A protective liner for personal protective equipment comprises a foam component and a polymer component. The foam component is embedded in parallel with the polymer component such that the foam component and the polymer component absorb energy in parallel during impact.
PERSONAL PROTECTIVE EQUIPMENT LINER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a non-provisional application of, and claims priority to, U.S. Provisional Application No. 61/983,127, filed on Apr. 23, 2014 and titled “ENERGY ABSORBING PROTECTIVE HEADGEAR LINER COMPOSITE,” which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] Mild Traumatic Brain Injury (MTBI), commonly referred to as “a concussion,” is an injury that frequently occurs in contact sports, such as football. Sport-related brain injuries have been estimated to occur 1.6 to 3.8 million times every year. Additionally, it is estimated that some football players receive up to 1,500 head impacts per season. Although every impact may not result in MTBI, numerous impacts to the head can result in long-term brain damage through an impact induced neurodegenerative disease known as Chronic Traumatic Encephalopathy (CTE).

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

[0004] FIG. 1 is a drawing of an example of a configuration of a protective liner where a foam component is embedded in engineered chambers of a thermoplastic and/or thermoset component according to various embodiments of the present disclosure.

[0005] FIG. 2 is a drawing of an example of SKYDEX® brand engineered chamber thermoplastic urethane (TPU) which can be used for the thermoplastic component of the protective liner of FIG. 1.

[0006] FIG. 3 is a drawing of an example of a cross-sectional view of a helmet including the protective liner of FIG. 1 according to various embodiments of the present disclosure.

[0007] FIG. 4 is a drawing of an example of another cross-sectional view of the helmet of FIG. 3 including multiple protective liners of FIG. 1 according to various embodiments of the present disclosure.

[0008] FIG. 5 is a drawing of an example of another configuration of a protective liner a foam component is embedded in engineered chambers of a thermoplastic and/or thermoset component according to various embodiments of the present disclosure.

[0009] FIG. 6 is a drawing of an example of the protective liner of FIG. 5 according to various embodiments of the present disclosure.

[0010] FIGS. 7A-7C are drawings of examples of another configuration of a protective liner where a thermoplastic and/or thermoset component encapsulates a foam component according to various embodiments of the present disclosure.

[0011] FIG. 8 is a drawing of an example of a cross-sectional view of a helmet including multiple protective liners of FIGS. 7A-7B according to various embodiments of the present disclosure.

[0012] FIG. 9 is a drawing of an example a perspective view of a helmet including multiple protective liners of FIGS. 7A-7C according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

[0013] The present disclosure relates to protective liners for personal protective equipment. The protective liner provides energy absorption and may be disposed along the interior surface of personal protective equipment such as, for example, American football helmets, sports helmets, military helmets, boxing headgear, construction helmets, bump caps, shoulder pads, shin guards, body pads, ballistic vests, shoes, and/or any other appropriate type of personal protective equipment. For example, the protective liner may be used in helmets and/or headgear to protect a wearer’s head and reduce the likelihood of Mild Traumatic Brain Injury (MTBI), Chronic Traumatic Encephalopathy (CTE), or other types of injuries.

[0014] The protective liner comprises a foam component and a thermoplastic and/or thermoset component. The foam component may comprise one or more layers of open-cell, closed-cell, semi-open cell, and/or viscoelastic foam (VEF). The thermoplastic and/or thermoset component may comprise a thermoplastic elastomer (TPE), such as, thermoplastic urethane (TPU), a thermoset and/or any other type of thermoset. In some embodiments, the thermoplastic and/or thermoset component comprises a chambered component having one or more engineered chambers. The geometric configuration of the engineered chambers may comprise a hemisphere configuration, a honeycomb-shaped configuration, a tetrahedron-shaped structure and/or any other appropriate geometric configuration. The foam component may be inserted into the engineered chambers of the thermoplastic and/or thermoset component to form the protective liner.

[0015] In other embodiments, the thermoplastic and/or thermoset component may comprise a thermoplastic and/or thermoset encapsulant component that encapsulates the foam component that is in a base geometric form. The foam component may comprise a base geometric form such as, for example, a cylinder, a prism, a cube, a tetrahedron, a cuboid, and/or any other type of appropriate geometric shape. As such, the thermoplastic and/or thermoset component encapsulates the geometric form of the foam component to produce the protective headgear liner.

[0016] The foam component and the thermoplastic and/or thermoset component are configured with each other such that when an object impacts a helmet, headgear, and/or other type of personal protective equipment including the protective liner, a portion of the kinetic energy resulting from the impact is absorbed in parallel by the components, instead of being transferred to the wearer’s head and/or other protected portion of the body. The foam component allows for a higher energy absorption during impact while the thermoplastic and/or thermoset component allows for a higher resilience (or return to shape) of the foam component. Because the amount of energy that is transferred to the wearer’s head and/or other protected portion of the body is less than the amount that would otherwise be transferred if the personal protective
equipment did not comprise the protective liner, the risk in experiencing various types of injuries by the wearer is reduced.

[0018] In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same.

[0019] Turning now to FIG. 1, shown is a drawing of an example of one configuration of a protective liner 10a according to various embodiments of the present disclosure. The protective liner 10a comprises a foam component 12a embedded in a thermoplastic and/or thermoset chambered component 14a. One or more thermoplastic and/or thermoset sheets 16 are disposed along the top surface and the bottom surface of the protective headgear liner 10a. The foam component 12a may comprise one or more layers of open-cell, closed-cell, semi-open cell, and/or viscoelastic foam (VEF). In some embodiments, the foam component 12a comprises multiple layers of foam stacked in series, which may differ in density, base material, and/or cellular structure.

[0020] The thermoplastic chambered component 14a shown in FIG. 1 comprises a hemisphere shaped structure. However, it should be noted that although the thermoplastic and/or thermoset chambered component 14a of FIG. 1 comprises a hemisphere shaped structure, the thermoplastic and/or thermoset chambered component 14a may comprise a variety of geometric configurations such as, for example, a hemisphere configuration, a honeycomb-shaped configuration (FIGS. 5 and 6), a tetrahedron-shaped structure and/or any other appropriate geometric configuration. The thermoplastic and/or thermoset chambered component 14a may comprise thermoplastic elastomer, such as, for example, thermoplastic urethane, a thermoset, and/or other various types of TPE and/or thermoset material(s). In some embodiments, the thermoplastic and/or thermoset chambered component 14a may comprise an engineered chamber TPU configuration such as SKYDEX® brand engineered chamber TPU as shown in FIG. 2, U.S. Patent entitled “Construction method for cushioning component” issued on Nov. 2, 1999 and assigned patent number U.S. Pat. No. 5,976,451, and U.S. Patent entitled “Cushioning system with parallel sheets having opposing indentions for linear deflection under load” issued on Aug. 18, 2009 and assigned patent number U.S. Pat. No. 7,574,760 provide detailed descriptions of the SKYDEX® brand TPU and are incorporated by reference in their entirety. In other embodiments, the thermoplastic and/or thermoset chambered component 14a may comprise other suitable types of engineered chamber thermoplastic and/or thermoset configurations as described herein.

[0021] The foam component 12a may be disposed within the thermoplastic and/or thermoset chambered component 14a. The configuration of the foam component 12a being disposed within the thermoplastic and/or thermoset chambered component 14a allows the foam component 12a and the thermoplastic and/or thermoset chambered component 14a to absorb energy in parallel to each other. Further, the foam component 12a allows for a higher energy absorption during impact while the thermoplastic and/or thermoset chambered component 14a allows for a higher resilience (or return to shape) of the foam component 12a.

[0022] In some embodiments, the foam component 12a may be attached to the surrounding wall of the thermoplastic and/or thermoset chambered component 14a. The foam component 12a may be attached to the thermoplastic and/or thermoset chambered component 14a by an adhesive, a resin, and/or any other suitable substance that can be used to securely attach the foam component 12a to the thermoplastic and/or thermoset chambered component 14a.

[0023] In some embodiments, the top portion and the bottom portion the foam component 12a may comprise one or more thermoplastic sheets 16. Similar to the thermoplastic and/or thermoset chambered component 14a, the one or more thermoplastic and/or thermoset sheets 16 may comprise thermoplastic elastomer, such as, for example, thermoplastic urethane, a thermoset, and/or other various types of TPE and/or thermoset material(s). In some embodiments, the one or more thermoplastic sheets 16 are attached directly to the top and/or bottom portions of the protective liner 10a via an adhesive, a resin, and/or other suitable material that may be used to securely attach the one or more thermoplastic sheets 16 to the top and/or bottom portions of the protective liner 10a. The one or more thermoplastic and/or thermoset sheets 16 may provide additional energy absorption and protection of the protective liner 10a.

[0024] The manufacturing method of protective liner 10a entails injection molding and/or other type of molding process of the thermoplastic chambered component 14a and the insertion of the foam component 12a. The foam component 12a may be inserted after foam production or may be injection molded into the thermoplastic and/or thermoset chambered component 14a. The foam component 12a may also be inserted into the chamber of the thermoplastic and/or thermoset chambered component 14a during or between the injections for the molding process of the thermoplastic and/or thermoset chambered component 14a. The foam component 12a may be produced from slab, bonding, and/or molding processes. The thermoplastic and/or thermoset chambered component 14a may be produced from various types of molding processes.

[0025] Moving on to FIG. 3, shown is a drawing of an example of a cross-sectional view of a helmet 18a including the protective liner 10a according to various embodiments of the present disclosure. The helmet 18a comprises the protective liner 10a disposed along the interior curvature of the helmet shell 20. The helmet shell 20 may comprise the shell of a type of rigid and/or flexible headgear such as, for example, a sporting helmet, a military helmet, a construction helmet, a bump cap and/or any other type of helmet/headgear.

[0026] In some embodiments, the protective liner 10a may be attached to the helmet shell 20 by an adhesive, a resin, a hook and loop component, and/or any other appropriate attachment component for securely attaching the protective liner 10a to the interior curvature of the helmet shell 20. In some embodiments, a foam sheet 22 may be disposed along the curvature of the bottom layer of the protective liner 10a. The foam sheet 22 may comprise one or more layers of open-cell, closed-cell, semi-open cell, and/or viscoelastic foam in series. In some embodiments, the foam sheet 22 may differ from the foam component 12a in density, base material, and/or cellular structure. For example, the foam component 12a and the foam sheet 22 may both comprise the same open-cell foam. In other embodiments, the foam component 12a may comprise open-cell foam while the other foam sheet 22 may comprise closed-cell foam. Further, the densities of the foam component 12a and the foam sheet 22 may be different in some embodiments and the same in other embodiments.

[0027] Referring next to FIG. 4, shown is a drawing of an example of another cross-sectional view of the helmet 18a
according to various embodiments of the present disclosure. The helmet 18a may comprise one or more pieces of the protective liner 10a disposed along the interior of the helmet shell 20. In some embodiments, the protective liner 10a comprises a single piece that covers at least a portion of the interior of the helmet shell 20. In other embodiments, as shown in FIG. 4, the protective liner 10a may comprise multiple pieces disposed along preferred portions of the helmet shell 20. In some embodiments, the protective liner 10a may not be disposed along the portion of the helmet shell 20 that aligns with the ear of the helmet wearer.

Moving on to FIG. 5, shows a drawing of an example of another configuration of a protective liner 10b, according to various embodiments of the present disclosure. The protective liner 10b differs from the protective liner 10a in that the geometric configuration of the thermoplastic and/or thermoset chambered component 14b is honeycomb-shaped rather than hemisphere shaped. As with the protective liner 10a, the foam component 12b is embedded in the thermoplastic and/or thermoset chambered component 14b such that the foam component 12b and the thermoplastic and/or thermoset chambered component 14b absorb energy in parallel to each other in order to reduce risk of injury to the wearer of headgear including the protective liner 10b. As shown in FIG. 5, the protective liner 10b may comprise one or more thermoplastic and/or thermoset sheets 16 disposed along the top and bottom portions of the protective liner 10b. FIG. 6 illustrates the protective liner 10b without the one or more thermoplastic and/or thermoset sheets 16 disposed along the top and bottom portions of the protective liner 10b. In addition, the various methods of manufacture of the protective liner 10b are similar to the methods discussed above with respect to the protective liner 10a.

Referring next to FIGS. 7A-7C, shown are drawings of examples of another configuration of a protective liner 10c, according to various embodiments of the present disclosure. FIG. 7A illustrates a perspective view of the protective liner 10c. FIG. 7B illustrates a drawing of an example of a cross sectional view of the protective liner 10c where the foam component is a single foam layer. FIG. 7C illustrates a drawing of an example of cross sectional view of the protective liner 10c where the foam component comprises multiple foam layers.

The protective liner 10c differs from the protective liner 10a of FIG. 1 and the protective liner 10b of FIG. 5, in that the protective liner 10c of FIGS. 7A-7C comprises a foam component 12c encapsulated by a thermoplastic and/or thermoset encapsulant component 24. The foam component 12c may comprise one or more layers of open-cell, semi-open-cell, closed-cell, or viscoelastic foam that may also be a nanocomposite foam. In some embodiments, the foam component 12c may comprise one or more layers of foam, which may differ in density, base material, and/or cellular structure. In some embodiments, the foam component 12c may comprise a cylindrical geometric form. In other embodiments, the foam component 12c may comprise other base geometric forms such as, for example, a prism, a cube, a tetrahedron, a cuboid, and/or other type of appropriate geometric shape.

The thermoplastic and/or thermoset encapsulant component 24 comprises thermoplastic elastomer, such as, for example, thermoplastic urethane, a thermoset, and/or other various type of TPE and/or thermoset material(s). The thermoplastic and/or thermoset encapsulant component 24 encapsulates the geometric form of the foam component 12c. In some embodiments, the foam component 12c is attached to the wall of the thermoplastic and/or thermoset encapsulant component 24 by adhesive, resin, and/or other suitable material. In other embodiments, the foam component 12c is not directly attached to the wall of the thermoplastic and/or thermoset encapsulant component 24. In some embodiments, the protective liner 10c may comprise may be filled with Helium, Argon, and/or other gases to alter the temperature effects of the foam component 12c for heat dispersion and/or pressure effects of the protective liner 10c for increased energy absorption.

Turning now to FIG. 7C, shown is a drawing of an example of the protective liner 10c showing the foam component 12c comprising multiple layers of the foam component 12c, 12d. In some embodiments, the foam layers may be adhered to one another by an adhesive, resin, a gelatinous material, a hydrogel, and/or other suitable material. In other embodiments, the layers of the foam component 12c, 12d may be stacked in series, but are not adhered to one another.

The manufacturing method of protective liner 10c entails vacuum forming of the thermoplastic and/or thermoset encapsulant component 24 either directly on the foam base and/or vacuum forming of thermoplastic and/or thermoset encapsulant component 24 onto a mold from which the foam base is inserted and then sealed to a base thermoplastic and/or thermoset layer. The protective liner(s) 10c may be produced individually or in sections that are interconnected by the interconnected channels 26 (FIG. 8).

Turning now to FIG. 8, shown is a drawing of an example of cross-sectional view of a helmet 18c comprising multiple protective liners 10c. In some embodiments, the protective liners 10b may be connected to adjacent protective liners 10c by an interconnecting channel 26. The interconnecting channel 26 may comprise a foam material, a thermoplastic and/or thermoset material, and/or other suitable material that may be used to connect the protective liner 10c to one another. In other embodiments, the protective liners 10c are unconnected from one to another. In some embodiments, the protective liners 10c are attached to the interior curvature of the helmet shell 20. The protective liner 10c may be attached to the interior curvature of the helmet shell 20 via an adhesive, a resin, hook and loop component, and/or any other appropriate attachment material for attaching the protective liner(s) 10b to the interior curvature of the helmet shell 20.

Referring next to FIG. 9, shown is a drawing of an example of a perspective view of the helmet 18c comprising multiple protective liners 10c attached to a helmet shell 20 according to various embodiments of the present disclosure. The multiple protective liners 10c may be disposed along various preferred portions of the helmet 18b. In some embodiments, the protective liner 10a and/or the protective liner 10b may be used in conjunction with the protective liner 10c. As such, a helmet 18c, 18b (hereinafter referred to as 18) may comprise one or more pieces of the configuration of protective liner 10a with one or more pieces of the configuration of protective liner 10c. In addition, as shown in FIG. 3, a foam sheet 22 may be disposed along the bottom portion of the protective liner(s) 10c for additional protection.

The above-described embodiments of the present disclosure are merely examples of implementations to set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiments without departing substan-
tially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure. Disjunctive language used herein, such as the phrase “at least one of X, Y, or Z,” unless specifically stated otherwise, is used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

Therefore, the following is claimed:

1. A protective liner for use in personal protective equipment, comprising:
   - a polymer component; and
   - a foam component embedded in parallel with the polymer component.

2. The protective liner of claim 1, wherein the foam component comprises one or more layers of at least one of: open-cell foam, semi-open cell foam, closed foam, or viscoelastic foam.

3. The protective liner of claim 1, wherein the polymer component comprises at least one of a thermoplastic or a thermoset.

4. The protective liner of claim 1, wherein the polymer component comprises an engineered chamber configuration comprising one or more engineered chambers.

5. The protective liner of claim 4, wherein the engineered chambered configuration comprises at least one of: a honeycomb-shaped configuration, a hemisphere-shaped configuration, or a tetrahedron-shaped configuration.

6. The protective liner of claim 1, wherein the polymer component is an encapsulant that encapsulates the foam component.

7. The protective liner of claim 1, wherein the foam component comprises a geometric form of at least one of: a cylinder, a prism, a cube, a tetrahedron, or a cuboid.

8. The protective liner of claim 1, wherein the protective personal equipment is a helmet, the protective liner is disposed within an interior portion of the helmet, energy generated by an impact to the helmet is absorbed in parallel by the foam component and the polymer component, the polymer component increases rebound of the foam component impacted by absorption of the energy.

9. The protective liner of claim 1, wherein the protective liner comprises an inert gas for optimizing thermal conductivity of the protective liner.

10. The protective liner of claim 1, wherein the inert gas comprises at least one of helium or argon.

11. An item of personal protective equipment, comprising:
   - a shell; and
   - a protective liner disposed within an interior portion of the shell, the protective liner comprising a foam component embedded in parallel with a polymer component comprising at least one of a thermoplastic or a thermoset.

12. The item of personal protective equipment of claim 11, wherein the polymer component comprises an encapsulant, and the polymer component encapsulates a geometric form of the foam component.

13. The item of personal protective equipment of claim 12, wherein the geometric form comprises at least one of: a cylinder, a prism, a cube, a tetrahedron, or a cuboid.

14. The item of personal protective equipment of claim 11, wherein the polymer component comprises one or more engineered chambers, the foam component being embedded in the one or more engineered chambers.

15. The item of personal protective equipment of claim 14, wherein the polymer component comprises at least one of: a honeycomb-shaped configuration, a hemisphere-shaped configuration, or a tetrahedron-shaped configuration.

16. The item of personal protective equipment of claim 11, wherein the foam component comprises one or more layers of at least one of: open-cell foam, semi-open cell foam, closed foam, or viscoelastic foam.

17. The item of personal protective equipment of claim 11, wherein the polymer component comprises thermoplastic urethane.

18. The item of personal protective equipment of claim 11, wherein the protective liner is a single unit.

19. The item of personal protective equipment of claim 11, wherein the protective liner comprises a plurality of units that are separate relative to each other.

20. The item of personal protective equipment of claim 19, wherein individual ones of the plurality of units are connected to adjacent ones of the plurality of units via an interconnected channel, the interconnecting channel allowing for at least one of fluid transfer or gas transfer.

21. An item of personal protective equipment, comprising:
   - a shell; and
   - means for absorbing energy generated by an impact to the shell, wherein the means for absorbing the energy is disposed along an interior portion of the shell.

22. The item of personal protective equipment of claim 21, wherein the shell is flexible.

23. The item of personal protective equipment of claim 21, wherein the shell is rigid.

24. The item of personal protective equipment of claim 21, wherein the means for absorbing the energy comprises a protective liner.

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