



- (51) **International Patent Classification:**
H01L 23/48 (2006.01)
- (21) **International Application Number:**
PCT/CN2015/079570
- (22) **International Filing Date:**
22 May 2015 (22.05.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

- (54) **Title:** VISCOELASTIC ELECTROMAGNETIC INTERFERENCE (EMI), SHOCK AND VIBRATION ABSORBER AND METHODS OF MAKING THE SAME

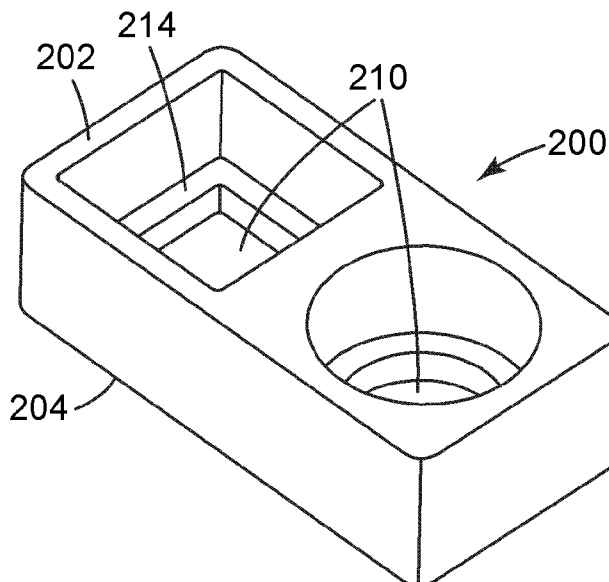


Fig. 2A

(57) **Abstract:** Monolithic housing for housing one or more electronic devices, and molding processes for making the same are provided. The monolithic housing is made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A. The shock absorbing material has EMI absorbing particles dispersed therein. The EMI absorbing particles includes magnetic particles. The shock absorbing material has 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles.



GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT,
LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE,

SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

**VISCOELASTIC ELECTROMAGNETIC INTERFERENCE (EMI), SHOCK AND
VIBRATION ABSORBER AND METHODS OF MAKING THE SAME**

5

TECHNICAL FIELD

The present disclosure relates to viscoelastic electromagnetic interference (EMI), shock and vibration absorbers, and methods of making and using the same.

10

BACKGROUND

Electromagnetic Interference (EMI) is a common problem for electronic devices, for example, when an electromagnetic (EM) field of an electronic component disrupts the operation or function of another electronic component. Sensitive wireless receivers may be highly impacted by EMI from nearby electronic components or devices. An EMI absorber can help absorb
15 electromagnetic interference thus improving the performance of wireless receivers (or any other electronic component in the system being affected by the EMI).

SUMMARY

Briefly, in one aspect, the present disclosure describes a monolithic housing for housing one or more electronic devices. The monolithic housing includes a three-dimensional body made of a
20 shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A. The shock absorbing material has electromagnetic interference (EMI) absorbing particles dispersed therein. The shock absorbing material has a composition including 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles. The three-dimensional body further includes one or more apertures configured to at least partially receive the
25 one or more electronic devices.

In another aspect, the present disclosure describes a method of producing a monolithic housing for an electronic device. The method includes providing a moldable thermoset resin composition comprising a mixture of a matrix material and EMI absorbing particles dispersed therein, and directing the mixture into a continuous, three-dimensional cavity to mold the resin into
30 a three-dimensional body. The three-dimensional body is made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having the absorbing particles dispersed therein, the shock absorbing material having a composition comprising 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles. The three-dimensional body further includes one or more apertures
35 configured to at least partially receive the one or more electronic devices.

In another aspect, the present disclosure describes a method of providing shock absorbing and electromagnetic interference (EMI) shielding for an electronic device. The method includes providing a monolithic housing made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having the absorbing particles dispersed therein, and the shock absorbing material having a composition comprising 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles. The monolithic housing further includes one or more apertures. A major surface of the monolithic housing is attached, via an adhesive, to a substrate to at least partially receive the electronic device.

In yet another aspect, the present disclosure describes a compression moldable EMI absorber which has 3D shapes with one or more apertures to receive electronic devices/components along with the ability to block electromagnetic interference (EMI) including infrared (IR) signals as well as provide damping for shock and vibration protection for the received electronic devices/components.

Various unexpected results and advantages are obtained in exemplary embodiments of the disclosure. One such advantage of exemplary embodiments of the present disclosure is that the housing or absorbers described herein have a continuous, monolithic structure that can provide damping for shock and vibration protection and provide EMI shielding or absorbing at the same time. The monolithic or one-piece structures described herein do not include any internal interfaces or joining means and can provide superior viscoelastic properties and mechanical strength compared to laminated structures. Also, the absence of any internal interfaces or joining means can prevent any gaps in the housing body through which an electromagnetic signals to be shielded may transmit.

Various aspects and advantages of exemplary embodiments of the disclosure have been summarized. The above Summary is not intended to describe each illustrated embodiment or every implementation of the present certain exemplary embodiments of the present disclosure. The Drawings and the Detailed Description that follow more particularly exemplify certain preferred embodiments using the principles disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure may be more completely understood in consideration of the following detailed description of various embodiments of the disclosure in connection with the accompanying figures, in which:

FIG. 1A is a top perspective view of a monolithic housing for housing one or more electronic devices, according to one embodiment.

FIG. 1B is a bottom perspective view of the housing of FIG. 1A.

FIG. 2A is a top perspective view of a monolithic housing for housing one or more electronic devices, according to another embodiment.

FIG. 2B is a bottom perspective view of the housing of FIG. 2A.

FIG. 3 is a flow diagram of a molding process for producing a monolithic housing, according to one embodiment.

FIG. 4A is a graph depicting the electrical permittivity of Example 1 as a function of frequency.

FIG. 4B is a graph depicting the magnetic permeability of Example 1 as a function of frequency.

FIG. 4C is a graph depicting the shielding effectiveness of Example 1 as a function of frequency.

FIG. 4D is a graph depicting the compression fore deflection (CFD) of Example 1.

FIG. 4E illustrates test results relating to shock and vibration absorbing performance of Example 1.

In the drawings, like reference numerals indicate like elements. While the above-identified drawing, which may not be drawn to scale, sets forth various embodiments of the present disclosure, other embodiments are also contemplated, as noted in the Detailed Description. In all cases, this disclosure describes the presently disclosed disclosure by way of representation of exemplary embodiments and not by express limitations. It should be understood that numerous other modifications and embodiments can be devised by those skilled in the art, which fall within the scope and spirit of this disclosure.

DETAILED DESCRIPTION

For the following Glossary of defined terms, these definitions shall be applied for the entire application, unless a different definition is provided in the claims or elsewhere in the specification.

Glossary

Certain terms are used throughout the description and the claims that, while for the most part are well known, may require some explanation. It should understood that:

The term “monolithic” means a one-piece structure that may be produced by a molding process with no internal interfaces and joining means.

The term “viscoelastic” with reference to properties of shock absorbing material that exhibit both viscous and elastic characteristics when undergoing deformation upon shock or vibration.

The term “absorbing” with reference to an EMI and shock absorbing material described herein that can convert received electromagnetic energy or shock/vibration energy to another form of energy to be dissipated inside the EMI and shock absorbing material.

By using terms of orientation such as “atop”, “on”, “over,” “covering”, “uppermost”, “underlying”, “bottom”, “top” and the like for the location of various elements in the disclosed coated articles, we refer to the relative position of an element with respect to a horizontally-disposed, upwardly-facing substrate. However, unless otherwise indicated, it is not intended that the substrate or articles should have any particular orientation in space during or after manufacture.

By using the term “molded structure” to describe a structure that is formed by a molding process and is a continuous, monolithic structure.

The terms “about” or “approximately” with reference to a numerical value or a shape means +/- five percent of the numerical value or property or characteristic, but expressly includes the exact numerical value. For example, a viscosity of “about” 1 Pa-sec refers to a viscosity from 0.95 to 1.05 Pa-sec, but also expressly includes a viscosity of exactly 1 Pa-sec. Similarly, a perimeter that is “substantially square” is intended to describe a geometric shape having four lateral edges in which each lateral edge has a length which is from 95% to 105% of the length of any other lateral edge, but which also includes a geometric shape in which each lateral edge has exactly the same length.

The term “substantially” with reference to a property or characteristic means that the property or characteristic is exhibited to a greater extent than the opposite of that property or characteristic is exhibited. For example, a substrate that is “substantially” transparent refers to a substrate that transmits more radiation (e.g. visible light) than it fails to transmit (e.g. absorbs and reflects). Thus, a substrate that transmits more than 50% of the visible light incident upon its surface is substantially transparent, but a substrate that transmits 50% or less of the visible light incident upon its surface is not substantially transparent.

As used in this specification and the appended embodiments, the singular forms “a”, “an”, and “the” include plural referents unless the content clearly dictates otherwise. Thus, for example, reference to fine fibers containing “a compound” includes a mixture of two or more compounds. As used in this specification and the appended embodiments, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

As used in this specification, the recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.8, 4, and 5).

Unless otherwise indicated, all numbers expressing quantities or ingredients, measurement of properties and so forth used in the specification and embodiments are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached listing of embodiments
5 can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings of the present disclosure. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claimed embodiments, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

10 The present disclosure describes monolithic housings for housing one or more electronic devices that can act as EMI and shock/vibration absorbers for protecting the electronic devices. The monolithic housing can be made of a shock absorbing material having a hardness in a range, for example, from about 20 Shore A to about 80 Shore A, from about 30 Shore A to about 70 Shore A, or from about 40 Shore A to about 60 Shore A. It is to be understood that the shock
15 absorbing material in some embodiments may have the hardness lower than 20 Shore A, and in some embodiments may be higher than 80 Shore A. The shock absorbing material has EMI absorbing particles dispersed therein to provide EMI absorbing properties. The EMI absorbing particles can include magnetic fillers such as, for example, iron alloy flakes or powders. The shock absorbing material may include 50 to 90 weight % of a thermosetting elastomer and 10 to 50
20 weight % of the EMI absorbing particles. In some embodiments, the thermosetting elastomer may be a moldable thermosetting elastomer including, for example, silicone, polyisoprene rubber, combinations thereof, etc.

While not to be bound by theory, it is believed that adding EMI absorbing particles (e.g., magnetic fillers) into a shock absorbing material (e.g., silicone, polyisoprene rubber) can also tune
25 mechanical properties of the shock absorbing material, for example, increasing the hardness of the shock absorbing material. For example, after mixing with magnetic fillers, a shock absorbing material including silicone can have its hardness increase, for example, from about 30 Shore A to about 50 Shore A. Thus, electrical and mechanical properties of the shock absorbing material can be adjusted by varying the amount of EMI absorbing particles dispersed therein.

30 The monolithic housings described herein have a continuous, monolithic structure with no internal interfaces and joining means, which is different from a laminated structure that is formed by laminating two or more layers. The EMI absorbing particles may be controlled to unevenly disperse inside the shock absorbing material (e.g., silicone, polyisoprene rubber, etc.) which serves as a continuous, monolithic matrix body to host the dispersed EMI absorbing particles.

The monolithic housing may include one or more apertures for receiving one or more electronic devices such as, for example, sensors, antennas, microphones, camera lens, etc. The apertures each include at least one opening adjacent to the major surfaces thereof for signal transmission (e.g., sound, light, wireless signals, etc.). The apertures may be formed during the formation of the monolithic housing by a molding process.

Figures 1A to 2B illustrate monolithic housing bodies for housing electronic devices to provide EMI, shock and vibration protection, according to various embodiments. The depicted monolithic housing bodies 100 and 200 each have a three dimensional (3D) shape with a thickness T in a range, for example, from several hundred microns to several millimeters, and a lateral dimension (e.g., length or width) in a range, for example, from several millimeters to several centimeters. The thickness T is measured between opposite major surfaces (e.g., 102 and 104, and 202 and 204) in a thickness direction thereof. In some embodiments, the thickness T may be no greater than 5 cm, no greater than 2 cm, no greater than 1 cm, or no greater than 5 mm. The thickness T may be no less than 0.1 mm, no less than 0.5 mm, no less than 1 mm, or no less than 2 mm. The lateral dimension is measured in a plan perpendicular to the thickness direction thereof. In some embodiments, the lateral dimension may be no greater than 10 cm, no greater than 5 cm, no greater than 2 cm, or no greater than 1 cm. The lateral dimension may be no less than 0.2 mm, no less than 0.5 mm, no less than 1 mm, or no less than 2 mm.

As shown in FIGS. 1A-B, the housing body 100 includes an aperture 110 that is a through-hole extending through the body in a thickness direction and with opposite first and second openings on the major surfaces 102 and 104, respectively. The aperture 110 has a circular cross-sectional shape, and is positioned to be off-center. The housing body 100 further includes a recess 120 formed into the major surface 102. The aperture 110 has the first opening on the major surface 102 inside the recess 120, and the second, opposite opening being flushed with the major surface 104. When in use, one or more electronic devices or components can be received by the aperture 110 and/or the recess 120.

As shown in FIGS. 2A-B, the housing body 200 includes two apertures 210 that are arranged along a longitudinal direction thereof. It is to be understood that the housing body may include three or more apertures that are appropriately arranged to accommodate electronic devices or components. The housing body 200 further includes a flange 214 adjacent the major surface 204 thereof. The flange 214 transversely projects into the aperture 210. It is to be understood that the flange 214 is an integral portion of the housing body 200 that has a continuous, monolithic structure with no internal interfaces or joining means.

The apertures 110 and 210 can have various shapes such as, for example, circular shape, rectangular shape, tapered shape, stepped shape, etc. For example, one of the apertures 210 has

rectangular cross-sectional shape and the other has a circular cross-sectional shape. In the embodiments shown in FIGS. 1A-2B, the apertures are through holes that extend through the respective housing bodies in the thickness direction. It is to be understood that some of the apertures may be partially extend through the housing body 100 in the thickness direction or other directions.

The housing bodies 100 and 200 are made of a shocking absorbing material including, for example, thermosetting elastomer (e.g., silicone, or polyisoprene rubber) and EMI absorbing fillers dispersed therein. In some embodiments, the composition of shocking absorbing material may include about 50 to about 90 weight % of thermosetting elastomer and about 10 to about 50 weight % of the EMI absorbing particles. In some embodiments, the composition of shocking absorbing material may include about 50 to about 80 weight % of thermosetting elastomer, about 15 to about 45 weight % of the EMI absorbing particles, about 0-6 weight % of carbon black filler, and about 1-2 weight % of peroxide curative. In some embodiments, the shocking absorbing material may include (i) no less than 50 weight %, no less than 55 weight %, or no less than 60 weight % of the thermosetting elastomer, (ii) no more than 50 weight %, no more than 45 weight %, or no more than 40 weight % of EMI absorbing particles (e.g., magnetic fillers), (iii) no more than 6 weight % of carbon black, and (iv) no more than 3 weight % of curatives (e.g., peroxide curative). It is to be understood that curable thermosetting polymers other than silicone and polyisoprene rubber such as, for example, epoxy resins, polyester resins, may also be used as along as the formed shocking absorbing material can exhibit desired viscoelastic properties and EMI shielding properties.

In some embodiments, the EMI absorbing particles can be substantially uniformly distributed within the shocking absorbing material. In other embodiments, the distribution may be non-uniform and the EMI absorbing particles can be dispersed in segments. For example, the EMI absorbing particles may have a higher density in a selected region of the monolithic housing body compared to other regions. When an electronic device or a component of the electronic device is received by one or more of the apertures 110, the selected region with higher density can be adjacent to and directly face the received electronic device or component that may generate EMI or need to be protected from EMI.

In some embodiments, the EMI absorbing particles in each region or section of a housing body can be the same or different particle types with similar or different EMI absorbing characteristics (e.g., permeability and permittivity values). In some embodiments, in a molding process to produce a housing body, EMI absorbing particles with different particle types varying in their permeability and permittivity characteristics can be blended in sections or regions to optimize performance in an enclosure with multiple or single EMI reflecting surfaces. Regions and/or sections of the molded part can be horizontal and/or vertical or variations of both to optimize

performance for various end user configurations (e.g., system level EMI reflected surfaces and EMI primary and secondary, tertiary EMI source locations).

The shock absorbing material described herein has a composition that can exhibit both viscoelastic properties and EMI shielding properties. In some embodiments, the shocking absorbing material may have a hardness in a range, for example, from about 20 Shore A to about 80 Shore A, from about 30 Shore A to about 70 Shore A, or from about 40 Shore A to about 60 Shore A. It is to be understood that the shocking absorbing material may have a hardness or a durometer range lower than 20 Shore A or higher than 80 Shore A, depending on the specific applications. In some embodiments, the thermosetting elastomer may be formed by molding and curing a moldable and curable thermosetting elastomer that by itself has a hardness in a range, for example, from about 10 Shore A to about 70 Shore A, from about 15 Shore A to about 50 Shore A, or from about 20 Shore A to about 40 Shore A. Without adding the EMI absorbing particles, the thermosetting elastomer may have a hardness lower than 10 Shore A or higher than 70 Shore A. The shock absorbing material may have a Compression Set B deflection at room temperature in a range from about 5% to about 20%, from about 8% to about 15%, or from about 9% to about 12%. At elevated temperatures (e.g., at 50 to 100 degree C), the Compression Set B deflection may be increased to, for example, about 20%.

The EMI absorbing particles described herein can include, for example, magnetic fillers. In some embodiments, the magnetic fillers may have a composition including iron alloy such as, for example, Fe-Si-Al alloy. The magnetic fillers can be provided in form of powders or flakes and dispersed within the shock absorbing material by, for example, roll mills. The average dimension of the magnetic fillers can be in a range, for example, from sub-microns to about 200 microns, from about 1 micron to 100 microns, from about 5 microns to about 50 microns, or from about 10 microns to about 30 microns. In some embodiments, about 90% of the dispersed magnetic fillers have an average dimension in the range from about 5 microns to about 50 microns. In some embodiments, the magnetic fillers may be ground into finer particles before mixed with the thermosetting elastomer. It is to be understood that the EMI absorbing particles may include any suitable ferromagnetic or ferrimagnetic material other than iron alloy, including, for example, doped or undoped carbonyl iron powder (CIP), iron silicide, ceramic magnetic ferrite, ceramic magnetic garnet, combinations thereof, etc. In some embodiments, the shock absorbing material dispersed in the shock absorbing material is capable of absorbing EMI in a frequency range, for example, from about 0.1 GHz to about 5.8 GHz, and may have a maximum absorbing efficiency in the frequency range from about 3 GHz to about 5 GHz. Higher frequencies above the tested 5.8 GHz can also be absorbed by the shock absorbing material described herein. Applications in the range

of 5.8-80 GHz and above range are possible with the optimized EMI filler particle selection with optimized permeability and permittivity characteristics.

In some embodiments, the shock absorbing material with the embedded magnetic fillers may have a surface resistivity in a semi-insulating range, for example, from about 1×10^{10} to about 1×10^{13} Ohm/Square. The shock absorbing material can exhibit anti-static properties that inhibit triboelectric charging and prevent possible electric shock for electric devices received therein. In some embodiments, the shock absorbing material may include, for example, 1 wt% or less, 0.5 wt% or less, or 0.1 wt % or less of electrically conductive fillers (e.g., metal fillers, carbon nanotube fillers, etc.) to tune the electrical resistivity thereof. In some embodiments, the shock absorbing material may be thermal insulating with a thermal conductivity in a range, for example, from about 0.01 to about 0.1 W/(m·K) at room temperature.

The shocking absorbing material may further include optional carbon black (CB) filler to absorb infrared signals. The carbon black filler dispersed within the shocking absorbing material can act as a color pigment to prevent infrared radiation from transmitting therethrough. The carbon black filler may have an average particle size in a range, for example, from about sub-microns to 100 microns. In some embodiments, the composition of shocking absorbing material may include about 6 wt% or less, about 5 wt% or less, or about 4 wt% or less of carbon black. It is to be understood that any suitable color pigment other than carbon black may be added into the shocking absorbing material to block light in one or more selected ranges of infrared, visible, or ultraviolet signal.

The housing bodies described herein can be produced by a molding process such as a method 300 illustrated in FIG. 3. At 310, a mixture of shock absorbing material including a shock absorbing material (e.g., thermosetting elastomer such as silicone or polyisoprene rubber) and EMI absorbing fillers is provided. In some embodiments, curable thermosetting elastomers such as gummy silicone rubber, with curative, and fillers such as magnetic filler and optional black pigment can be mixed by, for example, a two-roll mill. The method 300 then proceeds to 320.

At 320, the mixture is directed into a continuous, three-dimensional molding cavity that can be formed by, for example, two piece steel molds. The method 300 then proceeds to 330.

At 330, the mixture can be molded to form a three-dimensional continuous housing body under predetermined temperature and pressure. In some embodiments, the molding temperature can be at a range, for example, about 115 degree C to about 180 degree C. At the molding temperatures, the silicone rubber can be cured in the present of curatives (e.g., peroxide curative). It is to be understood that other types of curatives may be used to thermally or optically cure the silicone. The molding process can include, for example, compression molding, injection molding, etc. Molding parameters (e.g., temperature, pressure, flow rate, etc.) can be controlled to achieve

desired distribution of the EMI absorbing particles and/or carbon black fillers within the thermosetting elastomer (e.g., silicone or polyisoprene rubber).

Exemplary embodiments of the present disclosure may take on various modifications and alterations without departing from the spirit and scope of the present disclosure. Accordingly, it is to be understood that the embodiments of the present disclosure are not to be limited to the following described exemplary embodiments, but is to be controlled by the limitations set forth in the claims and any equivalents thereof.

Various exemplary embodiments of the disclosure will now be described with particular reference to the Drawings. Exemplary embodiments of the present disclosure may take on various modifications and alterations without departing from the spirit and scope of the disclosure. Accordingly, it is to be understood that the embodiments of the present disclosure are not to be limited to the following described exemplary embodiments, but are to be controlled by the limitations set forth in the claims and any equivalents thereof. It is to be understood that any of embodiments 1-19 below can be combined with any one of embodiments 20-35 below.

Embodiment 1 is a monolithic housing for housing one or more electronic devices, comprising:

a three-dimensional body made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having electromagnetic interference (EMI) absorbing particles dispersed therein, the shock absorbing material having a composition comprising 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles,

wherein the three-dimensional body further includes one or more apertures configured to at least partially receive the one or more electronic devices.

Embodiment 2 is the monolithic housing of embodiment 1, wherein the shock absorbing material forms a continuous, monolithic molded structure with no internal interfaces and joining means.

Embodiment 3 is the monolithic housing of embodiment 1, wherein the thermosetting elastomer includes silicone, or polyisoprene rubber.

Embodiment 4 is the monolithic housing of any one of embodiments 1-3, wherein the thermosetting elastomer is formed from a curable thermosetting elastomer that by itself has a hardness in a range from about 20 Shore A to about 40 Shore A after curing.

Embodiment 5 is the monolithic housing of any one of embodiments 1-4, wherein the shock absorbing material is semi-insulating with a surface resistivity in a range from about 1×10^{10} to about 1×10^{13} Ohm/Square.

Embodiment 6 is the monolithic housing of any one of embodiments 1-5, wherein the shock absorbing material is thermal insulating with a thermal conductivity in a range from about 0.01 to about 0.1 W/(m·K) at room temperature.

5 Embodiment 7 is the monolithic housing of any one of embodiments 1-6, wherein the shock absorbing material is capable of absorbing EMI in a frequency range from about 0.1 GHz to about 5.8 GHz.

Embodiment 8 is the monolithic housing of any one of embodiments 1-7, wherein the EMI absorbing particles comprise a magnetic filler.

10 Embodiment 9 is the monolithic housing of embodiment 8, wherein the shock absorbing material comprises 50 to 75 weight % of the silicone and 10 to 45 weight % of the magnetic filler.

Embodiment 10 is the monolithic housing of any one of embodiments 1-9, wherein at least one of the apertures is a through-hole extending in a thickness direction thereof.

15 Embodiment 11 is the monolithic housing of any one of embodiments 1-10, wherein the shock absorbing material further comprises carbon black filler dispersed therein and configured to absorb infrared light.

Embodiment 12 is the monolithic housing of any one of embodiments 1-11, wherein the shock absorbing material further include 0.5 weight % or less of an electrically conductive filler including metals, metal alloys, carbon nanotubes, or combinations thereof dispersed therein.

20 Embodiment 13 is the monolithic housing of any one of embodiments 1-12, wherein the body has an average thickness from about 0.1 mm to about 1 cm.

Embodiment 14 is the monolithic housing of any one of embodiments 1-13, wherein the body has an average lateral dimension from about 1 mm to 2 cm.

Embodiment 15 is the monolithic housing of any one of embodiments 1-14, wherein the EMI absorbing particles are substantially uniformly distributed within the elastomeric material.

25 Embodiment 16 is the monolithic housing of any one of embodiments 1-15, wherein the EMI absorbing particles are unevenly distributed in segments within the elastomeric material.

Embodiment 17 is an electronic circuit package comprising an electronic device and the monolithic housing of any one of embodiments 1-16 to accommodate one or more components of the electronic device.

30 Embodiment 18 is the electronic circuit package of embodiment 17, wherein the electronic device includes a radio frequency component.

Embodiment 19 is the electronic circuit package of embodiment 17 or 18, wherein the electronic device includes a sensing component that is sensible to electromagnetic interference.

Embodiment 20 is a method of producing a monolithic housing for an electronic device, the method comprising:

5 providing a moldable thermoset resin composition comprising a mixture of a matrix material and EMI absorbing particles dispersed therein; and

directing the mixture into a continuous, three-dimensional cavity to mold the resin into a three-dimensional body,

10 wherein the three-dimensional body is made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having the absorbing particles dispersed therein, the shock absorbing material having a composition comprising 40 to 90 weight % of a thermosetting elastomer and 10 to 60 weight % of the EMI absorbing particles, and

15 wherein the three-dimensional body further includes one or more apertures configured to at least partially receive the one or more electronic devices.

Embodiment 21 is a method of providing shock absorbing and electromagnetic interference (EMI) shielding for an electronic device, the method comprising:

20 providing a monolithic housing made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having the absorbing particles dispersed therein, the shock absorbing material having a composition comprising 50 to 90 weight % of a silicone and 10 to 50 weight % of the EMI absorbing particles, the monolithic housing further comprises one or more apertures; and

attaching, via an adhesive, a major surface of the monolithic housing to a substrate to at least partially receive the electronic device.

25 Embodiment 22 is the method of embodiment 20 or 21, wherein the shock absorbing material forms a continuous, monolithic molded structure with no internal interfaces and joining means.

Embodiment 23 is the method of any one of embodiment 20-22, wherein the thermosetting elastomer includes silicone, or polyisoprene rubber, and the silicone is formed from a curable silicone that by itself has a hardness in a range from about 20 Shore A to about 40 Shore A after
30 curing.

Embodiment 24 is the method of any one of embodiment 20-23, wherein the shock absorbing material is semi-insulating with a surface resistivity in a range from about 1×10^{10} to about 1×10^{13} Ohm/Square.

Embodiment 25 is the method of any one of embodiments 20-24, wherein the shock absorbing material is thermal insulating with a thermal conductivity in a range from about 0.01 to about 0.1 W/(m·K) at room temperature.

5 Embodiment 26 is the method of any one of embodiments 20-25, wherein the shock absorbing material is capable of absorbing EMI in a frequency range from about 0.1 GHz to about 5.8 GHz.

Embodiment 27 is the method of any one of embodiments 20-26, wherein the EMI absorbing particles comprise a magnetic filler including Fe-Si-Al alloy.

Embodiment 28 is the method of embodiment 27, wherein the shock absorbing material comprises 50 to 75 weight % of the silicone and 10 to 45 weight % of the magnetic filler.

10 Embodiment 29 is the method of any one of embodiments 20-28, wherein at least one of the apertures is a through-hole extending in a thickness direction thereof.

Embodiment 30 is the method of any one of embodiments 20-29, wherein the shock absorbing material further comprises carbon black filler dispersed therein and configured to absorb infrared light.

15 Embodiment 31 is the method of any one of embodiments 20-30, wherein the shock absorbing material further include 0.5 weight % or less of an electrically conductive filler including metals, metal alloys, carbon nanotubes, or combinations thereof dispersed therein.

Embodiment 32 is the method of any one of embodiments 20-31, wherein the body has an average thickness from about 0.1 mm to about 1 cm.

20 Embodiment 33 is the method of any one of embodiments 20-32, wherein the body has an average lateral dimension from about 1 mm to 2 cm.

Embodiment 34 is the method of any one of embodiments 20-33, wherein the EMI absorbing particles are substantially uniformly distributed within the elastomeric material.

25 Embodiment 35 is the method of any one of embodiments 20-34, wherein the EMI absorbing particles are unevenly distributed in segments within the elastomeric material.

30 The operation of the present disclosure will be further described with regard to the following detailed examples. These examples are offered to further illustrate the various specific and preferred embodiments and techniques. It should be understood, however, that many variations and modifications may be made while remaining within the scope of the present disclosure.

EXAMPLES

These Examples are merely for illustrative purposes and are not meant to be overly limiting on the scope of the appended claims. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the present disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

Test Methods

The following test methods have been used in evaluating some of the Examples of the present disclosure.

Viscoelasticity Measurement

Viscoelasticity measurements were made including hardness measurement under ASTM D2240, compressive force deflection measurement under ASTM D575, compression set measurement under ASTM D395 Method B, tensile modulus measurement under ASTM D412, and tensile strength measurement under ASTM D412.

EMI absorbing and Electrical Measurements

Complex dielectric and magnetic properties were measured over the frequency range of 0.1 to 5.8 GHz by using an Agilent E8364C PNA Network Analyzer coupled with Models M1000T and M07T from Damaskos Inc., Concordville, PA. The RF and microwave properties up to 5.8 GHz were tested in 25mm and 7 mm coaxial waveguides available from Damaskos Inc. Magnetic permeability and electrical permittivity measured in bands using the desired waveguide (100-800 MHz used the 25mm and 0.8 to 5.8 GHz bands used the 7mm waveguide). S parameter measurements were performed in the 7mm coax waveguide where sample (about 3-6 mm thick) was placed directly against a metal planar short. Volume resistivity and surface resistivity were measured for samples about 1 mm thick per ASTM D257.

Example 1

Uncured silicone rubber (about 61.4 wt%), magnetic filler (about 33.1 wt%), carbon black filler (about 4.3 wt%), and peroxide curative (about 1.2 wt%) were mixed by two-roll mills. The uncured silicone rubber is commercially available from Shin-Etsu Chemical Co., Ltd, Tokyo, Japan, under trade designation KE-931U. The magnetic filler includes about 85-90.5 wt% iron (Fe), about 5.5-7.5 wt% silicon (Si), about 1.5-3.5 wt% chromium (Cr), about 2.0-3.0 wt% boron

(B), and about 0.5-1.0 wt% carbon (C). The magnet filler is commercially available from Mate Co., Ltd, Okayama, Japan, under trade designation FP-2. Carbon black filler for silicone rubber and peroxide curative for curing silicone are standard materials that are well known. Finished piece from the two-roll mills were molded and cured inside a molding cavity formed by two molding plates at 170 degree C for ten minutes to form a viscoelastic composite plaque having a thickness in the range of about 1 mm, or about 3-6 mm used for various measurements.

Table 1

Typical Properties (plaques)	
Hardness, ASTM D2240 Type A Durometer 15 sec impact	53
Compressive Force Deflection ASTM D575 at 0.51cm/min (0.2 in/min) 10% kPa (psi) 20 % kPa (psi) 30% kPa (psi)	3454 (501) 7260 (1053) 11796 (1711)
Compression Set (%), ASTM D395 Method B 22 hrs at 23C (73F) 22 hrs at 70C (158F)	10.5 14.1
Thermal conductivity ASTM C-518 on Netzsch HFM-436 Heat Flow Meter	0.0699
Tensile Modulus ASTM D412 at 100% psi at 200% psi	362 561
Tensile Strength psi, ASTM D412	606
Tensile Elongation %	269
Abrasion Resistance Taber Abrasion: CS-17 wheel with 1000 gram load. % wt. loss per	0.51% (1000 cycles)
Magnetic Filler Base	Fe Alloy
Magnetic Filler Composition	33.10%
Carbon Pigment Composition	4.30%
Temperature Range C Peak Damping Performance	-60°C to > +80°C
IR Absorption Depth of penetration 0.25 to 1 micron	Opaque @ > 1 micron
Surface Resistivity (Ohms/Square)	2.3E+11 Ω/sq at 100 mVolts
Volume Resistivity (Ohms/cm)	3.5E+12 Ω/cm at 100 mVolts
UL	Meets HBF
ROHS Compliant	Yes
Halogen Free	Yes (per IEC 61249-2-21)
PBDE	Pass

The properties of the sheet were measured and listed in Table 1 above, and shown in FIGS. 4A-E. In particular, FIG. 4C illustrates test results relating to the EMI performance of Example 1 having a thickness of about 3 mm. The composite of Example 1 exhibited a Reflected Absorbed Power loss of greater than about 8 dB in the frequency range from about 3.0 GHz to about 5.8 GHz, and greater than about 3dB (a 50% power loss) from even a lower frequency (about 2 GHz) and indicating extrapolated performance above the tested 5.8 GHz range. FIG. 4E illustrates test results relating to shock and vibration absorbing performance of Example 1. The composite of Example 1 absorbed about 50% of the shock energy. Example 1 with a 6mm thick showed a Reflected Power Loss of 8dB or more from approximately 1.1GHz to 2.2 GHz. The material configuration can be tuned to the desired Reflected Power Loss requirements of an application for a frequency band that is most related to optimizing the end electronics products (component level) performance, or the related overall electronics device system performance.

Comparative Example 1

A control sample was the same as Example 1 but without adding the magnetic filler. Comparative Example 1 had a hardness of about 30 Shore A, which is lower than Example 1 (53 Shore A). Without adding the magnetic filler, Comparative Example 1 exhibited zero shielding effectiveness (e.g., a straight line at zero in FIG. 4C not shown).

Reference throughout this specification to "one embodiment," "certain embodiments," "one or more embodiments" or "an embodiment," whether or not including the term "exemplary" preceding the term "embodiment," means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the certain exemplary embodiments of the present disclosure. Thus, the appearances of the phrases such as "in one or more embodiments," "in certain embodiments," "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily referring to the same embodiment of the certain exemplary embodiments of the present disclosure. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

While the specification has described in detail certain exemplary embodiments, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. Accordingly, it should be understood that this disclosure is not to be unduly limited to the illustrative embodiments set forth hereinabove. In particular, as used herein, the recitation of numerical ranges by endpoints is intended to include all numbers subsumed within that range (e.g., 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5). In addition, all numbers used herein are assumed

to be modified by the term "about." Various exemplary embodiments have been described. These and other embodiments are within the scope of the following claims.

What is claimed is:

1. A monolithic housing for housing one or more electronic devices, comprising:

a three-dimensional body made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having electromagnetic interference (EMI) absorbing particles dispersed therein, the shock absorbing material having a composition comprising 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles,

wherein the three-dimensional body further includes one or more apertures configured to at least partially receive the one or more electronic devices.

2. The monolithic housing of claim 1, wherein the shock absorbing material forms a continuous, monolithic molded structure with no internal interfaces and joining means.

3. The monolithic housing of claim 1, wherein the thermosetting elastomer includes silicone, or polyisoprene rubber.

4. The monolithic housing of any one of claims 1-3, wherein the thermosetting elastomer is formed from a curable thermosetting elastomer that by itself has a hardness in a range from about 20 Shore A to about 40 Shore A after curing.

5. The monolithic housing of any one of claim 1-4, wherein the shock absorbing material is semi-insulating with a surface resistivity in a range from about 1×10^{10} to about 1×10^{13} Ohm/Square.

6. The monolithic housing of any one of claims 1-5, wherein the shock absorbing material is thermal insulating with a thermal conductivity in a range from about 0.01 to about 0.1 W/(m·K) at room temperature.

7. The monolithic housing of any one of claims 1-6, wherein the shock absorbing material is capable of absorbing EMI in a frequency range from about 0.1 GHz to about 5.8 GHz.

8. The monolithic housing of any one of claims 1-7, wherein the EMI absorbing particles comprise a magnetic filler.

9. The monolithic housing of claim 8, wherein the shock absorbing material comprises 50 to 75 weight % of the silicone and 10 to 45 weight % of the magnetic filler.

10. The monolithic housing of any one of claims 1-9, wherein at least one of the apertures is a through-hole extending in a thickness direction thereof.

11. The monolithic housing of any one of claims 1-10, wherein the shock absorbing material further comprises carbon black filler dispersed therein and configured to absorb infrared light.

12. The monolithic housing of any one of claims 1-11, wherein the shock absorbing material further include 0.5 weight % or less of an electrically conductive filler including metals, metal alloys, carbon nanotubes, or combinations thereof dispersed therein.

13. The monolithic housing of any one of claims 1-12, wherein the body has an average thickness from about 0.1 mm to about 1 cm.

14. The monolithic housing of any one of claims 1-13, wherein the body has an average lateral dimension from about 1 mm to 2 cm.

15. The monolithic housing of any one of claims 1-14, wherein the EMI absorbing particles are substantially uniformly distributed within the elastomeric material.

16. The monolithic housing of any one of claims 1-15, wherein the EMI absorbing particles are unevenly distributed in segments within the elastomeric material.

17. An electronic circuit package comprising an electronic device and the monolithic housing of any one of claims 1-16 to accommodate one or more components of the electronic device.

18. The electronic circuit package of claim 17, wherein the electronic device includes a radio frequency component.

19. The electronic circuit package of claim 17 or 18, wherein the electronic device includes a sensing component that is sensible to electromagnetic interference.

20. A method of producing a monolithic housing for an electronic device, the method comprising:

providing a moldable thermoset resin composition comprising a mixture of a matrix material and EMI absorbing particles dispersed therein; and

5 directing the mixture into a continuous, three-dimensional cavity to mold the resin into a three-dimensional body,

wherein the three-dimensional body is made of a shock absorbing material having a hardness in a range from about 20 Shore A to about 80 Shore A, the shock absorbing material having the absorbing particles dispersed therein, the shock absorbing material having a composition
10 comprising 50 to 90 weight % of a thermosetting elastomer and 10 to 50 weight % of the EMI absorbing particles, and

wherein the three-dimensional body further includes one or more apertures configured to at least partially receive the one or more electronic devices.

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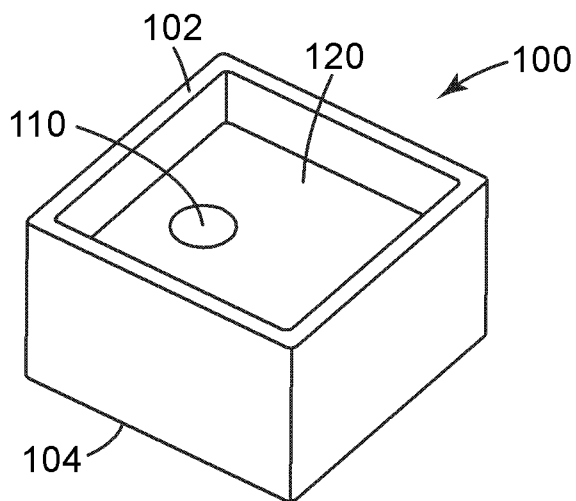


Fig. 1A

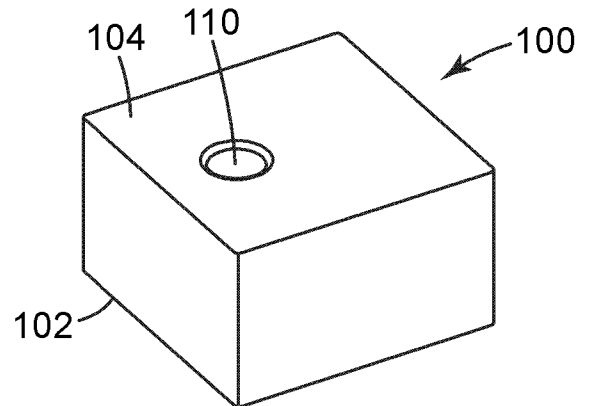


Fig. 1B

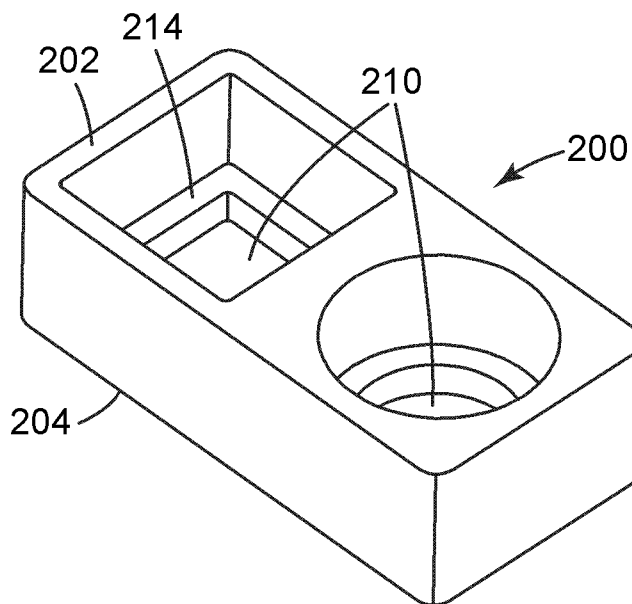


Fig. 2A

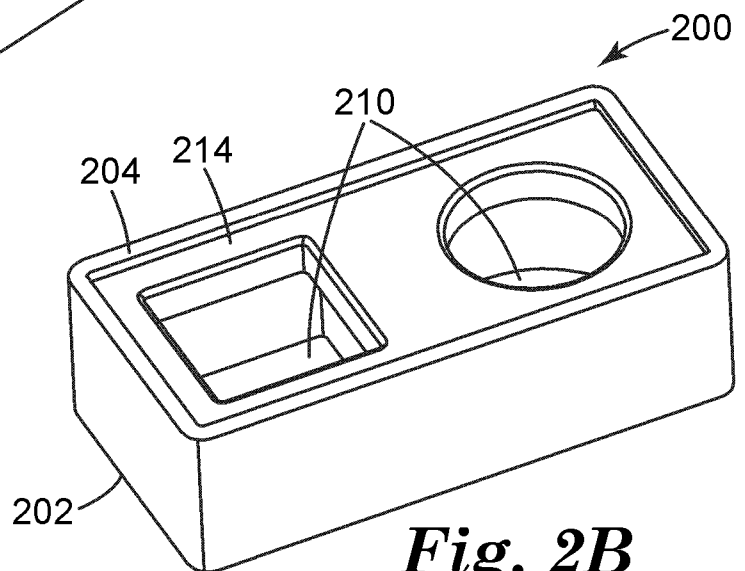
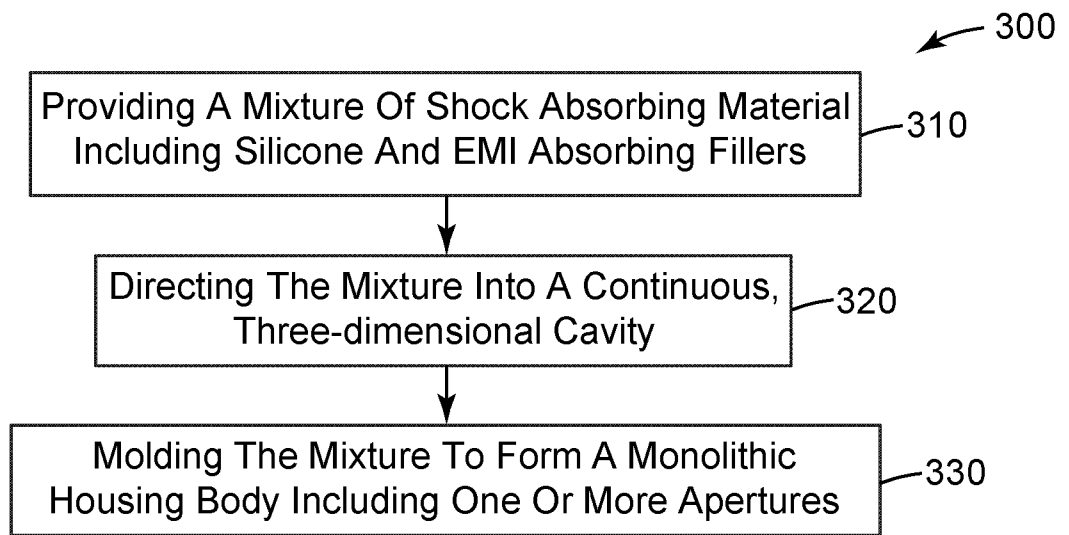
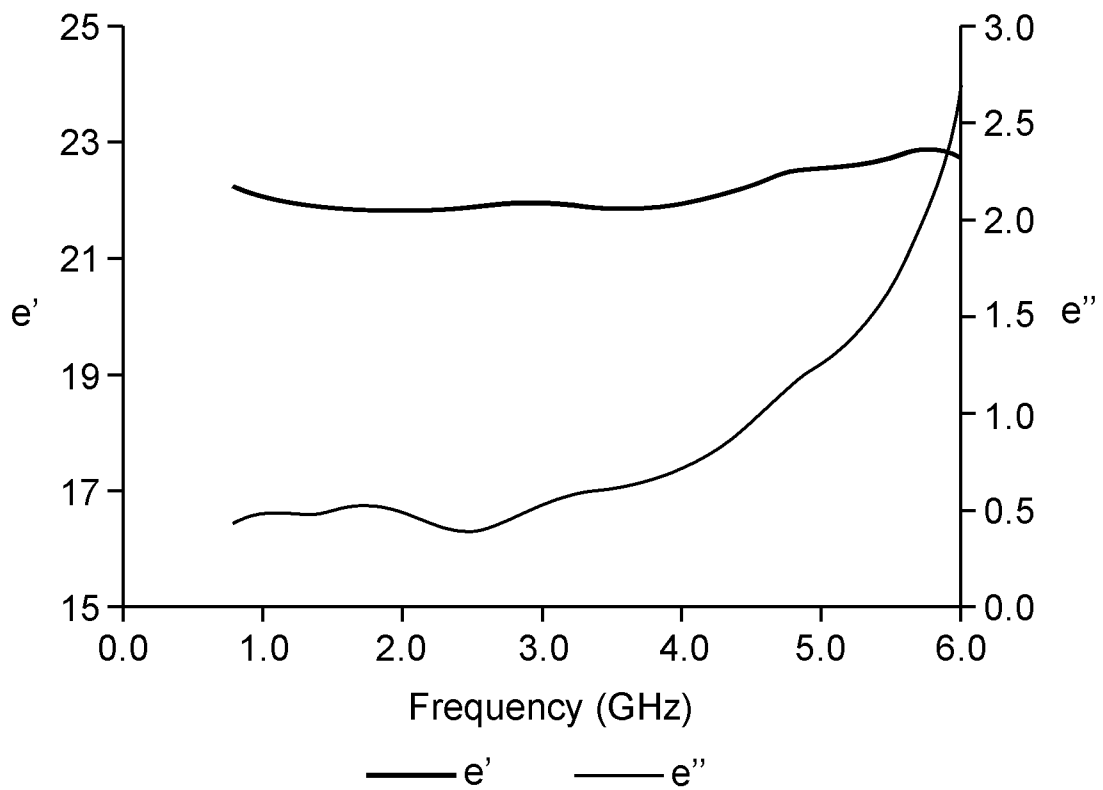


Fig. 2B

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**Fig. 3****Fig. 4A**

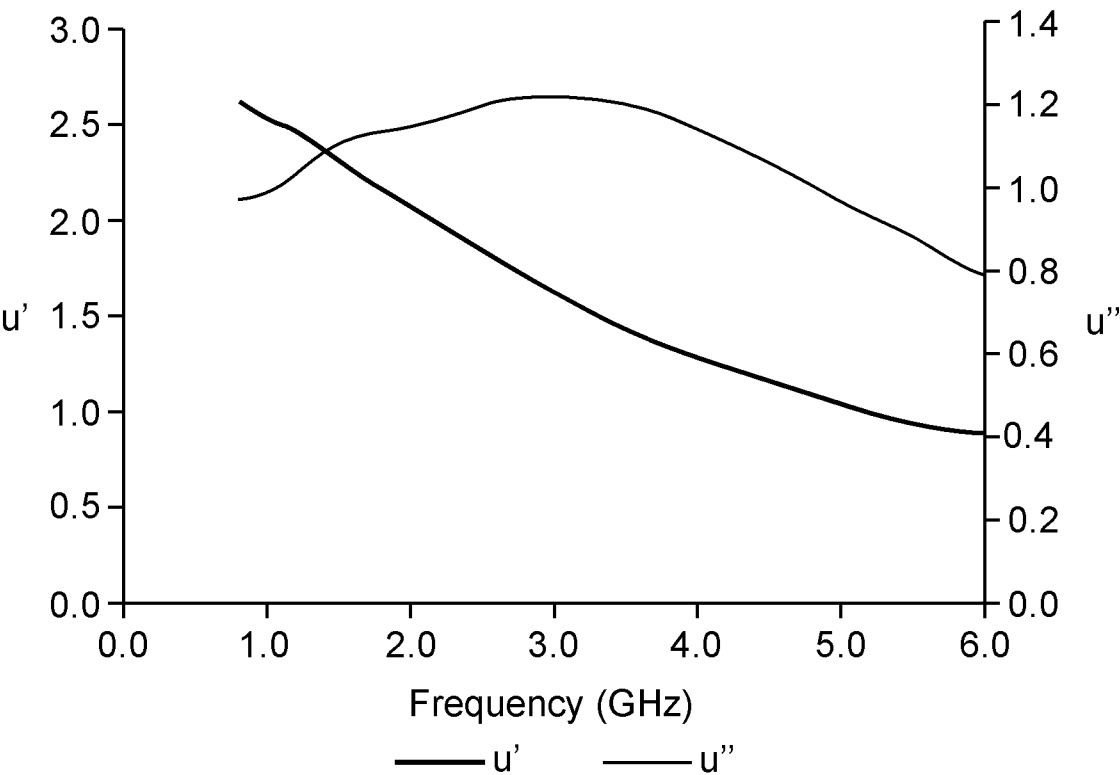


Fig. 4B

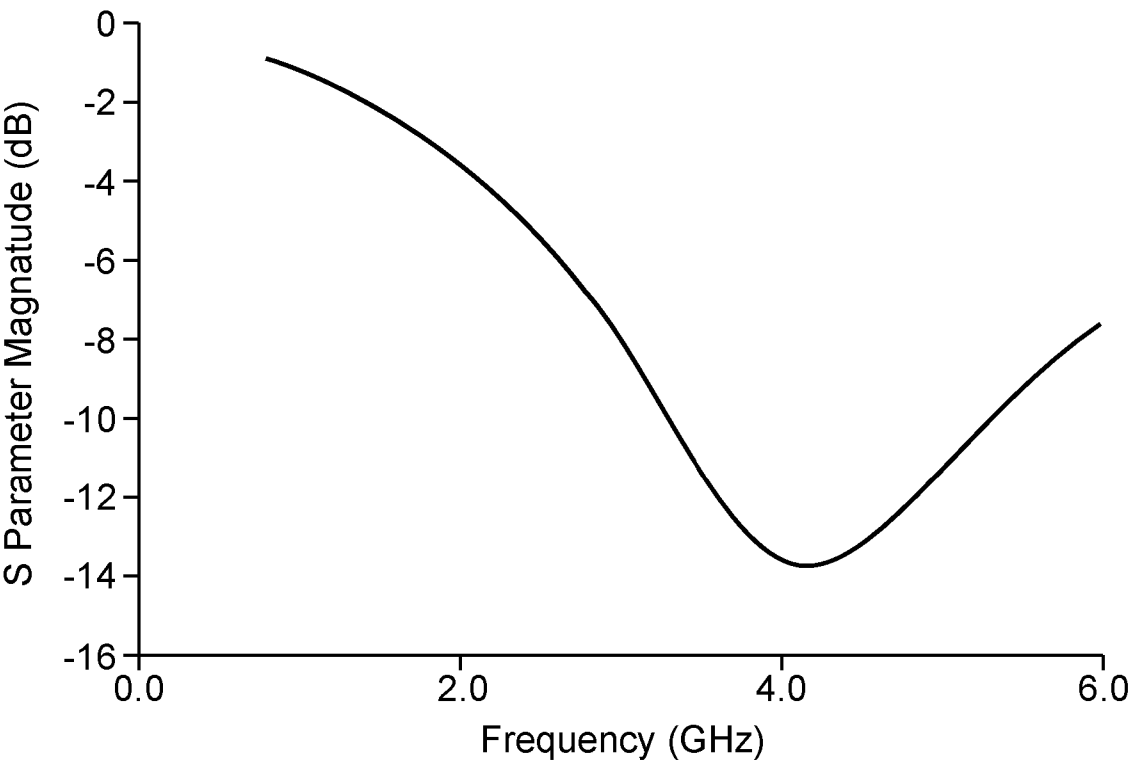
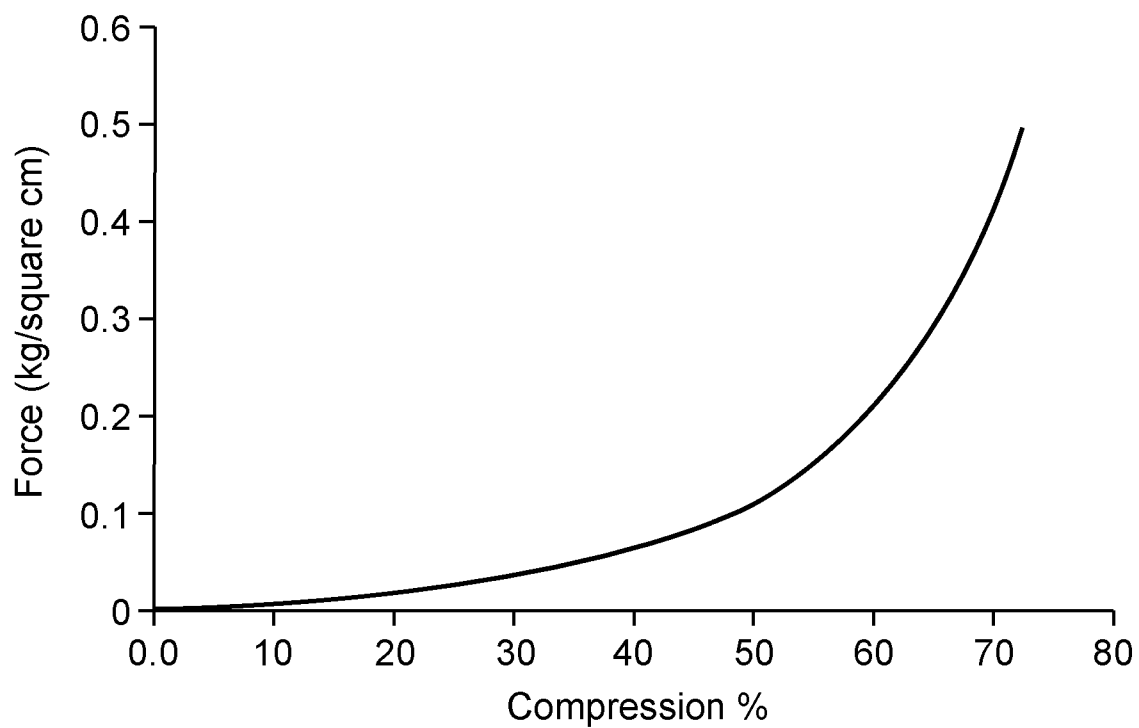
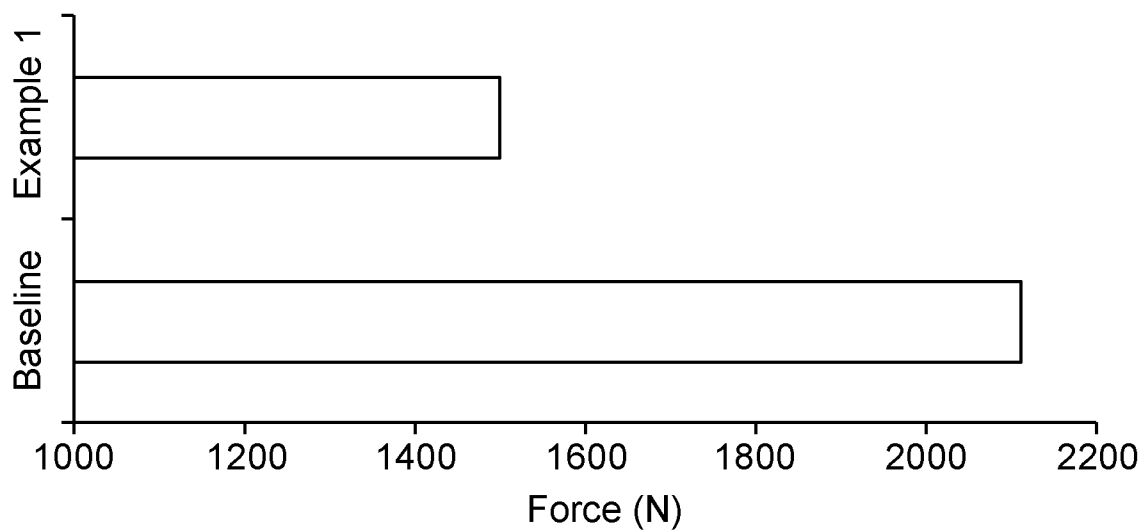


Fig. 4C

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***Fig. 4D******Fig. 4E***

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/079570**A. CLASSIFICATION OF SUBJECT MATTER**

H01L 23/48(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)

H01L B32B

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

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

CPRS, VEN:thermally, conductive,EMI, suppression, electromagnetic, hardness, resistivity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014182924 A1 (BERGQUIST COET AL.) 03 July 2014 (2014-07-03) see the description, paragraphs 0003 to 0060	1-20
A	WO 2006128741 A1 (BEKAERT SA NVET AL.) 07 December 2006 (2006-12-07) see the whole document	1-20
A	US 2011241186 A1 (NALLA RAVI KET AL.) 06 October 2011 (2011-10-06) see the whole document	1-20

☐ 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	“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
“E”	earlier application or patent but published on or after the international filing date	“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
“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)	“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
“O”	document referring to an oral disclosure, use, exhibition or other means	“&”	document member of the same patent family
“P”	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

29 January 2016

Date of mailing of the international search report

26 February 2016

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/079570

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