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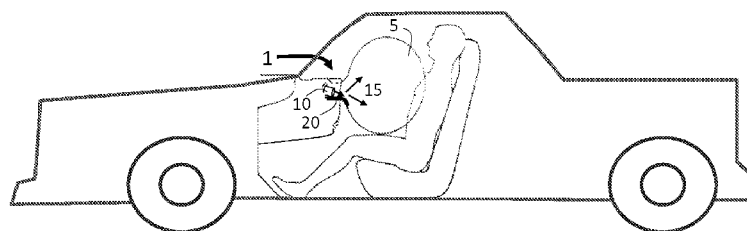


Figure 1

- (57) **Abstract:** An inflatable vehicle safety device (1) is provided that comprises an inflator (10), a fluid compartment, and a heat shield. The inflator (10) is capable of providing an inflation fluid (15) used to inflate the fluid compartment. The heat shield, which is located within the fluid compartment, comprises a fabric layer and a thermal barrier layer located adjacent to the film. The barrier layer includes at least one layer of cellular silicone foam. The heat shield has a thermal resistance value of six seconds or more at 725°C when tested in a hot rod thermal resistivity test.



FLEXIBLE HEAT SHIELD WITH SILICONE FOAM FOR INFLATIBLE SAFETY DEVICES

[0001] This disclosure relates generally to inflatable safety devices. More specifically, this disclosure relates to a flexible heat shield for use in protecting the integrity of fabric used in the construction of the safety device from high temperatures generated upon inflation of the device.

[0002] Inflatable safety device systems are used by the automotive industry to protect vehicle occupants in the event of an accident. These inflatable safety device systems typically include a sensor, an inflator, and an airbag or other inflatable component. In the event of an accident, the sensor is set off, thereby activating the inflator to fill the airbag with a gas in order to place a cushion between the occupant and potentially harmful surfaces in the vehicle. All of these operations need to occur within milliseconds after the accident in order to effectively protect the occupant.

[0003] The inflator used in these safety devices is generally classified as a cold-gas type, which releases compressed gas, or a pyrotechnic type, which burns a compound, such as sodium azide or alkali metal azide. Pyrotechnic types of inflators are desirable because the burn rate of the azide compound is controllable and reproducible, thereby, making these devices quite reliable. Pyrotechnic types of inflators also tend to be smaller in overall size, weigh less, and be less expensive to manufacture than compressed gas inflators.

[0004] The purpose of a heat shield is to protect and maintain the integrity of the airbag during its deployment and prevent the burn through by the hot inflator after deployment. A pyrotechnic inflator can reach temperatures of 700°C to 800°C in 10 to 20 milliseconds but remains at an elevated temperature of 300°C to 500°C for 2 to 3 minutes. As a result of this, the inflator can burn through the bag by melting the uncoated or coated fabric that it comes into contact with.

[0005] During the deployment or inflation of the airbag, hot gases leave the inflator and pass through channels formed of coated fabric sewn together to allow the heated gas to deflect off and throughout the airbag. Accordingly, the seams and fabric of the air bag must be protected from the heat of the gas generated by the inflator by the incorporation of a heat shield. The heat shield is typically woven fabric coated at various coat weights of silicone that can be and are layered at 2 or more layers depending on the desired coat weight.

[0006] A variety of fabrics with filament or yarn densities ranging between 470 to 700 decitex or dtex are currently used. The most common fabric is a polyamide, such as nylon 6,6 with a yarn density of about 580 dtex. These fabrics are typically coated with a silicone elastomer coating having a coating weight ranging between 20 grams per square meter

(gsm or g/m²) and 150 g/m². Other known fabric compositions include polyesters and fiberglass although most manufacturers of airbags are moving away from fiberglass in order to avoid the common handling issues associated with this material. The assembly of the heat shield may also include metal liners to prevent the burn through of the hot gases. Other known approaches include using a calendared high consistency rubber sheet between two layers of fabric or in some instances adhered onto the surface of one layer of fabric. These high consistency rubber sheets incorporate between 600 g/m² to 900 g/m² of silicone and can be quite difficult to handle in that they can be excessively stiff or non-flexible and difficult to sew through.

[0007] While conventional heat shields are useful, they remain less than ideal. More specifically, airbags with a coated inside surface are still susceptible to burn-through because known coatings are only capable of providing limited protection when applied thinly, while a thickly applied coating defeats the safety system's overall goal of being lightweight and occupying a small volume. Thickly applied coatings are also difficult to sew because of a high coefficient of friction and may cause assembly problems when inserting the inflator into the module. Liners are also problematic because they introduce more bulk and weight to the airbag. Thus conventional heat shields suffer from either being unacceptably bulky and non-flexible or being able to only provide a limited degree of protection.

BRIEF SUMMARY OF THE INVENTION

[0008] In overcoming the enumerated drawbacks and other limitations of the related art, the present disclosure provides a thermally resistant layered composite sheet for use as a heat shield in an inflatable safety device, as well as an inflatable safety device incorporating such a layered composite sheet.

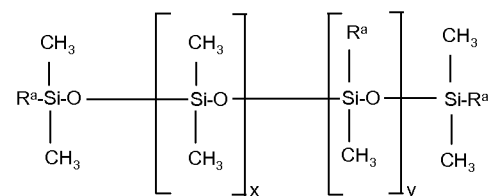
[0009] The thermally resistant layered composite sheet generally comprises a first fabric layer having a top side and a bottom side; and a thermal barrier layer located adjacent to one of the top side or bottom side in which the thermal barrier layer includes at least one layer of cellular foam. The composite sheet exhibits a thermal resistance value of six seconds or more at 725°C in a thermal penetration test; alternatively twelve seconds or more; alternatively 30 seconds or more.

[0010] Optionally, the fabric layer may comprise a fabric material and one or more silicone coatings. The silicone coating may be adjacent to the top side or bottom side of the fabric material either on the same side adjacent to the thermal barrier layer or opposite the side that is adjacent to the thermal barrier layer. Optionally, the thermal barrier layer may include one or more surfaces that are either smooth or textured.

[0011] The composite sheet may further comprise a second fabric layer, such that the second fabric layer is located adjacent to the thermal barrier layer on the side that is opposite to the first fabric layer. Optionally, the second fabric material may comprise a fabric material and at least one silicone coating.

[0012] The fabric layer can be a woven fabric, a nonwoven fabric, or a polymeric film or composite selected from polypropylene, polyethylene, fiberglass, polyamides, poly(ethylene) terephthalate, and compositions or mixtures thereof. The woven fabric may have threads with a thickness that is equal to or greater than 20 dtex. When the fabric layer is a nonwoven fabric or a polymeric film it may have a basis weight between about 40 g/m² and about 400 g/m².

[0013] Alternatively, the cellular foam of barrier layer is silicone cellular foam. This silicone cellular foam may be prepared from a composition comprising liquid silicone rubber (LSR). The polymers used in such compositions are of the following general structure:



where R^a represents -OH, -CH=CH₂, -CH₃, or another alkyl or aryl group, and the degree of polymerization (DP) is the sum of subscripts x and y. In liquid silicone rubber elastomers, the DP of the polymers used typically ranges from 10 to 1000 resulting in molecular weights ranging from 750 to 75,000 these polymers generally have a viscosity of less than 1,000,000 mPa-s at 25°C alternatively less than 750,000 mPa-s at 25°C. The polymer systems used in the formulation of these elastomers can be either a single polymer species or a blend of polymers containing different functionalities or molecular weights. The remaining ingredients of the composition are selected to conform with the R^a groups so that the composition can be cured into an elastomer. The silicone cellular foam used in the composite sheet exhibits a weight that is greater than about 400 g/m².

[0014] The optional silicone coating of the fabric layer may comprise a curable composition that is flowable at 25°C and cures to form an elastomer upon heating; such composition comprising an organopolysiloxane having two or more silicon atom-bonded alkenyl groups on average in one molecule: an organohydrogenpolysiloxane having at least 3 silicon atom-bonded hydrogen groups; a hydrosilylation reaction catalyst present in any amount capable of curing the coating composition; and a reinforcing filler, such as silica, among others. The silicone coating may be applied such that it exhibits a weight between about 10 to about 300 g/m².

[0015] According to another aspect of the present disclosure, an inflatable vehicle safety device comprises an inflator capable of providing an inflation fluid; a fluid compartment inflatable by the inflator; and one selected from the group of (i) an inflator wrap located adjacent to the inflator in which the inflator wrap comprises at least one layer of silicone cellular foam; (ii) a heat shield located within the fluid compartment; and (iii) a combination thereof. The inflator wrap or heat shield used in the inflatable vehicle safety device exhibits a thermal resistance value of six seconds or more at 725°C. The heat shield in (ii) comprises a first fabric layer having a top side and a bottom side; and a thermal barrier layer located adjacent to one of the top side or bottom side in which the thermal barrier layer includes at least one layer of cellular foam, such as silicone cellular foam. Within the vehicle safety device, the fluid compartment may be selected as one from a front air bag, a side air bag, an air curtain, H- or Y-socks, knee bag, and belt bag.

[0016] Optionally, the fabric layer may also comprise one or more silicone coatings. The heat shield may include at least one silicone coating adjacent the top side or bottom side of the fabric layer opposite the side that is adjacent to the thermal barrier layer. The heat shield may also comprise a second fabric layer located adjacent to the thermal barrier on the side that is opposite to the first fabric layer. The second fabric layer may also include an optional silicone coating when desired. The silicone coating may exhibit a coat weight between about 10 g/m² to about 400 g/m². The cellular foam may be silicone cellular foam having a weight between about 100 g/m² to about 600 g/m².

[0017] Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

[0019] Figure 1 is a schematic representation of an inflatable safety device used in a vehicle and includes an inflator, a heat shield, and an airbag;

[0020] Figures 2(a-d) are cross-sectional views of layered composite sheets used in the construction of the heat shield in Figure 1 according to the teachings of the present disclosure;

[0021] Figures 3(a-e) are cross-sectional views of layered composite sheets used in the construction of the heat shield of Figure 1 according to another aspect of the present disclosure;

[0022] Figure 4 is a cross-sectional view of a layered composite sheet at 30X magnification obtained using a scanning electron microscope (SEM);

[0023] Figure 5 is a graphical representation of the thermal resistivity of a layered composite sheet plotted as a function of cellular foam weight;

[0024] Figure 6 is a graphical representation of the thermal resistivity of another layered composite sheet plotted as a function of cellular foam weight in a sandwich configuration;

[0025] Figure 7 is a graphical representation of the thermal resistivity of various layered composite sheets having an open or sandwiched configuration plotted as a function of the cellular foam weight in the barrier layer highlighting preferred orientations; and

[0026] Figure 8 is a graphical comparison of the thermal resistivity of various composite sheets having an open or sandwiched configuration plotted as a function of cellular foam weight.

DETAILED DESCRIPTION OF THE INVENTION

[0027] The following description is merely exemplary in nature and is in no way intended to limit the present disclosure or its application or uses. It should be understood that throughout the description, corresponding reference numerals indicate like or corresponding parts and features.

[0028] The present disclosure generally relates to a heat shield for use in an inflatable safety device capable of protecting the occupants of a vehicle during an accident. For example, a heat shield made and used according to the teachings contained herein is described throughout the present disclosure in conjunction with an airbag for use in protecting the driver or passenger of an automobile in order to more fully illustrate the concept. The incorporation and use of such a heat shield in conjunction with other types of inflatable safety devices including but not limited to inflatable seat belts, inflatable knee bolsters, inflatable head liners, H-socks, Y-socks, head thorax bags, SAB cushions, and inflatable side curtains, as used in automobiles, as well as in other vehicles, such as motorcycles, boats, trucks, tractors, and off-road vehicles, among others, is contemplated to be within the scope of the disclosure.

[0029] Referring to Figure 1, an inflatable safety device 1 generally includes an air bag 5 and an inflator 10 that is capable of inflating the air bag 5. The inflator 10 contains an ignitable gas generating material, which, when ignited, produces a volume of inflation fluid 15 that inflates the air bag 5. Alternatively, the inflator 10 could contain a stored quantity of pressurized inflation fluid 15, or could contain a combination of pressurized inflation fluid 15 and ignitable material for heating the pressurized inflation fluid. Alternatively, the inflation fluid 15 is a gas.

[0030] In operation, when the inflator 10 is activated, the inflation fluid 15 flows out of the inflator 10 through outlets made in the outer side surface of the housing of the inflator 10. The flow of inflation fluid 15 from the inflator 10 is typically transverse to the central axis of the inflator 10. The inflation fluid 15 impinges on the inner surface of the heat shield 20, which diverts the fluid 15 away from the surface of the air bag 5. In other words, the heat shield 20 directs the inflation fluid 15 to flow into the air bag 5.

[0031] The presence of a heat shield 20 maintains the integrity of the fabric from which the air bag 5 is made during the operation of the inflatable safety device 1. The purpose of the heat shield 20 is to provide thermal resistance thereby preventing the burn through or melting of the fabric in the airbag 5 caused by the impingement of the hot inflation fluid 15 generated by the inflator 10 or from contact with the hot surface of the inflator 10 during or after the airbag 5 is inflated. The heat shield also allows the manufacturer to remove or eliminate the presence of a variety of metal subcomponents in the air bag 5 that may pose a long-term wear issue and potential threat to the occupant. For example, in a driver's side airbag 5, a sodium azide propellant in the inflator 10 upon activation will decompose at 3,000°C to produce nitrogen gas as the inflation fluid 15. During activation, the inflator 10 can reach temperatures of 700 to 800°C in 10 to 20 milliseconds and will remain at elevated temperatures of 300°C to 500°C for 2 to 3 minutes. As a result of this, the impingement of the hot inflation fluid 15 or the surface of the inflator 10 is capable of burning through the bag or melting the uncoated or coated fabric upon contact.

[0032] According to one aspect of the present disclosure, a flexible heat shield 20 is provided for use in an inflatable safety device 1. This heat shield 20 generally comprises a thermally resistant, layered composite sheet that includes a first fabric layer having a top side and a bottom side and a thermal barrier layer. The thermal barrier layer is located adjacent to one of the top side (side A) or bottom side (side B) of the first fabric layer. The thermal barrier layer further comprises at least one layer of cellular foam. The layered composite sheet has a thermal resistance value of six seconds or more at 725°C; alternatively, greater than 12 seconds at 725°C; and alternatively, greater than or equal to 30 seconds at 725°C.

[0033] When used in a heat shield, the layered composite sheet will have one side that is directly exposed to the hot inflator and heated gases arising from the inflator. The thermal resistance value, which is also known as the "burn-through rate", "burn-through time", or "thermal resistivity", represents the time it takes for a rod at a given temperature to contact the exposed side of the layered composite sheet and burn through the sheet. Each thermal resistance value reported herein is determined using a "Hot Rod" thermal resistivity test. More specifically, a type 304 stainless steel cylindrical rod (the "penetrator") weighing

50 grams and having a diameter and length of 1.27 cm (0.5 inch) and 5.08 cm (2 inches), respectively, is heated to an equilibrated temperature of 725°C. After heating, the hot penetrator is positioned 13.30 cm (5.25 inches) above the exposed surface of a test sample that is held taut in a test stand. The penetrator is then allowed to drop so that the end of the cylindrical rod contacts the exposed surface of the test sample. Sensors start a timer when the rod contacts the fabric and stop the timer when the rod passes through the fabric. The amount of time the heated rod is resting on the surface of the test sample is the measurement of the "thermal resistance" of the test sample. A thermal resistance time of greater than 30 seconds is widely considered the best possible rating since the penetrator will have sufficiently cooled after 30 seconds, thereby making it highly unlikely it will burn through the test sample once a time of 30 seconds is surpassed.

[0034] In the layered composite sheet, the cellular foam may include silicone foam comprised of liquid silicone rubber (LSR). For example, according to one aspect of the present disclosure, the use of foam generating liquid silicone rubber (LSR) may be used to develop a surface of silicone foam cells as part of the barrier layer located adjacent to the surface of the fabric layer. The fabric layer may be a woven fabric material or a non-woven, solid polymeric composite or film. The foam cells provide a sacrificial surface that abates the damage done to the fabric layer when the layered composite sheet is used as a heat shield. Although not wanting to be constrained by theory, the use of a foam structured surface is believed to provide thermal protection to the layered composite sheet through surface charring.

[0035] Referring now to Figures 2(a-d), the layered composite sheet 50 comprises a first fabric layer 55 and a thermal barrier layer 60. The first fabric layer 55 has a top side (A-side) and a bottom side (B-side). The thermal barrier layer 60 may be located adjacent to either the A-side of the fabric layer 55 (Figure 2a) or the B-side of the fabric layer 55 (Figure 2b). Optionally, the layered composite sheet 50 may further comprise a second fabric layer 56 also having an A-side and a B-side. In this configuration the barrier layer 60 may be located adjacent to both the first and second fabric layers 55, 56 (Figure 2c) or the barrier layer 60 may be located adjacent to only one of the first or second fabric layers 55, 56 (Figure 2d). The composition of each of the first and second fabric layers 55, 56 is independently selected. Alternatively, the first and second fabric layer 55, 56 may have the same composition.

[0036] Referring now to Figures 3(a-e), the barrier layer 60 comprises at least one layer of cellular foam (Figure 3a). The cellular foam of the barrier layer 65 is applied to the composite sheet 50 having a weight between 100 to 600 g/m². Alternatively, the cellular foam is silicone cellular foam. The first fabric layer 55 and/or the second fabric layer 56

may further comprise fabric material 65 and at least one silicone coating 70. The silicone coating 70 may be applied to the fabric material 65 such that the coating 70 is adjacent to the barrier layer 60 (Figure 3b) or on the side of the fabric layer 55, 56 that is opposite the barrier layer 60 (Figure 3c).

[0037] When the layered composite sheet 50 includes a second fabric layer 56, the second fabric layer 56 may be adjacent to the barrier layer 65 (Figure 2c) or located on the side of the first fabric layer 55 that is opposite the barrier layer 65 (Figure 2d) as previously described. Alternatively, the second fabric layer 56 may comprise a fabric material 66 and at least one second silicone coating 71. The second silicone coating 71 may be located adjacent to the barrier layer 60 (Figure 3d) or on the side of the second fabric material 66 that is opposite to the barrier layer 60 (Figure 3e).

[0038] The first silicone coating 70 and second silicone coating 71 are independently selected. Alternatively, the first silicone coating 70 and second silicone coating 71 may have the same composition. In each of the configurations shown in Figures 3(a-e) the side of the layered composite sheet that will be exposed to the hot temperature of the inflator gases may be either side as found desirable.

[0039] The layered composite sheet 50 of the present disclosure provides multiple benefits over conventional materials when used as a heat shield 20. For example, a layered composite sheet 50 comprising various liquid silicone rubber (LSR) based foams applied as a barrier layer 60 to various fabric layers 55, 56, such as woven and nonwoven systems of polyamide (e.g., nylon 6,6) and polyester demonstrate substantial thermal resistance when brought into contact with temperatures of 725°C or higher. Coat weights for the LSR-based foams of about 100 g/m² to about 600 g/m² outperform conventional materials at 40-50% less coated fabric weight. Alternatively, LSR-based foams having a coat weight of about 150 g/m² to about 350 g/m² are utilized. The use of the layered composite sheet 50 results in greater flexibility and simplification of the construction or assembly of the airbag 5 near the location of the inflator 15.

[0040] The barrier layer 60 may be silicone cellular foam prepared using liquid silicone rubber (LSR), including without limitation any gum or base material. In creating the cellular foam any blowing agent known to one skilled in the art, including but not limited to, hydrogen gas, nitrogen gas, water vapor, and mixtures thereof can be added to the mixture or generated by a reaction in situ to create a foam or sponge-like structure.

[0041] The liquid silicone rubber foam may be a single component LSR or a two-component LSR. Examples of suitable commercial LSR products for the production of liquid silicone rubber foams include SHS-1000 Silicone Foam, Dow Corning® 3-8277 Foam, Dow Corning® 3-8186 Thixotropic Foam, Dow Corning® 3-8235 Silicone Foam, and

Dow Corning® 3-6584 Silicone Foam (Dow Corning Corporation, Midland, Michigan), among others.

[0042] The barrier layer 60 prepared as a two-component LSR foam may comprise at least one organohydrogensiloxane, at least one polydiorganosiloxane exhibiting unsaturation reacted in the presence of a hydrosilylation catalyst or free radical generator. Suitable polyorganosiloxanes contain at least two alkenyl radicals per molecule and exhibit a viscosity at 25°C that is about 10 to 1,000,000 mPa-s. alternatively between about 100 to 250,000 mPa-s at 25°C. The alkenyl radicals include vinyl, allyl and hexenyl groups or mixtures thereof; alternatively the alkenyl radicals are vinyl groups. About 90 percent of the repeating units in the polyorganosiloxane backbone are diorganosiloxane units represented by the general formula R^1R^2SiO , where R^1 and R^2 are independently selected from monovalent unsubstituted and substituted hydrocarbon radicals that typically contain from 1 to about 10 carbon atoms. The alkenyl radicals that characterize the curable polyorganosiloxane are preferably located at the terminal siloxane unit of the molecule; however one or more can be bonded to non-terminal siloxane units. A specific example of the polydiorganosiloxane includes dimethylvinylsiloxy-terminated dimethyl siloxane, tetramethyldivinylidisiloxane.

[0043] The organohydrogensiloxane in the silicone cellular foam functions as a curing agent, such that the silicon-bonded hydrogen atoms in the organohydrogensiloxane react with the alkenyl radicals of the polyorganosiloxane. The silicon-bonded hydrogen atoms in the organohydrogensiloxane are also used to generate hydrogen gas for foaming the composition when desirable. Organohydrogensiloxanes that may be used contain an average of at least three silicon-bonded hydrogen atoms per molecule. The other valences on the silicon atoms are occupied with organic groups selected from alkyl having 1 to 6 carbon atoms and phenyl groups. Preferred alkyl groups include methyl, ethyl and hexyl. The most preferred organic groups are methyl groups.

[0044] The organohydrogensiloxane can have a linear, cyclic, or branched structure, and can be a homopolymer, a copolymer, mixtures of two or more different homopolymers, mixtures of two or more different copolymers or mixtures of these types of polymers. Polymers that are suitable for use include, but are not limited to, polymethylhydrogensiloxane, trimethylsiloxy-terminated polymethylhydrogensiloxane, copolymers of dimethylsiloxane, methylhydrogensiloxane and trimethylsiloxane units and copolymers of dimethylsiloxane, methylhydrogensiloxane and dimethylhydrogensiloxane units. Alternatively, the organohydrogensiloxanes have a linear structure, exhibit a viscosity of about 1 mPa-s at 25°C to about 10,000 mPa-s at 25°C, and comprise dialkylsiloxane

and alkylhydrogensiloxane units with trialkylsiloxy terminal units, where the alkyl radicals contain from 1 to 4 carbon atoms.

[0045] The amount of the organohydrogensiloxane used should be sufficient to provide the desired degree of crosslinking during cure and to produce the required amount of hydrogen gas for foaming the mixture. Generally, the proportion of the organohydrogensiloxane will be within the range of from about 2 to about 80 parts, and alternatively from about 5 to about 40 parts by weight per 100 parts by weight of the polydiorganosiloxane. Additional information regarding the composition of the silicone cellular foam is provided in U.S. Patent No.'s 6,084,002, 5,574,073, 4,433,069, 5,670,556, 5,733,946, and 5,708,043, the entire contents of which are incorporated by reference.

[0046] Optionally, the silicone cellular foam may include a hydroxyl containing compound selected from the group consisting of polyols, monofunctional alcohols, silanol group-containing organosilanes, silanol group-containing organosiloxanes, and water or mixtures thereof. The hydroxyl groups in the compound react with some of the silicon-bonded hydrogen of organohydrogensiloxane to produce hydrogen, which creates the cells in the foam. These hydroxyl containing compounds may be referred to by one skilled in the art as a blowing agent. When the hydroxyl containing compound comprises a polyol, it is an organic alcohol having from about 3 to about 12 carbon atoms and containing an average of at least two hydroxyl groups per molecule. The carbon chain which makes up the backbone of the polyol may be straight-chained or branched, or may have an aromatic ring to which a hydroxyl group is not directly bonded. Several specific examples of such polyols include aliphatic polyhydric alcohols, e.g., diols, such as 1,2-ethanediol, 2,3-propanediol, 1,3-propanediol, 1,4-butanediol, 1,5 pentanediol, and 1,6 hexane diol; 1,2,3-propanetriol; 2,2-bis-hydroxymethyl-1butanol; tetritols, such as erythritol and pentaerythritol (2,2bis-hydroxymethyl-1,3-propane diol); pentitols, such as arabitol, xylitol, and methylpentitol; hexitols, such as mannitol and sorbitol; and cycloaliphatic polyhydric alcohols, such as cyclohexanediols, cyclohexane tirols, and inositol. Sufficient polyol should be used to obtain the necessary amount of hydrogen for the foaming process. Generally about 0.05 to 8 parts by weight of the hydroxyl containing compound should be used per 100 parts of the combined weight of the polydiorganosiloxane and organohydrogensiloxane. Alternatively, the amount of the hydroxyl containing compound is 0.2 to 5 parts by weight per 100 parts of the combined weight of the polydiorganosiloxane and organohydrogensiloxane

[0047] Optionally, the cellular foam may further comprise heat resistant fibrous or cellular materials as finely divided reinforcing fillers and non-reinforcing mineral fillers. Such heat resistant and fibrous or cellular materials may include, but not be limited to, various amorphous or crystalline inorganic compounds, such as fumed silica, precipitated silica,

quart and calcium carbonate; and metal oxides such as alumina, hydrated alumina, ferric oxide and titanium dioxide; or mixtures thereof. The amount of the fibrous or cellular materials added to the cellular foam may range from about 5 wt.% to about 50 wt.% with respect to the overall weight of the cellular foam; alternatively, from about 15 wt.% to 35 wt.%; alternatively, from about 30 wt.% to 35 wt.%. Such fillers may be treated to render them hydrophobic. A compound used to treat the fillers may be silane, such as an alkoxy silane, an alkoxy-functional oligosiloxane, a cyclic polyorganosiloxane, a hydroxyl-functional oligosiloxane, such as a dimethyl siloxane or methyl phenyl siloxane, a stearate, or a fatty acid.

[0048] The cellular foam may also include other additives and pigments for thickening, as well as other purposes. Examples of such additives include siloxane resins, hydrogenated castor oil, pigments, such as carbon black, zinc oxide, dyes, and hexamethyldisiloxane, as well as a variety of anti-oxidants, heat stabilizers, thixotropic agents, foam stabilizers, ultraviolet light stabilizers, flame retarding agents, and catalyst inhibitors such as cyclic methylvinylsiloxanes to increase working time. The cellular foam may also include a solvent, such as xylene to assist in the dispersion of the various components.

[0049] The curative molecule or process may be any molecule or process known to one skilled in the art, including but not limited to the use of hydrosilylation catalysts or free radical generators, such as organic peroxides or ultraviolet radiation. The organic peroxide selected for use may include any peroxide known to one skilled in the art to be useful in silicone rubber processing. Several examples of organic peroxides include any peroxide that belongs without limitation to the peroxide family of diperoxyketals, peroxydicarbonates, peroxyesters, diacyl peroxides, benzoyl peroxide, ketone peroxides, dialkyl peroxides, or hydroperoxides.

[0050] The hydrosilylation catalyst may comprise a platinum group metal catalyst including any rhodium, ruthenium, palladium, osmium, iridium or platinum-containing catalysts known to one skilled in the art to facilitate hydrosilylation reactions. Alternatively, the platinum group catalyst is a platinum catalyst. Such catalysts are also efficient in promoting the reaction between SiH groups and C-OH groups in organic alcohols to provide hydrogen for the foaming process. Suitable forms of platinum catalysts include but are not limited to chloroplatinic acid, 1,3-diethenyl-1,1,2,2-tetramethyldisiloxane platinum complex, complexes of platinous halides or chloroplatinic acid with divinylsiloxane and complexes formed by the reaction of chloroplatinic acid, divinyltetramethyldisiloxane and tetramethyldisiloxane.

[0051] The amount of platinum catalyst is generally the amount that provides from 5 to 250 parts by weight of platinum metal per million parts of the combined weights of the polydiorganosiloxane and organohydrogensiloxane. An amount of platinum less than 5 parts per million by weight is insufficient for a rubber to form, while an amount greater than 200 parts per million by weight is not economical. The silicone cellular foam may be either low-density or high-density in nature; alternatively, the cellular foam is low-density. The cellular foam is cured at a temperature less than about 240°C, alternatively at a temperature ranging from about 25°C to about 100°C with or without added relative humidity. The conditions under which the cellular foam layer is allowed to cure can impact the resulting material density. Referring now to Figure 4, a thermal barrier layer, shown in this specific example with a cellular foam structure in the layered composite sheet can exhibit a smooth surface or an uneven or textured surface 80.

[0052] Optionally, a silicone coating 70, 71 may also comprise part of the fabric layers 55, 56. This silicone coating 70, 71 may be any conventional silicone coating known to one skilled in the art. The silicone coating 70, 71 may comprise an organopolysiloxane having aliphatically unsaturated hydrocarbon or hydrocarbonoxy substituents, an organosilicon cross-linker having at least 3 silicon-bonded hydrogen atoms, a catalyst able to promote the reaction of the aliphatically unsaturated hydrocarbon or hydrocarbonoxy substituents with Si-H groups and a silica reinforcing filler. The silica filler may include 2% to 60% by weight based on the silica filler of an oligomeric organopolysiloxane containing Si-bonded methyl and vinyl groups and silanol end groups.

[0053] The silicone coating 70, 71 may be a liquid silicone rubber (LSR) coating, which includes a mixture of four components (A), (B), (C), and (D), such that (A) is an organopolysiloxane having two or more silicon atom-bonded alkenyl groups on average in one molecule: 100 parts by weight of the organopolysiloxane; (B) is an organohydrogenpolysiloxane; (C) is a hydrosilylation reaction catalyst present in any amount capable of curing the coating composition, and (D) is a reinforcing silica fine powder present 0.1 to 50 parts by weight of the coating composition. Component (B) is further described as being either (b-1) an organohydrogenpolysiloxane having at least three silicon atom-bonded hydrogen atoms in one molecule with at least one of the hydrogen atoms being present as a siloxane unit represented by the formula of $R\text{HSiO}_{2/2}$ (wherein R represents a non-substituted or substituted monovalent hydrocarbon group containing no aliphatic unsaturated bond) in the molecule, (b-2) a linear organohydrogenpolysiloxane having one silicon atom-bonded hydrogen atom only at each of both terminals of the molecular chain and having no aliphatic unsaturated bond(s) in the molecule, or a mixture of (b-1) and (b-2),

[0054] The organohydrogenpolysiloxanes in (b-1) and (b-2) may be blended such that the molar ratio of silicon atom-bonded hydrogen atoms contained in (b-1) and (b-2) : alkenyl groups contained in component (A) ranges from about 0.8:1.0 to about 2.5:1.0, and the total number of silicon atom-bonded hydrogen atoms contained in organohydrogenpolysiloxane (b-2) is 70 to 100% of the total number of silicon atom-bonded hydrogen atoms contained within component (B). When the silicon atom-bonded hydrogen atoms contained in organohydrogenpolysiloxane (b-2) is 100%, component (B) consists only of organohydrogenpolysiloxane (b-2).

[0055] The silicone coating 70, 71 may be applied to the fabric layers 55, 56 with a coating weight between 10 g/m² and 400 g/m²; alternatively, 25 g/m² to 200 g/m². A further description of the silicone coating 70, 71 that may comprise part of the first and/or second fabric layer 55, 56 is provided in International Patent Publication No.'s WO 2011/137121 and WO 2011/82134, the entire contents of which are hereby incorporated by reference.

[0056] The first and second fabric layers 55, 56 may include any polymeric film or composite, as well as any woven or nonwoven fabric materials 65, 66 having filament or yarn density that is equal to or greater than 20 decitex or dtex, alternatively, ranging between about 200 to about 900 dtex, alternatively, between about 470 dtex to about 700 dtex; alternatively about 580 dtex. One example of a fabric material 65, 66 is a polyamide with a yarn density of about 580 dtex woven in the warp and weft directions. Another example of a woven fabric material 65, 66 includes polyamide fibers woven in one direction, such as the warp direction, and polyester fibers woven in another direction, such as the weft direction. The fabric material 65, 66 of the fabric layer 55, 56 may have a composition comprised of polypropylene, polyethylene, polyamides, fiberglass, poly(ethylene) terephthalate, and compositions or mixtures thereof. Specific examples of polyamides that may be used as the fabric material include nylon 6,6 and Kevlar®.

[0057] When the fabric layer 55, 56 is a woven fabric material 65, 66, the weave density of the fabric material may be any range preselected based upon the application criteria; alternatively the weave density may range from about 41x41 to about 53x53. When the fabric layer 55, 56 is a nonwoven fabric material or composite 65, 66, the thickness of the film may be determined as a function of weight per unit area. A nonwoven fabric material or a polymeric composite when used as the fabric layer 55, 56 will have a weight that ranges between about 40 g/m² and about 400 g/m², alternatively between about 70 g/m² and 135 g/m². The fabric layer 55, 56 may further include any additives or be exposed to any surface treatments known to one skilled in the art, including but not limited to surface fluorination.

[0058] The barrier layer 60 may be applied to the fabric layer 55, 56 through the use of a nip roller, a knife blade, or any other process known to one skilled in the art in order to control the coating weight to any desired or targeted amount and to apply a release liner. The liquid silicone rubber (LSR) foam is coated onto the surface of the fabric layer 55 or between two fabric layers 55, 56 and then passed through rollers with the initial gap set to accommodate the desired thickness of the cellular foam layer. A release liner (not shown) then may optionally be applied. Alternatively, a silicone coating 70, 71 may be applied onto the fabric layer 55, 56 using knife coating, dip coating, flow coating, or any other conventional technique known to one skilled in the art. The resulting layered composite sheet 50 may be supplied as a finished product in the form of a converter roll or as individual pieces. Individual pieces may be cut from a roll using lasers or the like.

[0059] According to another aspect of the present disclosure, a vehicle safety device is provided that comprises an inflator capable of generating an inflation fluid; a fluid compartment that can be inflated by the inflator; and a heat shield located within the fluid compartment. The fluid compartment is selected as one from a front air bag, a side air bag, an air curtain, H or Y socks, a knee bag, and a belt bag, among others. Alternatively, the fluid compartment is selected as a front air bag or a side air bag.

[0060] The heat shield in the vehicle safety device comprises one or more of the layered composite sheets including a fabric layer and a barrier layer as previously described herein. The barrier layer used in the layered composite sheets comprises at least one layer of cellular foam. Alternatively, the fabric layer may comprise a fabric material and one or more silicone coatings applied to the surface of the fabric material. The cellular foam may be silicone cellular foam. The heat shield may also include, at least one silicone coating adjacent the side of the fabric layer that is opposite the side adjacent to the barrier layer. When desired, the layered composite sheets used in the heat shield may also include a second fabric layer. This second fabric layer may be located adjacent to the thermal barrier on the side that is opposite to the first fabric layer. At least one silicone coating may optionally be applied to the fabric material of the second fabric layer. Optionally, the heat shield may include additional protective features or materials, such as the incorporation of a metal plate or liner. The heat shield may also be attached or located adjacent to the surface of the inflator. In fact, the heat shield can be constructed such that it encompasses or surrounds the inflator.

[0061] According to yet another aspect of the present disclosure, the inflator may be encompassed or surrounded by an inflator wrap that is comprised of a silicone cellular foam layer. The inflator wrap may be attached to or located adjacent to the inflator. The general purpose of the inflator wrap is to provide thermal resistance against direct contact

between the hot inflator and the fabric or internal surface of the inflatable safety device. The cellular foam layer associated with the inflator wrap may be similar to or the same in composition as that previously described with respect to the thermal barrier layer used in the heat shield. Alternatively, the cellular foam layer used as the inflator wrap is silicone rubber foam. Such an inflator wrap may also be used in combination with a heat shield to further enhance the thermal resistance of the inflatable safety device.

[0062] Several examples of thermal barrier layers are prepared and compared according to the teachings of the present disclosure using the following method. In Run No. 1, a 473 mL a weight of 125 grams of the base material and 12.5 grams of curative are added together to form a foamable mixture (Dow Corning® 3-8277 Foam, Dow Corning Corporation) and stirred for 60 seconds. In Run No. 2, a total of 65 grams of Part A and 65 grams of Part B of a two-part LSR (SHS-1000 Silicone Foam, Dow Corning Corporation) are added and stirred together to form the foamable mixture. The foamable mixture (Run No.'s 1 or 2) is poured onto a sheet of Mylar™ plastic or a fabric layer, a second sheet of Mylar or a fabric layer is then placed over the base/curing agent mixture. The foamable mixture is then hand-drawn between two parallel rollers or cylinders in a coating apparatus with the gap between the rollers set at the desired thickness, e.g., at 0.0457 cm – 0.140 cm (0.018" to 0.055") plus the thickness of the 2 sheets of Mylar or fabric. Once the foamable mixture is drawn down it is cured for several minutes, e.g., 3-5 minutes, at less than about 100°C, alternatively between about 50°C and 100°C.

[0063] The thermal resistivity of conventional 470 dtex nylon 6,6 fabric including a silicone coating applied to the surface of the fabric when tested in a Hot Rod Test using a penetrator at a temperature of 725°C is less than about 4 seconds. Even when multiple layers (e.g., 2 or 3 layers) of the fabric including a silicone coating of 25-30 g/m² are stacked together the thermal resistivity of the stacked composite is less than about 5 seconds.

[0064] In comparison, the addition of a barrier layer including at least one cellular foam layer dramatically enhances the thermal resistivity of the coated fabric as shown in Figure 5. The thermal resistivity of the coated polyamide fabric increases to 20 or more seconds with the application of a silicone cellular foam a layer (Run No.'s 1 and 2) at an applied weight of about 250 g/m² to 370 g/m². Similarly, the application of a silicone cellular foam layer having an applied weight of about 150 g/m² to 250 g/m² (Run No.'s 1 and 2) sandwiched between two coated polyamide fabrics increases the thermal resistivity to about 10 seconds or more as shown in Figure 6.

[0065] A variety of layered composite sheets prepared according to the teachings of the present disclosure exhibit improved or enhanced thermal resistivity. Each of these

composite sheets comprises a fabric layer having the composition of a polyamide with different weave densities (Fabric 1 = 49 x 49; Fabric 2 = 46 x 46). A description of the barrier layer used in composite sheets, as well as the thermal resistivity exhibited by the composite sheets is provided in Figure 7 as a plot of thermal resistivity versus weight of the cellular foam used in the barrier layer. The barrier layer comprises various combinations of Foam 1 (SHS-1000 Silicone Foam, Dow Corning Corp.), Foam 2 (Dow Corning® 3-8277 Foam, Dow Corning Corp.), and fabric layers with and without a silicone coating (Si) against the foam surface. The structure of the composite sheets with the side of the sheet exposed to the heat source being identified with an arrow (→) is also provided in Figure 7. For example, the nomenclature of → Si Fabric 2/Foam 1/Si Fabric 2 refers to the heat source being placed against a silicone coating in a sandwiched composite sheet layered such that the silicone coating is adjacent to Fabric 2, which is adjacent to Foam 1, which is adjacent to a second silicone coating, which is adjacent to Fabric 2. As shown in Figure 7, each of the composite (sandwich) sheets exhibits a thermal resistivity in excess of 20 seconds when tested using the Hot Rod Resistivity Test at a temperature of 725°C. Figure 7 also shows there is a preferred orientation for both the composite and single layer heat shield sample for the heat source to be placed against. For example, in Figure 7 the preferred orientation is shown by a triangular point (▲) while the alternate orientation is shown by a circular point (●) and in all cases the thermal resistivity increased ranging from 10% to 900%, the difference depending on the foam and fabric utilized.

[0066] The following specific examples are given to further illustrate the preparation and testing of a heat shield in an inflatable safety device according to the teachings of the present disclosure and should not be construed to limit the scope of the disclosure. Those skilled-in-the-art, in light of the present disclosure, will appreciate that many changes can be made in the specific embodiments which are disclosed herein and still obtain alike or similar result without departing from or exceeding the spirit or scope of the disclosure.

[0067] In each of the following examples, the fabric layer and the barrier layer is identified as Fabric (i-xi) and Foam (a-d). A description of the composition associated with each Fabric layer (i-xi) and each foam layer (a-d) is provided below in Tables 1 and 2.

[0068] Table 1

Fabric Reference No.	Description of Fabric Layer	Basis Weight (gsm)
Fab-i	470 dtex uncoated PolyAmide 6,6 fabric material with weave density of 46x46	185
Fab-ii	470 dtex PolyAmide 6,6 fabric material with weave density of 46x46 and 25 gsm silicone coating	205
Fab-iii	470 dtex PolyAmide 6,6 fabric material with weave density of 46x46 and 30 gsm silicone coating	210
Fab-iv	470 dtex PolyAmide 6,6 fabric material with weave density of 46x46 and 120 gsm silicone coating	305
Fab-v	470 dtex PolyAmide 6,6 fabric material with weave density of 46x46 and 25 gsm silicone coating	205
Fab-vi	550 dtex uncoated PET fabric material	220
Fab-vii	550 dtex PET fabric material and 25 gsm silicone coating	245
Fab-viii	700 dtex uncoated PolyAmide 6,6 fabric material	227
Fab-ix	470 dtex PolyAmide 6,6 OPW fabric material coated on both sides with 35 gsm silicone coating	532
Fab-x	Uncoated nonwoven composite or film	145
Fab-xi	470 dtex PolyAmide 6,6 fabric material with weave density of 49x49 and 30 gsm silicone coating	210

[0069] Table 2

Foam Reference No.	Source of Barrier Layer
Foam (a)	No. SHS 1000 (Dow Corning, Midland, Michigan)
Foam (b)	No. 3-8277 (Dow Corning, Midland, Michigan)
Foam (c)	No. 3-8186 (Dow Corning, Midland, Michigan)
Foam (d)	No. 3-6584 (Dow Corning, Midland, Michigan)

[0070] Example 1 – Preparation and Testing of Heat Shield in an Airbag

[0071] Six inflatable safety devices are assembled with each safety device including an airbag, an inflator, and a heat shield. The heat shield in each safety device includes a woven fabric layer of the same composition as the polyamide fabric from which the airbag is made and a layer of silicone rubber. The silicone cellular foam layer is Foam (a). The weight of the cellular foam applied to the woven fabric layer is (1) 188 g/m², (2) 212 g/m², (3) 216 g/m², (4) 240 g/m², (5) 260 g/m², and (6) 300 g/m². Each inflatable safety device was activated with the inflator filling the airbag with gas. The heat shield protected the fabric of the airbag from burn through in each of the trials. All of the airbags sustained acceptable breakthrough of the sewing support.

[0072] Example 2 – Preparation and Testing of Heat Shield in SAB Cushions

[0073] Three inflatable safety devices are assembled with each safety device including an inflatable cushion, an inflator, and a heat shield. The cushion is constructed of a 470 dtex fabric coated with a silicone coating having a coating weight of 25 g/m², Foam (b) The heat shield in each safety device includes a woven fabric layer having the same

composition as the polyamide fabric from which the airbag is made and a layer of silicone cellular foam, Foam (a). The weight of the silicone cellular foam applied to the woven fabric layer is (1) 224 g/m², (2) 198 g/m², and (3) 188 g/m². Each inflatable safety device was activated with the inflator filling the cushion with gas. The heat shield protected the fabric of the cushion from burn through in each of the trials. No visual thermal anomalies are observed from the outside of the cushion.

[0074] Example 3 – Thermal Resistance of Composite Sheet with Sandwiched Barrier Layer

[0075] Two configurations of the composite sheet are prepared and tested using the hot rod test. The first configuration (A) comprises a first fabric layer with a silicone coating located on the side of the fabric that is away from or opposite the barrier layer. The silicone coating of the first fabric layer represents the surface that makes initial contact with the hot rod during the performance of the test. The second fabric layer is located adjacent the barrier layer on the opposite side of the barrier layer away from the first fabric layer. Thus the barrier layer is “sandwiched” between the first and second fabric layers. The second fabric layer also includes a silicone coating that is located on the surface of the fabric material that is adjacent to the barrier layer. Thus according to the previously described nomenclature, the first configuration (A) is described as → Si Fabric / Foam / Si Fabric.

[0076] The second configuration (A') is a similar sandwich configuration except that the silicone coating is located on the opposite side of the fabric material as previously described for configuration (A). Thus configuration (A') is defined according to the nomenclature as being → Fabric Si / Foam / Fabric Si. Thus in configuration (A') the uncoated side of the fabric material makes initial contact with the hot rod during the performance of the test protocol.

[0077] A total of 16 runs were performed with a description of the composite sheet used in each run provided in Table 3 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 3-1 to Run 3-2, Run 3-3 to Run 3-4, Run 3-5 to Run 3-6, Run 3-7 to Run 3-8, Run 3-9 to Run 3-10, Run 3-11 to Run 3-12, Run 3-13 to Run 3-14, and Run 3-15 to Run 3-16 demonstrates that a composite sheet having orientation A exhibits a greater thermal resistance than a composite sheet having orientation A'. The comparison of Run No.'s 3-1 and 3-2 with Run No.'s 3-5 and 3-6 demonstrate that a composite sheet with a barrier layer comprised of Foam (a) exhibits a greater thermal resistance than a composite sheet comprised of a similar amount of Foam (b). In addition, comparison of Run No.'s 3-11 and 3-12 with Run No.'s 3-13 through 3-16 demonstrates that a composite sheet with approximately one-half the amount of Foam (a),

e.g., 98 g/m², exhibits a similar thermal resistance as a composite sheet with Foam (c), e.g., 172-174 g/m².

[0078] Table 3

<i>Run Reference No.</i>	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Description of 2nd Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 3-1	A	Foam (b)	Fabric v	Fabric v	230	28.5
Run 3-2	A'	Foam (b)	Fabric v	Fabric v	230	22.5
Run 3-3	A	Foam (b)	Fabric v	Fabric xi	225	34.3
Run 3-4	A'	Foam (b)	Fabric xi	Fabric v	225	22.0
Run 3-5	A	Foam (a)	Fabric v	Fabric v	230	120.0
Run 3-6	A'	Foam (a)	Fabric v	Fabric v	230	91.0
Run 3-7	A	Foam (a)	Fabric v	Fabric v	222	34.7
Run 3-8	A'	Foam (a)	Fabric v	Fabric v	222	28.3
Run 3-9	A	Foam (a)	Fabric iii	Fabric iii	76	5.0
Run 3-10	A'	Foam (a)	Fabric iii	Fabric iii	76	5.0
Run 3-11	A	Foam (a)	Fabric iii	Fabric iii	98	6.6
Run 3-12	A'	Foam (a)	Fabric iii	Fabric iii	98	8.6
Run 3-13	A	Foam (c)	Fabric iii	Fabric iii	172	8.9
Run 3-14	A'	Foam (c)	Fabric iii	Fabric iii	172	6.9
Run 3-15	A	Foam (c)	Fabric ii	Fabric ii	174	8.6
Run 3-16	A'	Foam (c)	Fabric ii	Fabric ii	174	6.7

[0079] Example 4 – Thermal Resistance of Composite Sheet with Single Barrier Layer

[0080] Two additional configurations of the composite sheet are prepared and tested using the hot rod test. The third configuration (B) comprises a first fabric layer with a silicone coating located on the side of the fabric that is towards or facing the barrier layer. The barrier layer represents the surface that makes initial contact with the hot rod during the performance of the test. Thus according to the previously described nomenclature, the third configuration (B) is described as → Foam / Si Fabric. Both Run No.'s 4-9 and 4-11 are prepared with the surface of the barrier layer being textured.

[0081] The fourth configuration (B') is similar to configuration (B) except that the fabric material represents the surface that makes initial contact with the hot rod during the performance of the test protocol. Thus configuration (B') is defined according to the nomenclature as being → Fabric Si / Foam.

[0082] A total of 12 runs were performed with a description of the composite sheet used in each run provided in Table 4 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 4-1 to Run 4-2, Run 4-3

to Run 4-4, Run 4-5 to Run 4-6, Run 4-7 to Run 4-8, Run 4-9 to Run 4-10, and Run 4-11 to Run 4-12 demonstrates that a composite sheet having orientation B exhibits a thermal resistance that is between 2.0 to about 5.5 times greater than the thermal resistance of a composite sheet having orientation B'. The comparison of Run No. 4-1 with Run No. 4-7 demonstrates that a composite sheet with Foam (a) exhibits a greater thermal resistance than a composite sheet with the about the same amount of Foam (b). Finally, the comparison of Run No.'s 4-9 and 4-11 with Run No.'s 4-5 and 4-7 demonstrate that texturing the surface of the barrier layer initially exposed to the hot rod increases the thermal resistance of the composite sheet.

[0083] Table 4

<i>Run Reference No.</i>	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 4-1	B	Foam (a)	Fabric xi	239	53.9
Run 4-2	B'	Foam (a)	Fabric xi	239	16.5
Run 4-3	B	Foam (a)	Fabric xi	244	93.0
Run 4-4	B'	Foam (a)	Fabric xi	244	16.9
Run 4-5	B	Foam (b)	Fabric xi	214	20.7
Run 4-6	B'	Foam (b)	Fabric xi	214	10.4
Run 4-7	B	Foam (b)	Fabric xi	217	24.5
Run 4-8	B'	Foam (b)	Fabric xi	217	10.0
Run 4-9	B w/ texture	Foam (b)	Fabric xi	216	33.4
Run 4-10	B'	Foam (b)	Fabric xi	216	10.2
Run 4-11	B w/ texture	Foam (b)	Fabric xi	222	29.8
Run 4-12	B'	Foam (b)	Fabric xi	222	8.0

[0084] Example 5 – Thermal Resistance of Composite Sheets Exhibiting Additional Single Barrier Layer Configuration

[0085] Two additional configurations of the composite sheet are prepared and tested using the hot rod test. The fifth configuration (C) comprises a first fabric layer with a silicone coating located on the side of the fabric that is away from or opposite the barrier layer. The barrier layer represents the surface that makes initial contact with the hot rod during the performance of the test. Thus according to the previously described nomenclature, the third configuration (C) is described as → Foam / Fabric Si.

[0086] The sixth configuration (C') is similar to configuration (C) except that the silicone coating on the fabric material represents the surface that makes initial contact with the hot rod during the performance of the test protocol. Thus configuration (C') is defined according to the nomenclature as being → Si Fabric / Foam.

[0087] A total of 6 runs were performed with a description of the composite sheet used in each run provided in Table 5 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 5-1 to Run 5-2, Run 5-3 to Run 5-4, and Run 5-5 to Run 5-6 demonstrates that a composite sheet having orientation C exhibits a thermal resistance that is between about 5 to about 11 times greater than the thermal resistance of a composite sheet having orientation C'.

[0088] Table 5

Run Reference No.	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 5-1	C	Foam (a)	Fabric iii	211	56.3
Run 5-2	C'	Foam (a)	Fabric iii	211	11.0
Run 5-3	C	Foam (b)	Foam ii	224	110.3
Run 5-4	C'	Foam (b)	Fabric v	224	12.6
Run 5-5	C	Foam (b)	Foam ii	276	120.0
Run 5-6	C'	Foam (b)	Fabric iii	276	11.6

[0089] Example 6 - Thermal Resistance of Composite Sheet with Additional Sandwiched Barrier Layer Configurations

[0090] Two additional configurations of the composite sheet are prepared and tested using the hot rod test. The seventh configuration (D) comprises a first fabric layer with a silicone coating located on the side of the fabric that is facing or adjacent the barrier layer. The fabric material of the first fabric layer represents the surface that makes initial contact with the hot rod during the performance of the test. The second fabric layer is located adjacent the barrier layer on the opposite side of the barrier layer away from the first fabric layer. Thus the barrier layer is "sandwiched" between the first and second fabric layers. The second fabric layer is uncoated in that it does not comprise a silicone coating in addition to the fabric material.. Thus according to the previously described nomenclature, the first configuration (D) is described as → Fabric Si /Foam / Fabric.

[0091] The eighth configuration (D') is a similar sandwich configuration except that the second fabric layer makes initial contact with the hot rod during the performance of the test protocol.. Thus configuration (D') is defined according to the nomenclature as being → Fabric / Foam / Si Fabric.

[0092] A total of 9 runs were performed with a description of the composite sheet used in each run provided in Table 6 along with the thermal resistance results obtained for each

composite sheet in the Hot Rod Test. The comparison of Run 6-3 to Run 6-4 and Run 6-5 to Run 6-6 demonstrates that a composite sheet having orientation D exhibits a greater thermal resistance than a composite sheet having orientation D'.

[0093] Table 6

Run Reference No.	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Description of 2nd Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 6-1	D	Foam (a)	Fabric iii	Fabric vi	230	120.0
Run 6-2	D'	Foam (a)	Fabric vi	Fabric iii	230	120.0
Run 6-3	D	Foam (a)	Fabric iii	Fabric vi	220	120.0
Run 6-4	D'	Foam (a)	Fabric vi	Fabric iii	220	25.9
Run 6-5	D	Foam (a)	Fabric iii	Fabric vi	206	67.2
Run 6-6	D'	Foam (a)	Fabric vi	Fabric iii	206	21.1
Run 6-7	D	Foam (d)	Fabric vii	Fabric vi	101	4.5
Run 6-8	D	Foam (b)	Fabric iii	Fabric i	256	16.2
Run 6-9	D'	Foam (b)	Fabric i	Fabric iii	256	19.7

[0094] Example 7 – Thermal Resistance of Composite Sheet with Additional Sandwiched Barrier Layer Configurations

[0095] Two additional configurations of the composite sheet are prepared and tested using the hot rod test. The ninth configuration (E) comprises a first fabric layer with a silicone coating located on the side of the fabric that is opposite the barrier layer. The silicone coating of the first fabric layer represents the surface that makes initial contact with the hot rod during the performance of the test. The second fabric layer is located adjacent the barrier layer on the opposite side of the barrier layer away from the first fabric layer. Thus the barrier layer is “sandwiched” between the first and second fabric layers. The second fabric layer is uncoated in that it does not comprise a silicone coating in addition to the fabric material.. Thus according to the previously described nomenclature, the first configuration (E) is described as → Si Fabric / Foam / Fabric.

[0096] The tenth configuration (E') is a similar sandwich configuration except that the second fabric layer makes initial contact with the hot rod during the performance of the test protocol.. Thus configuration (E') is defined according to the nomenclature as being → Fabric / Foam / Fabric Si.

[0097] A total of 4 runs were performed with a description of the composite sheet used in each run provided in Table 7 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 7-1 to Run 7-2 and Run 7-3

to Run 7-4 demonstrates that a composite sheet having orientation E exhibits a greater thermal resistance than a composite sheet having orientation E'.

[0098] Table 7

Run Reference No.	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Description of 2nd Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 7-1	E	Foam (d)	Fabric vii	Fabric vi	183	10.2
Run 7-2	E'	Foam (d)	Fabric vi	Fabric vii	171	7.1
Run 7-3	E	Foam (d)	Fabric iii	Fabric i	323	94.6
Run 7-4	E'	Foam (d)	Fabric i	Fabric iii	323	20.7

[0099] Example 8 - Thermal Resistance of Composite Sheet with Additional Sandwiched Barrier Layer Configurations

[00100] One additional configuration of the composite sheet is prepared and tested using the hot rod test. The eleventh configuration (F) comprises a first fabric layer with a silicone coating located on the side of the fabric that is facing or adjacent to the barrier layer. The fabric material of the first fabric layer represents the surface that makes initial contact with the hot rod during the performance of the test. The second fabric layer is located adjacent the barrier layer on the opposite side of the barrier layer away from the first fabric layer. Thus the barrier layer is "sandwiched" between the first and second fabric layers. The second fabric layer also comprises a silicone coating that is located adjacent to the barrier layer. Thus according to the previously described nomenclature, the first configuration (F) is described as → Fabric Si / Foam / Si Fabric.

[00101] A total of 5 runs are performed with a description of the composite sheet used in each run provided in Table 8 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 8-1 through Run 8-5 demonstrates that a composite sheet having a greater amount of foam exhibits a greater thermal resistance than a composite sheet a lower amount of foam.

[00102] Example 9 - Thermal Resistance of Composite Sheets Exhibiting Additional Single Barrier Layer Configuration

[00103] Two additional configurations of the composite sheet are prepared and tested using the hot rod test. The twelfth configuration (G) comprises a first fabric layer located on the side of the fabric that is away from or opposite the barrier layer. The first fabric layer does not comprise a silicone coating in addition to a fabric material. The barrier layer represents the surface that makes initial contact with the hot rod during the performance of

the test. Thus according to the previously described nomenclature, the third configuration (G) is described as → Foam / Fabric.

[00104] Table 8

Run Reference No.	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Description of 2nd Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 8-1	F	Foam (c)	Fabric ii	Fabric ii	172	15.1
Run 8-2	F	Foam (c)	Fabric iii	Fabric iii	216	27.7
Run 8-3	F	Foam (c)	Fabric iii	Fabric iii	234	44.1
Run 8-4	F	Foam (c)	Fabric iii	Fabric iii	239	41.2
Run 8-5	F	Foam (c)	Fabric iii	Fabric iii	122	5.9

[00105] The thirteenth configuration (G') is similar to configuration (G) except that the fabric material represents the surface that makes initial contact with the hot rod during the performance of the test protocol. Thus configuration (G') is defined according to the nomenclature as being → Fabric / Foam.

[00106] A total of 23 runs are performed with a description of the composite sheet used in each run provided in Table 9 along with the thermal resistance results obtained for each composite sheet in the Hot Rod Test. The comparison of Run 9-6 to Run 9-7, Run 9-11 to Run 9-12, Run 9-13 to Run 9-14, and Run 9-17 to Run 9-18 demonstrates that a composite sheet having orientation G exhibits a thermal resistance that is between about 2 to about 10 times greater than the thermal resistance of a composite sheet having orientation G'.

[00107] Example 10 – Thermal Resistance of Conventional Fabric Layers

[00108] A total of 12 runs are conducted to establish the thermal resistance of conventional fabric layers. A description of the fabric layer used in each run along with the thermal resistance results obtained for each fabric sheet in the Hot Rod Test is provided in Table 10. Control Run No.'s 1-3, Run No.'s 4-7, Run No.'s 8-12, and Run No.'s 13-14 compare different fabric layer compositions. Within each of the groupings, e.g., Run No.'s 8-12, the difference between each of the runs is the number of fabric layers that are stacked together for comparison. In each of the runs, the silicone coating on the fabric material represents the surface that initially makes contact with the hot rod during the performance of the test protocol. In Run No.'s Control -1, Control -4, and Control -8, one fabric layer exhibits a thermal resistance less than 4 seconds. As the number of fabric layers increases, e.g., fabric layers are stacked together, the thermal resistance is

observed to increase. This example demonstrates that the barrier layer of the present disclosure can be used to displace the need to stack multiple fabric layers together in order to achieve a desirable level of thermal resistance.

[00109] Table 9

Run Reference No.	Composite Orientation	Description of Barrier Layer	Description of 1st Fabric Layer	Foam Weight gsm	725°C Thermal Resistance (seconds)
Run 9-1	K	Foam (a)	Fabric viii	180	16.4
Run 9-2	K	Foam (a)	Fabric viii	190	17.8
Run 9-3	K	Foam (a)	Fabric x	230	31.2
Run 9-4	K	Foam (a)	Fabric viii	204	18.5
Run 9-5	K	Foam (a)	Fabric viii	310	120.0
Run 9-6	K	Foam (a)	Fabric vi	170	18.0
Run 9-7	K'	Foam (a)	Fabric vi	170	6.6
Run 9-8	K	Foam (a)	Fabric vi	234	120.0
Run 9-9	K'	Foam (a)	Fabric vi	234	120.0
Run 9-10	K	Foam (a)	Fabric i	180	9.4
Run 9-11	K	Foam (a)	Fabric i	317	120.0
Run 9-12	K'	Foam (a)	Fabric i	317	51.9
Run 9-13	K	Foam (a)	Fabric i	271	120.0
Run 9-14	K'	Foam (a)	Fabric i	271	27.9
Run 9-15	K	Foam (a)	Fabric i	184	12.1
Run 9-16	K	Foam (a)	Fabric vi	202	120.0
Run 9-17	K	Foam (b)	Fabric i	276	120.0
Run 9-18	K'	Foam (b)	Fabric i	276	11.6
Run 9-19	K	Foam (c)	Fabric viii	217	8.2
Run 9-20	K	Foam (c)	Fabric viii	243	11.1
Run 9-21	K	Foam (c)	Fabric i	180	10.9
Run 9-22	K	Foam (c)	Fabric i	251	36.7
Run 9-23	K	Foam (d)	Fabric vi	187	6.5

[00110] Table 10

Run Reference No.	Number of Fabric Layers	Description of 1st Fabric Layer	725°C Thermal Resistance (seconds)
Control -1	1	Fabric iv	3.20
Control - 2	2	Fabric iv	10.80
Control -3	3	Fabric iv	30.00
Control -4	1	Fabric iii	1.10
Control - 5	2	Fabric iii	2.20
Control -6	3	Fabric iii	4.40
Control -7	4	Fabric iii	7.40
Control - 8	1	Fabric v	1.40
Control -9	2	Fabric v	2.70
Control - 10	3	Fabric v	4.10
Control - 11	4	Fabric v	7.20
Control -12	5	Fabric v	12.30
Control -13	1	Fabric ix	3.70
Control -14	2	Fabric ix	12.40

[00111] Example 11 – Thermal Resistance of Composite Sheets having Open Face Versus Sandwich Configuration

[00112] The thermal resistance of several configurations in which the barrier layer of a composite sheet is initially exposed to the hot rod during the performance of the hot rod test is graph is measured and graphically compared against the thermal resistance of composite sheets in which the barrier layer is sandwiched between two fabric layers. The composition and construction of the composite sheets tested, and the measured thermal resistance values are provided in Figure 8. This example demonstrates that fabric orientation makes an impact on performance of the foam when used in the open face position. Having the coated fabric side of the coated fabric against the foam versus the uncoated side of the coated fabric against the foam increases thermal resistance nearly 5 times for Foam (b) (Point 1 versus Point 2) and nearly 2 times over Foam (a) (Point 3) at similar coat weights. In addition, comparing the foam (a) (Point 5) to foam (b) (Point 4) with the same fabric orientation and similar coat weights when used in the sandwich orientation shows an increase in the thermal resistance nearly 2.5 times over foam (b). Finally, comparing the foam (a) (Point 3) to foam (b) (Point 2) with the same fabric orientation and similar coat weight of the foam in the open face position shows an increase in the thermal resistance nearly 2.5 times over foam (b).

[00113] One skilled in the art will understand that the properties measured for the layered composite sheets and heat shield products made there from represent properties that are routinely measured and can be obtained by multiple different methods. The methods

described herein represent one such method and other methods may be utilized without exceeding the scope of the present disclosure. For example, the viscosity measurements are conducted using a Brookfield viscometer with a number 3 spindle at 10 rpm.

[00114] One skilled in the art will further understand the benefits associated with using a composite sheet of the present disclosure. More specifically, existing art that utilized fiberglass fabric is difficult to cut, introduces fiberglass particles when being cut, shortens needle life during sewing operations, is stiffer than foam, and is not accepted in all workplace environments. The use of a composite sheet prepared according to the present disclosure provides a composite sheet that is lighter in overall weight, easier to pack and when used in the sandwich configuration yields lower number of fabric layers than conventional solutions. In addition, the use of cellular foam as a heat sink in the airbag or other inflatable safety device can eliminate the use of metal reinforcements in the airbag to prevent the post melt through of the inflator through the bag.

[00115] The foregoing description of various embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise embodiments disclosed. Numerous modifications or variations are possible in light of the above teachings. The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

What is claimed is

1. A thermally resistant layered composite sheet, the composite sheet comprising:
a first fabric layer having a top side and a bottom side; and
a thermal barrier layer located adjacent to one of the top side or bottom side, the thermal barrier layer comprising at least one layer of a cellular foam;
wherein the composite sheet has a thermal resistance value of six seconds or more at 725°C.
2. The composite sheet of Claim 1, wherein the first fabric layer comprises a fabric material and one or more silicone coatings located on the top side or bottom side either adjacent to the thermal barrier layer or opposite the side that is adjacent to the thermal barrier layer.
3. The composite sheet of Claims 1 or 2, wherein the composite sheet further comprises a second fabric layer having a top side and bottom side; the second fabric layer comprising a fabric material and one or more silicone coatings; the second fabric layer being located either adjacent to the thermal barrier layer or on the side of the first fabric layer that is opposite to the thermal barrier layer.
4. The composite sheet of Claims 1-3, wherein the composite sheet has a thermal resistance value of 30 seconds or more at 725°C.
5. The composite sheet of Claims 1-4, wherein the fabric material of the fabric layer is a woven fabric, a nonwoven fabric, or a polymeric film or composite selected from polypropylene, polyethylene, fiberglass, polyamides, poly(ethylene) terephthalate, and compositions or mixtures thereof.
6. The composite sheet of Claims 1-5, wherein the fabric layer is a woven fabric having threads with a thickness that is equal to or greater than 20 dtex or a nonwoven fabric or a polymer film having a thickness between 40 g/m² and 400 g/m².
7. The composite sheet of Claims 1-6, wherein the cellular foam is a silicone cellular foam having a weight between 100 to 600 g/m².

8. The composite sheet of Claims 2-7, wherein the silicone coating of the fabric layer comprises:

an organopolysiloxane having one or more silicon atom-bonded alkenyl groups on average in one molecule:

an organohydrogenpolysiloxane;

a hydrosilylation reaction catalyst present in any amount capable of curing the coating composition; and

a reinforcing silica;

wherein the silicone coating of the fabric layer exhibits a weight between 10 to 400 g/m².

9. The composite sheet of Claims 2-8, wherein the thermal barrier layer comprises one or more surfaces that is either smooth or textured.

10. An inflatable vehicle safety device comprising:

an inflator capable of providing an inflation fluid;

a fluid compartment inflatable by the inflator; and

one selected from the group of

(i) an inflator wrap located adjacent to the inflator; the inflator wrap comprising at least one layer of a cellular foam;

(ii) a heat shield located within the fluid compartment; the heat shield comprising:

a first fabric layer having a top side and a bottom side; and

a thermal barrier layer located adjacent to one of the top side or bottom side, the thermal barrier layer comprising at least one layer of a cellular foam; and

(iii) a combination thereof;

wherein the inflator wrap or heat shield has a thermal resistance value of six seconds or more at 725°C.

11. The vehicle safety device of Claim 10, wherein the first fabric layer comprises a fabric material and one or more silicone coatings located on the top side or bottom side of the first fabric layer such that the silicone coating is either adjacent to the thermal barrier layer or opposite the side that is adjacent to the thermal barrier layer .

12. The vehicle safety device of Claims 10 or 11, wherein the heat shield further comprises a second fabric layer having a top and bottom side; the second fabric layer being located adjacent to the thermal barrier on the side that is opposite to the first fabric layer.

13. The vehicle safety device of Claim 12, wherein the second fabric layer comprises a fabric material and at least one silicone coating located on the top side or bottom side.

14. The vehicle safety device of Claims 10-13, wherein the fluid compartment is selected from a front air bag, a side air bag, an air curtain, H- or Y-socks, knee bag, and belt bag.

15. The vehicle safety device of Claims 10-14, wherein the cellular foam is a silicone cellular foam having a weight between 100 to 600 g/m².

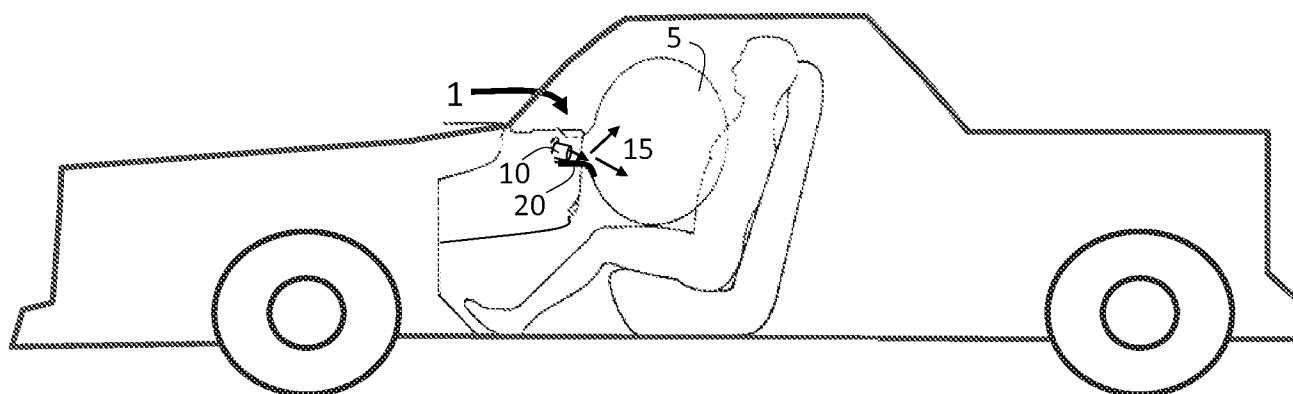


Figure 1

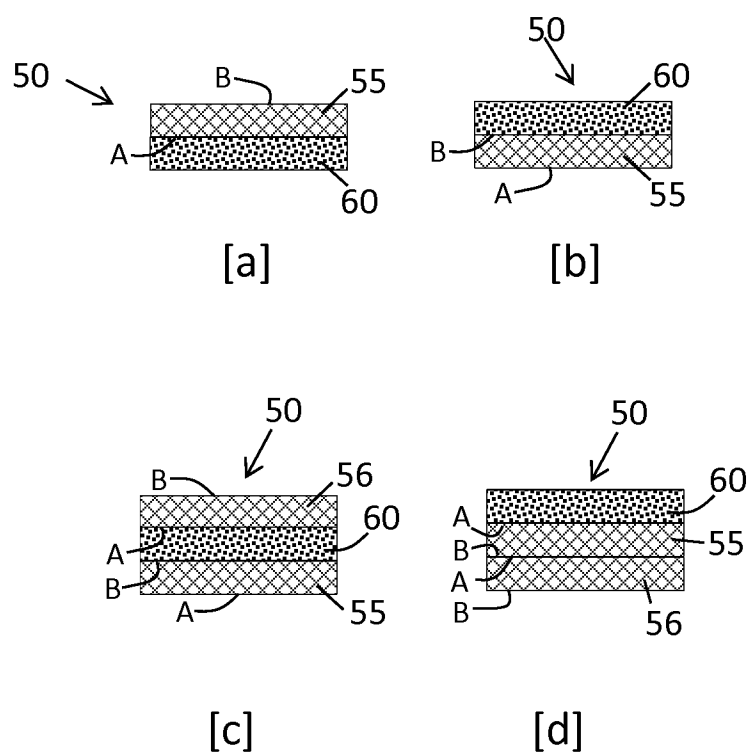


Figure 2

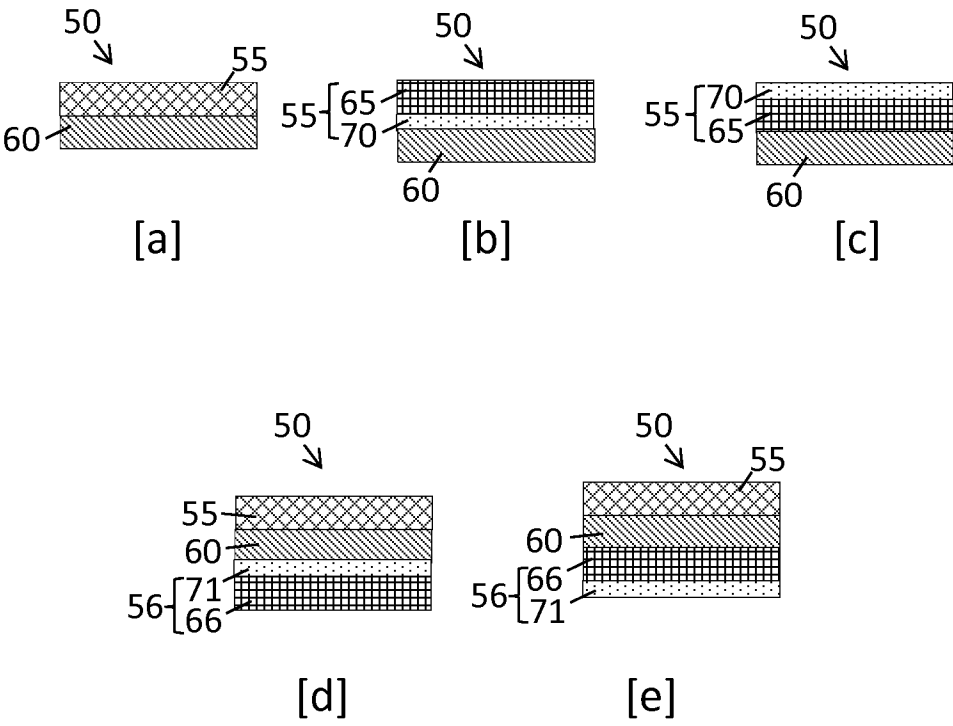


Figure 3

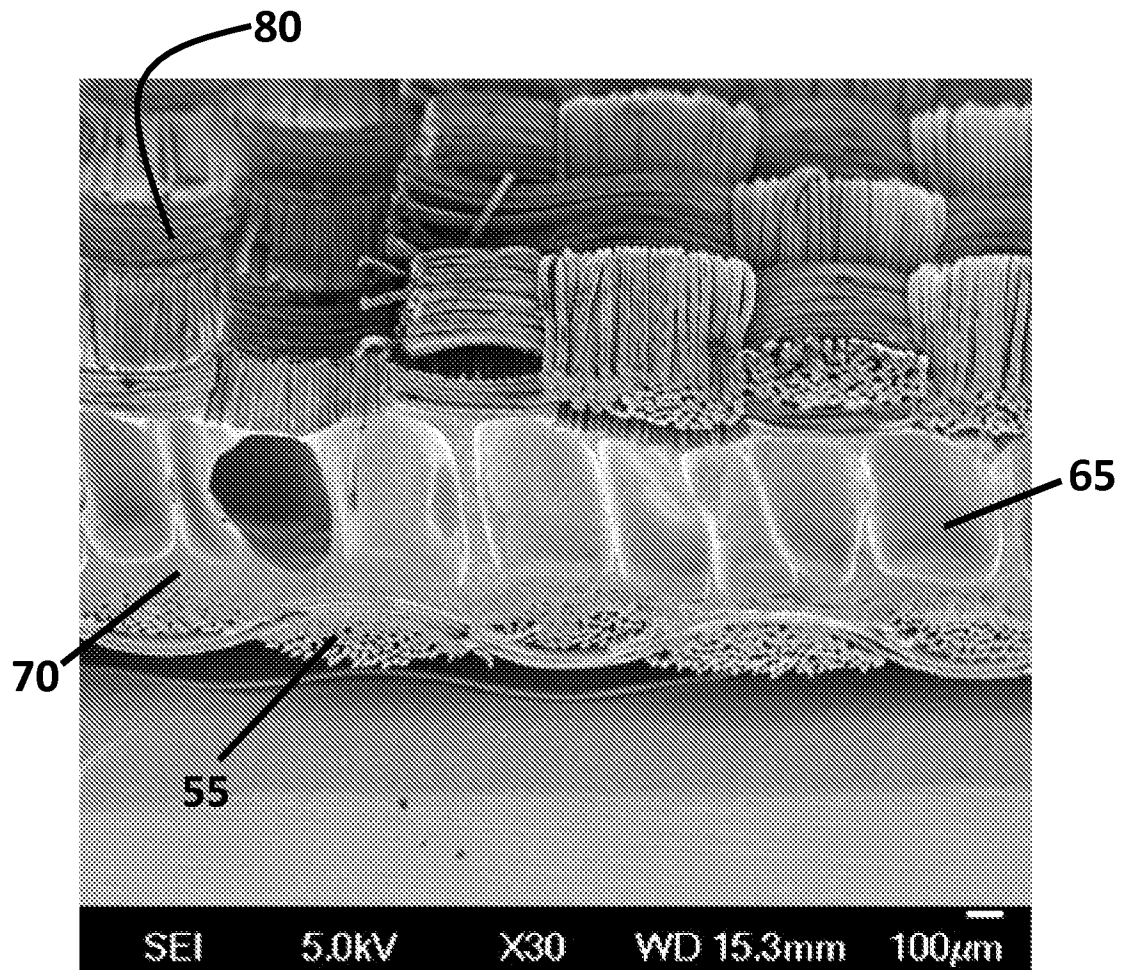


Figure 4

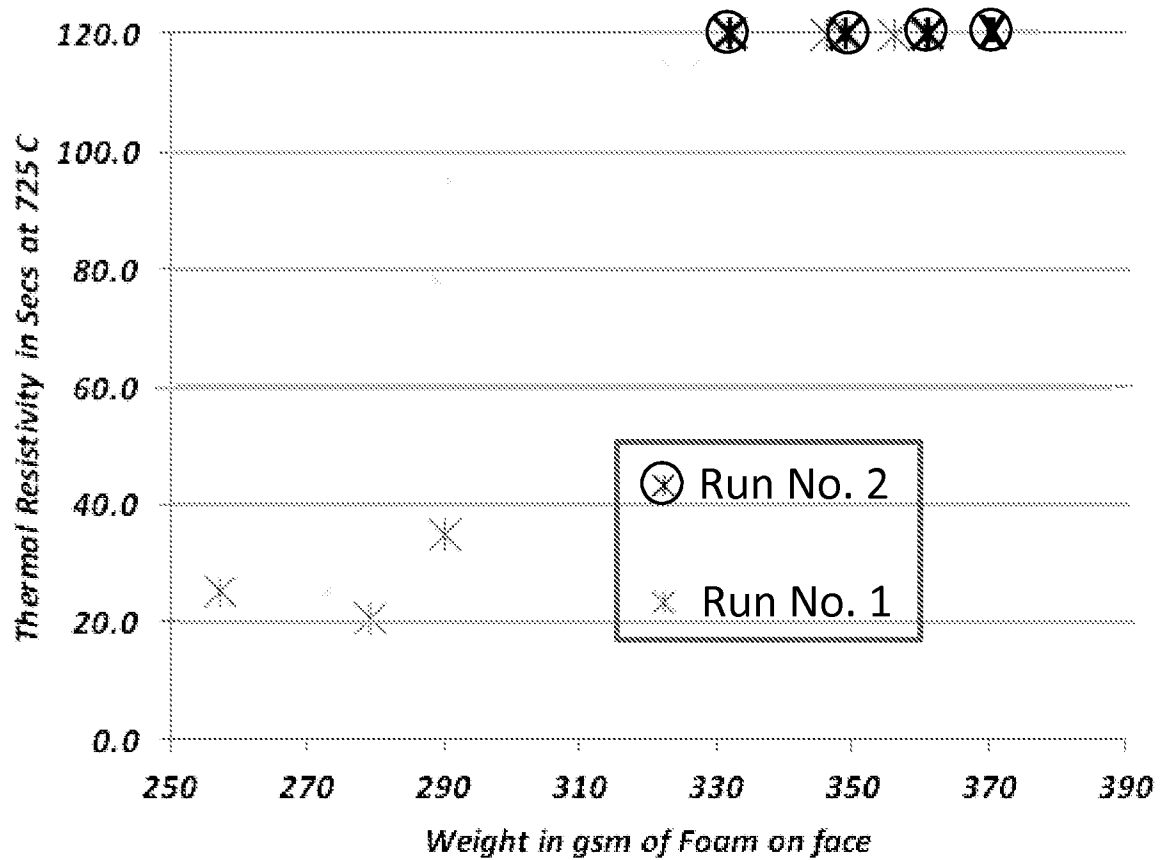


Figure 5

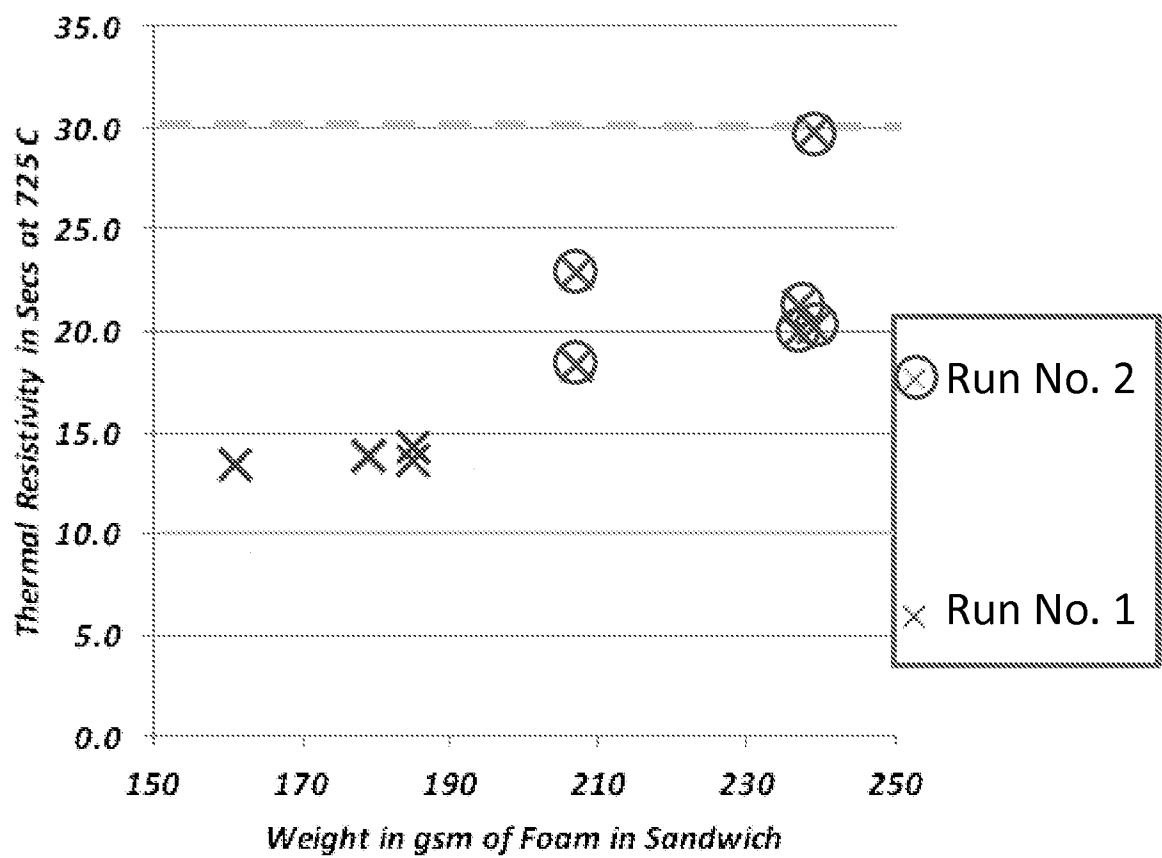


Figure 6

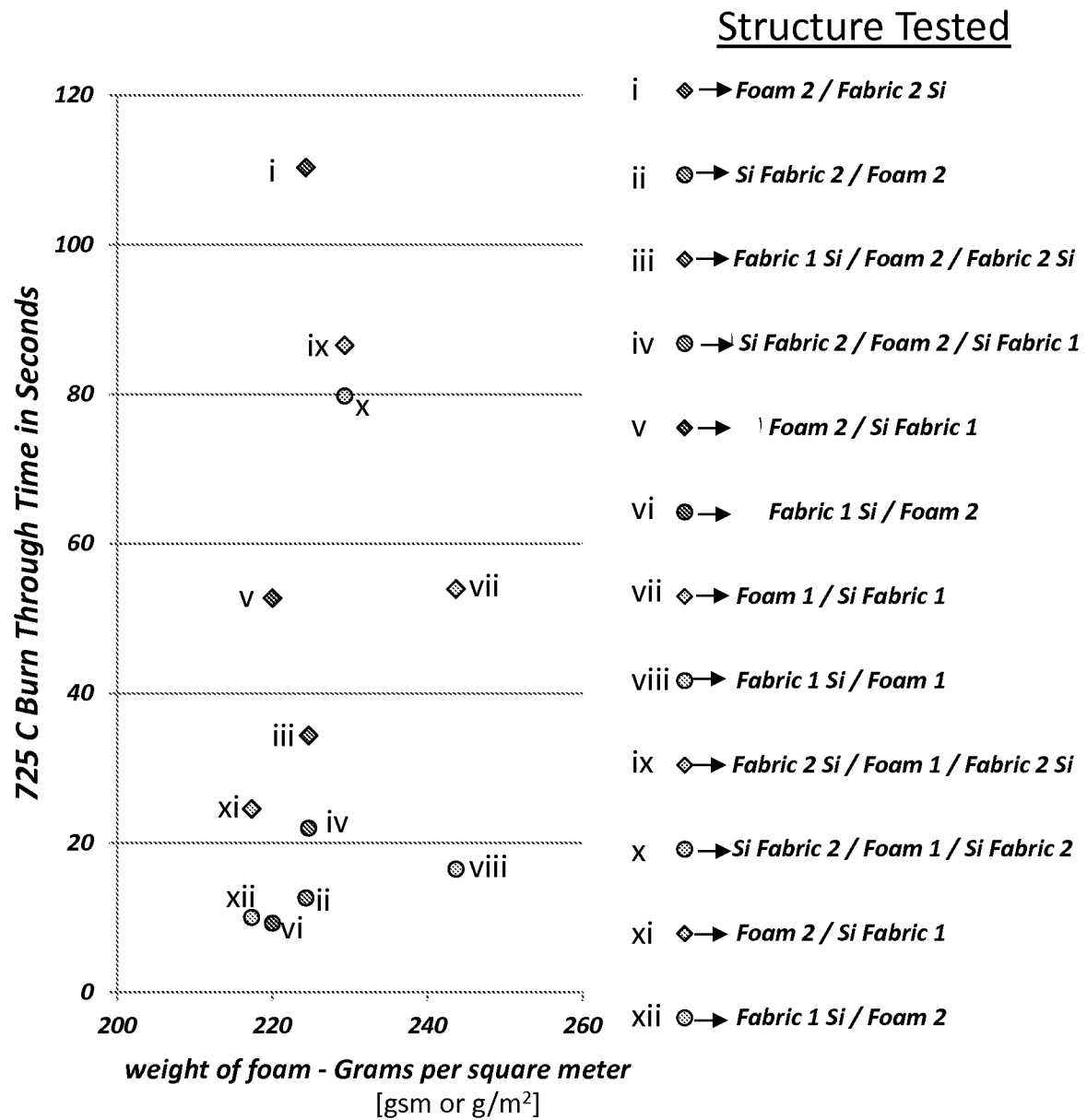


Figure 7

Point

- (1) 224 gsm Foam (b) / Fabric v Si
- ◆ (2) 217 gsm Foam (b) / Si Fabric ii
- ▣ (3) 218 gsm Foam (a) / Si Fabric ii
- ▲ (4) Fabric ii Si / 225 gsm Foam (b) / Fabric v Si
- △ (5) Fabric v Si / 229 gsm Foam (a) / Fabric v Si

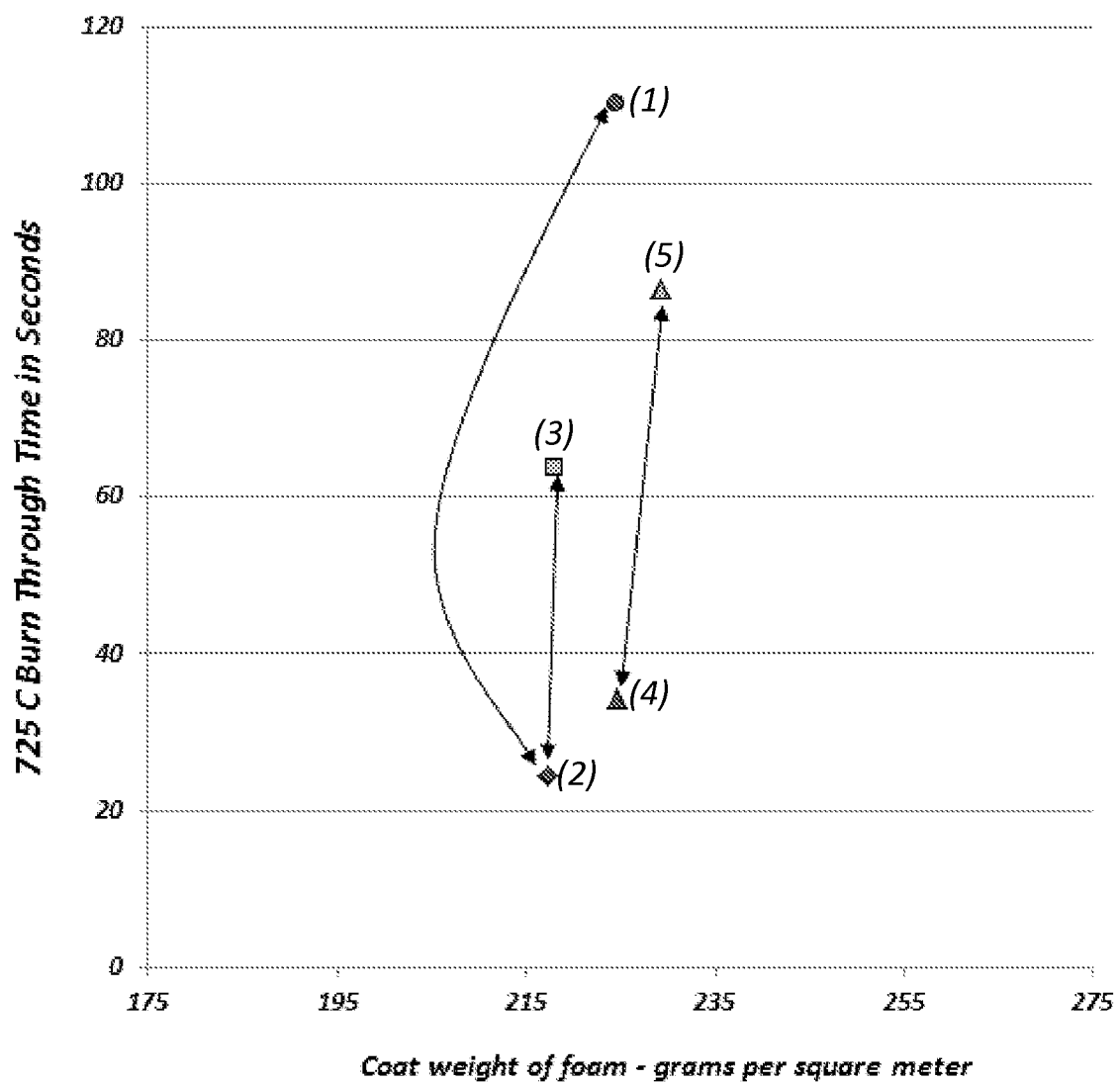


Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/049184

A. CLASSIFICATION OF SUBJECT MATTER
INV. B32B5/24 B60R21/231 B60R21/235
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B B60R

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

4 October 2013

Date of mailing of the international search report

11/10/2013

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/049184

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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