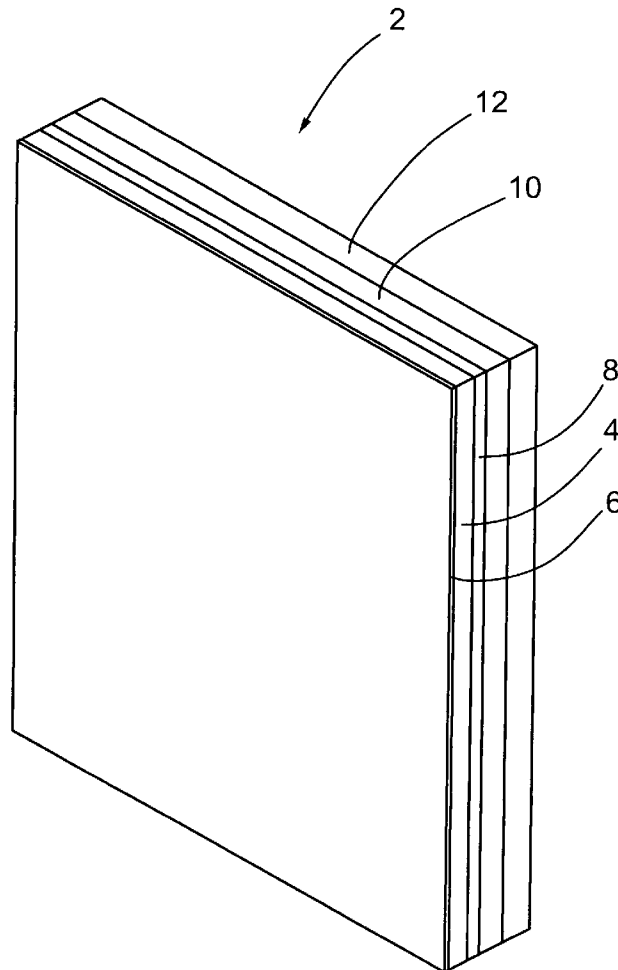




US 20120174754A1

(19) **United States**(12) **Patent Application Publication**
Salisbury et al.(10) **Pub. No.: US 2012/0174754 A1**(43) **Pub. Date: Jul. 12, 2012**(54) **CERAMIC ARMOUR AND METHOD OF
CONSTRUCTION**(60) Provisional application No. 60/514,621, filed on Oct.
28, 2003.(75) Inventors: **Christopher Peter Salisbury,**
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James Worswick, Waterloo (CA)**Publication Classification**(51) **Int. Cl.**
F41H 5/04 (2006.01)(52) **U.S. Cl. 89/36.02; 89/917; 89/907; 89/910;**
89/921; 89/914(73) Assignee: **STRIKE FACE TECHNOLOGY**
INCORPORATED, Waterloo (CA)(57) **ABSTRACT**

An armor for protection against armor piercing and/or high energy projectiles has a ceramic layer with a confinement layer on a front thereof. The ceramic layer is backed by a first metal layer and the first metal layer in turn is backed by a composite layer. A second optional confinement layer may be included between the ceramic and first metal layers. The composite layer is backed by an optional second metal layer, which in turn is backed by an optional anti-trauma layer. The armor is used to protect personnel and objects such as vehicles.

(21) Appl. No.: **12/457,117**(22) Filed: **Jun. 1, 2009****Related U.S. Application Data**(63) Continuation-in-part of application No. 10/960,284,
filed on Oct. 8, 2004, now Pat. No. 7,540,228.

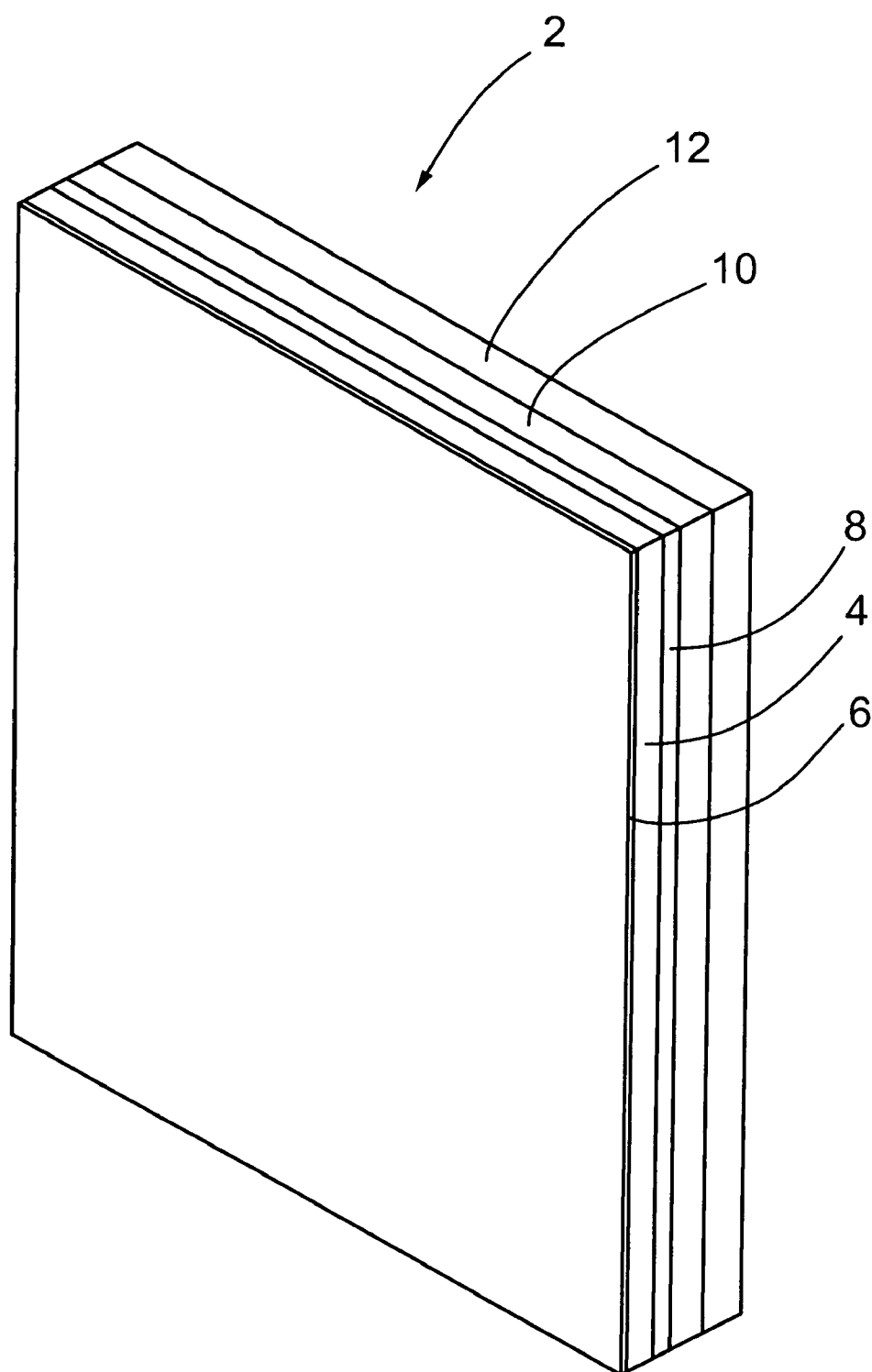


FIG. 1

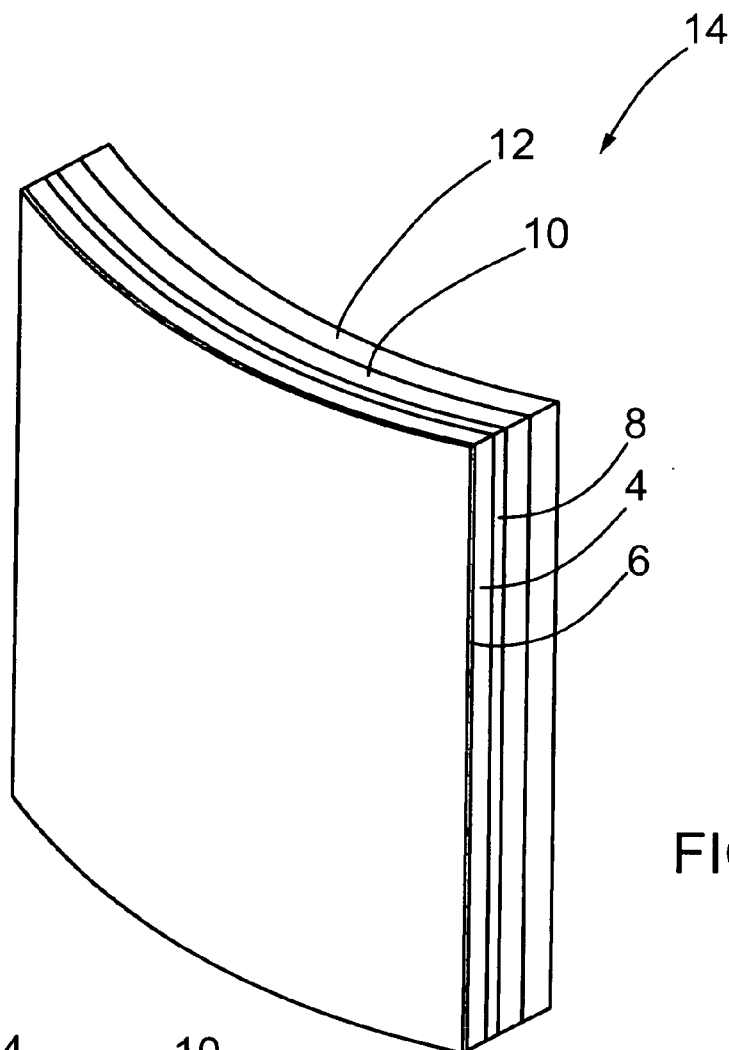


FIG. 2

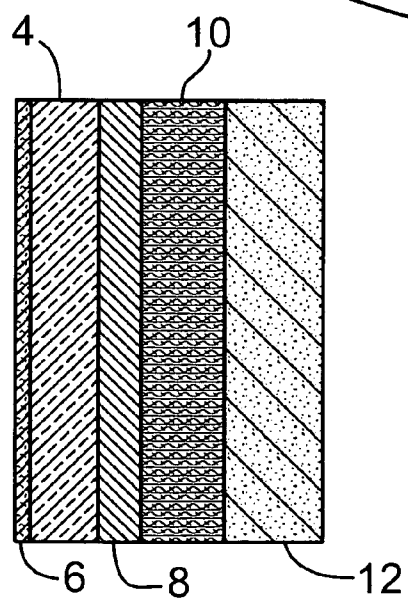


FIG. 3

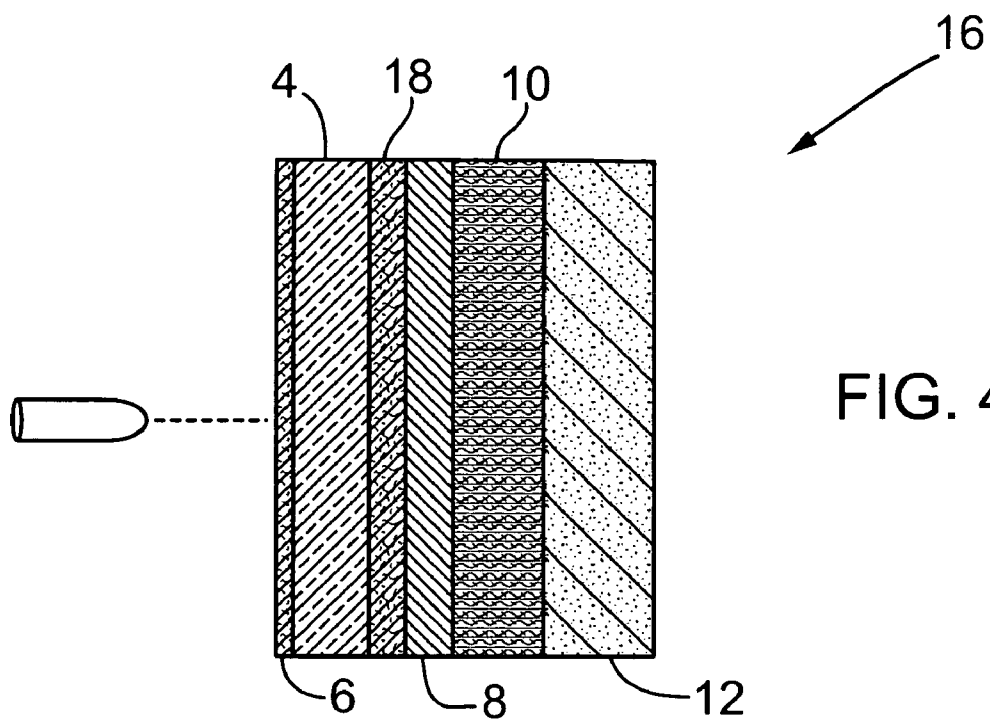


FIG. 4

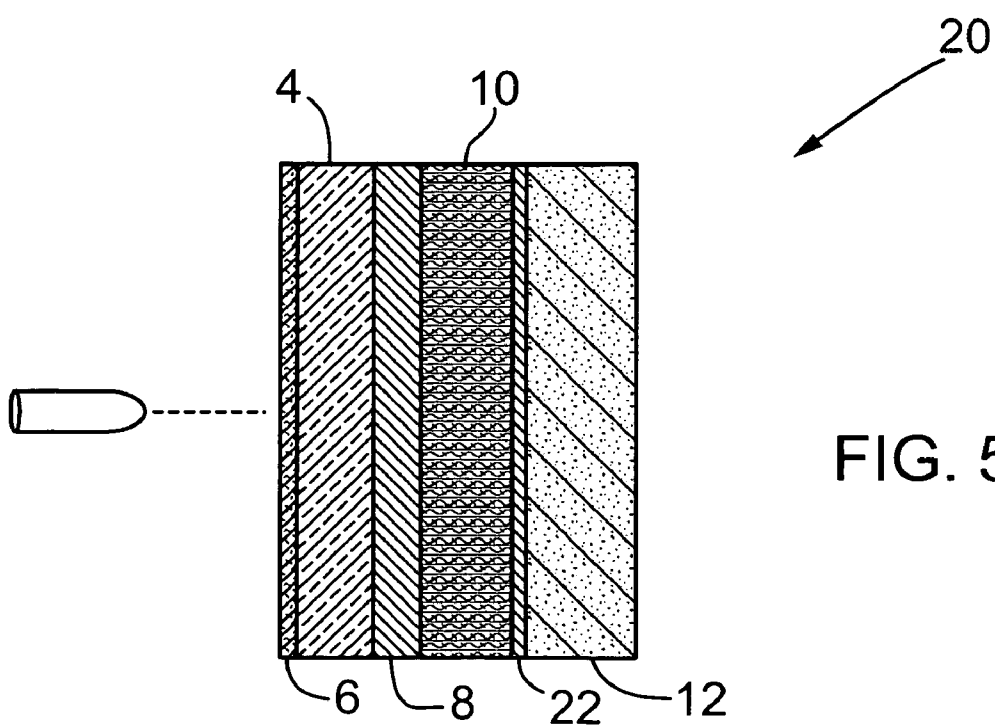


FIG. 5

CERAMIC ARMOUR AND METHOD OF CONSTRUCTION

CROSS REFERENCE TO RELATED APPLICATION

[0001] This patent application is a Continuation-In-Part application of U.S. patent application Ser. No. 10/960,284 entitled CERAMIC ARMOUR AND METHOD OF CONSTRUCTION filed on Oct. 8, 2004 in the name of the same inventors, now issued as U.S. Pat. No. 7,540,228 on Jun. 2, 2009 which relates to, and claims the priority benefit from, U.S. Provisional Patent Application Ser. No. 60/514,621 filed on Oct. 8, 2003 entitled CERAMIC ARMOUR AND METHOD OF CONSTRUCTION, all of which are incorporated herein in its entirety.

FIELD OF INVENTION

[0002] This invention relates to an armor for protection against armor piercing and/or high energy projectiles where the armor has a nonporous ceramic layer which is struck by an incoming projectile, a solid nonporous metal layer backing the ceramic layer, and a ballistic composite layer backing the metal layer, where said composite layer is placed closest to the person or object being protected.

BACKGROUND OF THE INVENTION

[0003] Ceramic armors are known. However, previous armors are much too heavy or too bulky or too expensive or they do not provide sufficient protection or any protection against armor piercing and/or high-energy projectiles. Traditional soft armors used in many types of protective vests are typically made of layers of flexible woven fabric or non-woven textile using fibers such as aramid (such as Kevlar™ or Twaron™) or polyethylene (such as Spectra Shield™ or Dyneema™) or other types of fibers. When a bullet strikes these armors, the impact produces a bulge which deforms the back surface of the armor. Since the armor is worn adjacent to the body, this bulge, or deformation, projects into the body of the wearer which can cause injury to the wearer, known as behind armor blunt trauma. Traditional hard or plate armors include a ceramic layer to disrupt or break up the projectile, and a ballistic composite layer to stop the projectile and ceramic debris.

[0004] U.S. Pat. No. 5,534,343 teaches the use of an inner layer of flexible cellular material in a flexible armor.

[0005] U.S. Pat. No. 5,349,893 discloses a ceramic armor having an inner layer of rigid, semi-flexible or semi-rigid cellular material.

[0006] U.S. Pat. No. 5,847,308 issued to Singh et al. teaches a passive roof armor system which includes a stack of ceramic tiles and glass layers.

[0007] U.S. Pat. No. 6,203,908 issued to Cohen is directed to an armor having an outer steel layer, layers of high density ceramic bodies bonded together, and an inner layer of high-strength anti-ballistic fibers such as KEVLAR™.

[0008] U.S. Pat. No. 6,135,006 issued to Strasser et al. discloses a multi-layer composite armor which includes alternating hard and ductile layers formed of fiber-reinforced ceramic matrix composite.

[0009] Canadian Patent application Serial No. 2,404,739 to Lucuta et al. discloses a multi-layer ceramic armor with improved ceramic components to deflect a projectile on impact, bonded to a shock absorbing layer constructed of a

polymer-fiber composite material, and further bonded to a backing of ballistic composite or metallic material. In the designs presented by Lucuta et al. all ceramic materials are backed by: polymer-fiber composite, additional ceramic components, or polymeric components while the current design uses a metallic layer directly bonded to the ceramic. The backing layer in traditional armors is made of a ballistic composite material. Lucuta et al. claim the use of a ballistic composite or metallic layer.

[0010] United States Patent Publication No. US2004/0118271A1 to Puckett et al. is directed to reducing the impact of armor deformation by reducing the peak load using a trauma reduction layer such as cellular honeycomb urethane materials. The current design proposes the use of a polymeric layer between the armor and the wearer to further reduce the impact, and this process is generally known and used in the armor industry.

[0011] U.S. publication No. 2006/006511 to Henry discloses an armor using an outer ballistic cloth layer backed by a steel mesh which in turn is backed by a ceramic component contained within a confinement bag. The outer surface of the confinement bag includes a pressure sensitive adhesive bonded to one side thereof for quick application to the body being protected.

[0012] U.S. Pat. No. 5,191,166 issued to Smirlock et al. is directed to an armor for vehicles and other structures and includes a hook and loop fastener system, (Velcro™) made of nylon and the like on the back surface of the metal plate for affixing the armor to the vehicle or structure. See column 3, line 34 to 49 and lines 60 to line 2 of column 4.

[0013] U.S. Pat. No. 6,253,655 issued to Lyons et al. discloses a durable spall cover concept.

[0014] U.S. Pat. No. 5,996,115 issued to Mazelsky discloses a flexible ballistic body armor with a soft fabric backing layer and beveled overlapping ceramic tiles.

[0015] U.S. Pat. No. 7,150,217 issued to Kershaw discloses an armor designed for lower velocity impacts as in protective equipment for sports or as a shoulder rest for a gun butt recoil, which is not capable of withstanding high velocity ballistic threats.

[0016] U.S. Patent Publication 2006/0065111 to Park et al. describes various combinations of ballistic fabric but does not address the incorporation of metallic or ceramic layers.

[0017] Therefore there is a need for an armor that provides better protection to the person or object being protected by the armor.

SUMMARY OF THE INVENTION

[0018] It is an object of the invention to provide an armor that is lightweight and relatively thin, yet provides protection against armor piercing and/or high energy projectiles. It is a further object of the present invention to provide an armor where the armor can be used as a body armor or as protection for vehicles or other objects with reduced deformation and improved penetration resistance when impacted by armor piercing and/or high energy projectiles.

[0019] An embodiment of the invention provides an armor for protection against armor piercing and/or high energy projectiles comprising a nonporous ceramic layer with a first confinement layer bonded to a front surface thereof, said nonporous solid ceramic layer being backed by a first nonporous solid metal layer of high strength and ductility with a front surface of the first nonporous solid metal layer being bonded to a back surface of the nonporous solid ceramic layer

for distributing an impact load from a projectile impacting on said first confinement layer and resulting ceramic debris and for confining the ceramic debris in an impact zone within said ceramic layer, said first nonporous solid metal layer being backed by a ballistic composite layer with a front surface of the ballistic composite layer being bonded to a back surface of the first nonporous solid metal layer, the nonporous solid ceramic layer having a thickness in a range from 1 mm to about 40 mm, and the first nonporous solid metal layer having a thickness in a range from about 0.1 mm to about 5 mm.

[0020] An optional second metal layer may be used behind the ballistic composite layer to reduce back face deformation. An optional second confinement layer may be used between the ceramic and metal layers for enhanced performance in some impact scenarios. An optional anti-trauma layer may be placed at the rear surface of the armor to further reduce back face deformation.

[0021] Preferably, the first metal layer is thin relative to the thickness of the ceramic layer.

[0022] Still more preferably, the confinement layer is a fiber reinforced polymeric layer or polymeric layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In FIG. 1, there is shown a perspective view of a flat armor having five layers;

[0024] FIG. 2 is a perspective view of a curved armor having five layers;

[0025] FIG. 3 is a schematic side view of an armor having five layers;

[0026] FIG. 4 is a schematic side view of an armor having six layers; and

[0027] FIG. 5 is a schematic view of an armor having six layers with a second metal layer located between the ballistic composite layer and the anti-trauma layer.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Generally speaking, the systems described herein are directed to ceramic armors. As required, embodiments of the present invention are disclosed herein. However, the disclosed embodiments are merely exemplary, and it should be understood that the invention may be embodied in many various and alternative forms.

[0029] The Figures are not to scale and some features may be exaggerated or minimized to show details of particular elements while related elements may have been eliminated to prevent obscuring novel aspects. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention. For purposes of teaching and not limitation, the illustrated embodiments are directed to a ceramic armor and methods of producing same.

[0030] As used herein, the terms “about”, and “approximately” when used in conjunction with ranges of sizes, thicknesses, dimensions or other physical properties or characteristics are meant to cover slight variations that may exist in the upper and lower limits of the ranges of dimensions so as to not exclude embodiments where on average most of the dimensions are satisfied but where some dimensions may exist outside this region. For example, in embodiments of the present invention dimensions of components of the armor are given but it will be understood that these are not meant to be limiting.

[0031] As used herein the phrase “metal layer” means a nonporous, solid metal layer such as metal sheet or plate depending on the thickness, which has high strength and ductility. Metals/alloys that are brittle would not work in this invention.

[0032] In FIG. 1, an armor 2 has a ceramic layer 4 with a confinement layer 6 on a front thereof. The ceramic layer 4 is backed by a metal layer 8, which in turn is backed by a ballistic composite layer 10. For personal armor the ballistic composite layer 10 may be backed by an optional anti-trauma layer 12. The various layers are held together by a suitable method of joining. Examples of suitable methods of bonding include but are not limited to adhesive bonding, transient liquid phase bonding, microwave joining, direct ceramic-metal joining, and mechanical joining (ultrasonic joining, compression fit, brazing).

[0033] The confinement layer 6 is preferably a glass fiber reinforced layer with a polymeric matrix, but may include other reinforcement such as carbon fiber, aramid fibers or polyethylene fibers, or may be a metal or polymeric layer such as polycarbonate that does not use fiber reinforcement. Preferably, the confinement layer 6 is bonded to the ceramic layer with a structural adhesive. The adhesive is preferably a thermoset (for example, urethane-based adhesives) or a thermoplastic (for example, Nolax V764-2 based on polyolefines). These adhesives may be used to bond all the different layers to one another.

[0034] The metal layer 8 is preferably made from titanium and, still more preferably, is a titanium alloy containing substantially 6% aluminum (for example, Titanium alloy ASTM B265, Grade 5, with nominal weight contents of 6% Aluminum, 4% Vanadium). The metal layer 8 is thin relative to the ceramic layer 4. The armor disclosed herein is oriented in such a way that the bullet or other projectile first impacts the confinement layer 6 and the person or object being protected is adjacent to or behind the composite layer 10. For personal armor, the optional anti-trauma layer 12 may be added adjacent to the wearer's torso.

[0035] While titanium and titanium alloys are preferred, it will be understood the present invention is not limited to these materials. A key feature that is exhibited by the metal layer 8 is that it be of high tensile strength and ductility so that it will be appreciated that other alloys may be specifically developed exhibiting these properties.

[0036] To date, the use of metal layers in personal body armors does not represent the conventional approach due to weight concerns. However, the current design disclosed herein utilizes a thin metal layer to improve performance and reduce the weight of other components including the ceramic and ballistic composite backing so that no significant weight penalty is incurred. The metal layer 8 enhances performance through distribution of the impact load from the projectile and ceramic debris on the ballistic composite, confinement of the ceramic debris in the impact zone, and through impedance matching between the ceramic layer 4 and metal layer 8. The enhanced performance resulting from this metal layer 8 also allows for the use of lower ballistic performance ceramics in applications. The preferred material is titanium due to light weight and exceptional performance in these conditions. Other metallic materials could be considered including aluminum, requiring increased thickness, and high-strength steel, resulting in added weight.

[0037] While as stated above the metal layer is thin relative to the ceramic layer 4, it will be appreciated that the relative

thickness ranges of the metal layer **8** and the ceramic layer **4** will depend on the impact conditions including the projectile construction, weight and velocity for which the armor is being designed. However it will be appreciated that the armor may be designed for particular applications with specific impact conditions in mind. For example, for all anticipated applications, regardless of the threat level, the thickness of the ceramic layer **4** may vary in a range from about 1 mm to about 40 mm, and the thickness of the metal layer may vary in a range from 0.1 mm to about 5 mm.

[0038] Studies by the inventors have shown that the ballistic performance of the ceramic layer **4** is improved significantly by being backed by the thin metal layer **8**. The metal layer **8** preferably has high strength and ductility. The use of the confinement layer **6** and the metal backing layer **8** improves the performance of the ceramic layer **4** by improving penetration resistance, and resistance to multiple impacts. For example, an armor constructed according to the present invention using a silicon carbide ceramic layer and titanium metal layer can withstand multiple noncoincident impacts from tungsten-carbide cored projectiles without penetration whereas armors excluding the metal layer would be penetrated.

[0039] The ballistic composite backing layer **10** is preferably comprised of various ballistic fabric weaves, unidirectional fibers and polymeric matrix materials to maximize the ballistic performance. The purpose of the ballistic composite backing layer **10** is to stop the projectile and ceramic debris penetrating into the torso of the person wearing the armor.

[0040] The ballistic composite layer **10** may be formed of multiple layers, preferably multiple layers of Kevlar™ (for example, K129™ or KM2™) or Twaron™ fibers within a polymeric matrix or polyethylene fibres (Dyneema™ or Spectra™) or polyethylene fibres within a polymeric matrix. The ceramic layer **4** is preferably any one of boron carbide, silicon carbide, alumina, or other common ballistic ceramic materials or ceramic composite materials.

[0041] The ceramic layer **4** may be a mosaic (a series of smaller solid nonporous tiles shaped to fit together to cover a larger area without gaps) but is preferably a single, solid ceramic layer. The anti-trauma layer **12** is preferably a foam layer.

[0042] In FIG. 2, the armor **14** is identical to the armor **2** of FIG. 1 with the exception that the layers of the armor **14** are curved as shown in FIG. 2. A curved armor is preferred for objects that are not flat and when used by a person as the curved armor fits much better on the chest of a user than a flat armor. Generally, the armor can be shaped as desired to best fit the shape of the body or object (not shown) that is being protected by the armor. The same reference numerals are used in FIG. 2 to describe those components that are identical (except for curvature) to the components of FIG. 1.

[0043] In FIG. 3, the relative thicknesses of the various layers shown in FIGS. 1 and 2 can be seen with the thickness of the ceramic layer **4** varying in the above mentioned range from about 1 mm to about 40 mm, and the thickness of the metal layer **8** varying in the above mentioned range from 0.1 mm to about 5 mm.

[0044] The confinement layer **6** may have a thickness in a range from about 0.1 mm to about 5 mm, the ballistic composite layer **10** typically has a thickness in the range from about 5 mm to about 30 mm, and the anti-trauma layer **12** typically has a thickness in the range from about 5 mm to about 50 mm. However it will be appreciated that the present

invention is not restricted to an armor with component thickness for layers **6**, **10** and **12** in these ranges.

[0045] The same reference numerals are used in FIG. 3 to describe those components that are identical to the components of FIGS. 1 and 2. It can be seen that the first metal layer **8** is thin relative to the ceramic layer **4**.

[0046] While the relative thicknesses of the various layers shown can vary substantially from that shown in FIG. 3, it has been found that the thicknesses shown work very well. Alternatively, the ceramic layer **4** could be made much thicker. However, adding thickness will make the armor much heavier and bulkier as well as much more expensive.

[0047] In FIG. 4, the same reference numerals are used to describe those components that are identical to the components of FIG. 3. An armor **16** shown in FIG. 4 is identical to the armor shown in FIG. 3 except that there is a second confinement layer **18** located between the ceramic layer **4** and the first metal layer **8**. It has been found that the second confinement layer **18** can provide enhanced performance, but with added weight. The second confinement layer **18** is preferably a polymeric layer, or fiber reinforced polymeric layer that may have an identical or different composition to the confinement layer **6**. It may be a metal or polymeric layer such as polycarbonate that does not use fiber reinforcement. Preferably, the second confinement layer **18** is a glass fibre reinforced polymer layer.

[0048] In FIG. 5, there is shown a further embodiment of the invention where an armor **20** has a second metal layer **22** located between the ballistic composite layer **10** and the anti-trauma layer **12**. The armor **20** does not have a second confinement layer located between the ceramic layer **4** and the first metal layer **8**, but an armor could be designed containing that feature. The same reference numerals are used in FIG. 5 to describe those components that are identical to the components of FIG. 3.

[0049] In some uses of the armor, it will be unnecessary to use the anti-trauma layer **12** so that the armor consists, from front to rear, of the confinement layer **6**, the ceramic layer **4**, the first metal layer **8** and the ballistic composite layer **10** respectively. The armor is further described in the following exemplary and non-limiting example.

Example 1

[0050] A multi-component armor plate has a confinement layer **6**, ceramic layer **4** and first metal layer **8** that is 250 mm wide and 300 mm in height. The ballistic composite layer **10**, a second metal layer **22** and anti-trauma layer **12** have dimensions of 250 mm in width by 300 mm in height. The total mass is approximately 4.8 kg.

[0051] In Example 1, the layers have the following thicknesses:

Thickness	Material
2 mm	Confinement Layer (S-Glass with Structural Adhesive)
11.1 mm	Ceramic Layer (Silicon Carbide Manufactured by Saint-Gobain)
1 mm	First Metal Layer—Titanium
18.5 mm	Ballistic composite layer consisting of 37 Layers of Kevlar™ 129 with PVB Phenolic Matrix
1 mm	Second Metal Layer—Titanium
15 mm	Anti-Trauma Layer

[0052] All layers in the example are bonded using a structural adhesive such as a urethane-based adhesive.

[0053] The design set out in Example 1 was evaluated using NIJ (National Institute of Justice) Standard 0101.04 (June 2001) (an applicable ballistic testing standard at the time of testing), which incorporates impact of armor on a clay backing. A deformation level greater than, or equal to, 44 mm in clay is considered a failure in the standard. The above design resulted in a deformation level of less than 44 mm when impacted by a .50 caliber armor piercing projectile. The layer materials and relative thicknesses will vary in accordance with the specific requirements or circumstances of use. The armor of Example 1 was backed with a vest (not shown) incorporating layers of woven Kevlar™ fibers without a polymeric resin when the tests were conducted.

[0054] The anti-trauma layer 12 is preferably a polymeric foam layer. The purpose of the anti-trauma layer 12 is to reduce blunt trauma and to increase separation between the armor and the torso of a user. The anti-trauma layer reduces impact loading, improves load distribution and energy absorption. Preferably, the anti-trauma layer is 128 kg/m³ rigid polyurethane foam having a thickness of 15 mm. The foam layer is preferably FR6708™ sold by General Plastics Manufacturing Company.

[0055] Improved bonding and performance of the ceramic and metal layers is achieved by ensuring a surface roughness of at least 1.0 micrometers Ra, which is attained through sand blasting the ceramic tiles.

[0056] The armor of the present invention has withstood impacts by armor piercing, high energy projectiles, resulting in low back face deformation. An example of such projectiles is a .50 caliber APT C44 round.

[0057] The armor of Example 1 had a maximum total areal density of 70 kg/m². In some applications, lower areal densities could be used in adjacent areas of an armor to minimize overall weight. While the armor of the present invention can be used in various applications such as personal armor or vehicle armor, for personal armor applications it is preferred to use the armor in a vest such as one containing layers of woven Kevlar fibers without a polymeric matrix.

[0058] The armor 20 described in Example 1 has an overall maximum thickness of substantially 49 mm. It may be desirable to vary the thickness and/or material in a specific area or areas of the armor to achieve the desired results, which may be a lower overall weight.

[0059] To date, the use of metal layers in personal body armor does not represent the conventional approach due to weight concerns. However, the current design disclosed herein utilizes a thin metal layer to improve performance and reduce the weight of other components including the ceramic and ballistic composite backing so that no significant weight penalty is incurred. The metal layer 8 enhances performance through distribution of the impact load from the projectile and ceramic debris on the ballistic composite, confinement of the ceramic debris in the impact zone, and through impedance matching between the ceramic layer 4 and metal layer 8. The enhanced performance resulting from this metal layer 8 also allows for the use of lower ballistic performance ceramics in some applications. The preferred material is titanium due to light weight and exceptional performance in these conditions. As mentioned above, other metal materials could be considered including aluminum, requiring increased thickness, and high-strength steel, resulting in added weight.

[0060] By comparison, Canadian Patent application Serial No. 2,404,739 to Lucuta et al. discloses a multi-layer ceramic armor with improved ceramic components to deflect a projectile on impact, bonded to a shock absorbing layer constructed of a polymer-fiber composite material, and further bonded to a backing of ballistic composite or metallic material. This differs from the armor design disclosed herein in component stacking sequence and purpose. In particular, the first metal layer 8 of the present invention is used to support the ceramic layer 4 and enhance penetration resistance. The first and second metal layers also act to minimize deformation of the ballistic composite material upon impact. In the designs disclosed in Lucuta et al. all ceramic materials are backed by: polymer-fiber composite, additional ceramic components, or polymeric components while the present invention uses a metal layer 8 bonded to the ceramic layer 4. The backing layer in traditional armors is made of a ballistic composite material. The armor of the present invention uses a metal layer to back the ceramic layer and then a ballistic composite layer to back the metal layer, which may be further supported by an optional second metal layer to enhance performance.

[0061] The armor of the present invention is based upon the unexpected discovery that the introduction of a relatively thin layer of high strength, ductile metal between the ceramic and composite layers (the “ceramic-metal-composite” configuration) dramatically increases the ballistic performance of the armor relative to that achieved through use of a conventional “ceramic-composite” layering sequence. There are two aspects to this improvement in performance. The first is an increase in penetration resistance over that of an armor of equivalent weight, but without the additional thin metal layer. The second and more critical improvement is a dramatic reduction in the displacement of the rear surface of the armor, known as the Back Face Signature (BFS), of approximately 30% in an armor designed for protection against the APT C44 round attributed to the introduction of the metal layer 8. The Back Face Signature is particularly important in personal armor since it is an indication of the blunt trauma that could be imparted to the wearer of the armor. This reduction in displacement or Back Face Signature is achieved without an increase in armor weight.

[0062] The addition of the second thin metal layer (the “ceramic-metal-composite-metal” configuration) results in a further unexpected increase in performance. This performance gain leads to further reduced deformation and trauma when impacted by projectiles.

[0063] The aforementioned results are significant to the field of protective armor and represent a major benefit to the wearers of the armor system in the case of personal armor.

[0064] The armor is constructed by affixing the confinement layer 6 to a front surface of the ceramic layer 4 and the first metallic layer 8 is bonded to a back surface of the ceramic layer 4 so that in operation the metal layer 8 is between the torso of the user or between the object (vehicle) and the ceramic layer such that the projectile hits the confinement layer 6 first (see FIGS. 4 and 5). The composite layer 10 is bonded to the back surface of metal layer 8 and the antitrauma layer 12 is affixed to the back surface of layer 10 when being used as personal armor. The layers are all bonded to one another using the aforementioned techniques and the order of bonding them to one another does not matter.

[0065] As used herein, the terms “comprises”, “comprising”, “including” and “includes” are to be construed as being inclusive and open ended, and not exclusive. Specifically,

when used in this specification including claims, the terms “comprises” and “comprising” and variations thereof mean the specified features, steps or components are included. These terms are not to be interpreted to exclude the presence of other features, steps or components.

[0066] The foregoing description of the preferred embodiments of the invention has been presented to illustrate the principles of the invention and not to limit the invention to the particular embodiment illustrated. It is intended that the scope of the invention be defined by all of the embodiments encompassed within the following claims and their equivalents.

1. An armor for protection against armor piercing and/or high energy projectiles comprising:

a nonporous solid ceramic layer with a first confinement layer bonded to a front surface thereof;

said nonporous solid ceramic layer being backed by a first continuous nonporous solid metal layer of high strength and ductility with a front surface of the first continuous nonporous solid metal layer being bonded to a back surface of the nonporous solid ceramic layer for distributing an impact load from a projectile impacting on said first confinement layer and resulting ceramic debris and for confining the ceramic debris in an impact zone within said nonporous solid ceramic layer; and

said first continuous nonporous solid metal layer being backed by a ballistic composite layer with a front surface of the ballistic composite layer being bonded to a back surface of the first continuous nonporous solid metal layer, said nonporous solid ceramic layer having a thickness in a range from 1 mm to about 40 mm, and the first continuous nonporous solid metal layer having a thickness in a range from about 0.1 mm to about 5 mm.

2. An armor as claimed in claim 1 wherein said first nonporous solid metal layer is thinner than said nonporous ceramic layer.

3. An armor as claimed in claim 1 including an anti-trauma layer being bonded to a back surface of said ballistic composite layer for reducing blunt trauma and to increase separation between the armor and the torso of a user or object being protected.

4. An armor as claimed in claim 1 including a second nonporous solid metal layer of high strength and ductility having a front surface which is bonded to a back surface of said ballistic composite layer.

5. An armor as claimed in claim 4 including an anti-trauma layer, said second nonporous solid metal layer being backed by said anti-trauma layer bonded to a back surface of said second nonporous solid metal layer for reducing blunt trauma and to increase separation between the armor and the torso of a user or object being protected.

6. An armor as claimed in claim 4 wherein said second nonporous solid metal layer is thinner than said ceramic layer.

7. An armor as claimed in claim 1 wherein said nonporous ceramic layer, said first confinement layer, said first nonporous solid metal layer, and said ballistic composite layer have a curvature such that the armor is fitted to a user or object being protected.

8. An armor as claimed in claim 1 wherein said first nonporous solid metal layer is a titanium metal layer.

9. An armor as claimed in claim 4 wherein said second nonporous solid metal layer is a titanium metal layer.

10. An armor as claimed in claim 8 wherein said first nonporous solid metal layer is a titanium alloy containing substantially 6% aluminum.

11. An armor as claimed in claim 9 wherein said second nonporous solid metal layer is a titanium alloy containing substantially 6% aluminum.

12. An armor as claimed in claim 10 wherein said titanium alloy is Titanium alloy American Society for Testing and Materials B265, Grade 5, with nominal weight contents of 6% Aluminum, 4% Vanadium.

13. An armor as claimed in claim 11 wherein said titanium alloy containing said substantially 6% aluminum is Titanium alloy American Society for Testing and Materials B265, Grade 5, with nominal weight contents of 6% Aluminum, 4% Vanadium.

14. An armor as claimed in claim 3 wherein said anti-trauma layer is made of a polymeric foam layer.

15. An armor as claimed in claim 5 wherein said anti-trauma layer is made of a polymeric foam layer.

16. An armor as claimed in claim 14 wherein said polymeric foam layer is about 128 kg/m³ rigid polyurethane foam having a thickness of about 15 mm.

17. An armor as claimed in claim 15 wherein said polymeric foam layer is about 128 kg/m³ rigid polyurethane foam having a thickness of about 15 mm.

18. An armor as claimed in claim 1 wherein said first confinement layer includes a glass or other fiber reinforced polymer layer or other polymeric layer.

19. An armor as claimed in claim 1 wherein said first confinement layer includes any one of a glass or other fiber reinforced polymer layer and a polymeric layer not reinforced by fibers.

20. An armor as claimed in claim 1 wherein said ballistic composite layer is formed of multiple layers.

21. An armor as claimed in claim 20 wherein said multiple layers are multiple layers of ballistic fabric selected from the group consisting of aramid fibers in a polymeric matrix and polyethylene fibers in a polymeric matrix.

22. An armor as claimed in claim 1 wherein said ceramic layer is made of any one of boron carbide, silicon carbide and alumina.

23. An armor as claimed in claim 1 wherein said nonporous ceramic layer is a single ceramic tile.

24. An armor as claimed in claim 1 wherein said nonporous ceramic layer is a mosaic of a plurality of coextensive ceramic tiles.

25. An armor as claimed in claim 1 including a second confinement layer located between the nonporous ceramic layer and the first metal layer.

26. An armor as claimed in claim 25 wherein said second confinement layer includes any one of a glass or other fiber reinforced polymer layer and a polymeric layer not reinforced by fibers.

27. An armor as claimed in claim 26 wherein said second confinement layer is bonded to the ceramic layer and the first nonporous metal layer using any one or combination from the group consisting of thermoplastic and thermoset polymers, microwave joining, and mechanical joining including ultrasonic joining.

28. An armor as claimed in claim 1 wherein said first nonporous solid metal layer is equal to, or less than about 20% of the thickness of the ceramic layer.

29. An armor as claimed in claim 3 wherein said first confinement layer is similar in thickness to the first nonporous solid metal layer, and wherein said ballistic composite

layer is similar in thickness to said nonporous ceramic layer, and wherein said anti-trauma layer is thicker than the ceramic layer.

30. An armor as claimed in claim **1** wherein said nonporous solid ceramic layer, said first confinement layer, said first nonporous solid metal layer, and said ballistic composite layer are joined to one another using any one selected from the group consisting of thermoplastic and/or thermoset polymers, microwave joining, direct ceramic-metal joining, and mechanical joining including any one or combination of ultrasonic joining and compression fit, and brazing.

31. An armor as claimed in claim **19** wherein said polymeric layer not reinforced by fibers is polycarbonate.

32. An armor as claimed in claim **26** wherein said polymeric layer not reinforced by fibers is polycarbonate.

33. An armor as claimed in claim **21** wherein said aramid fibers in a polymeric matrix is Kevlar™, and wherein said polyethylene fibers in a polymeric matrix is any one of Dyneema™ and Spectra™.

34. An armor as claimed in claim **1** wherein said armor has a variable thickness for providing thicker armor for pre-selected areas to provide higher levels of protection to a user or object to be protected.

35. An armor as claimed in claim **14** wherein said polymeric foam layer has a thickness in a range from about 5 mm to about 50 mm.

36. An armor as claimed in claim **15** wherein said polymeric foam layer has a thickness in a range from about 5 mm to about 50 mm.

37. An armor as claimed in claim **5** wherein said nonporous ceramic layer, said first confinement layer, said first nonporous solid metal layer, said ballistic composite layer, said anti-trauma layer, and said second nonporous solid metal layer have a curvature such that the armor is fitted to a user or object being protected.

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