US 20140033908A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2014/0033908 A1
(43) Pub. Date: Feb. 6, 2014
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(54) ENCAPSULATED PREFORMED SHAPES

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(21) Appl. No.: **13/563,419**

(22) Filed: **Jul. 31, 2012**

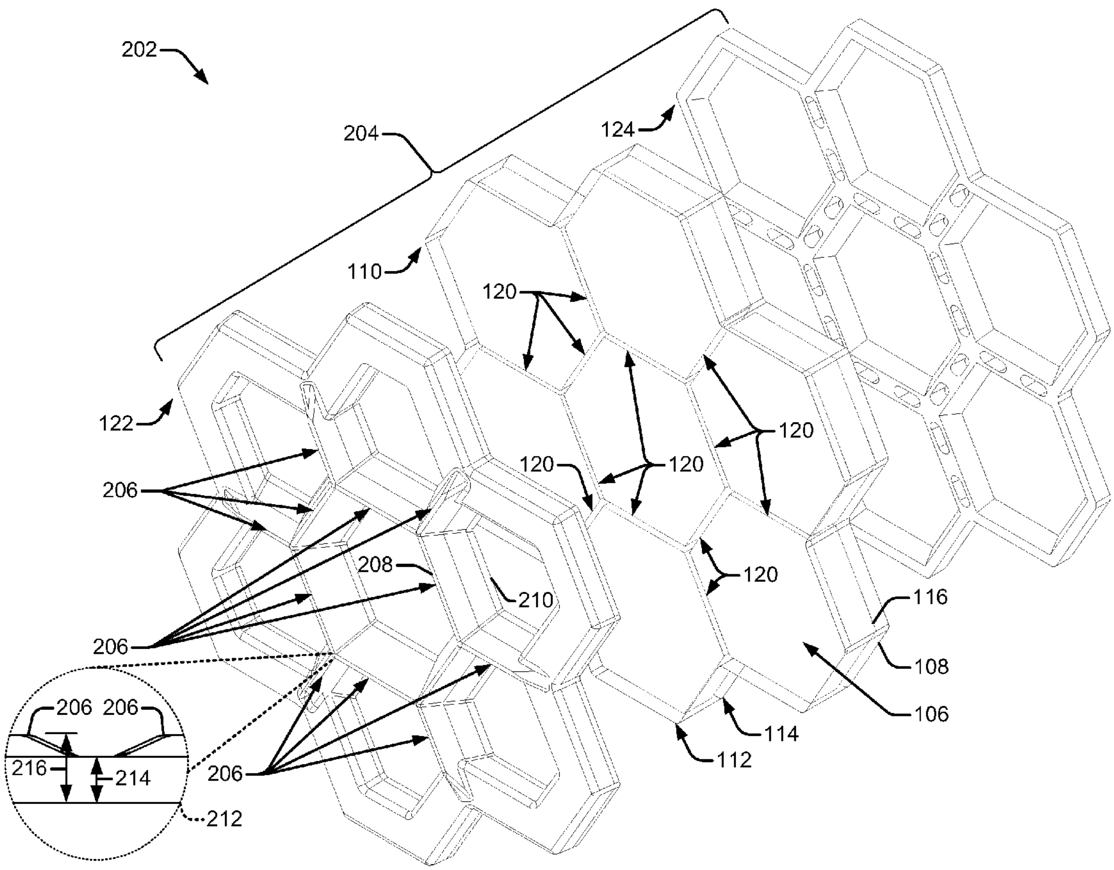
Publication Classification

(51) Int. Cl.
F41H 5/02 (2006.01)
F41H 5/04 (2006.01)

(52) U.S. Cl.
CPC ***F41H 5/02*** (2013.01); ***F41H 5/0421*** (2013.01)
USPC **89/36.02**; 164/98

(57) **ABSTRACT**

Anti-ballistic component including encapsulated preformed ceramic shapes are disclosed. Preformed ceramic shapes having a preformed geometry are encapsulated in a metal alloy to stiffen and lighten an anti-ballistic component. The preformed ceramic shapes may be arranged in layers of uniform arrays of preformed ceramic shapes and contained in a porous container to receive the metal alloy during a casting process. A truss structure may be integrated in the preformed ceramic shapes to compartmentalize the preformed ceramic shapes into multiple isolated sub regions to stiffen the anti-ballistic component.



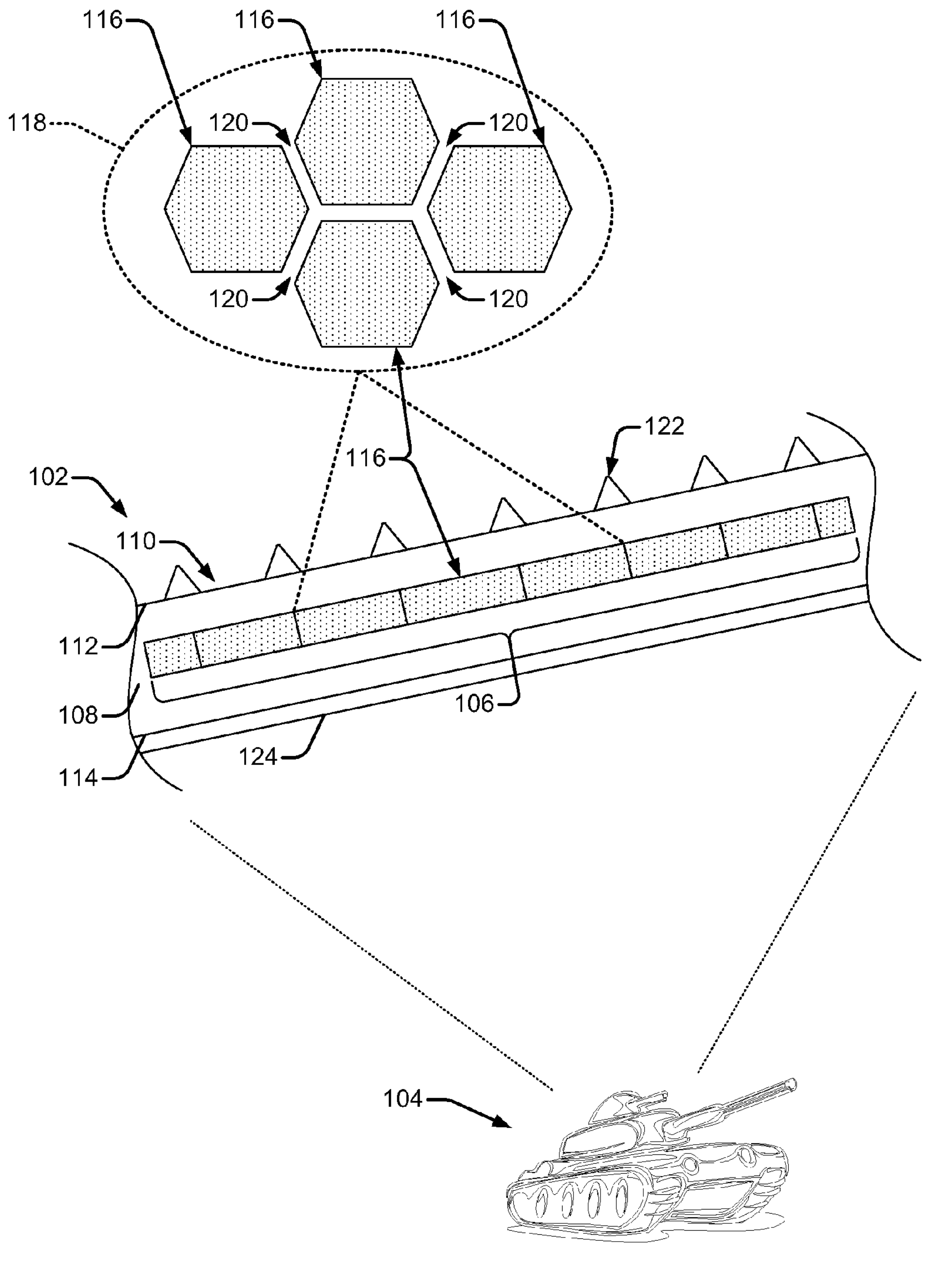

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FIG. 1

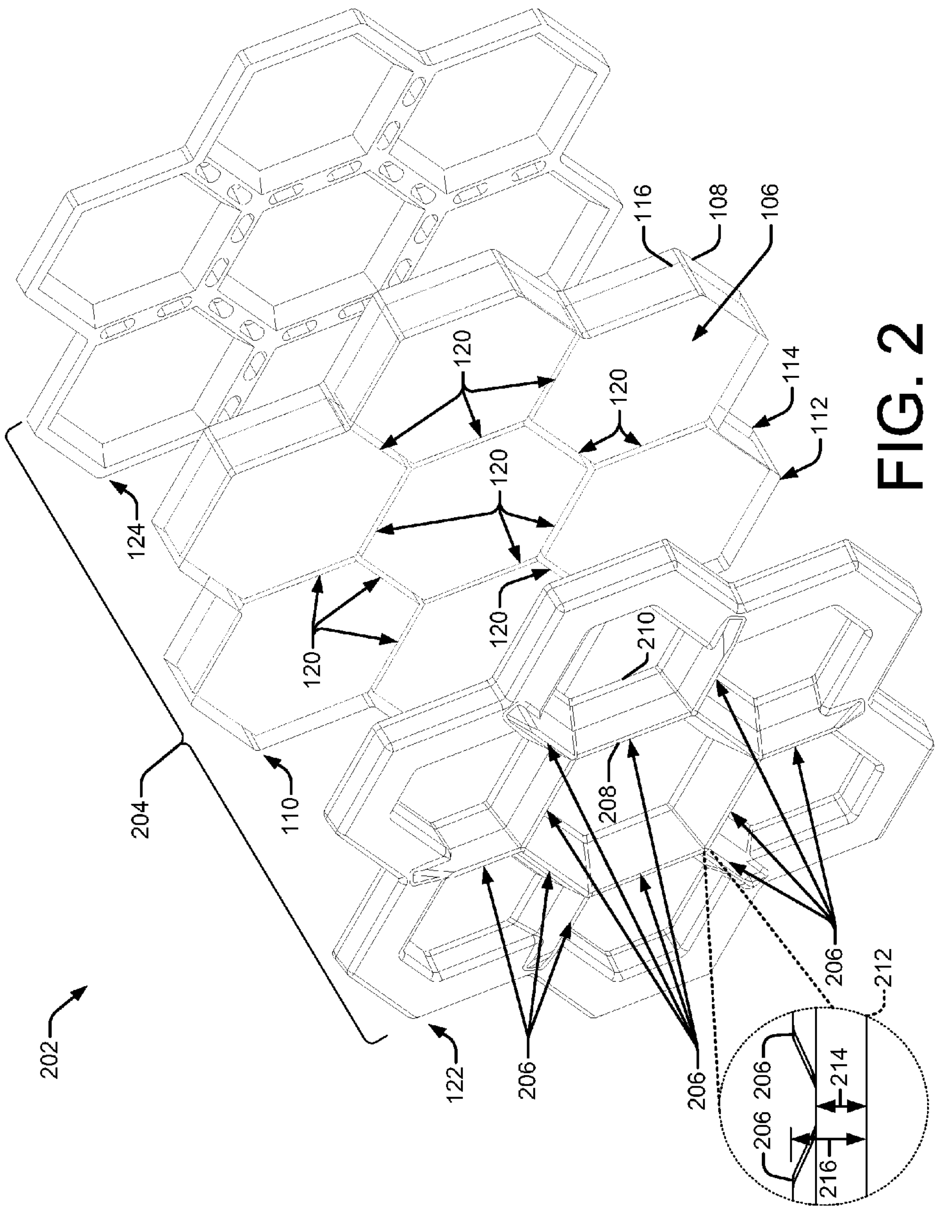
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FIG. 2

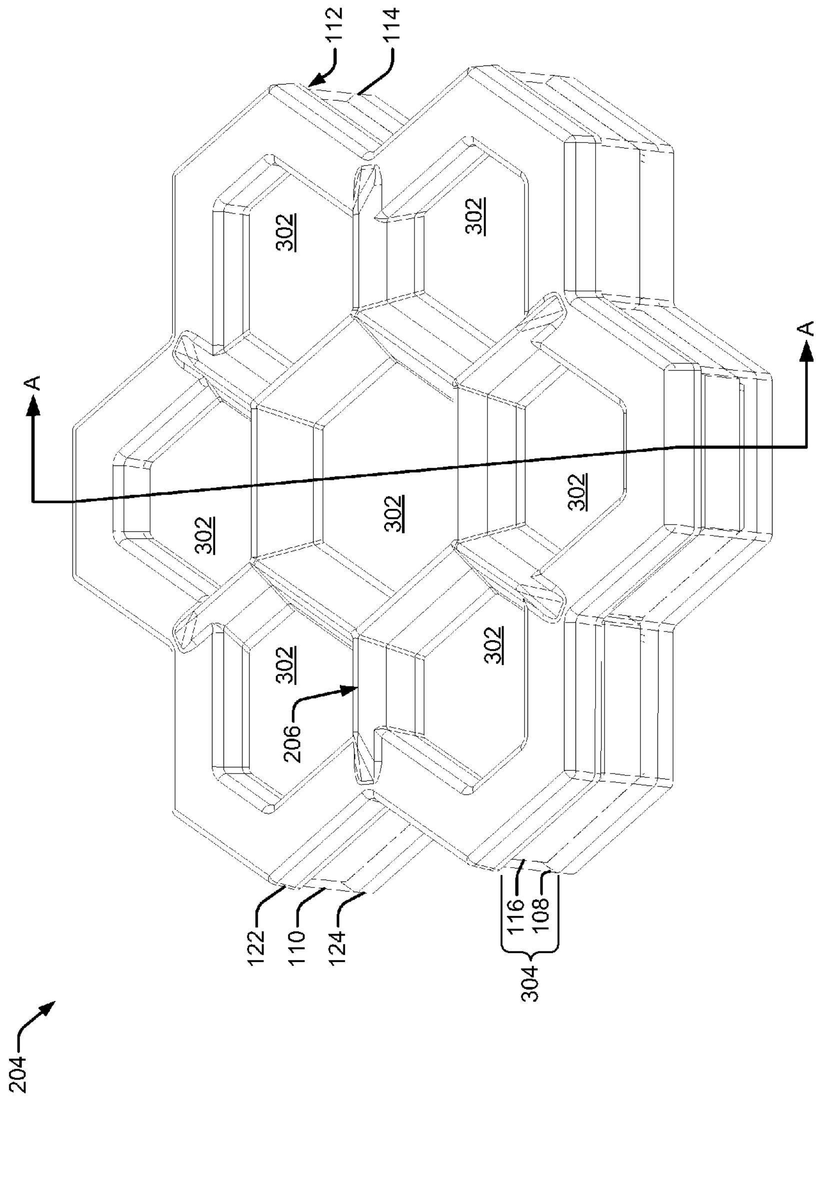
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FIG. 3

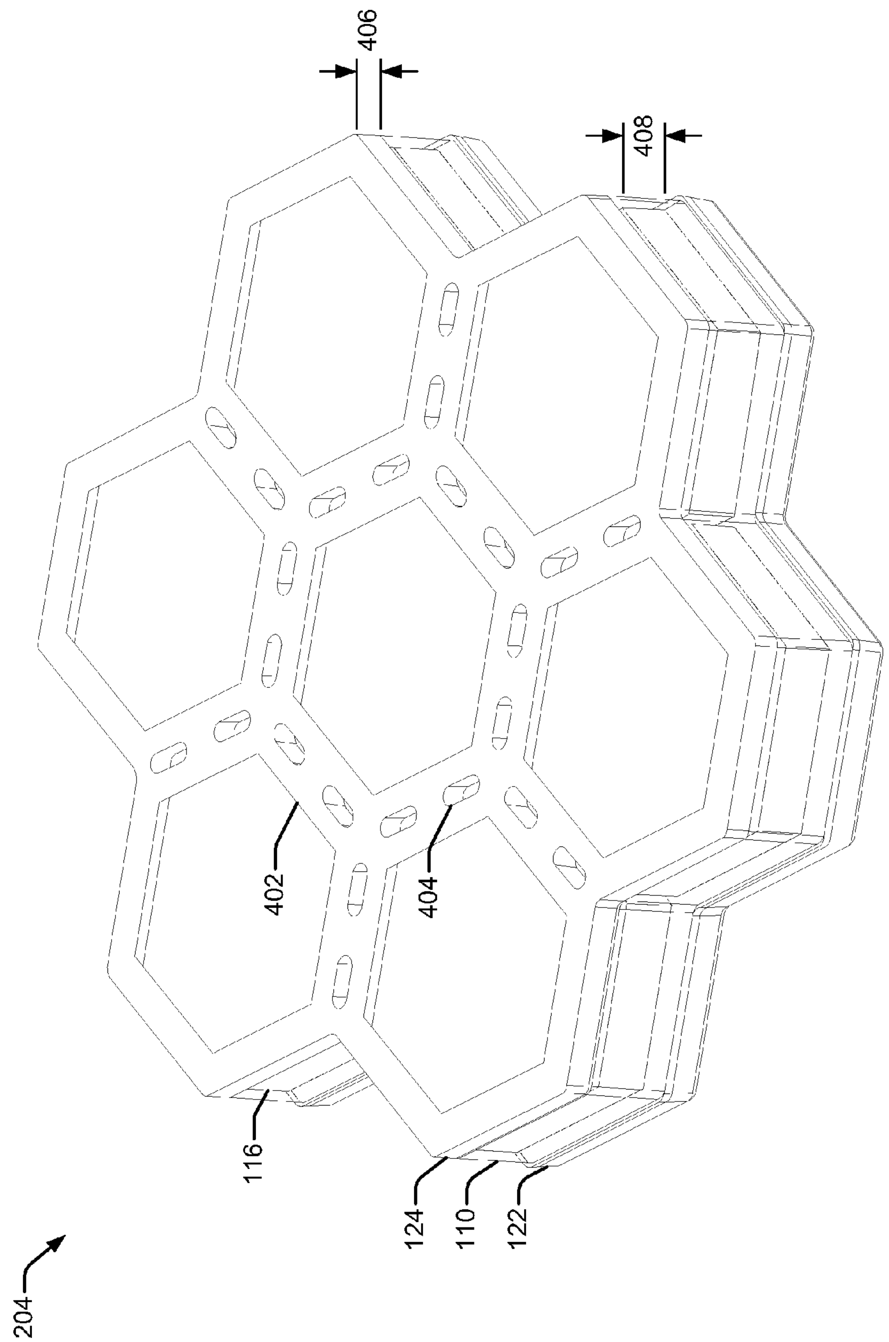

FIG. 4

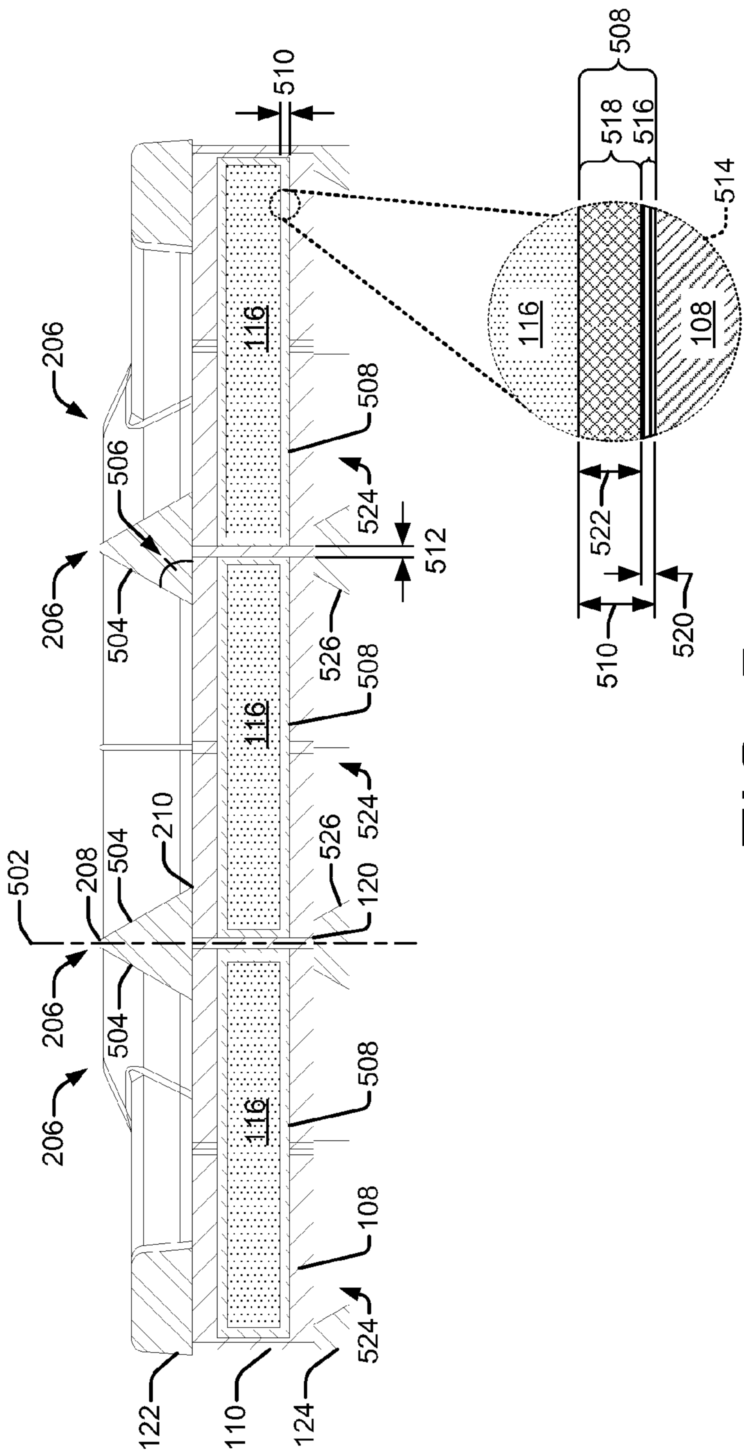

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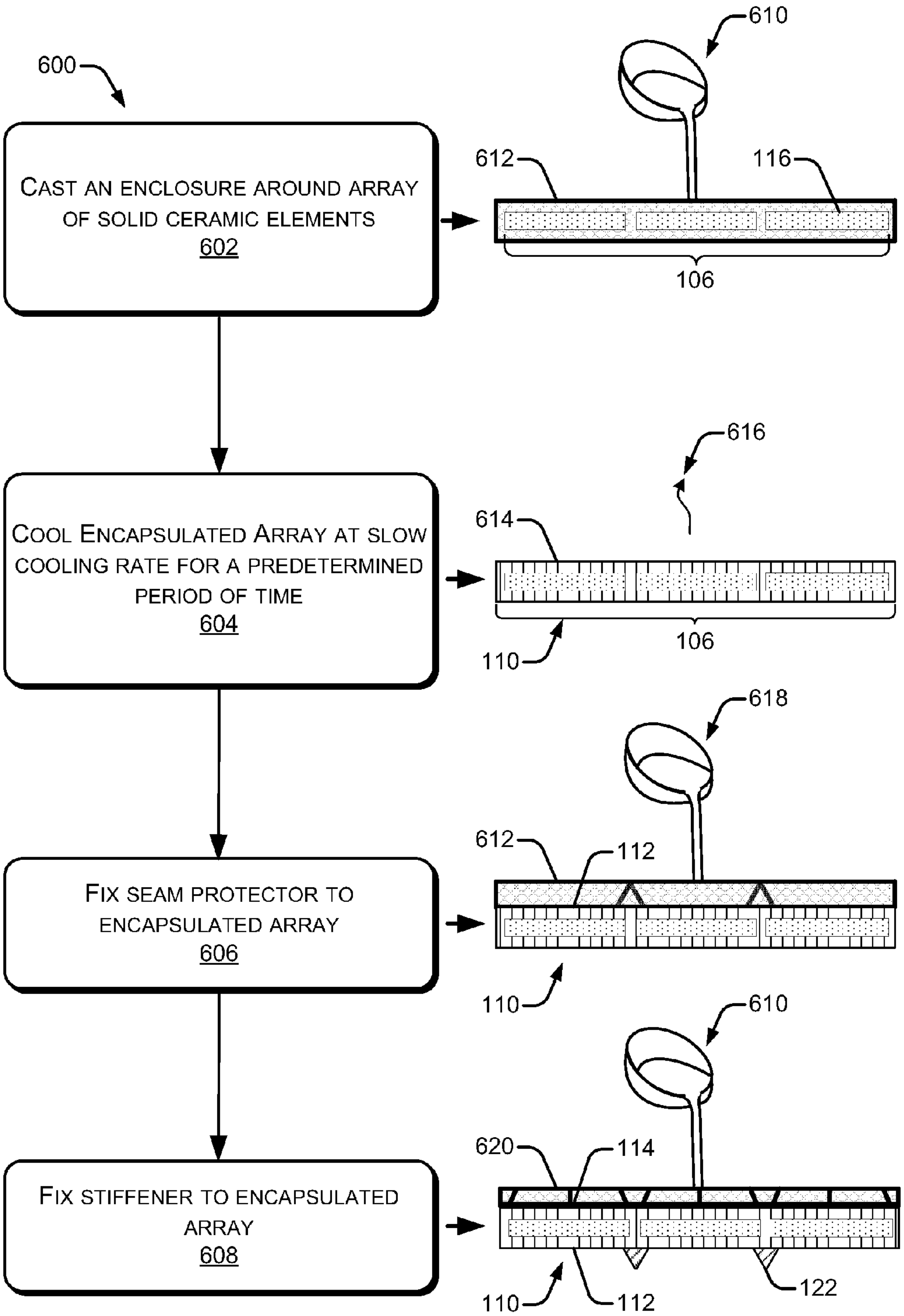
FIG. 5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CAST AN ENCLOSURE AROUND ARRAY OF SOLID CERAMIC ELEMENTS
602
COOL ENCAPSULATED ARRAY AT SLOW COOLING RATE FOR A PREDETERMINED PERIOD OF TIME
604
FIX SEAM PROTECTOR TO ENCAPSULATED ARRAY
606
FIX STIFFENER TO ENCAPSULATED ARRAY
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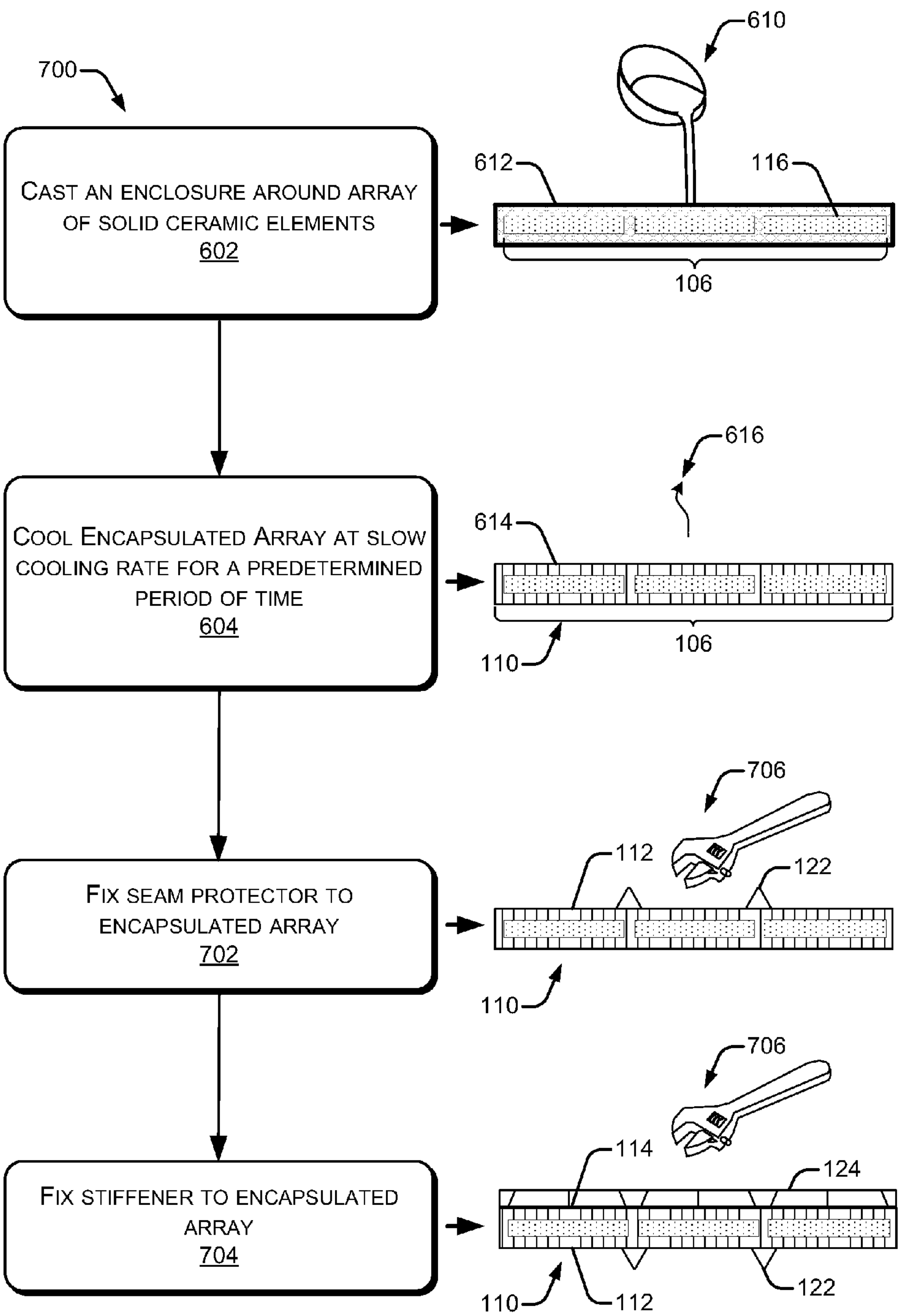
FIG. 6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COOL ENCAPSULATED ARRAY AT SLOW COOLING RATE FOR A PREDETERMINED PERIOD OF TIME
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106
FIX SEAM PROTECTOR TO ENCAPSULATED ARRAY
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FIX STIFFENER TO ENCAPSULATED ARRAY
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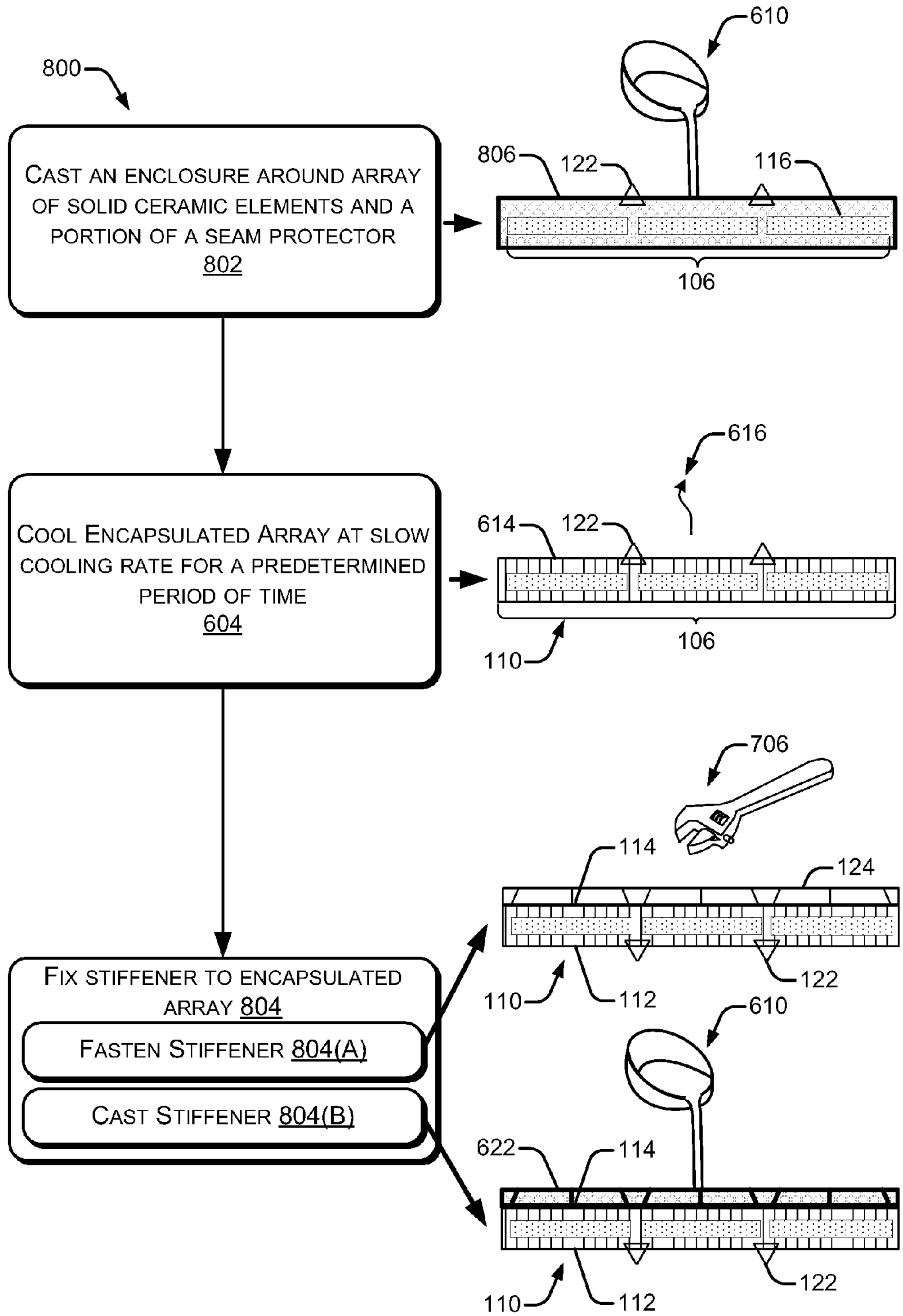
FIG. 7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CAST AN ENCLOSURE AROUND ARRAY OF SOLID CERAMIC ELEMENTS AND A PORTION OF A SEAM PROTECTOR
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COOL ENCAPSULATED ARRAY AT SLOW COOLING RATE FOR A PREDETERMINED PERIOD OF TIME
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FIX STIFFENER TO ENCAPSULATED ARRAY 804
FASTEN STIFFENER 804(A)
CAST STIFFENER 804(B)
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FIG. 8

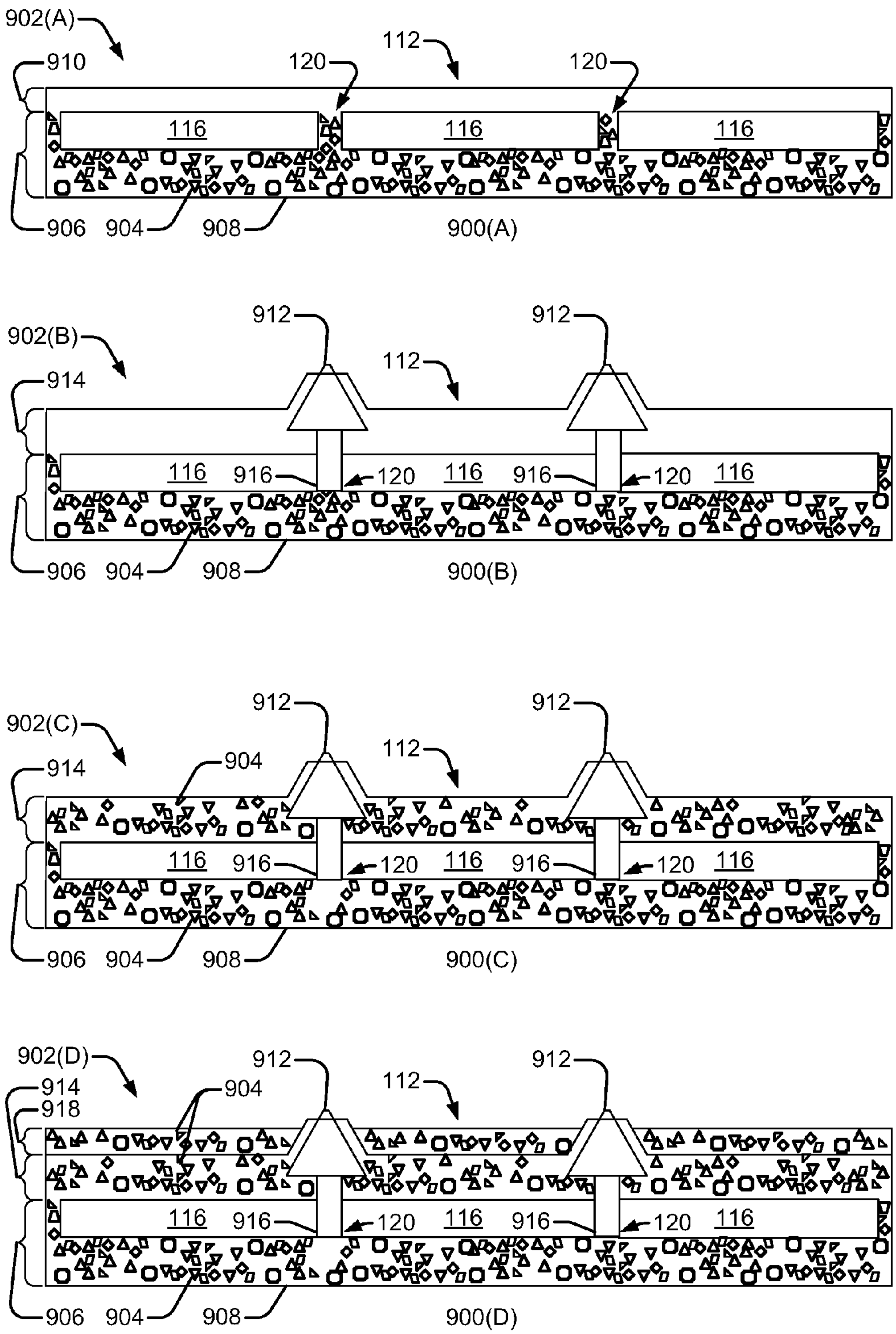
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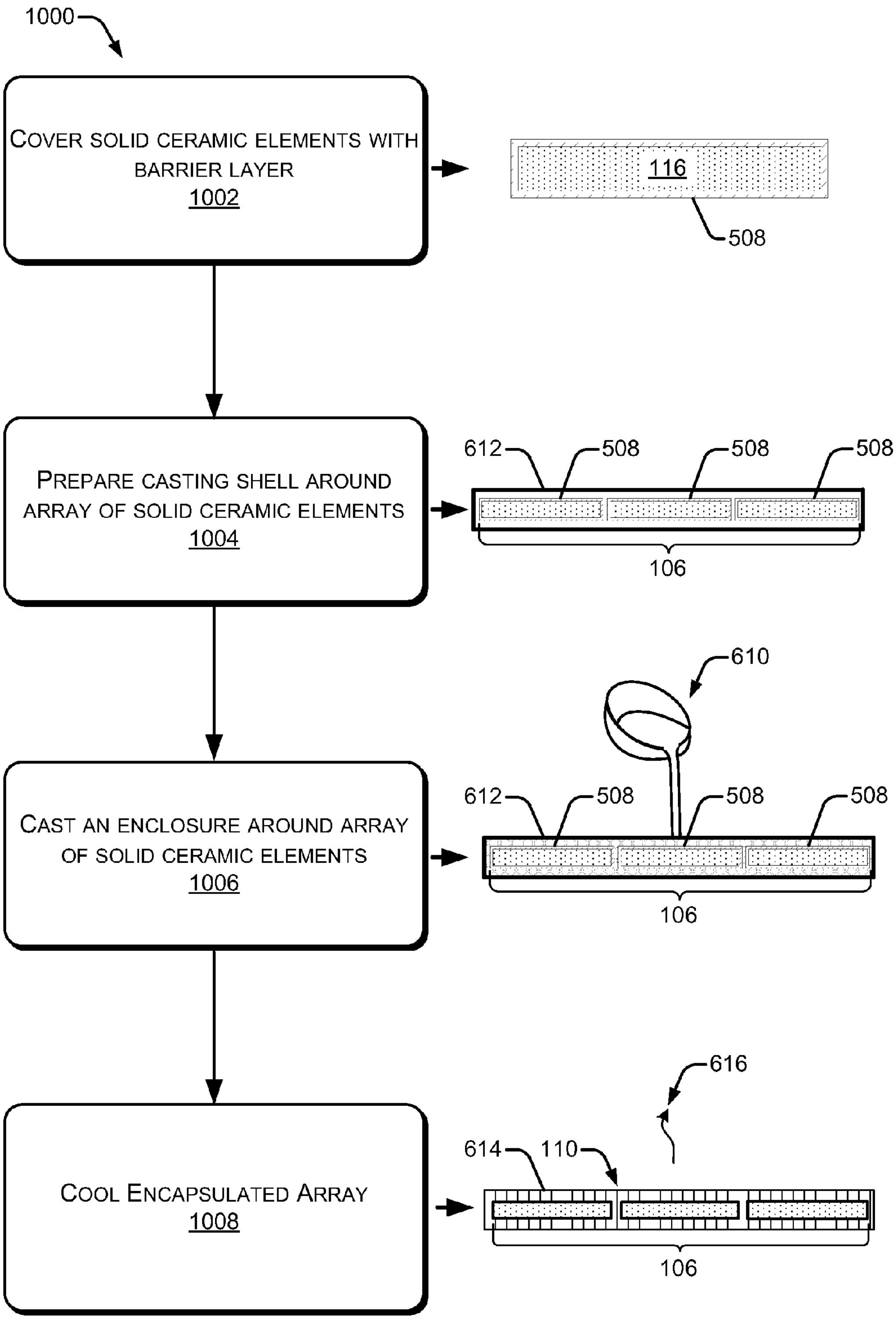
FIG. 9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COVER SOLID CERAMIC ELEMENTS WITH BARRIER LAYER
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PREPARE CASTING SHELL AROUND ARRAY OF SOLID CERAMIC ELEMENTS
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CAST AN ENCLOSURE AROUND ARRAY OF SOLID CERAMIC ELEMENTS
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COOL ENCAPSULATED ARRAY
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FIG. 10

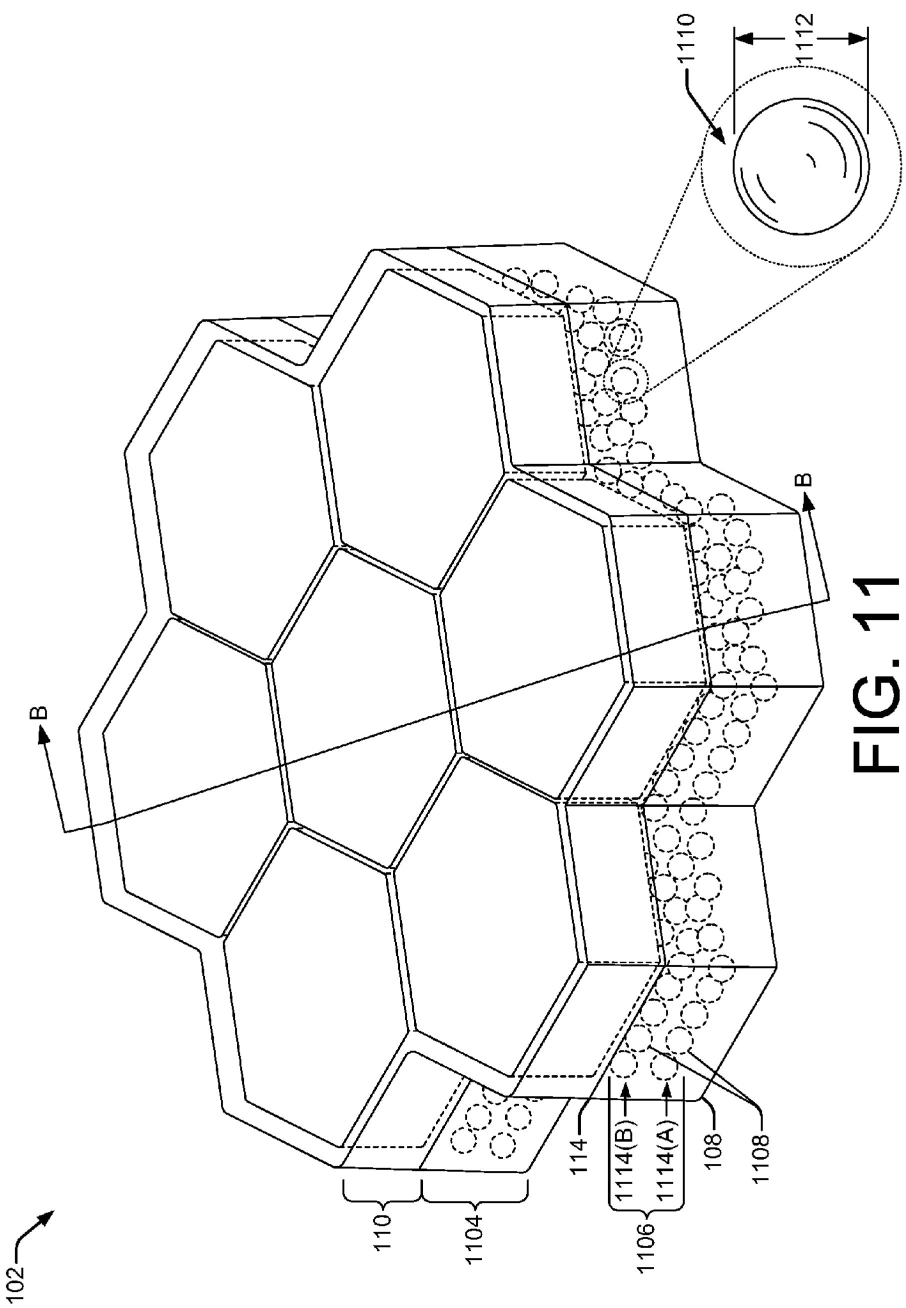
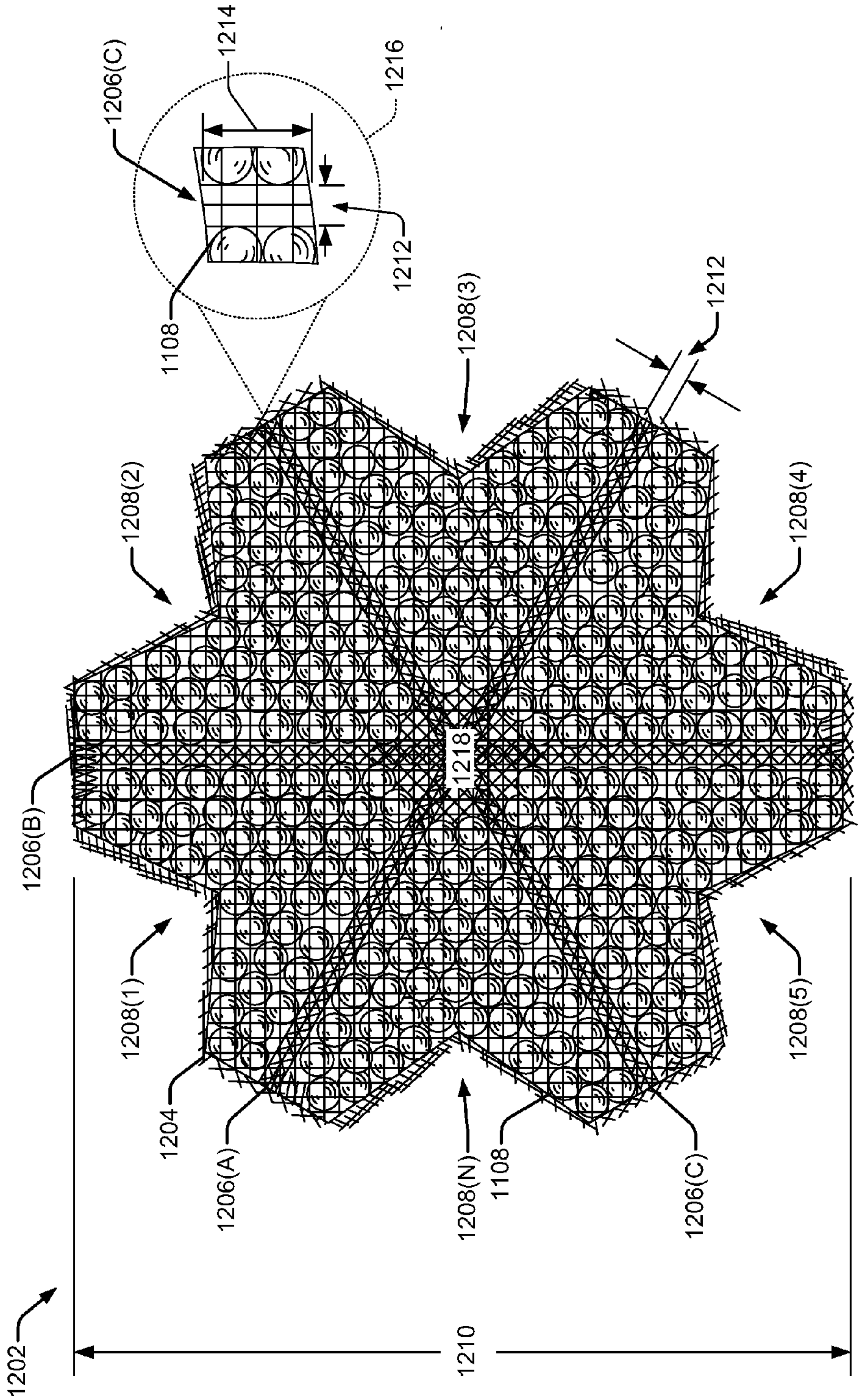


FIG. 11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1208(5)
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FIG. 12

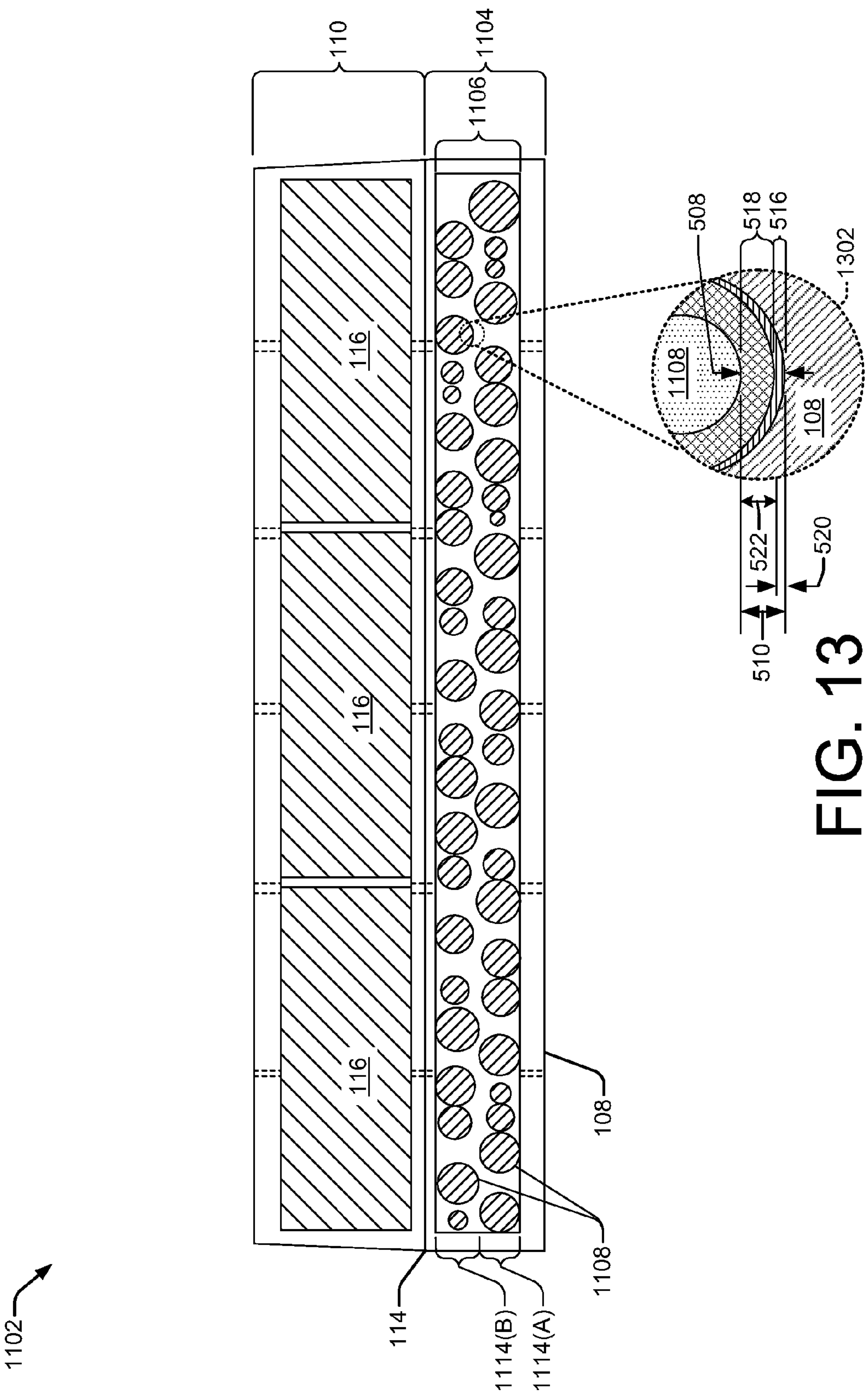

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FIG. 13

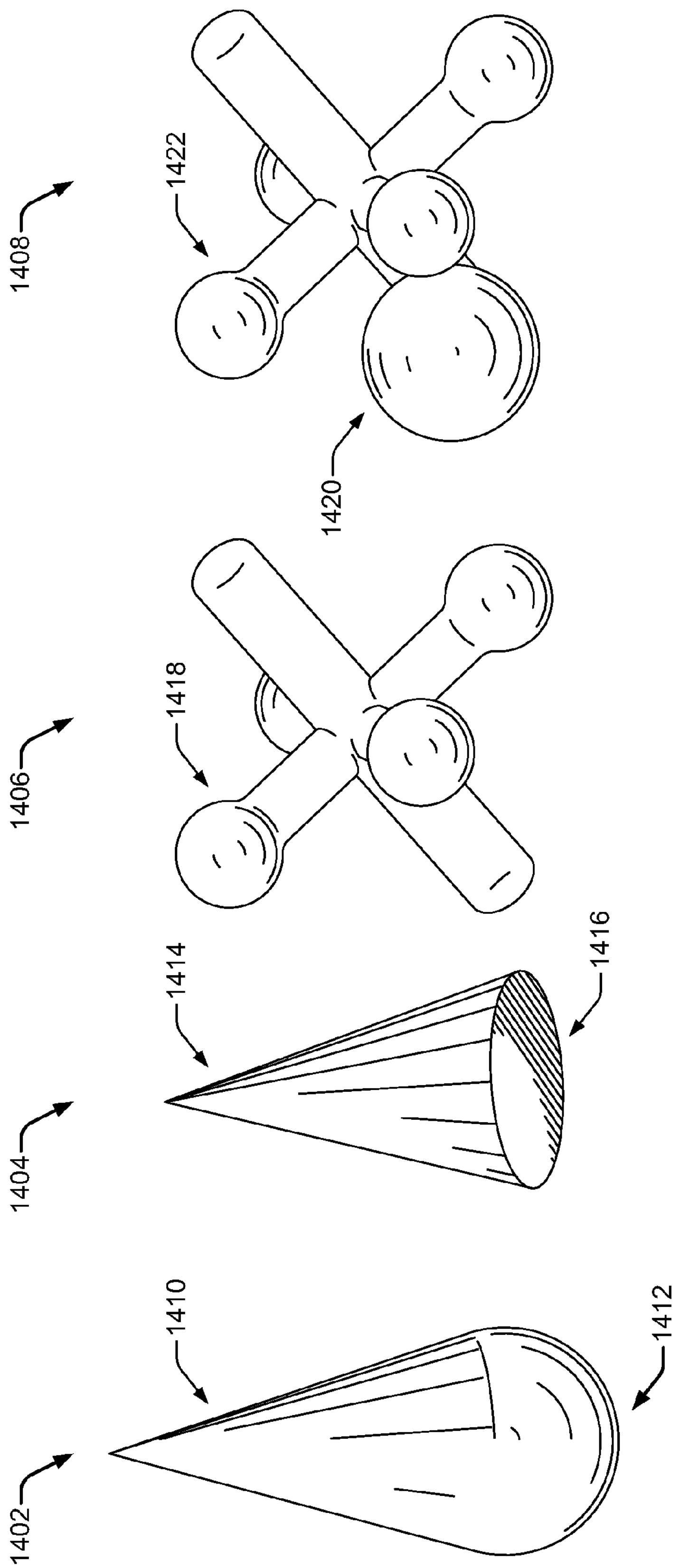

FIG. 14

ENCAPSULATED PREFORMED SHAPES

BACKGROUND

[0001] Ballistic impact resistant components are desirable in a variety of industrial, commercial, and military applications.

[0002] Recently, armor assemblies formed of multiple materials having different material properties (i.e., high hardness and toughness) have been used.

[0003] However, these armor assemblies still have weaknesses. For example, the armor assemblies may not be stiff enough to keep from deforming or deflecting during use. Further, the armor assemblies may be relatively heavy as compared to armor assemblies using less metal.

[0004] Thus, there remains a need to develop new armor assemblies that are stiffer and lighter.

BRIEF SUMMARY

[0005] This Brief Summary is provided to introduce simplified concepts relating to techniques for manufacturing anti-ballistic components, such as armor, comprising encapsulated preformed ceramic shapes, which are further described below in the Detailed Description. This Summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

[0006] This disclosure relates to composites including encapsulated preformed ceramic shapes, cast in situ or otherwise encapsulated in a base metal, and techniques for manufacturing such composites. In some embodiments, such composites may be configured to protect against, withstand, or resist ballistic impacts.

[0007] In some examples a composite component may be used on its own as anti-ballistic armor. In other examples the composite component may be used along with other components (e.g., an encapsulated array) as a "backing unit" to stiffen the other components.

[0008] In some examples the preformed ceramic shapes may be encapsulated in a base metal to stiffen a composite component made from the ceramic shapes and the base metal. For example, the preformed ceramic shapes may be formed of a ceramic having a higher material hardness than the base metal, that when integrated or added to the base metal provide stiffness to the composite. Moreover, the shape of the ceramic components may be chosen to provide a lattice-like or crystalline-like structure thereby providing a highly rigid, stiff component. Moreover, the shape of the ceramic components may be chosen to provide a lattice-like or crystalline-like structure to provide for packing the preformed ceramic shapes together tightly to prevent the preformed ceramic shapes from sliding relative to each other.

[0009] In other examples the preformed ceramic shapes may be encapsulated in the base metal to lighten the composite. For example, the preformed ceramic shapes may be formed of a ceramic having a density less than a density of the base metal and the preformed ceramic shapes may displace the base metal during a metal casting process, resulting in a lighter composite component than if the same size and shape component were made of base metal alone.

[0010] In some examples the preformed ceramic shapes may be arranged in one or more layers of arrays of preformed ceramic shapes to build up additional thickness of ceramic material to reduce weight and/or increase stiffness of the composite. For example, two or more layers of arrays of preformed ceramic shapes may be arranged in an adjacent, subjacent, and/or overlapping manner. The layers of arrays of preformed ceramic shapes may be arranged such that a preformed ceramic shape in a top layer covers, minimizes, or eliminates an interstitial space between preformed ceramic shapes in a lower layer.

[0011] In some examples one or more channels may be arranged in the preformed ceramic shapes to receive the base metal to compartmentalize the preformed ceramic shapes into multiple isolated sub regions within the composite component to stiffen the composite. For example, one or more channels, void of preformed ceramic shapes and having a length greater than a width and/or a depth, may receive the base metal to form a truss structure arranged in the preformed ceramic shapes for stiffening the composite. Because the one or more channels forming a truss structure compartmentalize the preformed ceramic shapes, this may provide for an increased compression force applied to the preformed ceramic shapes contained in the isolated sub regions. For example, during solidification of the base metal, the one or more channels forming the truss structure compartmentalizing the preformed ceramic shapes may provide a compression force directed inward towards the isolated sub regions in addition to the base metal providing a compression force inward from a top and/or a bottom of the isolated sub regions. Such inward force may pack the preformed shapes.

[0012] In some examples the composite may define a backing unit that may be formed integrally with a surface of an encapsulated array to stiffen the encapsulated array.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The Detailed Description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items.

[0014] FIG. **1** illustrates a vehicle having an example ballistic armor comprising a seam protected encapsulated array of solid ceramic elements, and which may include solid ceramic preformed shapes.

[0015] FIG. **2** illustrates an exploded assembly of a seam protected encapsulated array of solid ceramic elements.

[0016] FIG. **3** illustrates a front of the seam protected encapsulated array of solid ceramic elements illustrated in FIG. **2**.

[0017] FIG. **4** illustrates a back of the seam protected encapsulated array of solid ceramic elements illustrated in FIG. **2**.

[0018] FIG. **5** illustrates a section view of the seam protected encapsulated array of solid ceramic elements illustrated in FIG. **3**.

[0019] FIGS. **6-8** are flow diagrams illustrating example processes of casting seam protected encapsulated arrays of solid ceramic elements alongside corresponding schematic diagrams illustrating the acts being described in the flow diagrams.

[0020] FIG. **9** illustrates section views of example encapsulated arrays of solid ceramic elements. The section views of encapsulated arrays of solid ceramic elements illustrate an additive in portions of an encapsulating metal of each of the encapsulated arrays of solid ceramic elements.

[0021] FIG. 10 is a flow diagram illustrating an example process of manufacturing an encapsulated array with ceramic elements covered with a barrier layer alongside corresponding schematic diagrams illustrating the acts being described in the flow diagram.

[0022] FIG. 11 illustrates an anti-ballistic armor including a backing unit formed integral with a second surface of an encapsulated array.

[0023] FIG. 12 illustrates a top view of an exemplary porous body that may be encapsulated in the backing unit illustrated in FIG. 11.

[0024] FIG. 13 illustrates a section view of the anti-ballistic armor taken along the section line B-B illustrated in FIG. 11.

[0025] FIG. 14 illustrates multiple embodiments of preformed ceramic shapes that may be used to lighten and stiffen the anti-ballistic armor illustrated in FIG. 11.

DETAILED DESCRIPTION

Overview

[0026] As noted above, even though existing armor assemblies may be formed of a relatively tough metal, the armor assemblies may not be stiff enough to keep from deforming or deflecting during use. Further, because the armor assemblies may be formed of a relatively tough metal, the armor assemblies may be relatively heavy as compared to armor assemblies using less metal and/or using lighter weight alloys. This application describes anti-ballistic armor comprising preformed ceramic shapes encapsulated in an iron alloy that, together, exhibit an improved resistance to bending and a reduced weight. This application describes techniques for manufacturing such anti-ballistic armor assemblies using investment casting techniques. However, other casting techniques may also be used. By way of example and not limitation, the anti-ballistic armor herein may be used in the fields of military applications, security applications, or any other applications that may be exposed to impacts by ballistic projectiles or other high speed objects.

[0027] In general, the anti-ballistic armor includes a backing unit formed integrally with an encapsulated array. The backing unit may include a porous body encapsulated in a relatively tough iron alloy (e.g., steel alloys such as FeMnAl alloys). The porous body may be formed of a plurality of preformed ceramic shapes retained by a porous container (e.g., a metal mesh, wireframe cage, etc.). The preformed ceramic shapes may include a preformed geometry suitable to be used in the anti-ballistic armor assembly. For example, the preformed ceramic shapes may include a preformed geometry comprising a sphere. Depending on the specific application, the preformed geometry may be a cone, a jack, a half sphere, a cube, a pyramid, a bonded unit (e.g., bonded spheres, boned sphere and cone, bonded sphere and jack, bonded half spheres, etc.). For example, the preformed geometry may be chosen to provide for packing the preformed ceramic shapes together to form a lattice structure, simulating a crystalline structure that imparts stiffness to the backing unit. That is, the preformed geometry may be chosen to allow the preformed ceramic shapes to be packed together to prevent or limit an amount by which the preformed ceramic shapes can be displaced relative to one another. For example, the preformed ceramic shapes may interfere or abut with one another when the backing unit is deformed or displaced. Because the preformed ceramic shapes interfere with one another during deformation of the backing unit, and are formed of a harder material than that of the base metal of the backing unit, the preformed ceramic shapes resist being deformed or displaced, thereby increasing the stiffness of the backing unit as compared to a backing unit made of the base metal alone.

[0028] In an example where the preformed geometry is a sphere, the preformed ceramic shapes may comprise solid, substantially spherical shaped units (e.g., marbles) of ceramic that are arranged in contiguous arrays. While the preformed ceramic shapes are describes as being solid, the preformed ceramic shapes include one or more voids and/or through holes. For example, the preformed ceramic shapes may include a substantially hollow center. Further, the preformed ceramic shapes may include openings or holes arranged in the preformed ceramic shapes. For example, the preformed ceramic shapes may include one or more through holes extending through the preformed ceramic shapes. As used herein, a substantially spherical shaped unit includes a substantially round geometrical solid ceramic unit in three-dimensional space. For example, a series of silicon carbide marbles may be arranged in contact with one another to form a layer of an array of preformed ceramic shapes. In some examples, the spherical shaped unit of ceramic may have a diameter of about 0.5 inches (1.3 centimeters). In other examples, the spherical shaped unit of ceramic may have a diameter of at least about 0.25 inches (0.6 centimeters) to at most about 0.75 inches (1.9 centimeters). The diameter may vary depending on the specific application. The substantially spherical shaped unit may include flat spots, dimples, and/or bumps etc., over a portion of the surface of the substantially spherical shaped unit. For example, the substantially spherical shaped unit may include flat spots, dimples, and/or bumps etc., over less than about 20% of the surface.

[0029] Because the preformed ceramic shapes may be formed of a ceramic, the preformed ceramic shapes may have a higher material hardness than an encapsulating base metal, and a density less than the density of the encapsulating base metal which allows for stiffening and/or lightening the anti-ballistic armor. For example, the preformed ceramic shapes may displace and/or be integrated with the encapsulating base metal to provide for lightening and stiffening the anti-ballistic armor. In some embodiments, the stiffer and lighter preformed ceramic shapes may consume up to about a third of a total volume of a backing unit, thereby displacing about a third of the less stiff and heavier encapsulating base metal. As a result of the preformed ceramic shapes producing a stiffer and lighter backing unit, the anti-ballistic armor is made to be lighter and stiffer providing for lighter armored vehicles.

[0030] In some embodiments, one or more layers of arrays of preformed ceramic shapes may be arranged in an overlapping manner. For example, a top layer array of preformed ceramic shapes may be arranged above a bottom layer array of preformed ceramic shapes such that any interstitial space between contiguous preformed ceramic shapes is minimized. For instance, a preformed ceramic shape arranged in the top layer may cover an interstitial space between two preformed ceramic shapes in the bottom layer arranged below the preformed ceramic shape in the top layer.

[0031] In some embodiments, the porous body may include channels, void of preformed ceramic shapes to receive a base metal during a casting of a backing unit. For example, one or more channels may be arranged or formed in the porous container to receive the base metal during the casting of the backing unit. The base metal received by the channels may form a truss structure that compartmentalizes the preformed ceramic shapes into multiple isolated sub regions within the porous body to stiffen the backing unit. For example, the truss structure may provide for applying a compression force to the compartmentalized preformed ceramic shapes during a solidification of the base metal. The compression force applied during the solidification of the base metal may compress the preformed ceramic shapes into a tighter lattice structure than if the same porous body were made without the truss structure. The preformed ceramic shapes may provide for preventing the backing unit from deforming during pouring and/or cooling of the backing unit. For example, the preformed ceramic shapes may prevent the backing unit from warping during a pouring and/or a cooling of the backing unit. The preformed ceramic shapes may be made of alumina, zirconia, tungsten carbide, titanium carbide, boron carbide, zirconia-toughened alumina (ZTA), partially stabilized zirconia (PSZ) ceramic, silicon oxides, aluminum oxides with carbides, titanium oxide, brown fused alumina, combinations of any of these, or the like

[0032] In examples where the preformed ceramic shapes are formed of silicon carbide, the preformed ceramic shapes may be coated with one or more barrier layers or coatings to prevent interaction or reaction between the preformed ceramic shapes and the molten metal during the casting process. In one example, an interaction or reaction between the preformed ceramic shapes and the molten metal during the casting process may be characterized as a reaction between a molten metal comprising a steel alloy and the preformed ceramic shapes formed of silicon carbide. For example, during a casting process, a molten steel alloy may have a temperature of about 2732 degrees F. and may undesirably react with the ceramic element formed of silicon carbide. During the reaction, the steel alloy may react undesirably with the silicon carbide to form graphite. Further, multiple reaction layers at an interface between the solidified steel alloy and the silicon carbide may be produced during the reaction. In addition to the above, the steel alloy may penetrate the silicon carbide to some depth. All of these results compromise the integrity of the preformed ceramic shapes.

[0033] As such, casting preformed ceramic shapes formed of silicon carbide encapsulated with a steel alloy without utilizing one or more barrier layers or coatings during the casting process results in a compromised assembly. For example, casting a steel alloy onto preformed ceramic shapes formed of silicon carbide without utilizing one or more barrier layers or coatings may result in compromised preformed ceramic shapes (e.g., partially "dissolved" preformed ceramic shapes) encapsulated by a compromised steel alloy casing (e.g., cracked casing). To prevent the interaction or reaction between dissimilar materials during a casting process, a barrier layer and/or coating may be applied to the preformed ceramic shapes prior to casting the metal around the preformed ceramic shapes. The barrier layer and/or coating may provide an interface or zone that prevents the interaction or reaction between the preformed ceramic shapes and molten metal during a casting process.

[0034] In an example, where the barrier layer or coating may prevent the interaction or reaction between the preformed ceramic shapes and the molten metal, the barrier layer(s) or coating(s) may comprise, for example, a refractory layer encapsulating each preformed ceramic shape. For example, the refractory layer may comprise a metal film. The metal film may be, for example, a foil layer, a powder coat, an electroplating, a painted layer, dipped layer, etc. encapsulating the preformed ceramic shapes. In one specific example, preformed ceramic shapes may be wrapped in an aluminum foil layer.

[0035] In some embodiments, the barrier layer and/or coating may additionally or alternatively provide crush or compression protection between the preformed ceramic shapes and the base metal to allow for shrinkage of the encapsulating metal during and after solidification. For example, the preformed ceramic shapes and the base metal may have different coefficients of thermal expansion and the base metal may shrink disproportionately more relative to the preformed ceramic shapes. Specifically, the base metal may have a higher shrinkage percentage than a preformed ceramic shape. Stated otherwise, the preformed ceramic shape may shrink less than the base metal as the preformed ceramic shape and the base metal cool after solidification of the base metal. Because the preformed ceramic shape may shrink less than the base metal, the base metal may shrink down onto the preformed ceramic shape, resulting in the base metal being in tension and the preformed ceramic shape being in compression. The resulting forces may be sufficient to cause damage to either or both of the preformed ceramic shape and the base metal. For example, the resulting forces may be sufficient to crack the base metal and/or the preformed ceramic shapes. Cracking in either or both of the preformed ceramic shapes and the base metal may compromise or detract from the performance of the backing unit. The barrier layer and/or coating may provide an interface or zone that dampens the compression force during shrinkage of the solidified base metal, preventing cracking and/or voids from forming in either or both of the preformed ceramic shapes and base metal. That is the barrier layer may be crushable or compressible to allow the base metal to shrink around the ceramic elements without damaging the preformed ceramic shapes or the base metal.

[0036] In an example, where the barrier layer or coating may provide crush or compression protection (i.e., coefficient of thermal expansion mismatch protection) between the preformed ceramic shapes and the base metal during shrinkage after solidification, the barrier layer(s) or coating(s) may comprise, for example, a compressible, porous coating comprising alumina fiber, ceramic, copper, nickel, or the like. For example, porous coatings formed of fibers, granules, powders, etc. may include interstitial spaces that when crushed or compressed, reduce in size or volume.

[0037] In some embodiments, the barrier layer or coating may comprise more than one layer or coating to prevent interaction or reaction between the preformed ceramic shapes and the molten metal during the casting process, and to provide a crush or a compression protection between the preformed ceramic shapes and the molten metal during the casting process. For example, the barrier layer or coating may include a first layer (e.g., refractory layer) and a second layer (e.g., compressible layer).

[0038] In an example where the barrier layer or coating may prevent interaction or reaction and provide a crush or a compression protection between the preformed ceramic shapes and the molten metal during the casting process, the first layer may encapsulate the second layer.

[0039] Further, a wall thickness of the barrier layer or coating may vary depending on the specific application and/or on a density of the barrier layer. For example, the wall thickness may be dependent on thermal expansion coefficients of a base metal and a ceramic material to be accommodated. In a specific example, the base metal may be formed of an iron alloy (e.g., FeMnAl) that encapsulates preformed ceramic shapes formed of silicon carbide.

[0040] The encapsulating metal may comprise a relatively tough steel alloy, such as FeMnAl, stainless steel, 4140 AISI steel, or 8630 AISI steel. As used herein, the term "steel" includes alloys of iron and carbon, which may or may not include other constituents such as, for example, manganese, aluminum, chromium, nickel, molybdenum, copper, tungsten, cobalt, and/or silicon. As used herein, the term FeMnAl includes any iron based alloy including at least about 3% manganese by weight, and at least about 1% aluminum by weight. In another specific example, high-chrome iron (or white iron) may be used as a base metal for an encapsulating metal. In other examples, still other base metals (e.g., titanium, etc.) may be used to encapsulate preformed ceramic shapes according to this disclosure.

[0041] Ranges of what is considered "relatively hard" and "relatively tough" may vary depending on the application, but in one example "relatively hard" materials are those having a Vickers Hardness of at least about HV=1300 (13 GPa) or a Knoop hardness of at least about HK=800 (2.7 GPa), and "relatively tough" materials are those having a an impact toughness of at least about 10 ft-lbs at −40 degrees F. and/or a tensile strength of at least about 80,000 psi in the "as cast," non-heat treated state. In some examples, relatively tough materials may have an impact toughness of at least about 20 ft-lbs at −40 degrees F. and/or a tensile strength of at least about 100,000 psi in the "as cast," non-heat treated state. To be clear, however, this disclosure is not limited to using materials having the foregoing ranges of hardness or toughness.

[0042] These and other aspects of the anti-ballistic armor comprising preformed ceramic shapes will be described in greater detail below with reference to several illustrative embodiments.

Example Seam Protected Encapsulated Arrays

[0043] This section describes an exemplary encapsulated array of solid ceramic elements comprising an encapsulated array of solid ceramic elements including a barrier layer covering solid ceramic elements.

[0044] In some implementations, the encapsulated array of solid ceramic elements may include a seam protector and/or a stiffener. These and numerous other encapsulated arrays of solid ceramic elements can be formed according to the techniques described in this section.

[0045] FIG. **1** is a side view diagram of a seam protected encapsulated array **102** used, for example, as ballistic armor on a vehicle **104**. Metal/ceramic composite materials are well suited to ballistic-resistant applications due to the characteristics of the materials. For example, metals typically provide a relatively high strength-to-weight ratio and a high toughness, while ceramics have a relatively high hardness. Additionally, in part because the crack propagation speed of ceramics is below the speed of a ballistic projectile, ceramic materials provide extremely strong defense to ballistic impacts.

[0046] As shown in FIG. **1**, the seam protected encapsulated array **102** comprises an array of ceramic elements **106** encapsulated in a metal alloy **108**. The cast assembly includes the metal alloy **108**, and the array of ceramic elements **106** defines an encapsulated array **110**. As shown in the side view, the encapsulated array **110** may include a first surface **112** opposite a second surface **114**. In this embodiment, the first surface **112** of the encapsulated array **110** is substantially parallel to the second surface **114** of the encapsulated array **110**. However, in other embodiments, the first and second surfaces **112**, **114** of the encapsulated array **110** need not be parallel and may be sloped or curved relative to one another.

[0047] The seam protected encapsulated array **102** may be installed on, in, or around, the vehicle **104** so that the first surface **112** is facing outward from the vehicle **104**. Further, the seam protected encapsulated array **102** may be installed on the vehicle **104** based on a ballistic impact threat to different segments of the vehicle **104**. For example, the sides of the vehicle **104** may constitute the highest threat from ballistic impact, the top of the vehicle **104** may constitute the lowest threat from ballistic impact, and the bottom may constitute a medium threat from ballistic impact. A seam protected encapsulated array **102** may be installed on the vehicle **104** to protect the vehicle **104** from ballistic threats based on various factors (e.g., weight, performance, cost). For example, a seam protected encapsulated array **102** may be installed on the sides of the vehicle **104** to protect the vehicle **104** from the highest threat from ballistic impact.

[0048] The array of ceramic elements **106** may include two or more ceramic elements **116**. The geometry of a ceramic element **116** in the array of ceramic elements **106** may vary widely depending on the application, requirements, geometry, or other characteristics of the seam protected encapsulated array **102**. Each of the ceramic elements **116** may be arranged to minimize space between ceramic elements **116** or to achieve overlap between ceramic elements. In one example, top view diagram **118** illustrates each ceramic element **116** comprising a hexagonal perimeter. However, in other examples, the ceramic elements **116** may have a perimeter with any number of three or more sides. A thickness of the ceramic elements **116** may vary depending on an intended application. For example, for some ballistic applications, the ceramic elements **116** may be between about 0.5 inches (1.3 centimeters) and about 2 inches (5 centimeters). However, in other embodiments, the ceramic elements **116** may be thinner or thicker.

[0049] As shown in the side view, the array of ceramic elements **106** includes two or more ceramic elements **116** arranged in an adjacent manner where each ceramic element is encapsulated by the metal alloy **108**. In this specific example of the encapsulated array **110**, the ceramic elements **116** are arranged in the same plane. However the ceramic elements **116** may also be arranged in an overlapping or subjacent manner. As shown in the top view **118**, the ceramic elements **116**, in this example, may be arranged in pentagonal configuration. In this specific example, the ceramic elements **116** are arranged to minimize seams **120** between adjacent ceramic elements **116**.

[0050] The seams **120** may be defined by an interface between a ceramic element **116** arranged adjacent to another ceramic element **116** in the encapsulated array **110**, where the seams **120** may be a vulnerable area of the encapsulated array **110**. For example, because the seams **120** may be void of ceramic material (e.g., void of any ceramic element **116**), and consist primarily of the metal alloy **108**, the seams **120** may be areas of the encapsulated array **110** that are weaker than areas of the encapsulated array **110** having both the ceramic element **116** and the metal alloy **108** combined in layers.

[0051] As shown in the side view of FIG. **1**, the encapsulated array **110** may include a seam protector **122**. The seam protector **122** may be a lattice structure fixed to the first surface **112** of the encapsulated array **110** and arranged in-line with the vulnerable seams **120**. The geometry of the lattice structure may comprise a hexagonal prismatic honeycomb. For example, the lattice structure may comprise a plurality of hexagonal rings arranged adjacent to each other and each hexagonal ring may have a peak opposite a base configured to align with a seam. Because the seam protector **122** is fixed to the first surface **112** of the encapsulated array **110**, the seam protector **122** is exposed to projectiles first before the seams **120**. Further, because the seam protector **122** may be formed of a hard material (e.g., a white iron or a ceramic), when the projectile first encounters the seam protector **122**, the projectile is compromised, redirected, deflected, and/or broken apart upon impact.

[0052] FIG. **1** illustrates that the seam protected encapsulated array **102** may include a stiffener **124**. The stiffener **124** may be fixed to the second surface **114** of the encapsulated array **110**, and may provide the encapsulated array **110** with an increased stiffness. For example, the stiffener **124** may be a structural lattice member in the form of a truss (e.g., a flat truss), and increase the encapsulated array's **110** resistance to bending relative to the encapsulated array **110** without the stiffener **124**. The increased stiffness provided by the stiffener **124** keeps the encapsulated solid ceramic elements **116** in compression with the metal alloy **108** during use. For example, the stiffener **124** may substantially reduce an amount the encapsulated array **110** is displaced (e.g., bent, flexed, deformed, etc.) while the seam protected encapsulated array **102** is in use on a vehicle **104**.

[0053] FIG. **2** illustrates an exploded assembly view **202** of a seam protected encapsulated array of solid ceramic elements **204**. The seam protected encapsulated array **204** may include the seam protector **122** and/or the stiffener **124** fixed to the encapsulated array **110**.

[0054] The encapsulated array **110** may include the array of ceramic elements **106**. The array of ceramic elements **106** may include the ceramic elements **116** arranged in an adjacent manner and encapsulated in the metal alloy **108**. The encapsulated array **110** may include the seams **120**, which may be defined by the interfaces between adjacent ceramic elements **116**.

[0055] The seam protector **122** may include one or more members **206** arranged in a lattice structure. The lattice structure of the seam protector **122** may mirror the geometric pattern of the array of ceramic elements **106**. For example, the geometric pattern of the seam protector **122** may outline the geometric pattern of the array of ceramic elements **106**. The lattice structure of the seam protector **122** may have the bulk of the material of the seam protector **122** arranged around the edges of the ceramic elements **116** and apertures arranged above each ceramic element **116**.

[0056] Each member **206** may include a peak **208** opposite a base **210**. Each base **210** may be fixed to the first surface **112** of the encapsulated array **110** and each peak **208** may be arranged in-line with a respective vulnerable seam **120**.

[0057] While FIG. **2** illustrates each member **206** being connected or joined to each other, each member **206** may be an individual unit. For example, each member **206** may be a single unit including a peak **208** and a base **210**. The members **206** may be formed as a single unit to limit damage to only the impacted area and prevent crack propagation or shattering of the whole seam protector. In examples, where each member **206** is a single unit, each member **206** may be fixed to the first surface **112** of the encapsulated array **110**, respectively. For example, the base **210** of each member **206** may be fixed to the first surface **112** of the encapsulated array **110**, respectively.

[0058] Further, as illustrated in side view **212**, each member **206** may be segmented via a failure zone **214**. For example, the failure zone **214** may be a notch, a thin walled section, a groove, a perforation, or the like, disposed between each member **206**. Each of the failure zones **214** may be weaker than a wall thickness **216** of each of the members **206**. For example, each failure zone **214** may be configured to break upon a predetermined impact of a ballistic projectile on a member **206**. The predetermined impact on the member **206** may break a failure zone **214** between the member **206** receiving the impact and an adjacent member **206** not receiving an impact. Because each failure zone **214** may break upon a predetermined impact, the failure zones **214** prevent propagation of breakage from one member **206** to another member **206** in the seam protector **122**.

[0059] The stiffener **124** may comprise a similar or different lattice structure as the seam protector **122**. For example, the stiffener **124** may also outline the geometric pattern of the array of ceramic elements **106**, have the bulk of the material of the stiffener **124** arranged around the edges of the ceramic elements **116**, and have apertures arranged above each ceramic element **116**. The stiffener may have a similar or different geometric cross section as the seam protector. For example, the stiffener may comprise a plurality of hexagonal rings arranged adjacent to each other. Each of the hexagonal rings of the stiffener may include a planar surface opposite another planar surface. The stiffener **124** may be fixed to the second surface **114** of the encapsulated array **110** and arranged in-line with the vulnerable seams **120**.

[0060] FIG. **3** illustrates the front of the seam protected encapsulated array of solid ceramic elements **204** illustrated in FIG. **2**. FIG. **3** illustrates that the seam protector **122** may be fixed to the first surface **112** of the encapsulated array **110** and arranged in-line with the vulnerable seams **120**. For example, each member **206** of the seam protector **122** may fixed to the first surface **112** and arranged in-line with a vulnerable seam **120**. With the seam protector **122** arranged in-line with the vulnerable seams **120**, only areas **302** are exposed to a ballistic threat. Each of the areas **302** may comprise a composite layer **304** including at least a ceramic element **116** and the metal alloy **108**, and thus the areas **302** are configured to protect, withstand, or resist ballistic impacts.

[0061] FIG. **3** also illustrates a section line A-A. The section line A-A is approximate to a center of the seam protected encapsulated array of solid ceramic elements **204**. FIG. **5**, illustrates a section view of the seam protected encapsulated array of solid ceramic elements taken along the section line A-A, and is discussed below in more detail.

[0062] FIG. **4** illustrates a back of the seam protected encapsulated array **204** illustrated in FIG. **2**. FIG. **4** illustrates that the stiffener **124** may be fixed to the second surface **114** of the encapsulated array **110** and arranged in-line with the vulnerable seams **120** to provide a backing to the seams **120**. For example, structural lattice members **402** forming the geometric pattern of stiffener **124** may be arranged around the edges of the ceramic elements **116**. The stiffener **124** may include apertures **404** for receiving a metal alloy. For example, a molten alloy (e.g., aluminum) may be squeeze cast, die cast, or the like, into the apertures **404** of the stiffener **124**. The molten alloy received by the apertures **404** may then solidify inside voids arranged in the structural lattice members **402** of the stiffener **124**, fixing or locking the stiffener **124** to the second surface **114** of the encapsulated array **110**. The solidified alloy may be used as an attachment mechanism. For example, the solidified alloy may be used to attach the seam protected encapsulated array **204** to an armor assembly, to a vehicle, or to attach another member to the seam protected encapsulated array **204**.

[0063] The stiffener **124** may have a thickness **406** of about 1 to 1.5 times a thickness **408** of the array **110**. For example the thickness **408** of the array **110** may be about 1.4 inches (3.5 centimeters) thick, which may be substantially the same as a thickness of each ceramic element **116**. Thus, the thickness **406** of the stiffener **124** may be about 1.4 inches (3.5 centimeters) to about 2.1 inches (5.3 centimeters) thick.

[0064] FIG. **5** illustrates a section view of the seam protected encapsulated array **204** taken along the section line A-A illustrated in FIG. **3**. FIG. **5** illustrates that the seam protector **122**, the vulnerable seam **120**, and/or the stiffener **124** may be arranged in-line. For example, the seam protector **122**, the vulnerable seam **120**, and the stiffener **124** may be arranged in-line with line **502**. Further, each of the peaks **208** may be arranged in-line with the vulnerable seams **120**. For example, each peak **208** and respective vulnerable seam **120** may be arranged in-line with a line **502**.

[0065] Each of the members **206** may include a sloped surface **504** arranged between the peak **208** and the base **210**. An angle **506** of the sloped surface **504** may be any angle less than **180** degrees to provide for deflecting a projectile. For example, each of the members **206** may comprise a triangular cross-sectional shape (e.g., equilateral shaped triangle, isosceles shaped triangle, acute shaped triangle, etc.) where the angle **506** of sloped surface **504** provides for deflecting a projectile. For example, the sloped surface **504** may have an angle **506** that receives an indirect or glancing impact from a projectile rather than a direct or square impact. Further, the members **206** may compromise or break-up a projectile upon impact.

[0066] While the members **206** are illustrated as having a triangular shaped cross-section, in other embodiments, the members **206** may have a semicircle cross-sectional shape, oval shape, dome shape, etc. For example, the members **206** may have a curved sloped surface **504**. For example, the members **206** may have a convex and/or concave sloped surface **504** between the peak **208** and the base **210**. While the sloped surface **504** is illustrated as having a uniform or smooth surface, the sloped surface **504** may be non-uniform. For example, the sloped surfaces **504** may have one or more protruding or indenting features, such as ribs, ridges, grooves, channels, fins, quills, pyramids, mesh, nubs, dimples, or the like. The features may protrude or indent perpendicular to the respective sloped surface **504** or at an oblique angle relative to the respective sloped surface **504**. The non-uniform surface may provide for enhancing each of the member's **206** ability to compromise or break-up a projectile upon impact.

[0067] The section view of the seam protected encapsulated array **204** taken along section line A-A illustrates that a barrier layer **508** may cover (e.g., wrap, coat, enclose, etc.) the solid ceramic elements **116** in the array **106** of solid ceramic elements **116**. The barrier layer **508** may have a wall thickness **510** dependent on a thermal expansion coefficient of the metal alloy **108** to be accommodated, and/or on a desired seam size **512** of the encapsulated array **110**. For example, the metal alloy **108** may be an iron alloy (e.g., FeMnAl) that encapsulates ceramic elements **116** formed of silicon carbide. The ceramic elements **116** may be wrapped in a barrier layer **508** having a wall thickness **510** of about 0.060 inches (0.15 centimeters), which provides a desired seam size **512** of about 0.17 inches (0.4 centimeters). The wall thickness **510** may be substantially uniform around the solid ceramic element **116**.

[0068] Further, as illustrated in side view **514**, the barrier layer **508** may include a first barrier layer **516** (e.g., a refractory layer) and a second barrier layer **518** (e.g., a compressible layer) to integrate or combine the solid ceramic elements **116** formed of silicon carbide with the metal alloy **108**. For example, the first barrier layer **516** may be for preventing the metal alloy **108** from reacting with the solid ceramic elements **116** during a casting process, while the second barrier layer **518** may be for providing crush/compression protection during a cooling process. For example, the first barrier layer **516** may prevent a molten steel alloy from undesirably reacting with the solid ceramic elements formed of silicon carbide, while the second barrier layer **518** may prevent the steel alloy from shrinking down onto the solid ceramic elements **116** and undesirably cracking either or both of the solid ceramic elements and/or the solidified steel alloy.

[0069] While the side view **514** illustrates the barrier layer **508** including two barrier layers, (i.e., the first barrier layer **516** and second barrier layer **518**), the barrier layer may include any number of layers. For example, the barrier layer **508** may comprise multiple alternating layers of the first barrier layer **516** and the second barrier layer **518**.

[0070] The first barrier layer **516** may be formed of a metal film having a thickness **520** of at least about 0.001 inches (0.002 centimeters), and up to at most about 0.009 inches (0.02 centimeters). Further, the first barrier layer **516** may be an aluminum foil wrapped around both the second barrier layer **518** and the ceramic elements **116**, an electroplated deposit deposited around both the second barrier layer **518** and the ceramic elements **116**, a coating (e.g., a powder coating, a liquid coating, etc.) applied around both the second barrier layer **518** and the ceramic elements **116**, or the like suitable for preventing a molten steel alloy from undesirably reacting with the solid ceramic elements formed of silicon carbide. For example, the first barrier layer **516** may be formed of an aluminum foil having a thickness **520** of about 0.002 inches (0.005 centimeters), and wrapped around both the second barrier layer **518** and the ceramic elements **116**.

[0071] The second barrier layer **518** may be formed of an alumina fiber, a porous ceramic, a powder (e.g., a compacted powder, a powdered metallurgy), or the like suitable for preventing a steel alloy from shrinking down onto the solid ceramic elements formed of silicon carbide and undesirably cracking either or both of the solid ceramic elements and/or the solidified steel alloy. For example, the second barrier layer **518** may be formed of an alumina fiber having a thickness **522** of at least about 0.050 inches (0.13 centimeters), and up to at most about 0.060 inches (0.15 centimeters), and wrapped around the ceramic elements **116**. The second barrier layer **518** may be disposed between the first barrier layer **516** and each of the ceramic elements **116**.

[0072] The stiffener **124** may include voids **524** arranged in the structural lattice members **402** of the stiffener **124**. For example, the voids **524** may comprise dovetail shaped walls **526** arranged in the structural lattice members **402**. The dovetail shaped voids **524** may receive molten alloy via a squeeze cast process, and subsequent to solidification of the molten alloy, the dovetail shaped voids **524** may fix or lock the solidified alloy to the encapsulated solid ceramic tile array **110**.

[0073] Example Methods of Forming Seam Protected Encapsulated Arrays

[0074] FIG. **6** illustrates an example process **600** of manufacturing a seam protected encapsulated array of solid ceramic elements (e.g., seam protected encapsulated array of solid ceramic elements **204**), alongside corresponding schematic diagrams illustrating the operations being described in the process **600**. By way of example and not limitation, this process may be performed at a manufacturing facility, a plant, a foundry, a factory, or the like.

[0075] Process **600** includes operation **602**, which represents casting a metal around an array of solid ceramic elements. For example, a molten base metal **610** may be poured into a casting shell **612** and envelops the array of ceramic elements **106**. The base metal **610** may be any type of steel or metal that may be desirable for protection against ballistic impacts. In a specific example, the steel alloy may be steel alloy **4140** or **8630** under the American Iron and Steel Institute (AISI) standard. In other specific examples, the steel alloy may be a stainless steel alloy or FeMnAl.

[0076] In some embodiments, one or more of the ceramic elements **116** may be encapsulated with a barrier material. For example, the ceramic elements **116** may be covered (e.g., wrapped, coated, enclosed, etc.) with a barrier layer to integrated with the base metal **610** being poured into the casting shell. As discussed above the barrier layer may prevent the base metal **610** from reacting with the ceramic elements **116** during casting, and/or provide crush/compression protection during cooling.

[0077] Process **600** continues with operation **604**, which represents cooling the encapsulated array (e.g., encapsulated array **110**). For example, a metal layer **614** may solidify around the surface of the ceramic elements **116** as energy or heat **616** dissipates from the encapsulated array **110** at a relatively slow cooling rate for a predetermined period of time in a temperature controlled environment (e.g., a cooling tunnel, furnace, or the like). The casting, including the metal layer **614** and the array of ceramic elements **106** defining an encapsulated array **110**. The controlled cooling may be implemented by decreasing the amount of energy being exposed to the encapsulated array **110**. Alternatively, the encapsulated array **110** may be allowed to cool in a temperature controlled environment that limits the cooling rate without introducing outside energy or heat. The cooling rate and the predetermined period of time may be at a "slow rate." As used herein, the term "slow rate" means a rate slower than a rate at which the component would air cool if placed in a location at standard temperature and pressure. The specific slow rate of cooling and the specified period of time depend on the specific combination of ceramic material and base metal, size and shape of the ceramic elements, and the desired material properties of the composite material. In some embodiments, the casting shell and encapsulated array **110** may be cooled at a continuous slow rate until it reaches a predetermined temperature (e.g., 50% of the pouring temperature, 20% of the pouring temperature, room temperature, etc.). Examples of continuous slow rates of cooling that may be used in various embodiments include rates at most about 300 degrees F. per hour, at most about 200 degrees F. per hour, at most about 150 degrees F. per hour, or at most about 100 degrees F. per hour.

[0078] Operation **604** may be followed by operation **606**, which represents fixing a seam protector **122** to a first surface **112** of the encapsulated array **110**. For example, another molten base metal **618** different from the base metal **610** may be poured into another casting shell **620** to cast the seam protector **122** onto the first surface of the encapsulated array **110**. Here, in this embodiment, the other molten base metal **618** may be any type of steel or metal that is harder than the alloy formed around the array of ceramic elements **106**. For example, the molten base metal **618** may be a high-chrome iron (or white iron) that when solidified onto the encapsulated array **110** is harder than the encapsulating metal (e.g., a steel alloy, such as FeMnAl, stainless steel, 4140 AISI steel, 8630 AISI steel, etc.) around the array of ceramic elements **106**.

[0079] Process **600** may be completed at operation **608**, which represents fixing a stiffener **124** to a second surface **114** opposite to the first surface **112**. For example, the molten base metal **610** may be poured into another casting shell **622** to cast the stiffener **124** onto the second surface **114** of the encapsulated array **110**. Here, in this embodiment, the other casting shell **622** may be a separate unit for casting the stiffener **124** onto the encapsulated array **110**, or the casting shell **622** may be formed integral with the casting shell **612**. In the embodiment where the casing shell **622** is a separate unit, the stiffener **124** may be cast onto the encapsulated array **110** subsequent to the cooling operation **604**. In the embodiment where the casting shell **622** is formed integral with the casting shell **612**, the stiffener **124** may be cast with the encapsulated array **110** during the casting operation **602**. In this embodiment, the stiffener **124** and the encapsulated array **110** may be formed as a single unit.

[0080] FIG. **7** illustrates another example process **700** of manufacturing the seam protected encapsulated array **204**, alongside corresponding schematic diagrams illustrating the operations being described in the process **800**. Similar to process **600**, process **700**, by way of example and not limitation, may be performed at a manufacturing facility, a plant, a foundry, a factory, or the like. Further, one or more operations of process **700** may be performed in the field or at a second manufacturing facility (e.g., an assembly plant).

[0081] Process **700** includes operations **602** and **604**, which as discussed above with regard to FIG. **6**, represent casting an enclosure around an array of ceramic elements **106**, and cooling the encapsulated array **110**, respectively. Process **700** may include operation **702**, which represents fixing a seam protector **122** to a first surface **112** of the encapsulated array **110**, via a mechanical fastener. For example, a device **706** (e.g., a piece of equipment, an instrument, an apparatus, etc.) may be used along with a mechanical fastener (e.g., threaded fastener (s), pin(s), rivet(s), batten(s), or the like) to fix the seam protector **122** to the encapsulated array **110**. In addition to the mechanical fastener or as an alternative to the mechanical fastener, an adhesive may be used to fix the seam protector **122** to the encapsulated array **110**. Further, the seam protector **122** may be welded and/or braised to the encapsulated array **110**.

[0082] In the embodiment, where the seam protector **122** is fixed to the encapsulated array **110** via a fastener, the seam protector **122** may be pre-cast or pre-machined from the other base metal **618**, that when solidified is harder than the encapsulating metal. Further, the seam protector **122** may be prefabricated of a ceramic and subsequently fixed to the encapsulated array **110** via a mechanical fastener.

[0083] Process **700** may be completed at operation **704**, which represents fixing a stiffener **124** to a second surface **114** opposite to the first surface **112**, via a mechanical fastener. For example, the device **706** may be used along with a mechanical fastener to fix a stiffener **124** to the encapsulated array **110**. In addition to the mechanical fastener or as an alternative to the mechanical fastener, an adhesive may be used to fix the stiffener **124** to the encapsulated array **110**.

[0084] In the embodiment, where the stiffener **124** is fixed to the encapsulated array **110** via a fastener, the stiffener **124** may be pre-cast or pre-machined from the base metal **610** used to cast the enclosure in operation **602**.

[0085] FIG. **8** illustrates another example process **800** of manufacturing the seam protected encapsulated array **204**, alongside corresponding schematic diagrams illustrating the operations being described in the process **800**. By way of example and not limitation, this process may be performed at a manufacturing facility, a plant, a foundry, a factory, or the like.

[0086] Process **800** includes operation **802**, which represents casting an enclosure, formed of an alloy, around an array of ceramic elements **106** and at least a portion of a seam protector **122**. For example, a molten base metal **610** may be poured into a casting shell **806** and envelops the array of ceramic elements **106**, and envelops at least a portion of the seam protector **122**. While process **800** describes the base metal **610** enveloping a portion of the seam protector **122**, the base metal **610** may envelop substantially the entire seam protector **122**. For example, the base metal **610** may encapsulate both the seam protector **122** as well as the array of ceramic elements **106**.

[0087] In the embodiment, where the seam protector **122** is cast in situ or otherwise partially encapsulated or entirely encapsulated in the base metal **610** cast around the array of ceramic elements **106**, the seam protector **122** may be pre-cast or pre-machined from the other base metal **618**, that, when solidified, is harder than the encapsulating metal. Further, the seam protector **122** may be pre-fabricated of a ceramic.

[0088] Process **800** may include operation **604**, which again represents cooling the encapsulated array **110**.

[0089] Process **800** may be completed at operation **804**, which represents fixing a stiffener **124** to a second surface **114** opposite to the first surface **112**. Operation **804** may comprise operation **804**(A), which represents fixing the stiffener **124** to the second surface **114** opposite to the first surface **112**, via a mechanical fastener. Further, the stiffener **124** may be welded and/or braised to the encapsulated array **110**.

[0090] Alternatively, operation **804** may comprise operation **804**(B), which represents casting the stiffener **124** onto the second surface **114** of the encapsulated array **110**. For example, the molten base metal **610** may be poured into the other casting shell **622** to cast the stiffener **124** onto the second surface **114** of the encapsulated array **110**. The other casting shell **622** may be a separate unit for casting the stiffener **124** onto the encapsulated array **110**, or the casting shell **622** may be formed integral with the casting shell **806** for casting the stiffener **124** and the encapsulated array **110** as a single unit.

Example Encapsulating Materials

[0091] This section describes an exemplary encapsulated array of solid ceramic elements comprising an additive in an encapsulating metal (i.e., base metal) of the encapsulated array of solid ceramic elements.

[0092] In some examples, the encapsulating metal may be FeMnAl, high chrome iron, both FeMnAl and high chrome iron, or the like. In some implementations, the additive may be a ceramic grit formed of a metal matrix composite (MMC) (e.g., FeMnAl/alumina), a ceramic, a mixture of ceramic and metal, or the like. In some implementations, the additive may be added to the encapsulating base metal such that the additive is disposed in a portion (e.g., a first portion) of the encapsulating base metal and about the ceramic elements. In some implementations, seam protectors may be arranged above seams of the ceramic elements, and the additive may be added to the encapsulating base metal such that the additive is disposed in the portion of the encapsulating base metal below the ceramic elements. In some embodiments, the additive may be added to an encapsulating base metal such that the additive is disposed in multiple portions (e.g., first and second portions) of the encapsulating base metal. In some embodiments, the additive may be added to an encapsulating base metal formed around seam protectors. These and numerous other encapsulated arrays of solid ceramic elements comprising an additive in an encapsulating metal layer can be formed according to the techniques described in this section.

[0093] FIG. **9** illustrates section views **900**(A), **900**(B), **900**(C), and **900**(D) of encapsulated arrays of solid ceramic elements **902**(A), **902**(B), **902**(C), and **902**(D). The section views **900**(A)-(D) of the encapsulated arrays of solid ceramic elements **902**(A)-(D) illustrate an additive **904** in portions of an encapsulating metal of each of the encapsulated arrays of solid ceramic elements **902**(A)-(D).

[0094] Section view **900**(A) illustrates that the encapsulated array of solid ceramic elements **902**(A) may include the additive **904** in a first portion **906** (e.g., a bottom or backing portion) of an encapsulating metal **908** of the encapsulated array of solid ceramic element **902**(A). The additive **904** may be dispersed throughout the first portion **906**, while a second portion **910** (e.g., a top portion), opposite the first portion **906**, may be substantially free, or void, of the additive **904**. For example, the additive **904** may be dispersed evenly (e.g., with about a same density) in the first portion **906** generally below second portion **910** and about the solid ceramic elements **116** in the array **106** of solid ceramic elements **116**.

[0095] Section view **900**(A) illustrates an embodiment in which the encapsulated array of solid ceramic elements **900**(A) does not include a seam protector (e.g., seam protector **122**). In this example, the additive **904** may be dispersed in the encapsulating metal **908** between the solid ceramic elements **116** at the seams **120**. Because the seams **120** include the encapsulating metal **908** having the additive **904**, the seams **120** with the additive are harder than encapsulating metal **908** without the additive **904**. For example, when a projectile first encounters the seams **120** including the additive **904** below the first surface **112**, the projectile may be broken up or otherwise compromised, providing protection against projectiles.

[0096] Section view **900**(B) illustrates an embodiment of the encapsulated array of solid ceramic elements **902**(B) which includes a seam protector **912**. Similar to the seam protector **122** discussed above, the seam protector **912** may be formed of a hard material (e.g., a white iron, high chrome iron, or a ceramic). Section view **900**(B) illustrates the seam protector **912** may be aligned with, and disposed over, the seams **120**. The encapsulated array of solid ceramic elements

902(B) may include a second portion **914** of the encapsulating metal **908** that at least partially encapsulates the seam protector **912**. While section view **900**(B) illustrates the second portion **914** of the encapsulating metal **908** partially encapsulating the seam protector **912**, the second portion **914** of the encapsulating metal **908** may encapsulate substantially all of the seam protector **912**. For example, the encapsulating metal **908** may encapsulate the seam protector **912** such that no portion of the seam protector **912** is exposed on the first surface **112**.

[0097] Section view **900**(B) illustrates an embodiment of the encapsulated array of solid ceramic elements **902**(B) which includes a member **916** extending distally from the seam protector **912**. For example, the member **916** may extend away from the seam protector **912** down into, and be disposed in, the seams **120**. The member **916** may be formed of a hard material (e.g., a white iron, high chrome iron, or a ceramic), similar to the seam protector **912**. For example, the seam protector **912** and the member **916** may be formed as a single unitary unit of the hard material.

[0098] Section view **900**(C) illustrates the encapsulated array of solid ceramic elements **902**(C) including the additive **904** in the second portion **914** of the encapsulating metal **908**. For example, the additive **904** may be dispersed throughout the first portion **906** and the second portion **914** of the encapsulating metal **908**. Because the additive **904** may be dispersed in the encapsulating metal **908** of the second portion **914**, the first surface **112** is harder than without the additive **904**, adding protection against projectiles.

[0099] Section view **900**(D) illustrates an embodiment in which the encapsulated array of solid ceramic elements **902** (D) includes the additive **904** in a third portion **918** of the encapsulating metal **908**. For example, the additive may be dispersed throughout the third portion **918** of the encapsulating metal **908** layered on top of the second portion **914**. Because the additive **904** may be dispersed in the encapsulating metal **908** of the third portion **918** layered on top of the second portion **914** of the encapsulating metal **908** including the additive **904**, the first surface **112** is harder than a single layer (e.g., second potion **914**) of the encapsulating metal **908** having the additive **904**, adding greater protection against projectiles.

Example Method of Forming An Encapsulated Array With Barrier Layer Covered Tiles

[0100] FIG. **10** illustrates an example process **1000** of manufacturing an encapsulated array (e.g., encapsulated array **110**) with ceramic elements (e.g., ceramic elements **116**) covered with a barrier layer (e.g., barrier layer **508**), alongside corresponding schematic diagrams illustrating the operations being described in the process **1000**. By way of example and not limitation, this process may be performed at a manufacturing facility, a plant, a foundry, a factory, or the like.

[0101] Process **1000** includes operation **1002**, which represents covering (e.g., wrap, coat, enclose, etc.) each solid ceramic element in an array of solid ceramic elements (e.g., array of ceramic elements **106**) with the barrier layer. For example, a foundry casting the array of solid ceramic elements may manually cover each ceramic element, or the foundry casting the array of solid ceramic elements may be provided with the ceramic elements already covered with the barrier layer. For example an outside manufacturing facility may cover solid ceramic elements and provide the covered solid ceramic elements to the foundry casting the array of solid ceramic elements.

[0102] Process **1000** includes operation **1004**, which represents preparing a casting shell **612** around the array of solid ceramic elements with the barrier layer. For example, the array of solid ceramic elements may be encapsulated in a pattern material, which is then coated or encapsulated in a casting shell. Subsequently, the casting shell may be heated to remove the pattern material creating an air gap for receiving a molten metal alloy.

[0103] Process **1000** includes operation **1006**, which represents casting a metal around the array of solid ceramic elements with the barrier layer covering each solid ceramic element. For example, a molten base metal **610** may be poured into the casting shell **612** and envelops the array of solid ceramic elements. As discussed above, the base metal **610** may be any type of steel or metal that may be desirable for protection against ballistic impacts. In a specific example, the steel alloy may be FeMnAl. In the example where the steel alloy is FeMnAl, and as discussed above, the barrier layer covering each solid ceramic element prevents the base metal alloy **610** from reacting with the solid ceramic elements.

[0104] Process **1000** includes operation **1008**, which represents cooling the encapsulated array. For example, a metal layer **614** may solidify around the surface of the ceramic elements covered with the barrier layer as energy or heat **616** dissipates from the encapsulated array at a relatively slow cooling rate for a predetermined period of time in a temperature controlled environment (e.g., a cooling tunnel, furnace, or the like). The casting, including the metal layer **614** and the array of solid ceramic elements with the barrier layer covering each solid ceramic element defining an encapsulated array **110**. Here, and as discussed above, the barrier layer covering each solid ceramic element provides crush/compression protection during the cooling of the encapsulated array.

Example Anti-ballistic Armor Comprising Preformed Ceramic Shapes

[0105] This section describes an exemplary anti-ballistic armor including a backing unit with preformed shapes encapsulated in a metal alloy.

[0106] In some implementations, the backing unit may be formed integral with an encapsulated array of solid ceramic elements to stiffen the encapsulated array of solid ceramic elements. In other implementations, the backing unit may include a truss structure to provide for stiffening the backing unit. These and numerous other anti-ballistic armors comprising preformed ceramic shapes can be formed according to the techniques described in this section.

[0107] FIG. **11** illustrates an anti-ballistic armor **1102** including a backing unit **1104** formed integral with the second surface **114** of the encapsulated array **110**. The anti-ballistic armor **1102** may be installed on the vehicle **104** in an area that constitutes a threat from ballistic impact and used as anti-ballistic armor to provide protection against the threat from ballistic impact. While FIG. **11** illustrates the backing unit **1104** being formed integral with the encapsulated array **110**, the backing unit **1104** may not be integrated with an encapsulated array **110**. For example, the backing unit **1104** may be used as anti-ballistic armor without the encapsulated array **110** and used to provide protection against a threat from ballistic impact.

[0108] The backing unit **1104** may include an encapsulated porous body **1106**, cast in situ or otherwise encapsulated in a base metal (e.g., metal alloy **108**). The porous body **1106** may be formed of a plurality of preformed ceramic shapes **1108**. Each of the preformed ceramic shapes **1108** may comprise a uniform preformed geometry **1110**. For example, an engineer, a designer, an architect, etc., may specify or require a specific profile each of the preformed ceramic shapes **1108** must comply with in order to be used in the porous body **1106**. The engineer, designer, architect, etc., may explicitly describe a specific profile of the preformed ceramic shape **1108** via geometric dimensioning and tolerancing (GD&T). For example, an engineer may provide geometric dimensioning and tolerancing to a supplier, manufacturer, retailer, etc. of ceramics that explicitly describe a nominal geometry, and/or the nominal geometry's allowable variation, of the preformed geometry **1110** the preformed ceramic shapes **1108** must comply with in order to be used in the porous body **1106**. The preformed ceramic shapes **1108** may be manufactured by casting, electrofusion, sintering, flame spraying, pressing, or any other process allowing the preformed ceramic shapes **1108** to be manufactured to the preformed geometry **1110**.

[0109] The preformed ceramic shapes **1108** may be arranged in one or more layers **1114**(A) and **1114**(B) of uniform arrays of preformed ceramic shapes **1108**. For example, the preformed ceramic shapes **1108** may be arranged in multiple layers of preformed ceramic shapes **1108** to build up additional thickness of ceramic material to reduce weight and/or increase stiffness of the porous body **1106**. The layers **1114**(A) and **1114**(B) may include a series of preformed ceramic shapes arranged in contact with one another, and may be arranged in an overlapping manner. In this specific example of one or more layers **1114**(A) and **1114**(B), the preformed ceramic shapes **1108** are arranged in uniform arrays such that any interstitial space between the preformed ceramic shapes **1108** are minimized. For instance, a preformed ceramic shape **1108** arranged in the layer **1114**(B) may cover an interstitial space between two preformed ceramic shapes **1108** in the layer **1114**(A) arranged below the preformed ceramic shape **1108** in the layer **1114**(B).

[0110] FIG. **11** illustrates the preformed geometry **1110** as a sphere of ceramic having an outside diameter **1112** of about 0.5 inches (1.3 centimeters). While FIG. **11** illustrates the preformed geometry **1110** as a sphere, the preformed geometry **1110** may be a cone, a jack, a half sphere, a cube, a pyramid, a bonded unit (e.g., bonded spheres, boned sphere and cone, bonded sphere and jack, bonded half spheres, etc.), etc.

[0111] Further, while FIG. **11** illustrates the porous body **1106** being formed of a plurality of preformed ceramic shapes **1108** having substantially the same preformed geometry **1110** (i.e., spheres having an outside diameter of about 0.5 inches), the porous body **1106** may be formed of a plurality of different preformed geometries **1110**. For example, the plurality of preformed ceramic shapes **1108** forming the porous body **1106** may include a first quantity of preformed ceramic shapes having a first preformed geometry (e.g., a sphere having an outside diameter of about 0.5 inches), and a second quantity of preformed ceramic shapes having a second preformed geometry (e.g., a sphere having an outside diameter smaller or larger than 0.5 inches). Further, the porous body **1106** may be formed of a plurality of different preformed ceramic shapes **1108** including spheres, cones, jacks, and/or bonded units (e.g., bonded spheres, boned sphere and cone, bonded sphere and jack, bonded half spheres, etc.).

[0112] The preformed ceramic shapes **1108** may employ silicon carbide, alumina, zirconia, tungsten carbide, titanium carbide, boron carbide, zirconia-toughened alumina (ZTA), partially stabilized zirconia (PSZ) ceramic, silicon oxides, aluminum oxides with carbides, titanium oxide, brown fused alumina, combinations of any of these, or the like.

[0113] With the preformed ceramic shapes **1108** employing a ceramic, the preformed ceramic shapes **1108** may have a density less than a density of the metal alloy **108** encapsulating the porous body **1106**. Further, because the plurality of preformed ceramic shapes **1108** consume space in the porous body **1106**, the plurality of preformed ceramic shapes **1108** displace the metal alloy **108** during a casting of the backing unit **1104**. For example, the preformed ceramic shapes **1108** may consume about **36%** of a total volume of the backing unit **1104**, thereby displacing an amount of the metal alloy **108** needed to fill the total volume of the backing unit **1104**. Because the preformed ceramic shapes **1108** may have a density less than a density of the encapsulating metal alloy **108**, and displace the encapsulating metal alloy **108**, the plurality of preformed ceramic shapes **1108** lighten the backing unit **1104**. As a result of the backing unit **1104** being lighter, the lighter anti-ballistic armor **1102** armoring the vehicle **104** is made more efficient than a vehicle armored with heavier anti-ballistic armor.

[0114] Further, with the preformed ceramic shapes **1108** employing a ceramic, the preformed ceramic shapes **1108** may have a relatively high hardness, that may provide for increased stiffness of the backing unit **1104**. For example, the preformed ceramic shapes may increase the backing unit's **1104** resistance to bending relative to the backing unit **1104** without the preformed ceramic shapes **1108**. The increased stiffness provided by the preformed ceramic shapes **1108** keeps the encapsulated solid ceramic elements **116** in compression with the metal alloy **108** during use. For example, the backing unit **1104** may substantially reduce an amount the encapsulated array **110** is displaced (e.g., bent, flexed, deformed, etc.) while the anti-ballistic armor **1102** is in use on a vehicle **104**.

[0115] FIG. **11** also illustrates a section line B-B. The section line B-B is approximate to a center of the anti-ballistic armor **1102**. FIG. **13**, illustrates a section view of the anti-ballistic armor **1102** taken along the section line B-B, and is discussed below in more detail.

[0116] FIG. **12** illustrates a porous body **1202** for being cast in situ or otherwise being encapsulated in a base metal (e.g., metal alloy **108**). As discussed above with regard to FIG. **11**, the porous body **1202** may be formed of the plurality of preformed ceramic shapes **1108**. FIG. **12** illustrates a porous container **1204**, permeable to molten metal, may retain the plurality of preformed ceramic shapes **1108**. For example, a metal mesh, a ceramic mesh, a fabric, or other suitable structure may retain the plurality of preformed ceramic shapes **1108** in a desired shape during a casting process. In other examples, the plurality of preformed ceramic shapes **1108** may be unconstrained and may be arranged into a mold prior to or contemporaneously with the molten metal.

[0117] FIG. **12** illustrates one or more cannels **1206**(A), **1206**(B), and **1206**(C) arranged in the plurality of preformed ceramic shapes **1108**. Each of the channels **1206**(A)-**1206**(C) may have a length **1210**, greater than a width **1212**, and/or a depth **1214** (the depth **1214** illustrated in side view **1216**). The one or more channels **1206**(A)-**1206**(C) may receive the molten metal alloy cast around the porous body **1202**. The metal received in the one or more channels **1206**(A)-**1206**(C) defining a truss structure **1218**. Here, in this embodiment where the metal received in the one or more channels **1206**(A)-**1206**(C) define a truss structure **1218**, the truss structure **1218** may be formed integral with the base metal **108**.

[0118] While FIG. **12** illustrates one or more channels **1206**(A)-**1206**(C) to receive molten metal alloy cast around the porous body **1202**, the one or more channels **1206**(A)-**1206**(C) may be configured to receive a separate unit of solidified metal alloy. For example, a pre-cast metal unit, having the length **1210**, the width **1212**, and the depth **1214** of the one or more channels **1206**(A)-**1206**(C), may be received by the channels **1206**(A)-**1206**(C), and subsequently encapsulated by the base metal **108**. The length **1210** of the one or more channels **1206**(A)-**1206**(C) may be substantially long enough to traverse the encapsulated array **110** when the backing unit **1104** is fixed to the encapsulated array **110**. Here, in this embodiment where the one or more channels **1206**(A)-**1206**(C) receive a pre-cast truss structure, the metal alloy encapsulating the preformed ceramic shapes **1108** may be the same as the metal alloy forming the pre-cast truss, or the metal alloy encapsulating the preformed ceramic shapes **1108** may be another metal alloy different from the metal alloy forming the pre-cast metal unit.

[0119] The truss structure **1218** may provide for stiffening the backing unit **1104**. For example, the truss structure **1218** may increase the backing unit's **1104** resistance to bending relative to the backing unit **1104** without the truss structure **1218**. For example, the truss structure **1218** may compartmentalize the preformed ceramic shapes **1108** into a plurality of sub regions **1208**(**1**), **1208**(**2**), **1208**(**3**), **1208**(**4**), **1208**(**5**), and **1208**(N) to provide for applying a compression force to the preformed ceramic shapes **1108** contained in each of the sub regions **1208**(**1**)-**1208**(N). For example, during solidification of the base metal received by the one or more channels **1206**(A)-**1206**(C), the solidifying base metal received by the one or more channels **1206**(A)-**1206**(C) may provide a compression force directed towards the sub regions **1208**(**1**)-**1208**(N), packing the preformed ceramic shapes **1108** in each of the sub regions **1208**(**1**)-**1208**(N) together tightly. The tightly packed sub regions **1208**(**1**)-**1208**(N) of preformed ceramic shapes **1108** may prevent the preformed ceramic shapes **1108** from sliding or being displaced relative to each other, thereby stiffening the backing unit **1104**. The increased stiffness provided by the truss structure **1218** keeps the encapsulated solid ceramic elements **116** in compression with the metal alloy **108** during use. For example, the truss structure **1218** may substantially reduce an amount the encapsulated array **110** is displaced (e.g., bent, flexed, deformed, etc.) while the anti-ballistic armor **1102** is in use on a vehicle **104**.

[0120] FIG. **13** illustrates a section view of the anti-ballistic armor **1102** taken along the section line B-B illustrated in FIG. **11**. FIG. **13** illustrates that backing unit **1104** formed integral with the second surface **114** of the encapsulated array **110**. For example, backing unit **1104** may be cast with the encapsulated array **110** during a casting operation. Here, in the embodiment where the backing unit **1104** is cast with the encapsulated array **110**, the metal alloy encapsulating the ceramic elements **116** may be the same as the metal alloy encapsulating the preformed ceramic shapes **1108**. Further, in another embodiment, the encapsulated array **110** may be formed integral with the second surface **114** of the encapsulated array **110** by casting the backing unit **1104** onto the second surface **114** of the encapsulated array **110**. For example, a molten base metal may be poured into another casting shell to cast the backing unit **1104** onto the second surface **114**. Here, in this embodiment where the backing unit **1104** is cast onto the second surface **114**, the metal alloy encapsulating the preformed ceramic shapes **1108** may be the same as the metal alloy encapsulating the ceramic elements **116**, or the metal alloy encapsulating the preformed ceramic shapes **1108** may be another metal alloy different from the metal alloy encapsulating the ceramic elements **116**.

[0121] While FIG. **13** illustrates a the backing unit **1104** formed integral with the second surface **114** of the encapsulated array **110**, the backing unit **1104** may be fixed to the second surface of the encapsulated array **110** as a separate unit. For example, the backing unit **1104** may be cast separate from the encapsulated array **110** and subsequently fastened to the second surface **114** of the encapsulated array **110**. Here, in this embodiment where the backing unit **1104** is fixed to the second surface **114**, the metal alloy encapsulating the preformed ceramic shapes **1108** may be the same as the metal alloy encapsulating the ceramic elements **116**, or the metal alloy encapsulating the preformed ceramic shapes **1108** may be another metal alloy different from the metal alloy encapsulating the ceramic elements **116**. Further, and in this embodiment where the backing unit **1104** is fixed to the second surface **114**, the backing unit **1104** may be mechanically fastened to the second surface **114** via threaded fastener(s), pin(s), rivet(s), batten(s), adhesive(s), weld(s), or the like, to fix the backing unit **1104** to the encapsulated array **110**.

[0122] As illustrated in side view **1302**, the barrier layer **508** may cover (e.g., wrap, coat, enclose, etc.) each of the preformed ceramic shapes **1108**. As discussed above, with regard to FIG. **5**, the barrier layer **508** may have a wall thickness **510** dependent on a thermal expansion coefficient of the metal alloy **108** to be accommodated. The wall thickness **510** may also be dependent on a desired interstitial space between the preformed ceramic shapes **1108**. For example, the metal alloy **108** may be an iron alloy (e.g., FeMnAl) that encapsulates preformed ceramic shapes **1108** formed of silicon carbide. The preformed ceramic shapes **1108** may be wrapped in a barrier layer **508** having a wall thickness **510** which provides a desired interstitial space to allow the molten base alloy **108** to permeate the interstitial spaces between the preformed ceramic shapes **1108**. The wall thickness **510** may be substantially uniform around each of the preformed ceramic shapes **1108**.

[0123] Further, and as discussed above with regard to FIG. **5**, the barrier layer **508** may include the first barrier layer **516** (e.g., the refractory layer) and the second barrier layer **518** (e.g., the compressible layer) to integrate or combine the preformed ceramic shapes **1108** formed of silicon carbide with the metal alloy **108**.

[0124] FIG. **14** illustrates embodiments **1402**, **1404**, **1406**, and **1408** of preformed ceramic shapes that may be used to lighten and stiffen the anti-ballistic armor **1102** illustrated in FIG. **11**. Each embodiment **1402**-**1408** illustrating a different preformed geometry **1110** of a preformed ceramic shape **1108**. The embodiment **1402** illustrates a preformed geometry **1110** as a cone **1410** having a spherical base **1412**. The embodiment **1404** illustrates a preformed geometry **1110** as a cone **1414** with a planar base **1416**. Embodiment **1406** illustrates a preformed geometry **1110** as a jack **1418**. The jack **1418** may include a plurality of points, and or knobs extending from a common base. Here, the jack **1418** is illustrated in FIG. **14** having six points extending away from a common base. The jack **1418** may include any number of points extending away from a common base and may comprise different shaped points. For example, and as illustrated in FIG. **14**, four of the six points have a spherical shaped end, while the remaining two points have cylindrical shaped ends. The embodiment **1408** illustrates a preformed geometry as a sphere **1420** bonded to a jack **1422**.

[0125] Depending on the specific application, one or more of the preformed ceramic shape embodiments **1402-1408** may be used to form the porous body **1106**. For example, the jack **1418** may be arranged in the one or more layers **1114**(A) and **1114**(B) to form the porous body **1106**.

Conclusion

[0126] Although the disclosure uses language specific to structural features and/or methodological acts, the claims are not limited to the specific features or acts described. Rather, the specific features and acts are disclosed as illustrative forms of implementing the invention. For example, the various embodiments described herein may be rearranged, modified, and/or combined. As another example, one or more of the method acts may be performed in different orders, combined, and/or omitted entirely, depending on the preformed ceramic shapes to be produced.

1. A ballistic-resistant composite component comprising:
- a base metal encapsulating a porous body formed of a plurality of preformed ceramic shapes, the base metal compartmentalizing the plurality of preformed ceramic shapes into at least one sub region, the base metal substantially permeating the porous body, and the preformed ceramic shapes comprising:
  - a plurality of elements having a uniform, preformed geometry, the preformed geometry being such that the plurality of preformed ceramic shapes are configured to pack together in uniform way, and
  - a material having a density less than a density of the base metal of the ballistic-resistant composite component.

2. The ballistic-resistant composite component of claim **1**, wherein each of the plurality of preformed ceramic shapes forming the porous body have substantially the same preformed geometry.

3. The ballistic-resistant composite component of claim **2**, wherein the preformed geometry is substantially sphere shaped.

4. The ballistic-resistant composite component of claim **3**, wherein the sphere has an outer diameter of about 0.5 inches (1.3 centimeters).

5. The ballistic-resistant composite component of claim **2**, wherein the preformed geometry is a cone.

6. The ballistic-resistant composite component of claim **2**, wherein the preformed geometry is a jack.

7. The ballistic-resistant composite component of claim **1**, wherein the plurality of preformed ceramic shapes forming the porous body comprises a first quantity of the preformed ceramic shapes and a second quantity of the preformed ceramic shapes, and
- wherein each of the preformed ceramic shapes of the first quantity have a first preformed geometry, and each of the preformed ceramic shapes of the second quantity have a second preformed geometry different from the first preformed geometry.

8. The ballistic-resistant composite component of claim **1**, further comprising one or more trusses formed integral with the base metal encapsulating the porous body and arranged in the plurality of preformed shapes, wherein the truss structure compartmentalizes the plurality of preformed shapes into a plurality of sub regions to provide for packing the plurality of preformed ceramic shapes together into the uniform array.

9. The ballistic-resistant composite component of claim **1**, wherein the base metal is a steel alloy and the plurality of preformed ceramic shapes comprise silicon carbide preformed ceramic shapes, and wherein each silicon carbide preformed shape is encapsulated with a barrier layer.

10. The ballistic-resistant composite component of claim **9**, wherein the barrier layer comprises:
- a first layer, encapsulating each silicon carbide preformed shape, to prevent the steel alloy from reacting with the plurality of preformed silicon carbide ceramic shapes during the casting of the steel alloy around the porous body; and
- a second layer, disposed between the first layer and each silicon carbide preformed shape, to provide crush protection between the steel alloy and each silicon carbide preformed shape during a cooling of the ballistic-resistant composite.

11. The ballistic-resistant composite component of claim **10**, wherein the first layer is a metal film and the second layer is an alumina fiber.

12. An anti-ballistic armor comprising:
- a base metal cast around an array of solid ceramic tiles, the base metal around the array of solid ceramic tiles defining an encapsulated array, the encapsulated array including a first surface opposite a second surface; and
- another base metal cast around a porous body, the other base metal around the porous body defining a backing unit, the backing unit formed integral with the second surface of the encapsulated array, wherein
- the porous body is formed of a plurality of preformed ceramic shapes, each preformed ceramic shape including a preformed geometry, and the other base metal substantially permeates the porous body.

13. The anti-ballistic armor of claim **12**, further comprising a truss structure arranged in the porous body to stiffen the backing unit.

14. The anti-ballistic armor of claim **13**, wherein the truss structure is formed integral with the other base metal.

15. The anti-ballistic armor of claim **13**, wherein the truss structure is a separate unit formed of a pre-cast metal unit.

16. The anti-ballistic armor of claim **12**, wherein the base metal is different from the other base metal.

17. The anti-ballistic armor of claim **12**, wherein the base metal is the same as the other base metal.

18. A method of forming an anti-ballistic composite assembly, the method comprising:
- casting a metal around a porous body formed of a plurality of preformed ceramic shapes having a preformed geometry and a density less than a density of the base metal, the metal around the porous body defining a backing unit,
- compartmentalizing the plurality of preformed ceramic shapes into at least one sub region with the base metal,
- wherein the plurality of preformed ceramic shapes displace the metal cast around the porous body to lighten the backing unit.

19. The method of claim **18**, further comprising:

casting the metal around an array of solid ceramic tiles, the metal around the array of solid ceramic tiles defining an encapsulated array to provide protection against ballistic projectiles, the encapsulated array including a first surface opposite a second surface, and

wherein the backing unit is cast integral with the first surface, or the second surface, of the encapsulated array to stiffen the encapsulated array.

20. The method of claim **18**, further comprising forming the porous body including:

arranging, in a porous container, the plurality of preformed ceramic shapes into one or more layers of arrays of preformed ceramic shapes.

21. The method of claim **20**, further comprising arranging, in the porous container, the plurality of preformed ceramic shapes to include one or more channels having a length greater than a width and/or a depth, the one or more channels to receive the metal cast around the porous body, the metal received in the one or more channels defining a truss structure, and

wherein the truss structure stiffens the backing unit.

22. A ballistic-resistant composite component comprising:

a base metal encapsulating a porous body formed of a plurality of preformed ceramic shapes configured to interlock, the base metal substantially permeating the porous body, and the preformed ceramic shapes comprising:

a plurality of elements having a uniform, preformed geometry, the preformed geometry being such that the plurality of preformed ceramic shapes are configured to pack together and interlock in uniform way, and

a material having a density less than a density of the base metal of the ballistic-resistant composite component.

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