses, or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

WHAT IS CLAIMED IS:

1. A shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate, the shield comprising:
one or more soft and/or flexible sidewalls; and
a cover coupled to the one or more soft and/or flexible sidewalls.
2. The shield of claim 1, wherein:
the one or more soft and/or flexible sidewalls are dielectric; and
the cover is electrically-conductive.
3. The shield of claim 2, wherein the cover is wrapped about the one or more soft and/or flexible sidewalls such that outer and/or exposed surfaces of the shield are defined by the cover and electrically-conductive.
4. The shield of claim 1, wherein:
the one or more soft and/or flexible sidewalls are made of dielectric material;
the cover is made of electrically-conductive material; and
the electrically-conductive material of the cover is wrapped about the dielectric material of the one or more soft and/or flexible sidewalls such that the electrically-conductive material is disposed over and covers the dielectric material.
5. The shield of any one of claims 1 to 4, wherein:
the one or more soft and/or flexible sidewalls are made of rubber, plastic, foam, and/or surface-mount device high-density foam;
the cover includes one or more of electrically-conductive fabric, shielding film, metal foil, and/or tin-containing polyimide film; and
the cover is attached to the one or more soft and/or flexible sidewalls by one or more of pressure-sensitive adhesive, hot melt adhesive, high-temperature adhesive, epoxy, electrically-conductive pressure-sensitive adhesive, electrically-conductive hot melt adhesive, and/or solder.
6. The shield of any one of claims 1 to 4, wherein the one or more soft and/or flexible sidewalls comprise urethane foam, and wherein the cover comprises:
metal plated polyimide film attached to the urethane foam by solder; or

metal plated cloth attached to the urethane foam by an electrically-conductive pressure sensitive adhesive and/or an electrically non-conductive hotmelt adhesive; or

metal plated cloth attached to the urethane foam by an acrylic electrically-conductive pressure sensitive adhesive or an electrically non-conductive hotmelt polyethylene vinyl acetate adhesive film.

7. The shield of any one of the preceding claims, wherein:

the one or more soft and/or flexible sidewalls comprise urethane foam having a Shore A hardness value within a range from 30 to 53 or a Shore O hardness value within a range from 42 to 63; and/or

the shield is able to withstand solder reflow conditions and temperatures up to at least about 280 degrees Celsius and maintain operational structural integrity following a solder reflow operation.

8. The shield of any one of the preceding claims, wherein:

the one or more soft and/or flexible sidewalls include top edges, bottom edges, and middle portions between the top and bottom edges; and

the cover includes edges folded or wrapped around the top edges, the middle portions, and the bottom edges of the one or more soft and/or flexible sidewalls.

9. An electronic device including a printed circuit board and the shield of any one of the preceding claims attached to the printed circuit board, whereby the shield is operable for providing EMI shielding for one or more components on the printed circuit board that are within an interior cooperatively defined by the cover and the one or more soft and/or flexible sidewalls.

10. The electronic device of claim 9, wherein the shield is attached to the printed circuit board using an electrically-conductive pressure sensitive adhesive, a double sided tape, solder, or a clip without using any adhesive.

11. A shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate, the shield comprising:

one or more dielectric sidewalls; and

an electrically-conductive cover coupled to the one or more dielectric sidewalls, wherein the electrically-conductive cover is wrapped about the one or more dielectric sidewalls.

12. The shield of claim 11, wherein:

the one or more dielectric sidewalls are soft and/or flexible; and

the electrically-conductive cover is disposed over and covers the one or more dielectric sidewalls such that outer and/or exposed surfaces of the shield are defined by the electrically-conductive cover.

13. The shield of claim 11 or 12, wherein:

the one or more dielectric sidewalls are made of rubber, plastic, foam, and/or surface-mount device high-density foam;

the electrically-conductive cover includes one or more of electrically-conductive fabric, shielding film, metal foil, and/or tin-containing polyimide film; and

the electrically-conductive cover is attached to the one or more dielectric sidewalls by one or more of pressure-sensitive adhesive, hot melt adhesive, high-temperature adhesive, epoxy, electrically-conductive pressure-sensitive adhesive, electrically-conductive hot melt adhesive, and/or solder.

14. The shield of claim 11 or 12, wherein the one or more dielectric sidewalls comprise urethane foam, and wherein the electrically-conductive cover comprises:

metal plated polyimide film attached to the urethane foam by solder; or

metal plated cloth attached to the urethane foam by an electrically-conductive pressure sensitive adhesive and/or an electrically non-conductive hotmelt adhesive; or

metal plated cloth attached to the urethane foam by an acrylic electrically-conductive pressure sensitive adhesive or an electrically non-conductive hotmelt polyethylene vinyl acetate adhesive film.

15. The shield of any one of claims 11 to 14, wherein:

the one or more dielectric sidewalls comprise urethane foam having a Shore A hardness value within a range from 30 to 53 or a Shore O hardness value within a range from 42 to 63; and/or

the shield is able to withstand solder reflow conditions and temperatures up to at least about 280 degrees Celsius and maintain operational structural integrity following a solder reflow operation.

16. The shield of any one of claims 11 to 15, wherein:

the one or more dielectric sidewalls include top edges, bottom edges, and middle portions between the top and bottom edges; and

the electrically-conductive cover includes edges wrapped around the top edges, the middle portions, and the bottom edges of the one or more dielectric sidewalls.

17. An electronic device including a printed circuit board and the shield of any one of claims 11 to 16 attached to the printed circuit board, whereby the shield is operable for providing EMI shielding for one or more components on the printed circuit board that are within an interior cooperatively defined by the electrically-conductive cover and the one or more dielectric sidewalls.

18. The electronic device of claim 17, wherein portions of the electrically-conductive cover are attached to the printed circuit board using an electrically-conductive pressure sensitive adhesive, a double sided tape, solder, or a clip without using any adhesive.

19. A method comprising attaching a cover to one or more soft and/or flexible sidewalls to thereby provide an electromagnetic interference (EMI) shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate.

20. The method of claim 19, wherein:

the one or more soft and/or flexible sidewalls are dielectric; and
the cover is electrically-conductive.

21. The method of claim 20, further comprising wrapping the cover about the one or more soft and/or flexible sidewalls such that outer and/or exposed surfaces of the shield are defined by the cover and electrically-conductive.

22. The method of claim 19, wherein:

the one or more soft and/or flexible sidewalls are made of dielectric material;
the cover is made of electrically-conductive material; and
the method includes wrapping the electrically-conductive material of the cover about the dielectric material of the one or more soft and/or flexible sidewalls such that the electrically-conductive material is disposed over and covers the dielectric material.

23. The method of any one of claims 19 to 22, wherein attaching the cover comprises:
soldering the cover to the one or more soft and/or flexible sidewalls; or
adhesively attaching the cover to the one or more soft and/or flexible sidewalls.

24. The method of any one of claims 19 to 23, wherein the one or more soft and/or flexible sidewalls include top edges, bottom edges, and middle portions between the top and

bottom edges, and wherein the method includes folding edges of the cover around the top edges, the middle portions, and the bottom edges of the one or more soft and/or flexible sidewalls.

25. The method of claim 24, further comprising adhesively attaching or soldering portions of the cover's folded edges that are folded around the bottom edges of the one or more soft and/or flexible sidewalls to a substrate such that one or more components on the substrate are within an interior defined by the cover and the one or more soft and/or flexible sidewalls.

26. The method of any one of claims 19 to 24, further comprising using solder reflow to attach the cover to the one or more soft and/or flexible sidewalls and to attach the shield to a substrate such that one or more components on the substrate are within an interior defined by the cover and the one or more soft and/or flexible sidewalls.

27. The method of any one of claims 19 to 26, further comprising:
die cutting urethane foam to thereby make the one or more soft and/or flexible sidewalls;
and

die cutting an electrically-conductive fabric, film, or cloth to thereby make the cover.

28. A method comprising attaching an electrically-conductive cover to one or more dielectric sidewalls such that the electrically-conductive cover is wrapped about the one or more dielectric sidewalls, to thereby provide an electromagnetic interference (EMI) shield suitable for use in providing electromagnetic interference (EMI) shielding for one or more components on a substrate.

29. The method of claim 28, wherein:
the one or more dielectric sidewalls are soft and/or flexible; and
the method includes wrapping the electrically-conductive cover about the one or more dielectric sidewalls such that the electrically-conductive cover is disposed over and covers the one or more dielectric sidewalls and such that outer and/or exposed surfaces of the shield are defined by the electrically-conductive cover.

30. The method of claim 28 or 29, wherein attaching the electrically-conductive cover comprises:

soldering the electrically-conductive cover to the one or more dielectric sidewalls; or
adhesively attaching the electrically-conductive cover to the one or more dielectric sidewalls.

31. The method of claim 28, 29, or 30, wherein the one or more dielectric sidewalls include top edges, bottom edges, and middle portions between the top and bottom edges, and wherein the method includes folding edges of the electrically-conductive cover around the top edges, the middle portions, and the bottom edges of the one or more dielectric sidewalls.

32. The method of claim 31, further comprising adhesively attaching or soldering portions of the electrically-conductive cover's folded edges that are folded around the bottom edges of the one or more dielectric sidewalls to a substrate such that one or more components on the substrate are within an interior defined by the electrically-conductive cover and the one or more dielectric sidewalls.

33. The method of any one of claims 28 to 31, further comprising using solder reflow to attach the electrically-conductive cover to the one or more dielectric sidewalls and to attach the shield to a substrate such that one or more components on the substrate are within an interior defined by the electrically-conductive cover and the one or more dielectric sidewalls.

34. The method of any one of claims 28 to 33, further comprising:
die cutting urethane foam to thereby make the one or more dielectric sidewalls; and
die cutting an electrically-conductive fabric, film, or cloth to thereby make the electrically-conductive cover.

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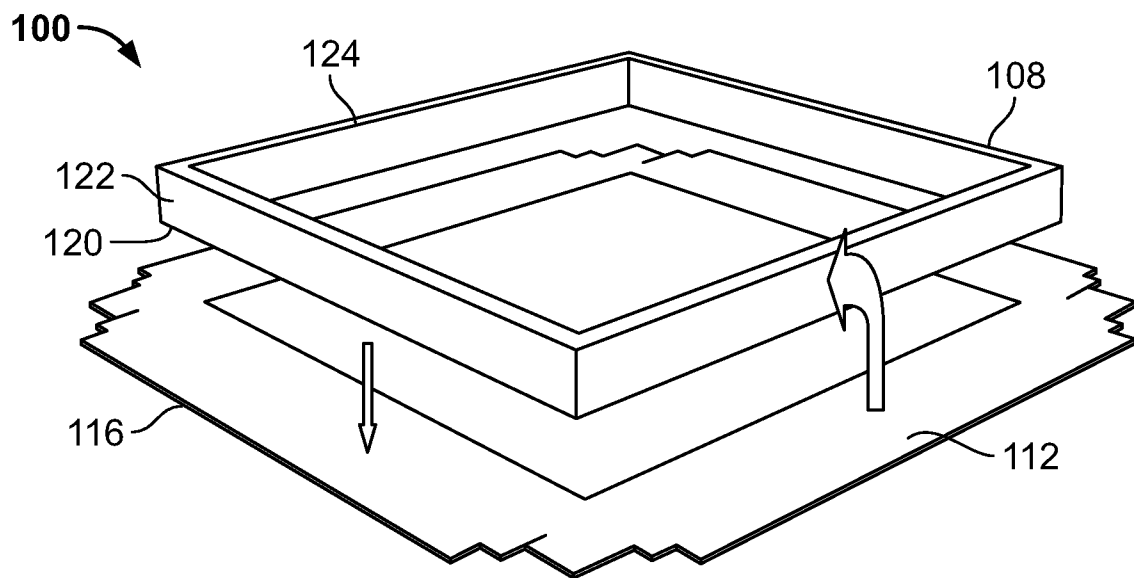


FIG. 1

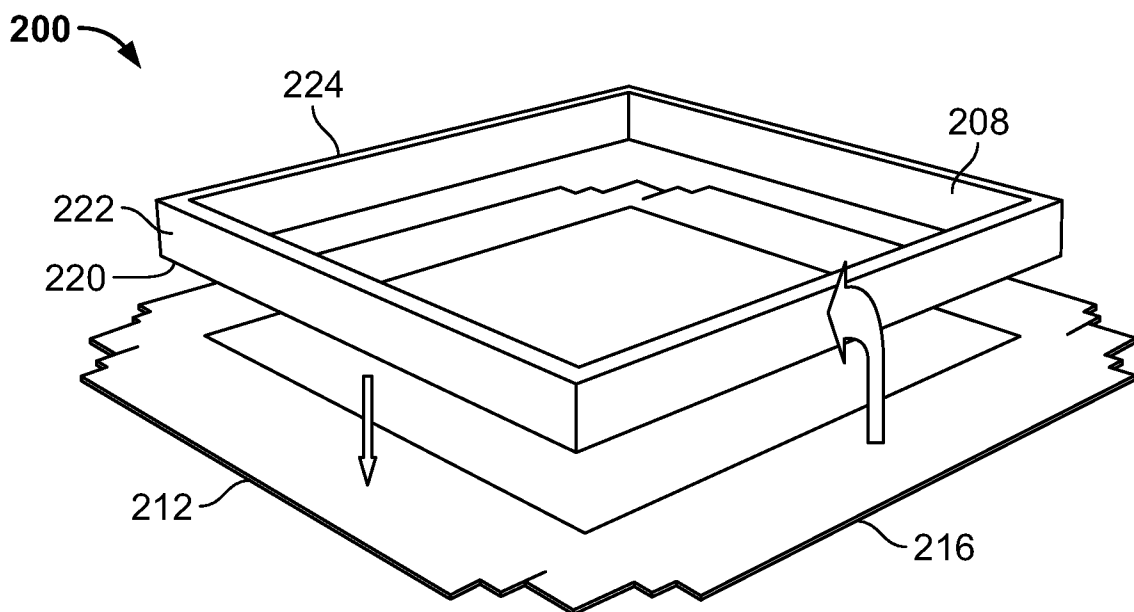
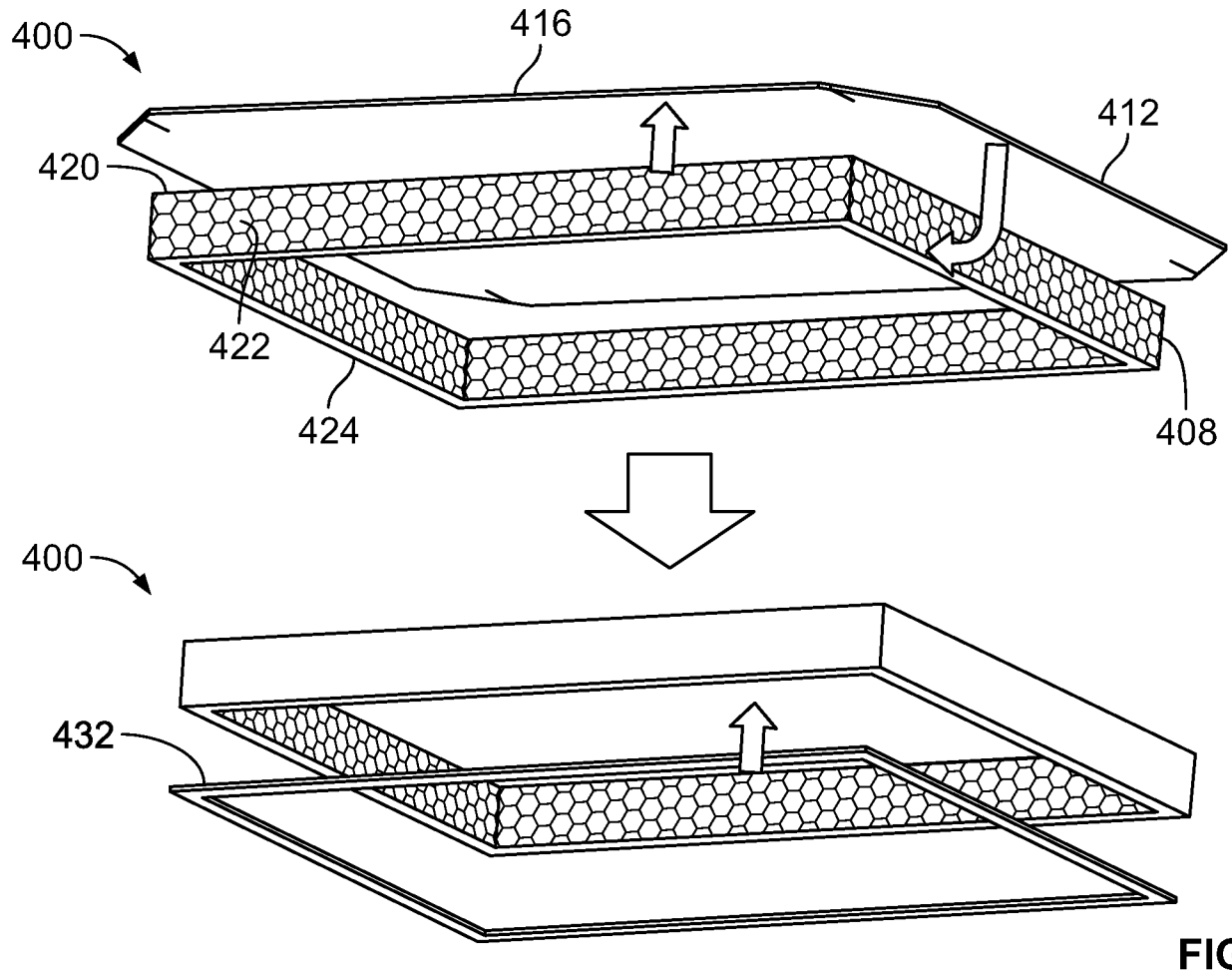
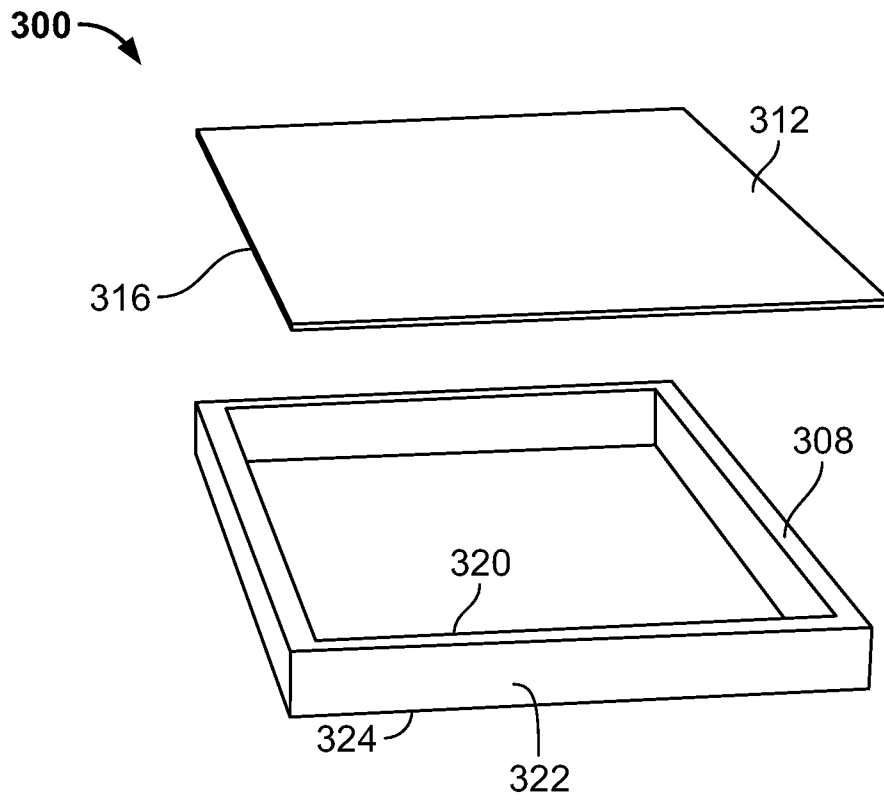


FIG. 2



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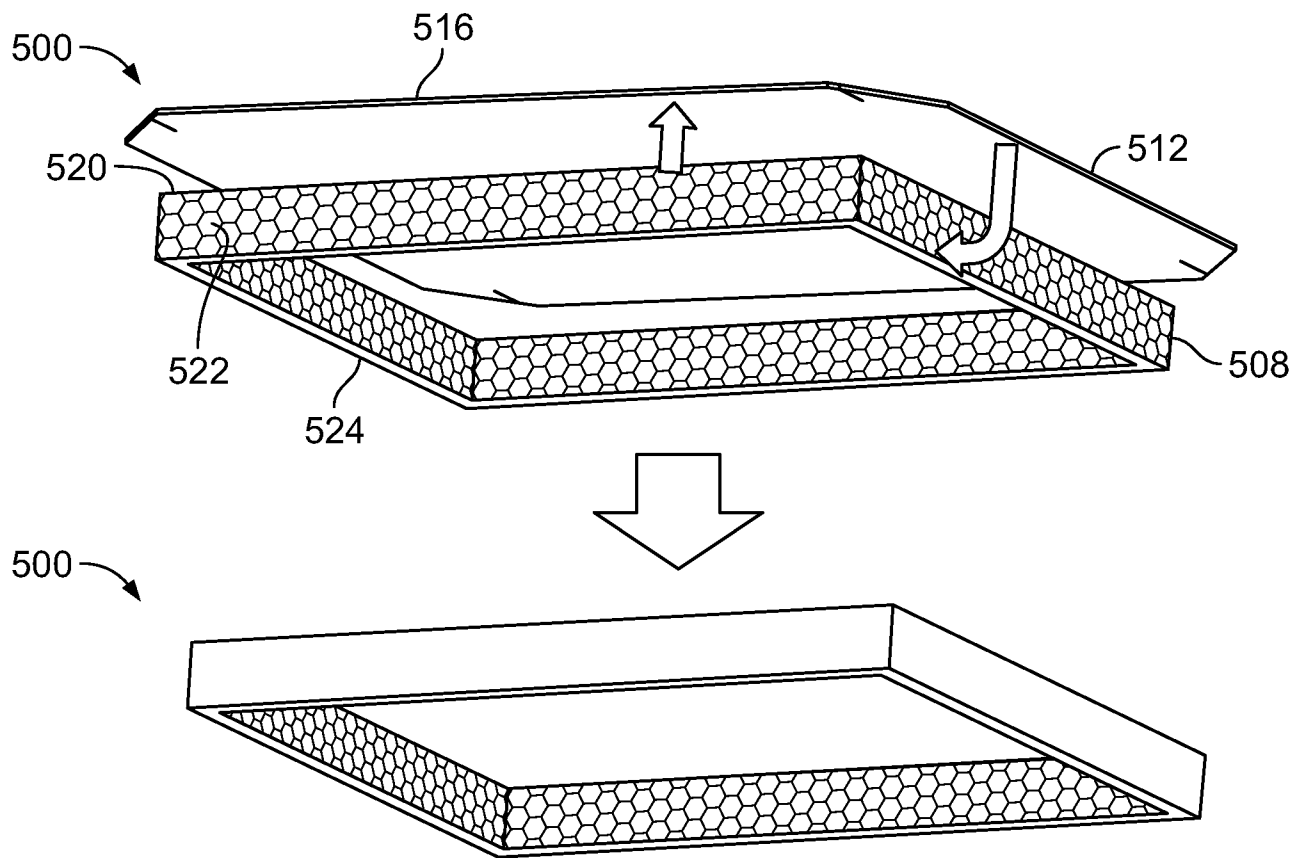


FIG. 5

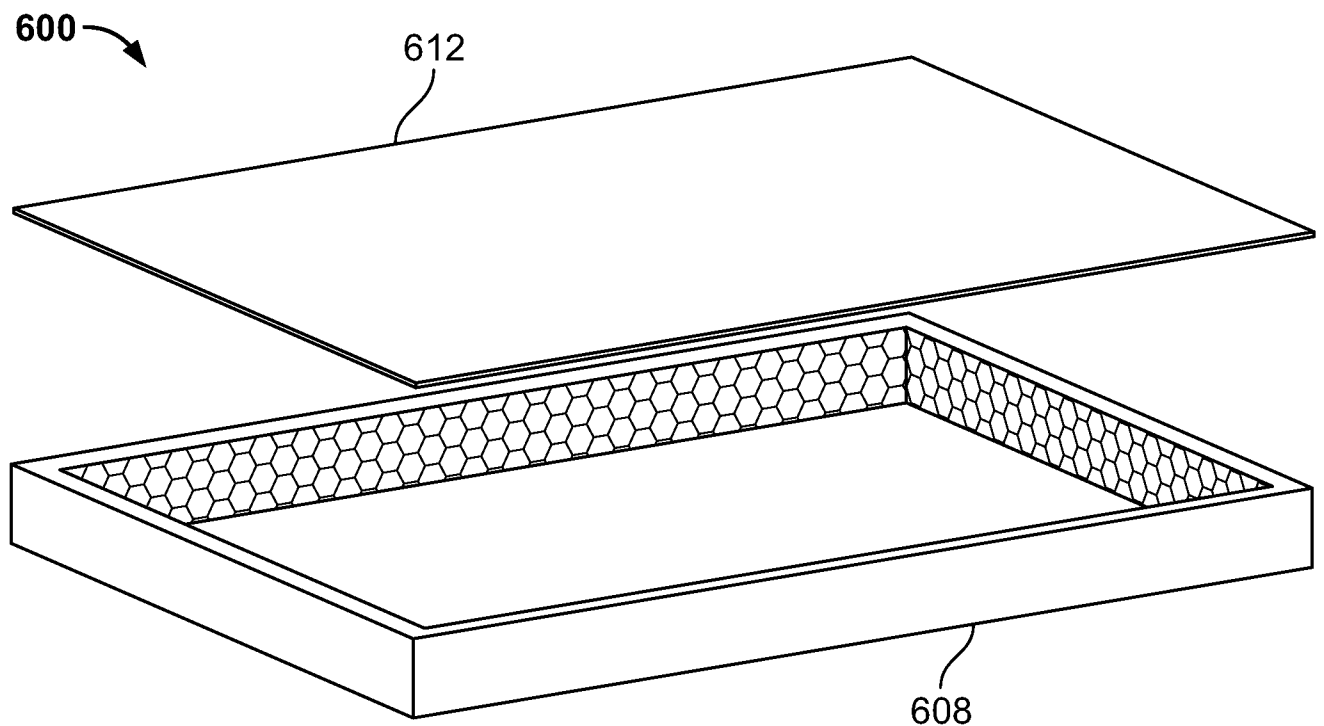


FIG. 6

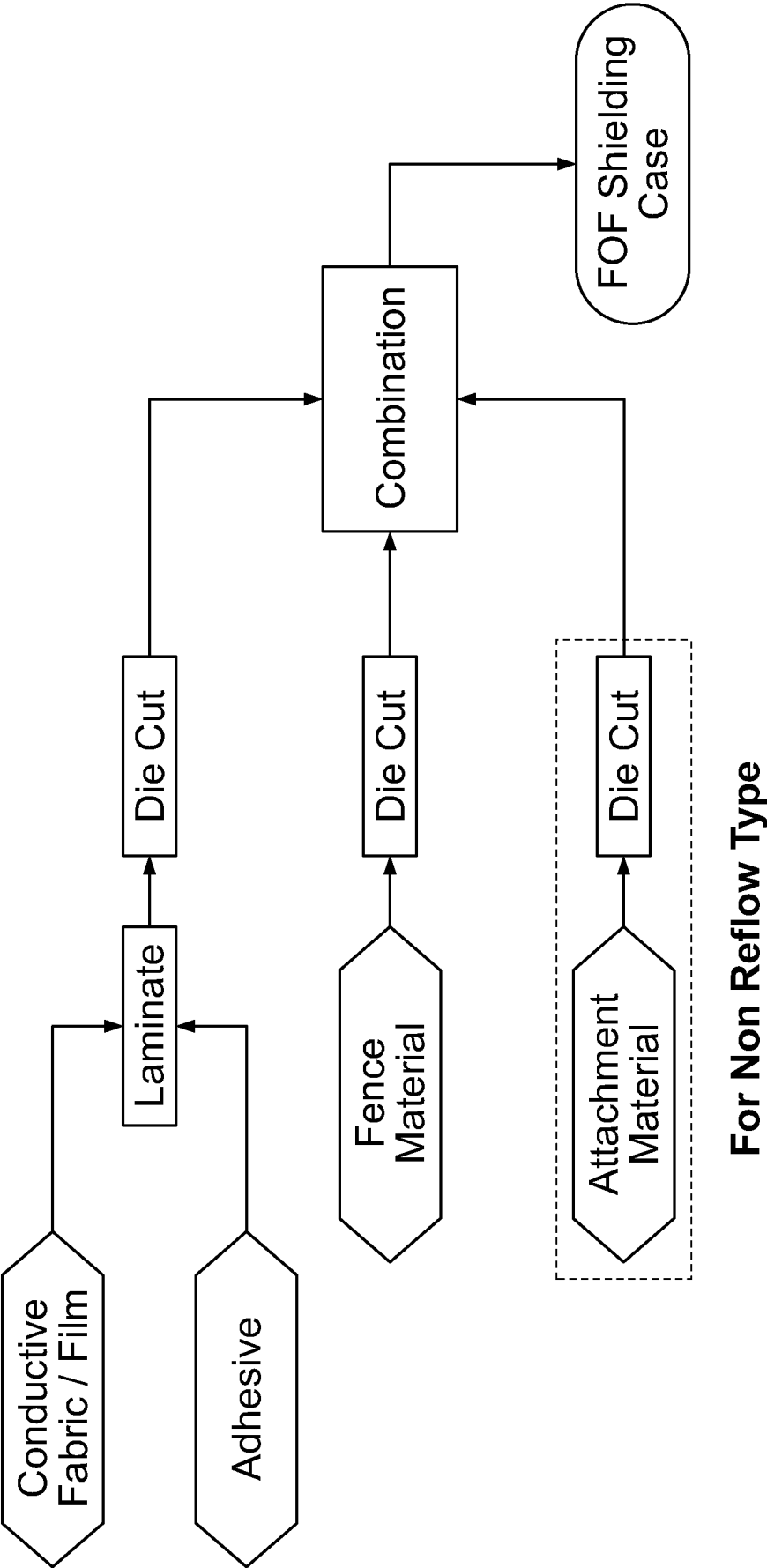
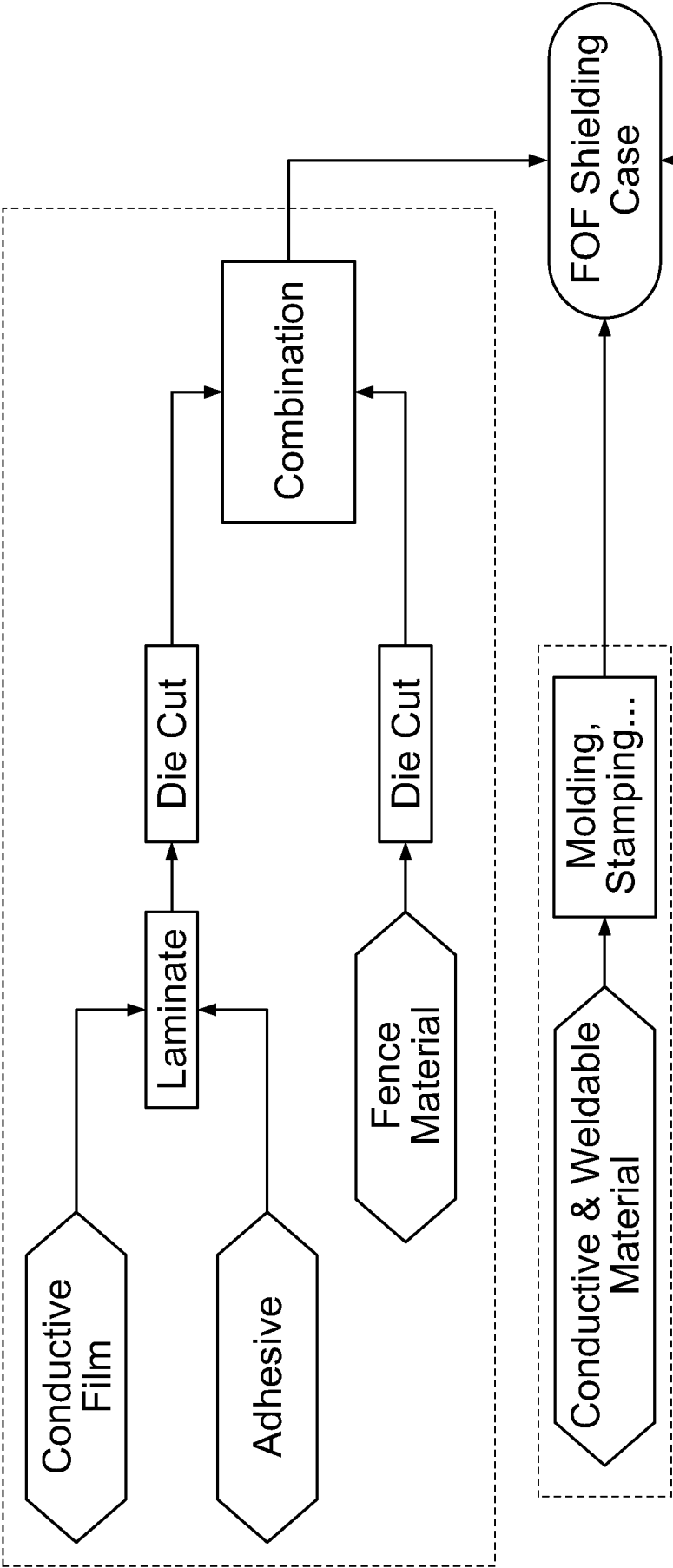


FIG. 7

Method A



Method B

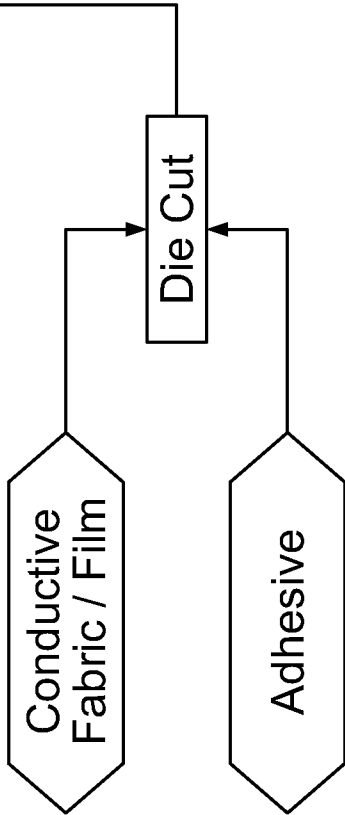


FIG. 8

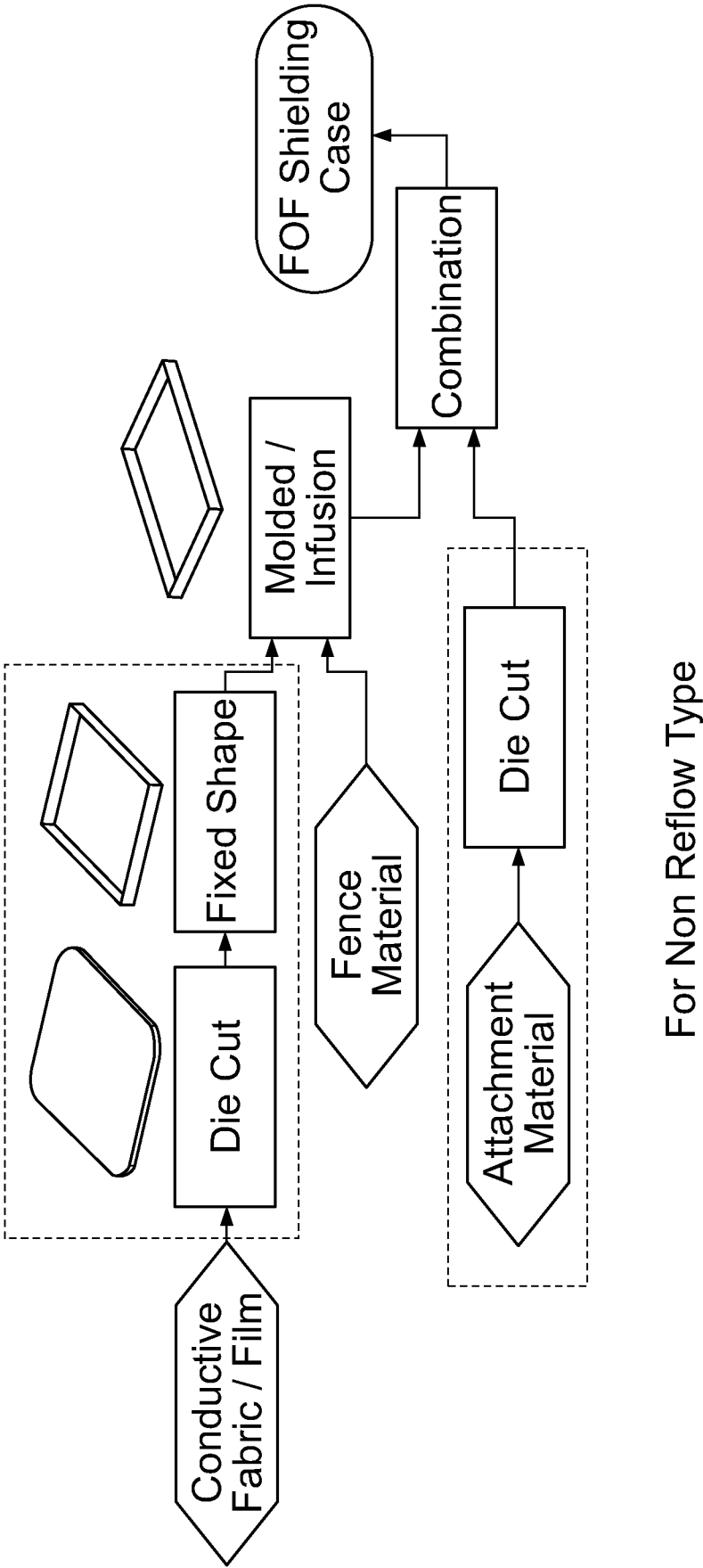


FIG. 9

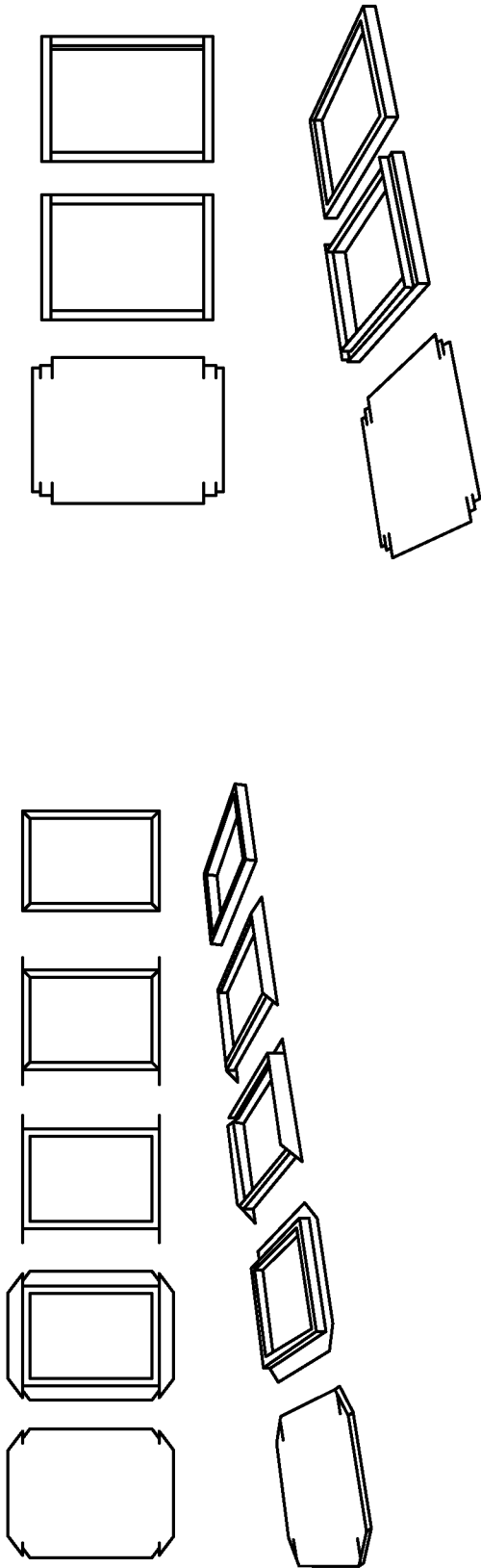


FIG. 11

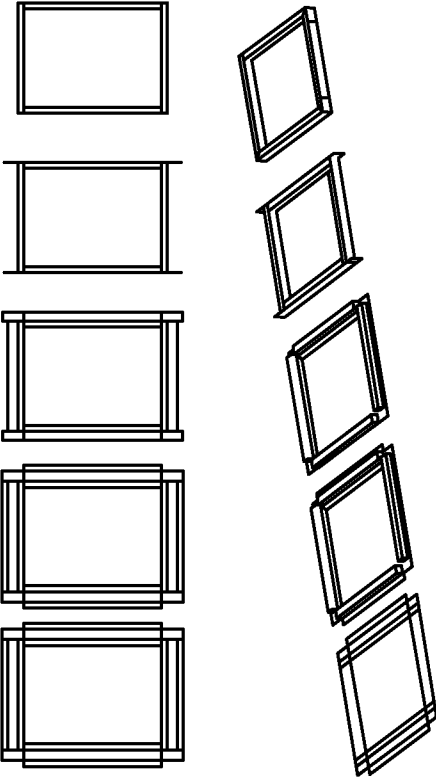


FIG. 12

FIG. 10

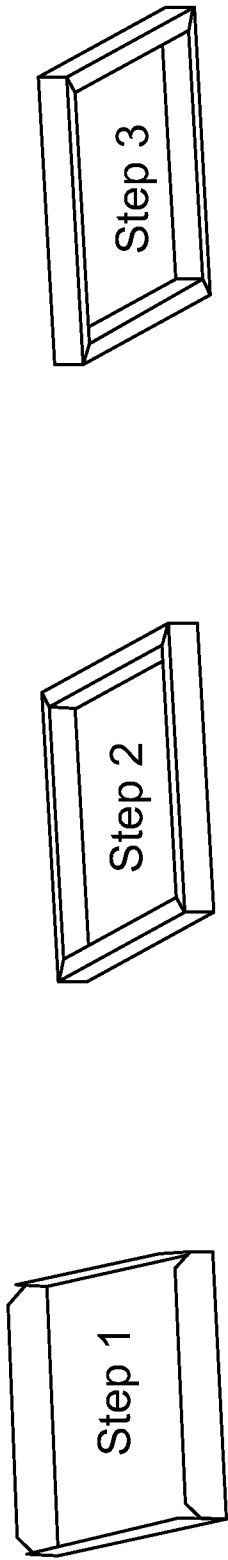


FIG. 13

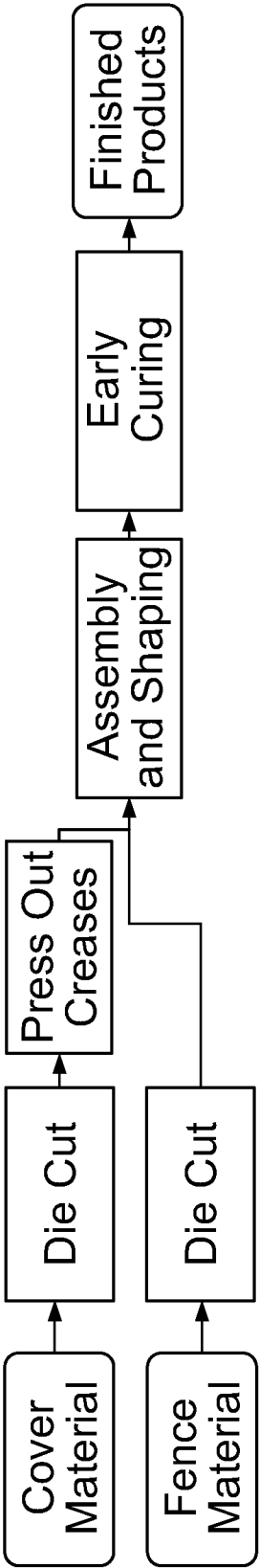


FIG. 14

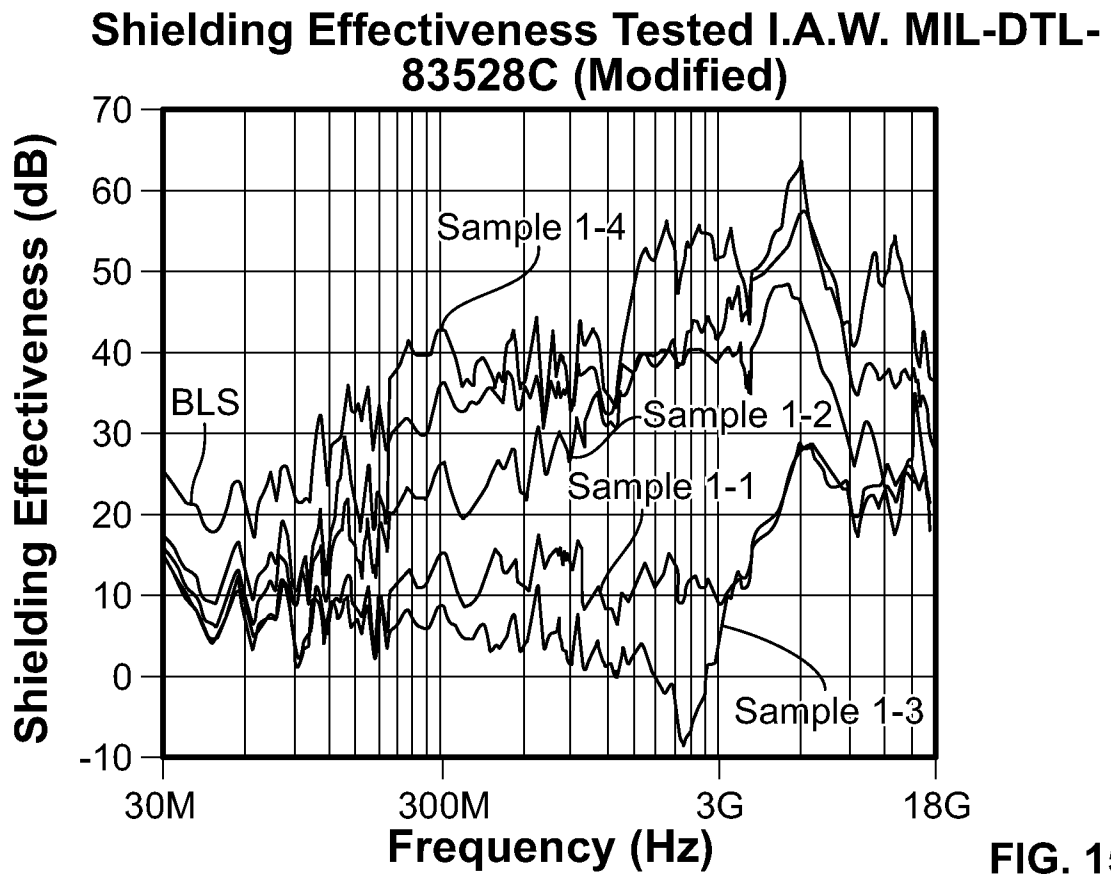


FIG. 15

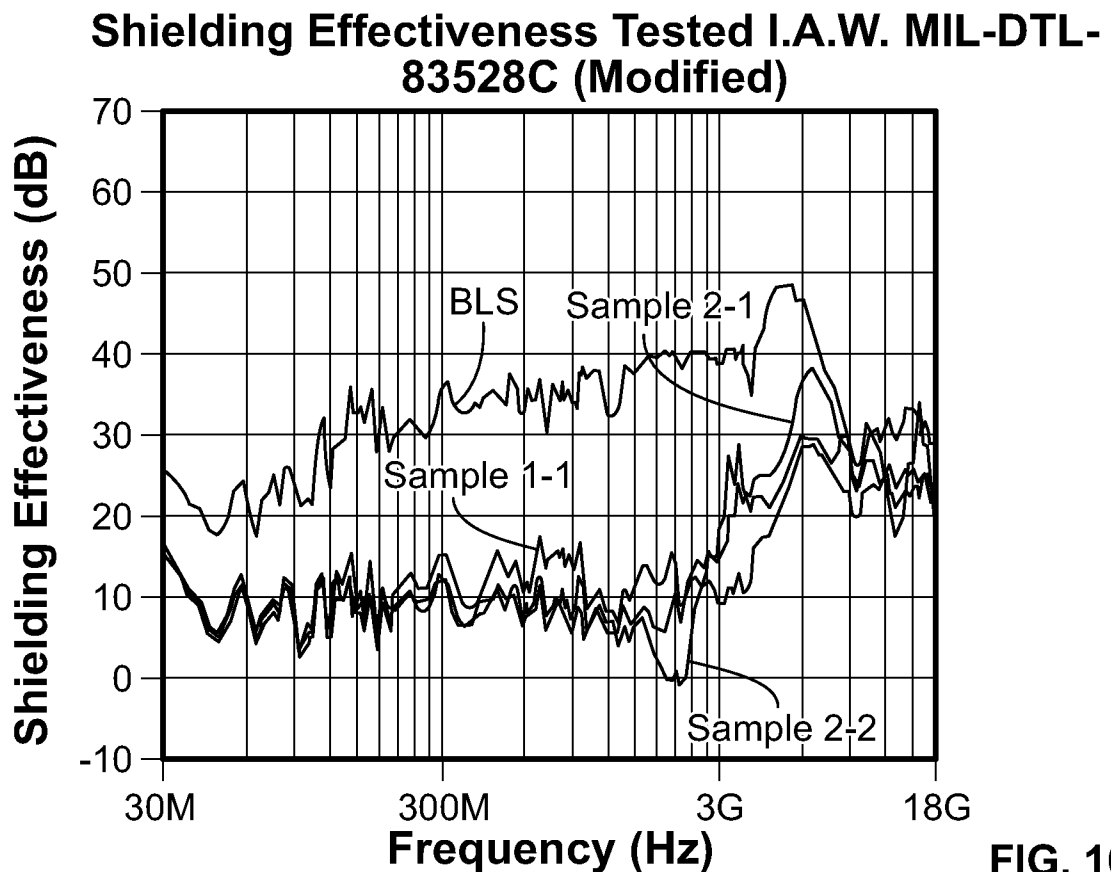


FIG. 16

Shielding Effectiveness Tested I.A.W. MIL-DTL-83528C (Modified)

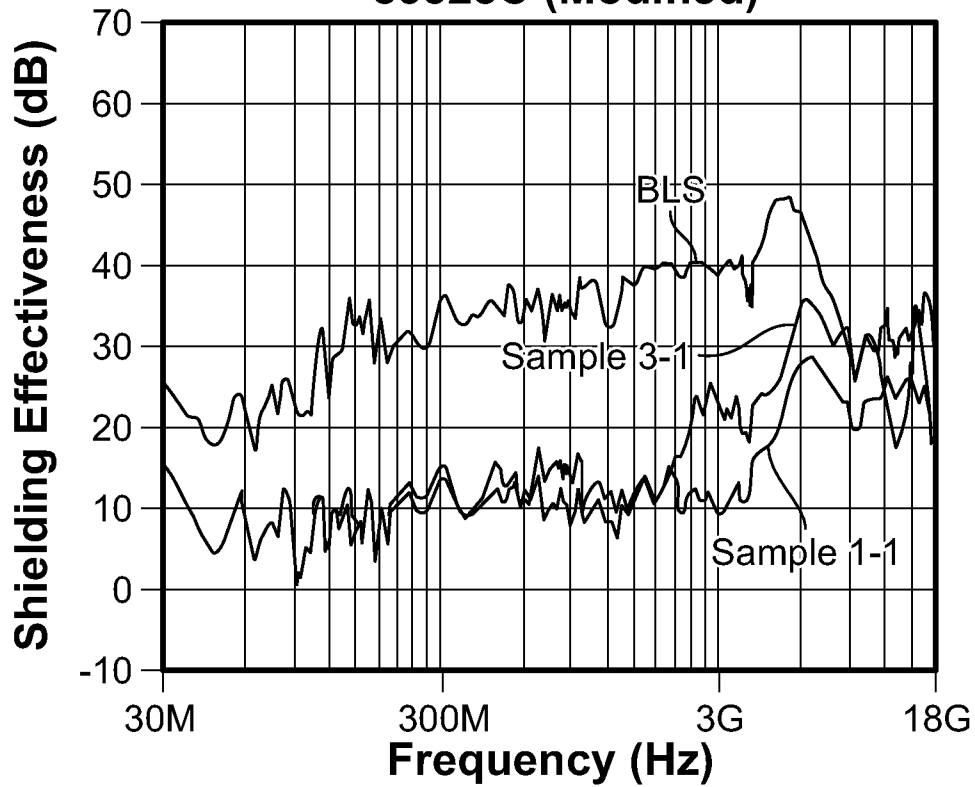


FIG. 17

Shielding Effectiveness Tested I.A.W. MIL-DTL-83528C (Modified)

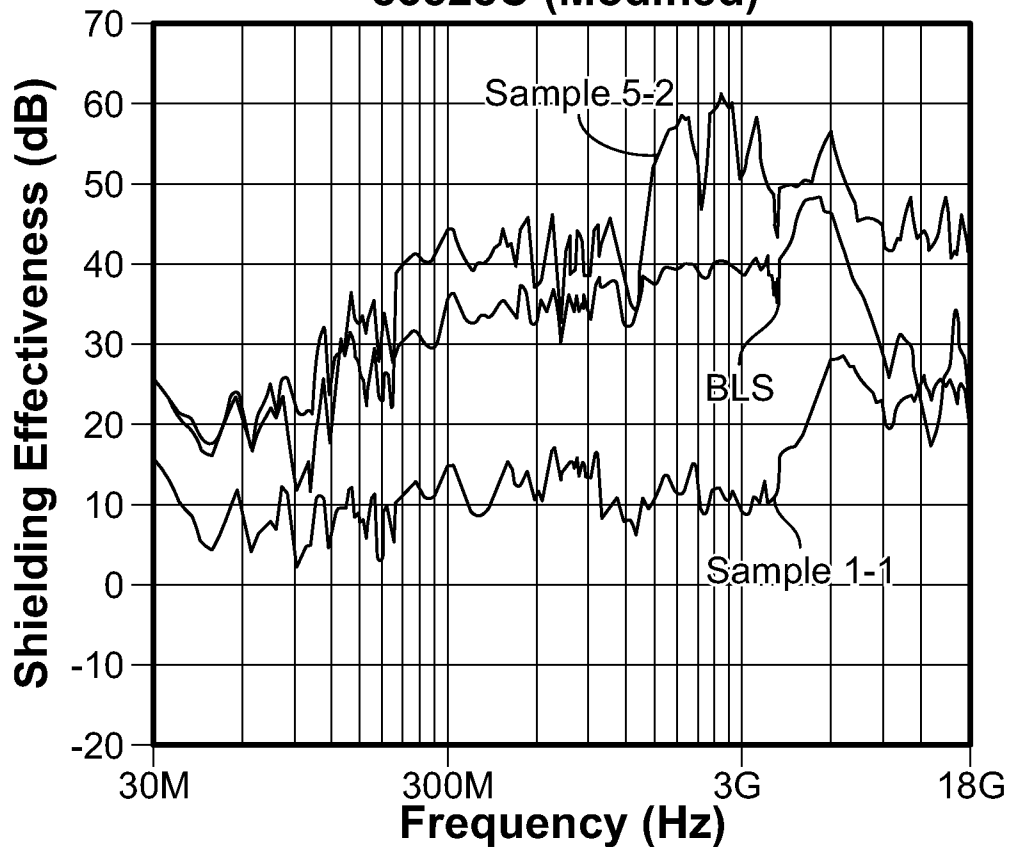


FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/031094**A. CLASSIFICATION OF SUBJECT MATTER****H05K 9/00(2006.01)I**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H05K 9/00; B29C 45/14; H01R 4/66; H04B 1/38

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: adhesive, shore, fold, bend, flex, polyimide, urethane, resin, substrate, shield, electromagnetic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001-0000392 A1 (JONATHAN E. MITCHELL et al.) 26 April 2001 See paragraphs [0028]-[0041] and figures 1-3B.	1-6, 8-14, 16-26 , 28-33
Y		7, 15, 27, 34
Y	US 2007-0052125 A1 (JOHN P. KALINOSKI et al.) 08 March 2007 See paragraphs [0033]-[0036], [0054], [0076]-[0077] and figures 1-2.	7, 15, 27, 34
A	US 6255581 B1 (BRADLEY E. REIS et al.) 03 July 2001 See column 5, line 47 - column 6, line 5 and figures 1A-1B.	1-34
A	JP 2010-021213 A (TOSHIBA CORP.) 28 January 2010 See abstract, paragraphs [0011]-[0034] and figures 1-3.	1-34
A	US 2002-0137371 A1 (HAIXIONG ZHAO) 26 September 2002 See abstract, paragraphs [0028]-[0046] and figures 1-6.	1-34



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" 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

"X" 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

"Y" 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

"&" document member of the same patent family

Date of the actual completion of the international search

08 August 2016 (08.08.2016)

Date of mailing of the international search report

08 August 2016 (08.08.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/031094

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