



(11)

EP 1 861 524 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
04.04.2012 Bulletin 2012/14

(51) Int Cl.:
D04H 1/00 ^(2006.01) **D04H 1/48** ^(2012.01)
D04H 1/54 ^(2012.01) **D04H 1/74** ^(2006.01)
D04H 1/42 ^(2012.01)

(21) Application number: **05858690.0**

(86) International application number:
PCT/US2005/043173

(22) Date of filing: **30.11.2005**

(87) International publication number:
WO 2007/061423 (31.05.2007 Gazette 2007/22)

(54) FLAME RESISTANT FIBER BLENDS

FLAMMWIDRIGE FASERMISCHUNGEN

MELANGES DE FIBRES RESISTANTES AU FEU

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI
SK TR**
Designated Extension States:
AL BA HR MK YU

- **DAWSON, William**
Duluth, GA 30097 (US)
- **EDWARDS, William**
York, SC 29745 (US)

(30) Priority: **30.11.2004 US 1539**
11.03.2005 US 660620 P

(74) Representative: **Sieckmann, Dirk Christoph et al**
Betten & Resch
Patentanwälte
Postfach 10 02 51
80076 München (DE)

(43) Date of publication of application:
05.12.2007 Bulletin 2007/49

(56) References cited:
US-A1- 2004 198 125

(73) Proprietor: **Propex Operating Company, LLC**
Chattanooga, TN 37421 (US)

- **DATABASE WPI Week 200306 Thomson**
Scientific, London, GB; AN 2003-064446
XP002575714 -& JP 2002 316009 A (JAPAN
VILENE CO LTD) 29 October 2002 (2002-10-29)
- **DATABASE WPI Week 200216 Thomson**
Scientific, London, GB; AN 2002-117335
XP002575717 -& JP 2001 262453 A (FUJI CORP)
26 September 2001 (2001-09-26)

(72) Inventors:

- **BASS, Derek**
Adairsville, GA 30103 (US)
- **SPARKS, Brian**
Hixson, TN 37343 (US)
- **HOPE, Doug**
Ringgold, GA 30736 (US)

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 861 524 B1

Description

BACKGROUND OF THE INVENTION

5 [0001] This invention relates to a flame resistant fiber blend useful in preparing fabrics having flame resistance, including particularly non-woven flame resistant materials such as barrier fabrics.

[0002] Flame resistant (FR) materials are employed in many textile applications. For example, FR materials are useful as barrier layers between the exterior fabric and the inner stuffing of furniture, comforters, pillows, and mattresses. Such materials can be woven or non-woven, knitted, or laminated with other materials.

10 [0003] Flame resistance is defined by ASTM as "the property of a material whereby flaming combustion is prevented, terminated, or inhibited following application of a flaming or non-flaming source of ignition, with or without the subsequent removal of the ignition source." The material that is flame resistant may be a polymer, fiber, or fabric. A flame retardant is defined by ASTM as "a chemical used to impart flame resistance."

15 [0004] Flame-blocking, heat-blocking and flame-resistant fabrics are commonly employed as protective barriers for other materials in an assembly. Recent examples of the escalating need for protective barriers include mattresses, bedding sets, upholstered furniture and bed clothing; all regulatory driven with most beginning through efforts by the State of California, in particular, the Bureau of Home Furnishings and Thermal Insulation of the Department of Consumer Affairs of the State of California. The State of California led the drive to regulate these materials in an attempt to reduce the number of lives lost in fires by restricting the quantity of released energy when the item is exposed to open flame.

20 [0005] In the case of mattresses and mattress sets, the proposed regulation became law January 1, 2005 in the State of California and is expected that similar national legislation will follow in 2007. Based on the market history established to date, the value to the end consumer is limited. Because significantly higher costs associated with meeting the newly imposed standards cannot be passed along, mattress manufacturers have demonstrated a need for low-cost, high performance barrier fabrics.

25 [0006] The flame resistance properties of such FR materials are typically determined according to various standard methods, such as California TB117 and TB 133 for upholstery; NFPA701 for curtains and drapes; California Test Bulletin 129, dated October 1992, concerning flammability test procedures for mattresses in public buildings, and California Test Bulletin 603 concerning mattresses for residential use. Desirably, the FR material does not melt or shrink away from the flame, but forms a char that helps control the burn and shield the materials surrounded by the fabric.

30 [0007] The protection required of the flame and heat barrier fabric is related to the other components used in the final assembly of the desired product. For example, mattresses normally contain layers of foam and fiber batting for cushioning and ticking for durable cover. Most cushioning material is comprised of foam and fibers that burn when exposed to open flame. Much of the regulatory-driven effort to date has gone towards shielding the inner cushioning layers from open flame or ignition from the heat of the open flame without compromising the comfort or aesthetics of the mattress.

35 [0008] Other desirable properties of FR barrier fabrics include a white or other neutral color so as to not contaminate the manufacturing facility or change the look of the composite article; the ability to remain unaffected by ultraviolet light so as not to yellow and change the look of light-colored mattress ticking or upholstery fabrics; being soft to the touch, thereby imparting the feel desired by the consumer; and cost effectiveness.

40 [0009] Some fibers are known to have FR properties, such as halogen-containing, phosphorus-containing, and anti-mony-containing materials. These materials, however, are heavier than similar types of non-FR materials, and they have reduced wear life.

[0010] There is still a need in the industry to create non-woven barrier fabric that can pass the stringent flammability testing guidelines. Moreover, there is a need in the industry to produce such a non-woven article from materials that are relatively inexpensive and have light batt weights. Additionally, other industries would benefit from the availability of flame resistant fabrics, made from fibers having flame resistant properties, to use in lieu of fabrics that do not have such properties.

45 [0011] As an example, baghouse filters are widely used to control particulate pollutants in many industries such as, food processing, cement, mineral, and aggregate processing, metal processing, power generation, and in production of various chemicals. A filter fabric of this type ideally will have (1) a sufficient mechanical strength to withstand pressures developed during use and multiple cycles of flexing, (2) a resistance toward harsh chemicals for long periods of time, (3) an ability to be unaffected by continuous operating temperatures as high as 482° C (900 °F), (4) a resistance toward hot sparks, (5) less than 1% shrinkage at use temperature, (6) a high filtration efficiency, and (7) a resistance to being attacked by microorganisms.

55 [0012] There still remains a need for lower-cost flame and heat barrier fabrics that protect other components of an assembly of a desired product so that the assembly meets all customer and regulatory requirements.

Prior art document JP 2002 316009 A provides a fire-resistant filter material comprising a fiber web of intertwined and/or coupled denatured silica fibers with a fiber length of 10-100 mm, and crimped organic fibers with a fiber length of 15-100 mm. The silica fiber contains (in weight %) silica (85-99), alumina (1-10), components (0-10) other than silica and alumina.

The fiber web contains silica fibers (5-95) and organic substance fibers (5-95).

Document JP 2001 262453 A discloses a felt material, which is formed by integrating a wrapping material comprising silica fibers for firing and heat-resistant organic fibers with melting point of 250 C° or more or with no sharp melting point, with a base material by needle punching, after removing soluble or organic components from the fibrils. The felt material is set to a preset thickness and density, after heat processing.

BRIEF SUMMARY OF THE INVENTION

[0013] In general, the present invention provides a flame resistant (FR) fiber blend comprising amorphous silica fibers as defined in claim 1; and at least one fiber selected from the group consisting of FR fibers, binder fibers and mixtures thereof.

[0014] A barrier fabric can be manufactured from a blend of fibers comprising amorphous silica fibers; and at least one fiber selected from the group consisting of FR fibers, binder fibers and mixtures thereof.

[0015] A flame resistant fabric can be manufactured from a blend of fibers comprising amorphous silica fibers; and at least one fiber selected from the group consisting of FR fibers, binder fibers and mixtures thereof.

[0016] A process for protecting materials in a product from fire and heat comprises assembling a flame resistant fabric adjacent to at least one component that comprises a material susceptible to damage due to exposure to fire and heat, occasioned by exposure to open flames.

[0017] Advantageously, it has been discovered that fiber blends containing amorphous silica show improved char strength when formed into non-woven fabric, compared to non-woven fabric not containing amorphous silica. The char strength to weight ratio of non-woven fabric containing amorphous silica is also improved, when compared to non-woven fabric containing other fibers conventionally used to improve char strength, such as para-aramid fibers and melamine fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The drawing figure is a perspective view exploded to show assembly of a tuft button test apparatus.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Two types of fiber blends: a first, comprising amorphous silica fibers and at least one type of FR fiber and a second, comprising amorphous silica fibers and at least one type of binder fibers are disclosed. As will be explained in greater detail herein, the fiber blends can then be used to form fabrics, both nonwovens and woven fabrics, for a variety of uses.

[0020] Generally, any amorphous silica fiber that improves the char strength when added to a fiber blend may be used. The term "silica" refers to silicon dioxide which occurs naturally in a variety of crystalline and amorphous forms. Silica is considered to be crystalline when the basic structure of the molecule (silicon tetrahedra arranged such that each oxygen atom is common to two tetrahedral) is repeated and symmetrical. Silica is considered to be amorphous if the molecule lacks crystalline structure. The SiO₂ molecule is randomly linked, forming no repeating pattern. Crystalline silica is not desired because of the associated health effects related to fragmentation of its brittle crystalline structure into fragments of respirable size.

[0021] The amorphous silica fiber is a high-content silica fiber having a silica (SiO₂) content of at least 90 percent by weight, based upon the total weight of the high silica fiber. In one or more embodiments, the high silica fibers have a silica content of at least 95 percent by weight, and in other embodiments, the high silica fibers have a silica content of at least 98 percent by weight. For example, the high silica fibers may contain 98 percent by weight silica, with the balance predominantly containing alumina. In certain embodiments, the amount of halogen in the high silica fiber is de minimus, less than 120 parts per million by weight.

[0022] As noted above, the silica fibers are substantially amorphous. While the fibers may contain some crystalline material, a substantial amount of crystallinity is not desired. Suitable silica fiber is commercially available, for example from Polotsk-Steklovokno, Belarus.

[0023] In one embodiment, the starting material composition for the high silica fibers is: from 72 to 77% SiO₂, from 2.5 to 3.5% Al₂O₃, from 20 to 25% Na₂O, from 0.01 to 1.0% CoO and from 0.01 to 0.5% SO₃, all percents by weight, based upon the total weight of the composition. The composition may be melted at 1480 ± 10°C to form a continuous fiber. This fiber may then be leached using hot sulfuric acid having a concentration of 2N at a temperature of 98 ± 2° C with a dwell time of 60 minutes. The fiber may then be rinsed with tap water until the pH is 3-5. In this embodiment, the resulting fiber has a SiO₂ content of from 95 to 99% ± 1 percent by weight, with the remainder being predominantly Al₂O₃.

[0024] A high silica glass composition and process for making high silica fibers is described in Russian Pat. No. 2,165,393 (the '393 patent), the disclosure of which is hereby incorporated by reference herein. The high silica fibers of

EP 1 861 524 B1

the '393 patent are described as having a lower coefficient of variation in the strength of the basic filaments, which gives the possibility to stabilize the strength characteristics of the resultant fiber, especially at exposure to high temperature. The following description of high silica fibers is taken from the '393 patent for exemplary purposes.

[0025] In one or more embodiments, a precursor glass composition may include SiO_2 , Al_2O_3 and Na_2O , as well as CoO and SO_3 in the following proportions (percent mass):

Al_2O_3 :	2.5-3.5
Na_2O :	20-25
CoO :	0.01-1.0
SO_3 :	0.01-1.0
SiO_2 :	remaining

[0026] The glass may further contain at least one oxide from the group CaO , MgO , ZrO_2 , TiO_2 , Fe_2O_3 in the following quantities (percent mass) :

CaO :	0.01-0.5
MgO :	0.01-0.5
TiO_2 :	0.01-0.1
Fe_2O_3 :	0.01-0.5
ZrO_2 :	0.01-0.5

[0027] A resultant, high-temperature silica fiber from the glass composition about would then include SiO_2 and Al_2O_3 , but also would contain Na_2O , CoO and SO_3 in the following proportions (percent mass):

SiO_2 :	94-96
Al_2O_3 :	3-4
Na_2O :	0.01-1.0
CoO :	0.01-1.0
SO_3 :	0.01-1.0

[0028] The silica fiber may also contain at least one oxide from the group CaO , MgO , TiO_2 , Fe_2O_3 , ZrO_2 in the following quantities (percent mass) :

CaO :	0.01-0.5
MgO :	0.01-0.5
TiO_2 :	0.01-0.1
Fe_2O_3 :	0.01-0.5
ZrO_2 :	0.01-0.5

[0029] In one embodiment, the silica fibers are substantially free of any metal oxide coating.

[0030] Diameter of the silica fibers may range from 5.6 microns to 12.6 microns and, in one embodiment, the diameter is 8 microns. Length of the silica fibers may range from 50 millimeters to 125 millimeters and, in one embodiment, the length is 75 millimeters, (shorter and longer fibers are available by adjusting the cut length of the fiber, but are not practical for needlepunch applications) .

[0031] One method of preparation of the silica fibers according to the aforementioned Russian patent, No. 2,165,393, as set forth in Example 1 hereinbelow, may be conducted as follows: To produce continuous filament glass fiber of the proposed composition, a vessel containing (percent mass) SiO_2 :72.39, Al_2O_3 :2.5, Na_2O :25, CoO :0.01, SO_3 :0.1 may be prepared. The vessel may be loaded into a furnace, and the composition melted at a temperature of $1480 \pm 10^\circ\text{C}$. From the molten glass mass, a continuous glass fiber may be formed with a diameter of 6-9 microns at a temperature of $1260 \pm 50^\circ\text{C}$ using 400-hole glass-forming aggregates. The resultant fiber has been shown to have a strength of 1030 Mpa and a surface tension of 0.318 H/m.

[0032] Leaching of the continuous glass fiber may then take place using a hot sulfuric acid solution having a concentration of 2N (10%) at a temperature of $98 \pm 2^\circ\text{C}$. Contact time for the fiber in the solution is 60 minutes. The leaching solution, reaction products, and sizing remains are then washed away from the leached fiber with tap water until the pH

is at 3-5. Final washing of the fiber is conducted with deionized water and simultaneous dehydration.

[0033] The preparation of the glass composition, its processing and leaching for Examples 2 and 3 below are analogous to that as set forth above for Example 1, but with different amounts of starting materials. Table 1 presents the starting amounts for the glass as well as the amounts of materials for the resultant silica compositions. Table 2 presents the characteristics of the molten product, the characteristics of processing, and the characteristics of the glass and silica fibers. Table 3 provides strength characteristics of the silica materials after exposure to 1000° C.

[0034] Tables 1- 3 also provide data confirming the introduction of cobalt and SO₃ into the glass composition increases the heterogeneity of the glass mass, lowers its surface tension, decreases the fragility of the fiber during processing and also increases the stability of the technical characteristics of the silica fiber and resultant materials based on this fiber.

TABLE 1

GLASS COMPOSITIONS AND RESULTANT SILICA COMPOSITIONS

Component	Glass Composition			Silica Composition		
Example No.	1	2	3	1	2	3
SiO ₂	72.39	73.0	76.94	95.65	93.87	96.58
Al ₂ O ₃	2.5	3.5	3.0	2.8	3.9	3.2
Na ₂ O	2/5	22	20	0.32	0.23	0.12
CoO	0.01	1.0	0.05	0.03	1.3	0.08
SO ₃	0.1	0.5	0.01	1.2	0.7	0.02

TABLE 2

GLASS AND SILICA FIBER PROPERTIES

Example No.	Glass or Silica Composition No.			
	1	2	3	prototype
<u>Precursor Glass Fiber</u>				
Strength, Mpa	1030	1150	1220	1020
Coefficient of strength variation, %	12.2	10.6	9.2	14.7
Coefficient of useful work (CUW) for crucible during glass production	0.75	0.72	0.78	0.68
Surface tension of molten glass, before fiber (N/m)	0.318	0.27	0.29	0.228
<u>Silica Fiber</u>				
Strength, Mpa	800	860	925	750
Coefficient of strength variation, %	12.4	11.7	9.6	15.9
<u>Silica Yarn</u>				
Strength, Mpa	61	69	73	---
Coefficient of strength variation, %	14.8	12.6	10.9	---
<u>Silica Tape</u>				
Strength, Mpa	1700	1920	2150	---
Coefficient of strength variation, %	13.2	12.7	10.3	---

TABLE 3

BREAKING LOAD SILICA MATERIAL AFTER HEAT PROCESSING AT 1000°C, N

Example No.	Silica Yarn	Silica Tape
1	12.1	142
2	14.3	157
3	18.1	164

[0035] Tables 4 and 5 show various glass fiber compositions from which it can be seen that the silica fibers taught by

EP 1 861 524 B1

the Russian Pat. No. 2,165,393 differ from all other glass fiber types by the presence of trace amounts of CoO and SO₃.

5

10

15

20

25

30

35

40

45

50

55

55 50 45 40 35 30 25 20 15 10 5

TABLE 4
VARIOUS GLASS FIBER COMPOSITIONS FOR PRODUCING HIGH SILICA FIBERS

Glass Type	Country	Org.	SiO ₂	Al ₂ O ₃	B ₂ O ₃	CaO	MgO	TiO ₂	ZrO ₂	ZnO	Na ₂ O + K ₂ O	Fe ₂ O ₃	F ₂
TYPE A													
Glass A	US		71.8	1.0		8.8	3.8				14.2	0.5	
Neutral	USSR	GIS	71.0	3.0		8.5	2.5				15.0		
No.65	USSR	VNIISV	60.0	3.0		8.0	3.0		6.0		12.0	2.0	
No.70	USSR	VNIISV	69.0	3.0		8.0	3.0		1.0		14.0	2.0	
TYPE E													
Std, Alkali Free with 10% B2O3	USSR	VNIISV	54.0	14.5	10.0	16.5	4.0				0-1.0	0.5	0.3
Alkali free with 8% B2O3	USSR	VNIISV	54.0	14.5	8.0	18.0	4.5				0-1.0	0.5	0.3
T-273A	USSR	VNIISPV	55.5	16.0		14.0	8.0	6.0			0-1.0	0.5	0.4
No. 2334961	US	Owens Corning	52-56	12.0-16.0		16.0-19.0							
No. 621 No. 2571074	US	Owens Corning	52-56	12.0-16.0	8.0-13.0	19.0- 25.0							UP TO 3.0
No. 4542106	US	PPG	58-60	11.0-13.0		21.0- 23.0	1.0-4.0	1.0-5.0			0-1.0		
No. 3037136	JAPAN	NIPPON	54-57	13.0-16.0		21.0- 23.0	0.6-3.0	0-1.0			0-1.0	0-1.0	
ECRGLAS	US	Owens Corning	54-65	9.0-15.0		17.0- 25.0	0-4.0			2.5-5.0	0-1.0		
Advantex, No. 5789329	US	Owens Corning	59.9	13.5		22.3	3.2	0.2			0.3	0-1.0	

(continued)													
TYPE C													
No. 2308857	US	Owens Corning	65.0	3.8	5.5	13.7	2.4					8.5	0.3
Glass Type	Country	Org.	SiO ₂	Al ₂ O ₃	B ₂ O ₃	CaO	MgO	TiO ₂	ZrO ₂	ZnO	Na ₂ O + K ₂ O	Fe ₂ O ₃	F ₂
No. 4628038	US	Owens Corning	53.3	16.0	3.0	15.8	2.5	0 - 2.0			7.0	0 - 2.0	
No.7, No. 289991	USSR	VNIISV	64.0	5.5		12.0	2.0	2.0 BaO	2.0	1.7 Mn ₃ O ₄	9.5		0.3
No.7-A, No.787382	USSR	VNIISPV	64.0	4.5		12.0	12.0	0.2	4.2		11.5		0.3
TYPE D													
D(US)	US		75.5	0.5	20.0	0.5					3.0		
D-4.5	USSR	VNIISPV	51-71	1.0-5.0	25.0-45.0								
No. 63002831	JAPAN	Nippon	70-80		15.0-21.5						2.0-5.0		
No. 8333137	JAPAN	Nitto- boseki	50-60	10.0-20.0	20.0-30.0								

TABLE 5
VARIOUS GLASS COMPOSITIONS FOR PRODUCTION OF HIGH SILICA FIBERS AND SILICA FIBER COMPOSITIONS

Glass Type	Country	Org.	SiO ₂	Al ₂ O ₃	B ₂ O ₃	CaO	MgO	TiO ₂	ZrO ₂	ZnO	Na ₂ O + K ₂ O	Fe ₂ O ₃	F ₂	CoO	SO ₃	B	CuO	Ni ₂ O ₃	CrO ₃
TYPE S																			
No. 3402055	US	Owens Corning	55.0-79.9	12.6-32.0			4.0-20.0												
No. 3459568	US	PPG Industries	54.0-62.0	20.0-27.0							0.2-0.2 LiO2								
R.No. 1435073	FRANCE	VETROTE X	55.0-65.0	20.0-30.0		5.0-20.0		10.0											
No. 11021147	JAPAN	Nitto-Boseki	60.0-70.0	17.0-27.0		7.0-17.0						0.1-0.5							
VM-P	USSR	VNIISPV	58.0-73.0	15.0-25.0		4.0-15.0		0.3-2.8	0.3-0.7			0.5							
VM-1	USSR	VNIISPV	55.0-57.0	24.0-26.0		14.0-16.0		1.3-2.7											
No. 2129102	USSR	Steklopl Astic co.	57.0-60.0	20.0-27.0		10.0-16.0		0.2-0.7	0.0-0.2		0.1-0.4	0.1-0.6							
Alkali-Res.																			
Cemfil, No. 1243972	UK	Pilkington	71.0	1.0				16.0	1.0	11.0									
AR. No. 5307116	JAPAN	Kanebo LTD.	60.7					21.5	16.5	1.3									
Sheh-15Zh, Inventors Certificate No. 451652	USSR	GIS	65.8	5.6															
Sheh-15Zh, Inventors Certificate No. 874689	USSR	GIS	63.0	4.1		7.4	0.3	6.2	3.5	9.0	8.3	4.7							

TABLE 5 CONT.

Glass Type	Country	Org.	SiO ₂	Al ₂ O ₃	B ₂ O ₃	CaO	MgO	TiO ₂	ZrO ₂	ZnO	Na ₂ O + K ₂ O	Fe ₂ O ₃	F ₂	CoO	SO ₃	B	CuO	Ni ₂ O ₃	CrO ₃
No.	USSR	D.I.medel	50.6-	12.0-		5.0-	0.5-		0.1-0.5		12.5-								
2083516		EEV	60.0	23.0		14.0	11.0				19.0								
		RkhTU																	
<i>Hi Silica</i>																			
Russian patent	USSR	Npob	72.0-	2.5-							20.0-			0.1-1.0	0.01-				
2165393-		Steklopl	77.0	3.5							25.0			0.5					
Precursor Glass		Astik									Na ₂ O								
		Aoot																	
Russian patent	USSR	Npob	94.0-	2.8-							0.12-			0.03-	0.02-				
2165393- Silica		Steklopl	97.0	3.9							0.32			1.3	1.2				
Fiber after		Astik									Na ₂ O								
leaching		Aoot																	
precursor																			
Q-Fiber	US	Johns Manville															0.01		
			99.68	0.13		0.3	0.01	0.01			0.03	0.04							
OMNISIL	USSR	Polotsk-steklov																	
		Olokno																	
REFRASIL	US	HITCO	98.8	0.16	0.29	0.044	0.0041	0.47	0.024								0.0004		0.0046
AMISIL	US	Auburn	97.9	0.71	0.16	0.23	0.17	0.8	0.01		0.03	0.01					<0.01		<0.01
		Manufacturing																	

[0036] Having discussed the amorphous silica component, the additive fibers will be discussed next. As noted hereinabove, two embodiments, one employing flame resistant (FR) fibers and another employing binder fibers are disclosed. In the following discussion, use of the term "silica fiber" shall be understood to mean those fibers containing amorphous (as opposed to crystalline) silica.

[0037] Beginning with the first type of additive fibers, namely the FR fibers, the amount of silica fiber in the fiber blend can vary, depending upon the other fibers used. In one embodiment, the amount of silica fiber in the blend is from 5 to 65 weight percent, based upon the total weight of the blend. In another embodiment, the amount of silica fiber in the blend is from 15 to 50 weight percent. In another embodiment, the amount of silica fiber in the blend is from 20 to 30 weight percent. The remaining fibers in the blend include the necessary amount of non-amorphous fibers, namely the FR fibers, to equal 100 weight percent.

[0038] Various FR fibers are known in the art. The FR fibers may be an inherent flame resistant fiber or a fiber (natural or synthetic) that is coated with an FR resin. The inherent flame resistant fibers are not coated, but have an FR component incorporated within the structural chemistry of the fiber. The term FR fiber, as used herein, includes both the inherent flame resistant fibers as well as fibers that are not inherently flame resistant, but are coated with FR resins. Accordingly, by way of example, a polypropylene fiber coated with an FR resin would be an FR polypropylene fiber.

[0039] Suitable inherently flame resistant fibers include polymer fibers having a phosphorus-containing group, an amine, a modified aluminosilicate, or a halogen-containing group. Examples of inherently flame resistant fibers include melamines, meta-aramids, para-aramids, polybenzimidazole, polyimides, polyamideimides, partially oxidized polyacrylonitriles, novoloids, poly(p-phenylene benzobisoxazoles), poly(p-phenylenebenzothiazoles), polyphenylene sulfides, flame retardant viscose rayons; (e.g., a viscose rayon based fiber containing 30% aluminosilicate modified silica, $\text{SiO}_2 + \text{Al}_2\text{O}_3$), polyetheretherketones, polyketones, polyetherimides, and combinations thereof).

[0040] Melamines include those sold under the tradenames Basofil by McKinnon-Land-Moran LLC. Meta-aramids include poly(m-phenylene isophthalamide), for example sold under the tradenames NOMEX® by E.I. Du Pont de Nemours and Co., TEIJINCONEX® and CONEX® by Teijin Limited and FENYLENE® by Russian State Complex. Para-aramids include poly(p-phenylene terephthalamide), for example sold under the tradename KEVLAR® by E.I. Du Pont de Nemours and Co., and poly(diphenylether para-aramid), for example sold under the tradename TECHNORA® by Teijin Limited, and under the tradenames TWARON® by Acordis and FENYLENE ST® (Russian State Complex).

[0041] Polybenzimidazole is sold under the tradename PBI by Hoechst Celanese Acetate LLC. Polyimides include those sold under the tradenames P-84® by Inspec Fibers and KAPTON® by E.I. Du Pont de Nemours and Co. Polyamideimides include for example those sold under the tradename KERMEL® by Rhone-Poulenc. Partially oxidized polyacrylonitriles include, for example, those sold under the tradenames FORTAFIL OPF® by Fortafil Fibers Inc., AVOX® by Textron Inc., PYRON® by Zoltek Corp., PANOX® by SGL Technik, THORNEL® by American Fibers and Fabrics and PYROMEX® by Toho Rayon Corp.

[0042] Novoloids include, for example, phenol-formaldehyde novolac, such as that sold under the tradename KYNOL® by Gun Ei Chemical Industry Co. Poly(p-phenylene benzobisoxazole) (PBO) is sold under the tradename ZYLON® by Toyobo Co. Poly(p-phenylene benzothiazole) is also known as PBT. Polyphenylene sulfide (PPS) includes those sold under the tradenames RYTON® by American Fibers and Fabrics, TORAY PPS® by Toray Industries Inc., FORTRON® by Kureha Chemical Industry Co. and PROCON® by Toyobo Co.

[0043] Flame retardant viscose rayons include, for example, those sold under the tradenames LENZING FR® by Lenzing A. G. and VISIL® by Sateri Oy Finland. Polyetheretherketones (PEEK) include, for example, that sold under the tradename ZYEX® by Zyex Ltd. Polyketones (PEK) include, for example, that sold under the tradename ULTRAPEK® by BASF. Polyetherimides (PEI) include, for example, that sold under the tradename ULTEM® by General Electric Co.

[0044] Modacrylic fibers are made from copolymers of acrylonitrile and other materials such as vinyl chloride, vinylidene chloride or vinyl bromide. Flame retardant materials such as antimony oxide can be added to further enhance flame resistant property. Modacrylic fibers are manufactured by Kaneka under the product names KANECARON PBX and PROTEX-M, PROTEX-G, PROTEX-S and PROTEX-PBX. The latter products contain at least 75% of acrylonitrile - vinylidene chloride copolymer. SEF PLUS by Solutia is a modacrylic fiber as well with flame retardant properties.

[0045] Further examples of inherent FR fibers suitable for use in the blend of the present invention include polyester with phosphalane such as that sold under the trademark TREVIRA CS® fiber or AVORA® PLUS FIBER by KoSa.

[0046] Also useful are chloropolymeric fibers, such as those sold under the tradenames THERMOVYL® L9S & ZCS, FIRBRAVYL® L9F, RETRACTYL® L9R, ISOVYL® MPS by Rhovyl S.A., PIVIACID®, Thuringische, VICLON® by Kureha Chemical Industry Co., TEVIRON® by Teijin Ltd., ENVILON® by Toyo Chemical Co., VICRON®, SARAN® by Pittsfield Weaving, KREHALON® by Kureha Chemical Industry Co., OMNI-SARAN® by Fibrasomni, S.A. de C.V., and combinations thereof. Fluoropolymeric fibers such as polytetrafluoroethylene (PTFE), poly(ethylene-chlorotrifluoroethylene) (ECTFE), polyvinylidene fluoride (PVDF), polyperfluoroalkoxy (PFA), and polyfluorinated ethylene-propylene (FEP) and combinations thereof are also useful.

[0047] Natural or synthetic fibers coated with an FR resin are also useful in the fiber blend of the present invention. Suitable fibers coated with an FR resin include those where the resin contains one or more of phosphorus, phosphorus

compounds, red phosphorus, esters of phosphorus, and phosphorus complexes; amine compounds, boric acid, bromide, urea-formaldehyde compounds, phosphate-urea compounds, ammonium sulfate, or halogen based compounds. Non-resin coatings like metallic coating are not generally employed for the present invention, because they tend to flake-off after continuous use of the product. Suitable commercially available FR resins are sold under the trade names GUARDEX FR[®], and FFR[®] by Glotex Chemicals in Spartanburg, S.C.

[0048] The manner in which the resin is coated onto the fiber is not particularly limited. In one embodiment, the FR resin is a liquid product that can be applied as a spray. In another embodiment, the FR resin is a solid that may be applied as a hot melt product to the fibers, or as a solid powder that is then melted into the fibers. In one embodiment, the FR resin is applied to the fibers in an amount of from 6 to 25 weight %, based upon the total weight of the coated fibers.

[0049] The amount of coated FR fiber in the blend can vary, but is from 35 to 95 weight percent, based upon the total weight of the blend. In one embodiment, the amount of coated FR fiber in the blend is from 40 to 90 weight percent. In another embodiment, the amount of coated FR fiber in the blend is from 45 to 85 weight percent.

[0050] The denier of the FR fibers is from 1.5 to 15 dpf (denier per filament). The foregoing listing of FR fibers illustrates the fact that any FR fiber known can be employed with an amorphous silica fiber and utilized. Thus, fiber types includes multifilament and monofilament yarns, having a variety of cross-sections and shapes as well as fibrillated yarns, typically manufactured from slit films or tapes.

[0051] The fiber blend of the present invention may further contain one or more non-FR fibers. The non-FR fibers may be synthetic or natural fibers. Suitable non-FR synthetic fibers include polyester such as polyethylene terephthalate (PET); cellulose, such as rayon and/or lyocell; nylon; polyolefin such as polypropylene fibers; acrylic; melamine and combinations thereof. The lyocell fibers are a generic classification for solvent-spun cellulosic fibers. These fibers are commercially available under the name TENCEL[®]. Natural fibers include flax, kenaf, hemp, cotton and wool. In one embodiment, non-FR fibers are employed to enhance certain characteristics such as loft, resilience or springiness, tensile strength, and thermal retention.

[0052] The fiber blend includes amorphous silica fiber and at least one type of FR fiber. Therefore, a fiber blend that contains amorphous silica fiber, an FR fiber, optionally additional FR fibers, and optionally one or more non-FR fibers is used. In one embodiment, the fiber blend includes: modacrylic fiber; a cellulosic fiber, lyocell, and amorphous silica fiber.

[0053] In another embodiment, the fiber blend further includes more than one type of FR fiber. In another embodiment, the fiber blend includes amorphous silica fiber, modacrylic fiber, and VISIL. In yet another embodiment, the fiber blend includes modacrylic fiber, FR rayon fiber, and amorphous silica fiber.

[0054] In another embodiment, the fiber blend includes modacrylic fibers, VISIL (FR viscose rayon) fibers, amorphous silica fibers, and FR polypropylene fibers. The amounts of each component can vary; however, advantageous char strength is obtained when a needlepunched fabric is prepared from a blend containing 40 weight percent modacrylic, 40 weight percent VISIL, 15 weight percent amorphous silica, and 5 weight percent FR polypropylene fibers.

[0055] The fibers of the present invention can be used to manufacture fabrics, where FR properties are desired or would be useful. Essentially any type of fabric, produced from fibers, such as non-woven fabrics; woven fabrics, both open and closed weave; knitted fabrics and various laminates can be made using the fibers of the present invention. The manufacture of such fabrics is not limited to a particular method or apparatus. For woven fabrics, it is possible to employ amorphous silica fibers in the machine direction or the cross machine direction, alternating with one or more of the FR fibers. Alternatively, the fibers can be alternated in the machine direction and woven with either an amorphous or an FR fiber in the cross machine direction. As a percentage, woven fabrics can comprise the compositions stated above for the blend of amorphous and FR fibers.

[0056] The non-woven fabric may be produced by mechanically interlocking the fibers of a web. The mechanical interlocking can be achieved through a needlepunch operation. Needle punch methods of preparing non-woven fabric are known in the art. In one embodiment, the nonwoven fabric, sometimes called a batt, may be constructed as follows: the fiber blend may be weighed and then dry laid/air laid onto a moving conveyor belt. The speed of the conveyor belt can be adjusted to provide the desired batt weight. Multiple layers of batts are fed through a needle loom where barbed needles are driven through the layers to provide entanglement.

[0057] There are several other known methods for producing nonwoven fabrics including hydroentanglement (spunlace), thermal bonding (calendering and/or through-air), latex bonding or adhesive bonding processes. The spunlace method is similar to needlepunch except waterjets are used to entangle the fibers instead of needles. Thermal bonding requires either some type of thermoplastic fiber or powder to act as a binder. It is to be appreciated that all forms of nonwovens can be made with the FR fiber blends of the present invention to produce barrier fabrics having FR properties. Accordingly, reference to nonwoven fabrics herein includes all forms of manufacture.

[0058] Suitable non-woven fabrics have a batt weight greater than 76.29 grams per square meter (g/m²). In one embodiment, the batt weight ranges from 76.29 (g/m²) to 678.12 (g/m²). In another embodiment the batt weight is 118.87 (g/m²). In one embodiment, the fibers are carded. Then the conveyor belt moves to an area where spray-on material may optionally be added to the nonwoven batt. For example, the FR resin may be sprayed onto the nonwoven batt as a latex. In one embodiment, the conveyor belt is foraminous, and the excess latex spray material drips through the belt

and may be collected for reuse later. After the optional spraying, the fiber blend is transported to a dryer or oven. The fibers may be transported by conveyer belt to the needlepunch loom where the fibers of the batt are mechanically oriented and interlocked to form a non-woven fabric.

[0059] The non-woven FR fabric is useful as a barrier fabric for bedding materials and bed clothing. The fabric is also useful in upholstery and drapery applications where flame resistance is desired. Another use for such fabrics is as hot gas filtration fabrics. Additionally, fabrics other than non-wovens can be made from the fibers where an FR fabric is desired.

GENERAL EXPERIMENTAL

[0060] In order to demonstrate the efficacy of various fiber blends as FR materials, a number of samples were prepared and tested, as described hereinbelow.

EXAMPLES

Example Nos. 4 -15

[0061] The samples were prepared on a miniature card and needleloom. The fiber was first hand-opened and layered on the card feed apron. The carded sample was run back through the card a second time to assure intimate blending of fibers. The carded web, layered around the wind-up roll, was cut transversely and removed from the card. Then it was fed into the needlepunch line for needling. A second pass was performed to accomplish needling from the opposite side.

[0062] Standard tensile strength testers were modified to measure the char strength of the barrier fabric. More specifically, the fabric stiffness test typically used with pocket coil material was modified to measure the amount of force, measured and reported in pounds, required to push a fabric sample through a hole with a plunger. To force the material to break, a template was fabricated so that the fabric could be sandwiched between the template and the existing test plate.

[0063] Specimens of the barrier fabric were cut into 10.16 cm by 20.32 cm (4" by 8") samples and weighed. The samples were placed in a charring frame and charred by using a Bunsen burner. The frame was then mounted into the modified stiffness tester and the char strength of the sample was measured. Table 6 summarizes the results for Example Nos. 4-15. As a standard, a blend comprising 40% modacrylic and 60% Visil was selected (Ex. No. 4). The following types of fiber were used: Basofil® (abbreviated Bas); modacrylic fiber KANECARON PBX; VISIL® (abbreviated Vis); polyethylene terephthalate (abbreviated PET); and amorphous silica (abbreviated Sil). Examples 5-11 and 13-14 are comparative examples of fabric prepared from various fiber blends as indicated. Examples 5 and 6 contained 10% Basofil fibers as a replacement for equal amounts of modacrylic fiber or Visil fiber; Examples 7 and 8 contained 10% and 20% PET fibers as a replacement for equal amounts of Visil fiber; Example 9 comprised a blend 10% Basofil fibers with PET fibers, modacrylic fiber and Visil fiber; Examples 10 and 11 contained 10% and 15% PET fibers as a replacement for varying amounts of modacrylic fiber and Visil fiber; Examples 13 and 14 contained 10% Basofil fibers as a replacement for varying amounts of modacrylic fiber and Visil fiber; Examples 12 and 15 were prepared from fiber blends containing amorphous silica fibers.

TABLE 6

CHAR STRENGTH TO WEIGHT RATIO FOR NON-WOVEN FABRIC MADE FROM VARIOUS FIBER BLENDS

Ex. No.	FIBER BLEND	(kg)	Strength (pounds)	(g)	Weight (ounces)	Strength/ Weight
4	40 PBX/60 Vis	0.145	0.32	153	5.4	0.06
5	10 Bas/30 PBX/60 Vis	0.141	0.31	167	5.9	0.05
6	10 Bas/40 PBX/50 Vis	0.163	0.36	196	6.9	0.05
7	10 PET/40 PBX/50 Vis	0.145	0.32	190	6.7	0.05
8	20 PET/40 PBX/40 Vis	0.145	0.32	184	6.5	0.05
9	10 Bas/10 PET/25 PBX/ 55 Vis	0.145	0.32	119	4.2	0.08

(continued)

CHAR STRENGTH TO WEIGHT RATIO FOR NON-WOVEN FABRIC MADE FROM VARIOUS FIBER BLENDS

	Ex. No.	FIBER BLEND	(kg)	Strength (pounds)	(g)	Weight (ounces)	Strength/ Weight
5	10	10 PET/25 PBX/65 Vis	0.136	0.30	133	4.7	0.06
	11	15 PET/25 PBX/60 Vis	0.132	0.29	142	5.0	0.06
10	12	10 Sil/35 PBX/ 55 Vis	0.191	0.42	150	5.3	0.08
	13	10 Bas/30 PBX/60 Vis	0.136	0.30	90.7	3.2	0.09
	14	10 Bas/40 PBX/50 Vis	0.136	0.30	93.6	3.3	0.09
15	15	10 Sil/35 Pyx/ 55 Vis	0.141	0.31	82.2	2.9	0.10

[0064] It can be seen that when the char strength of the fabric is correlated to the weight of the sample, the fabric formed from fiber blends containing amorphous silica (Examples No. 12 and 15) show a strength to weight ratio of from 0.08 to 0.10.

Example Nos. 16-45

[0065] Examples 16-45 were prepared and tested as for Examples 4-15, except that different blends of fiber were used, as summarized in Table 7. Strength of each fabric is reported in pounds, as discussed hereinabove. The fabrics have been reported in six groups of four blends and two groups of three blends. Examples 19, 23, 27, 31, 34, 38, 41, and 45 report a base fabric and the examples immediately preceding report the addition of various types of FR fiber. Char strength, in pounds, was measured and the results have been reported by decreasing values for each group.

[0066] For example, FR rayon and modacrylic fibers were used to prepare Example 19, denoted FR Rayon/Modacrylic Base Fabric. Examples 16-18 are variations of this base fabric, because in each case one other type of FR fiber was added: para-aramid fibers were added to Example 16, melamine fibers were added to Example 17, and amorphous silica fibers were added to Example 18, according to the present invention.

[0067] Similarly, Example 23 was prepared from FR rayon fibers and is denoted FR Rayon Base Fabric, while Examples 20-22 were variations of this base fabric: para-aramid fibers were added to Example 20, melamine fibers were added to Example 21, and amorphous silica fibers were added to Example 22.

[0068] Likewise, Example 27 is a rayon/modacrylic base fabric, and Examples 24-26 were variations of this base fabric: melamine fibers were added to Example 24, para-aramid fibers were added to Example 25, and amorphous silica fibers were added to Example 26.

[0069] Example 31 is a lyocell/modacrylic base fabric, and Examples 28-30 were variations of this base fabric: para-aramid fibers were added to Example 28, melamine fibers were added to Example 29, and amorphous silica fibers were added to Example 30.

[0070] In the next series, Example 34 is the Visil/modacrylic base fabric, and Examples 32, 33 and 35 were variations of this base fabric: para-aramid fibers were added to Example 32, amorphous silica fibers were added to Example 33; and melamine fibers were added to Example 35.

[0071] Example 38 is a Visil base fabric, while Examples 36-37 were variations of this base fabric: melamine fibers were added to Example 36, and amorphous silica fibers were added to Example 37.

[0072] Example 41 is a rayon base fabric, while Example 39 contains rayon and melamine, and Example 40 contains rayon and amorphous silica.

[0073] Example 45 is a lyocell base fabric, while Example 42 contains para aramid, Example 43 contains lyocell and melamine, and Example 44 contains lyocell and amorphous silica.

TABLE 7

CHAR STRENGTH OF NON-WOVEN FABRIC MADE FROM VARIOUS FIBER BLENDS

Ex. No.	FABRIC	STRENGTH
16	FR Rayon/Modacrylic/10% para aramid	3.22

EP 1 861 524 B1

(continued)

CHAR STRENGTH OF NON-WOVEN FABRIC MADE FROM VARIOUS FIBER BLENDS

	Ex. No.	FABRIC	STRENGTH
5	17	FR Rayon/Modacrylic/10% melamine	2.39
	18	FR Rayon/Modacrylic/10% silica	2.23
	19	FR Rayon/Modacrylic Base Fabric	1.77
10	20	FR Crayon/10% para aramid	2.98
	21	FR Rayon/10% melamine	2.37
	22	FR Rayon/10% silica	1.39
	23	FR Rayon Base Fabric	0.63
15	24	Rayon/Modacrylic/10% melamine	2.85
	25	Rayon/Modacrylic/10% para aramid	2.34
	26	Rayon/Modacrylic/10% silica	2.12
	27	Rayon/Modacrylic Base Fabric	0.74
20	28	Lyocell/Modacrylic/10% para aramid	2.37
	29	Lyocell/Modacrylic/10% melamine	1.49
	30	Lyocell/Modacrylic/10% silica	1.43
	31	Lyocell/Modacrylic Base Fabric	0.64
25	32	Visil/Modacrylic/10% para aramid	2.08
	33	Visil/Modacrylic/10% silica	1.76
	34	Visil/Modacrylic Base Fabric	1.54
	35	Visil/Modacrylic/ 10% melamine	1.32
30	36	Visil/10% melamine	1.65
	37	Visil/10% silica	1.29
	38	Visil Base Fabric	0.92
35	39	Rayon/10% melamine	1.55
	40	Rayon/10% silica	1.36
	41	Rayon Base Fabric	0.01
40	42	Lyocell/10% para aramid	1.27
	43	Lyocell/10% melamine	0.37
	44	Lyocell/10% silica	0.32
	45	Lyocell Base Fabric	0.01

[0074] It can be seen from the data in Table 7 that fabric containing 10 percent by weight amorphous silica shows improved char strength as compared to that same base fabric without amorphous silica e.g., Example No.18 compared to Example No. 19. It will be noted that while the use of other FR materials, namely para-aramid and melamine, with the base fabric generally provided greater strength than the blend containing amorphous silica, the former two materials are far more costly than the silica. In addition, the aramids present a golden yellow color to the fabric, while the melamines present an off-white color. The amorphous silica does neither and thus, the resulting fabric is white without the addition of pigments. Finally, the char strength of the fabrics comprising amorphous silica is more that adequate for usefulness in bedding, clothing, furniture, drapery and related purposes.

Example Nos. 46-53

[0075] Examples 46-53 were prepared by using a needlepunch line including a 12 inch card, a crosslapper, and a 60.96 cm (24 inch) Dilo OD-1 needle loom. Example No. 46 was the base blend 271.25 (g/m²) comprising 40 % modacrylic

and 60 % Visil) and in the Examples following, various materials or FR fibers were employed. Example 47 comprised a blend of the base blend (79 %) and leno weave carpet backing, 71.20 (g/m²) (21%). Example 48 comprised a blend of the base blend (89 %) and Conwed scrim. 33.91 (g/m²), (11 %). Conwed is a very lightweight polypropylene material with the "warp" and "fill" monofilaments "welded" together at the vertices to provide a "leno type" appearance. Example 49 comprised a blend of the base blend (85 %) and Basofil (melamine) (15 %). Example 50 comprised a blend of the base blend (85 %) and Conex (15 %). Conex is a meta-aramid. Example 51 comprised a blend of the base blend (85 %) and amorphous silica (15 %). Example 62 comprised a blend of the base blend (85 %) and Kynol (phenol-formaldehyde novolac) (15 %). Example 53 comprised a blend of amorphous silica (15 %), modacrylic fiber (40 %) and Visil fiber (45 %). Example No. 53 represents a fabric.

[0076] A tuft button simulation was designed to expose the charred fabric to stresses that it might see in an actual mattress burn, and gives a pass/fail indication of fabric strength. A small test rig was constructed out of wood. Components were assembled shown in the drawing figure to form tuft button test apparatus 10. Mattress component including 10.16 cm (4 inch) foam 12, two 1 inch super-soft foams 14, 16, barrier fabric 18, which was 152.57 (g/m²), PET fiber fill 20, and a PET ticking fabric 22 were assembled as described below, and then burned under tension.

[0077] The components were assembled on top of upper plate 24. The foam components 12, 14 and 16, were compressed and the barrier fabric 18, fiber fill 20, and ticking 22 were wrapped around all sides of upper plate 24. Lower plate 26 was positioned to sandwich fabrics 18, 20, 22 between upper plate 24 and lower plate 26. A tuft button simulator 28, was welded threaded rod 30, and rod 30 was pushed through all of the mattress components, and through aligned holes 32, 34 in upper and lower plates 24, 26. Wing nut 36 was fastened to rod 30 to apply tension to the assembly and draw tuft button simulator 28 down into the foam.

[0078] A TB 603 top burner 28 was placed in the center of tuft button simulator 10, ignited, and allowed to burn for 70 seconds. Results are summarized in Table 8.

TABLE 8
TUFT BUTTON SIMULATION

Ex. No.	FIBER BLEND	FIT-FOR-USE RESULTS
46	2712.5 (g/m ²) Base blend (comparative example)	Sample cracked within 30 seconds, and was fully aflame in 40 seconds.
47	271.25 (g/m ²) Base blend and 71.20 (g/m ²) leno weave	Sample cracked within 20 seconds of ignition.
48	271.26 (g/m ²) Base blend and conwed scrim	Sample cracked within 30 seconds.
49	203.43 (g/m ²) 15% Basofil and Base blend	Sample cracked within 30 seconds.
50	203.43 (g/m ²) 15% Conex and Base blend	Sample cracked within 25 seconds.
51	203.43 (g/m ²) 15% silica and Base blend	Sample did not crack, and self-extinguished in 8 minutes.
52	203.43 (g/m ²) 15% Kynol and 85% Base blend	Sample did not crack, and self-extinguished in 11½ minutes.
53	169.53 (g/m ²) 16% silica/40% modacrylic/45% Visil	Sample did not crack, and self-extinguished in 12-15 not crack, and in 12-15 minutes

[0079] In several previous full-mattress burns of various constructions, an 271.25 (g/m²) needlepunch fabric of 60% Visil/40% modacrylic had successfully passed according to the criteria set forth in California Test Bulletin 603. Only In constructions where this barrier was subjected to tension after charring was this fabric not successful. As a control, to show that known fabric performance in full scale testing performed comparably with this bench test, the 271.25 (g/m²) fabric was used (Ex No. 48). The sample cracked in the area surrounding the tuft button within 30 seconds, and the entire assembly was fully aflame within 40 seconds. This was the desired performance, since it accurately portrayed the performance of this fabric in full-scale burns. Ex No. 47 used the 271.25 (g/m²) fabric In a composite with a 71.20 (g/m²) leno weave secondary carpet backing fabric. Likewise, it cracked within 20 seconds, and was withdrawn as a possible solution. Similarly, Ex No 48 used a polypropylene scrim, very light in wt 33.91 (g/m²) that had a "leno-weave look" to it Though it was not a woven fabrics, the vertices of the "warp" and "fill" monofilaments were fused together. This sample also cracked well under 1 minute.

[0080] The remaining samples prepared were not composites, but needled blends of fibers performed on a pilot line card/crosslapper/needleloom assembly. These samples were also produced at lower weights to gain economic advantages. The first fabric evaluated, Ex No.49, was a 203.43 (g/m²) fabric consisting of 15% melamine, and 85% "base blend" of 60/40 Visil/modacrylic. This fabric cracked within 30 seconds and flamed out of control. It was eliminated as a candidate for this application. Ex. No. 50, a 203.43 (g/m²) fabric consisting of 15% meta aramid; and 86% "base blend"

of 60/40 Visil/modacrylic, also cracked and burned out of control within 25 seconds. Ex. No. 51, a 203.43 (g/m²) fabric consisting of 15% amorphous silica, and 85% "base blend" of 60/40 Visil/modacrylic did not crack, and the full assembly self-extinguished within 8 minutes of ignition. Similarly, Ex No. 52, a 203.43 (g/m²) fabric consisting of 16% novoloid, and 85% "base blend" of 60/40 Visil/modacrylic did not crack, and self-extinguished within 11.5 minutes. Though many other fibers were considered for this demonstration, the higher cost of some fibers prevented them from being considered economical. In a follow-up to these trials, a fabric. Ex. No. 53, a 169.53 (g/m²) fabric consisting of 16% amorphous silica, 40% modacrylic, and 45% Visil, was assembled in the tuft button simulator rig, and it also did not crack, and in fact, self-extinguished in about 13 minutes.

[0081] Having demonstrated that the use of amorphous silica fibers with FR fibers is highly effective in providing FR fabrics, the second embodiment shall be discussed next.

[0082] As noted hereinabove, a single layer nonwoven fabric useful in protecting items from fire and the related heat is disclosed and a process for protecting adjacent materials in an assembly using the fire and heat barrier fabric as well. The nonwoven barrier is of at least 15.28 (g/m²) of an amorphous silica fiber and at least 15.26 (g/m²) of a binder fiber; the single layer nonwoven fabric having a basis weight of at least 101.72 (g/m²). The fiber blend by weight of the nonwoven fabric comprises 15 to 80 percent by weight amorphous silica fiber, 15 to 85 percent by weight binder fiber and may, but not necessarily, contain up to 70 percent by weight of complimentary fibers with a reduction of the other two fibers to total 100 percent by weight without falling below the minimum amounts.

[0083] As stated previously, the amorphous silica fiber is always present in the nonwoven fabric composition and comprises at least 15 percent by weight of the fiber blend, but no more than 80 percent. In one embodiment the amorphous silica fiber comprises between 35 and 50 percent by weight of the fiber blend. As the blend percentage by weight of the silica fiber is reduced, the effectiveness of the single layer nonwoven to shield open flames and heat diminishes. Although the individual amorphous silica fibers continue to resist burning and melting at levels lower than 15 percent by weight in the nonwoven, at least this level must be maintained to offer adequate structure and integrity within the nonwoven fabric construction during and after exposure to an open flame. At least 15 percent by weight of the amorphous fibers by weight are required in the nonwoven to maintain any acceptable level of char strength.

[0084] The blend percentage by weight of the amorphous silica is limited to no more than 80 percent by weight in the described nonwoven to preserve the functional characteristics required of a fire and heat barrier fabric. The fiber-to-fiber cohesion of the amorphous silica is such that at least 20 percent by weight of more cohesive fibers are required for sufficient fiber web strength and fiber entanglement in the nonwoven. It is this entanglement combined with the thermal bond that makes this single layer nonwoven unique. The combination of the mechanical and thermal bond results in a nonwoven construction, in at least one embodiment, capable of at least one of the following without limiting its ability to shield flames and heat, in another embodiment, capable of a majority of the following without limiting its ability to shield flames and heat and, in another embodiment, capable of all of the following without limiting its ability to shield flames and heat:

- i) capable of maintaining a needled stitch in a sewn assembly without the support of additional fabric layers as required by conventional thermally bonded nonwovens for support and reinforcement
- ii) capable of maintaining a thermal stitch in an ultrasonically welded assembly without the support of additional fabric layers as required by conventional thermally bonded nonwovens for support and reinforcement
- iii) capable of maintaining a thermal stitch in a heat welded assembly without the support of additional fabric layers as required by conventional thermally bonded nonwovens for support and reinforcement
- iv) capable of maintaining the integrity of its nonwoven construction as the surface layer of an assembly without excessive abrasion along the exposed surface, especially as compared to materials utilizing FR surface coatings
- v) capable of blending colors to avoid aesthetically displeasing contrasts in assembly of different materials and colors common with many conventional flame-resistant materials (natural color is white and blending hues are achieved by heathering in colors of the binder fiber or other additional fibers)
- vi) capable of use in a moving and/or contacted assembly without excessive noise related to its nonwoven construction
- vii) capable of sufficient loft, lower density and greater thickness, to provide satisfactory quilted seam depth considered aesthetically pleasing in a needle-sewn assembly (conventional needlepunch constructions are not)
- viii) capable of sufficient loft, lower density and greater thickness, to provide satisfactory quilted seam depth considered aesthetically pleasing in an ultrasonically welded assembly (conventional needlepunch constructions are not)
- ix) capable of sufficient loft, lower density and greater thickness, to provide satisfactory quilted seam depth considered aesthetically pleasing in a heat welded assembly (conventional needlepunch constructions are not)
- x) capable of maintaining flame and heat shielding efficiency after exposure to moisture (no performance-based aqueous solutions that might be washed away)
- xi) capable of providing sufficient stiffness of hand to prevent wrinkling and/or gathering around cutting surfaces which is commonly an issue with softer constructions.

[0085] In addition to the amorphous silica fiber, a binder fiber is always present in the nonwoven fabric composition and comprises at least 15 percent by weight of the fiber blend. In one embodiment, the amorphous silica fiber comprises between 50 and 65 percent by weight of the fiber blend. The binder fiber is necessary for the required thermal bonding of the nonwoven barrier fabric, but a multi-component binder fiber may also serve both a mechanical and a thermal role in the nonwoven fabric construction. Mechanically, at least one fiber must offer sufficient fiber-to-fiber cohesion to maintain the integrity of the fiber web and sufficient structure after thermal bonding to maintain entanglement of the fibers among the amorphous silica fibers. This cohesive fiber may be a component of the binder fiber (in the case of a multi-component binder fiber) that remains intact after thermal bonding, or it may be a fiber, or fibers, additive to the amorphous silica and binder fiber in the blend.

[0086] The binder fiber may be a single component, low melting point fiber that strictly acts as a binding agent for the thermal bond necessary in the nonwoven. Exemplary single component fibers include low-melt polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6,6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic polymers that have sufficiently low melting points, whether inherent or modified. By "sufficiently low" is meant that such thermoplastic fibers will have the lowest melting point of all the component fibers present. Some polymers will inherently have the lowest melting point while others, such as the polyesters, may need to be modified with an appropriate additive to yield a lower melting point than inherently possessed by the unmodified polymer.

[0087] The single-component binder fiber comprises at least 15 percent by weight of the fiber blend in the nonwoven. Any instance where a single-component binder fiber is used requires the addition of at least 15 percent by weight of a higher cohesion fiber for mechanical fiber interlock after thermal bonding. The single-component binder fiber must have a melting temperature no less than 107° C, but the melting temperature cannot exceed a value 10° C less than the lowest melting temperature of any other structural fiber in the fiber blend of the nonwoven.

[0088] The maximum melt temperature of the single-component binder fiber allows for the binder fiber to melt and flow, forming a binding matrix along and between structural fibers as these fibers are left intact at a temperature lower than their melting point. The minimum temperature varies by end-use application of the nonwoven fire/heat barrier and is based on a temperature higher than the maximum temperature exposure of the nonwoven barrier in subsequent assembly processes and day-to-day operational use and environs. Optimally the melt temperature of the single-component binder fiber is minimized within the range to reduce the energy and time required to thermally bond the nonwoven barrier fabric.

[0089] Diameter of the single-component binder fiber ranges from 20 microns to 60 microns and in one embodiment, it is 31 microns. Length of the single-component fiber ranges from 50 millimeters to 125 millimeters and in one embodiment, it is 75 millimeters, for needlepunch applications. The single-component binder fiber should not act as a contributory fuel source for an open flame.

[0090] The binder fiber may be a multiple component, low melting point fiber that acts strictly as a binding agent for the thermal bond necessary in the nonwoven. Exemplary multiple component fibers include those fibers of co-extruded polymers in combinations containing at least two of the following polymers: polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6,6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic polymers that have sufficiently low melting points, whether inherent or modified. The term "sufficiently low" has the same meaning as set forth above for the single-component fibers. Similar to the single-component fibers, the multi-component fibers provide two polymers that melt to provide thermal bonding.

[0091] This multi-component thermal binding fiber comprises at least 15 percent by weight of the fiber blend in the nonwoven. Any case where a multi-component binder fiber acts only as a thermal binding agent, its use requires the addition of at least 15 percent by weight of a higher cohesion fiber, but no more than 70 percent by weight, for mechanical fiber interlock after thermal bonding. This multi-component thermal binding fiber must have a melting temperature no less than 107° C, but the melting temperature cannot exceed a value 10° C less than the lowest melting temperature of any other structural fiber in the fiber blend of the nonwoven.

[0092] The maximum melt temperature of the multi-component thermal binding fiber allows for the binder fiber to melt and flow, forming a binding matrix along and between structural fibers as these fibers are left intact at a temperature lower than their melting point. The minimum temperature varies by end-use application of the nonwoven fire/heat barrier and is based on a temperature higher than the maximum temperature exposure of the nonwoven barrier in subsequent assembly processes and day-to-day operational use and environs. Optimally the melt temperature of the multi-component binding fiber is minimized within the range to reduce the energy and time required to thermally bond the nonwoven barrier fabric.

[0093] Diameter of the multi-component binder fiber ranges from 20 microns to 60 microns and in one embodiment, it is 31 microns. Length of the single-component fiber ranges from 50 millimeters to 125 millimeters and in one embodiment, it is 75 millimeters, for needlepunch applications. The multi-component binder fiber should not act as a contributory fuel

source for an open flame.

[0094] The binder fiber may be a multiple component, multi-binding (both mechanical and thermal binding functions) low melting point fiber that acts as a binding agent for the thermal bond necessary in the nonwoven and as a mechanical actor that has fiber-to-fiber cohesion sufficient to maintain entanglement of the nonwoven fiber matrix. Exemplary multiple component, multi-binding component fibers include those fibers of co-extruded polymers in combinations containing at least two of the following polymers: polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terphthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6,6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic polymers that have sufficiently low melting points, whether inherent or modified. The term "sufficiently low" has the same meaning as set forth above for the single-component fibers. Similar to the single-component fibers, the multi-component, multi-binding fibers provide a polymer that melts to provide thermal bonding; however, the second polymer does not melt and provides the mechanical function for fiber entanglement. This latter difference is a distinction between the multi-component fibers and the multi-component multi-binding fibers.

[0095] In other words, the multi-component multi-binding fibers must contain at least one component comprised of a lower-melt binding agent and a higher melt point component that remains intact after exposure to heat in the thermal bonding stage. This latter difference is a distinction between the multi-component fibers and the multi-component, multi-binding fibers.

[0096] The multi-component multi-binding fiber comprises at least 15 percent by weight of the fiber blend in the nonwoven. Any case where a multi-component multi-binding fiber is used does not necessarily require the addition of another higher cohesion fiber for mechanical fiber interlock after thermal bonding provided all described criteria are met.

[0097] Diameter of the multi-component multi-binding fiber ranges from 20 microns to 60 microns and in one embodiment, it is 31 microns. Length of the single-component fiber ranges from 50 millimeters to 125 millimeters and in one embodiment, it is 75 millimeters, for needlepunch applications. The multi-component multi-binding fiber should not act as a contributory fuel source for an open flame and may, in fact, be flame resistant.

[0098] The multi-component, multi-binding fibers may be any of several different fiber configurations (*e.g.* concentric sheath/core, eccentric sheath/core, side-by-side or bilateral, pie wedge, hollow pie wedge, islands-in-the-sea or matrix, and the like.), but it must retain core fibers of near original length after thermal bonding. These remaining core fibers must have strength sufficient to maintain mechanical entanglement under stress and must not act as a contributory fuel source to an open flame. In one embodiment, a minimum of 10 percent, but no more than 90 percent, by weight of the individual fiber acts as the thermal binding agent and must have a melting temperature no less than 107° C, but no more than 150° C. In another embodiment the melting temperature is 110° C. The previously described core fiber comprises a minimum of 10 percent, but no more than 90 percent, by weight of the individual fiber and must have a melting temperature no less than 115° C.

[0099] A useful binder fiber is a core/sheath bi-component configuration comprised of a polyethylene terephthalate (PET) core and a lower melt temperature PET sheath wherein the sheath is 60 percent by weight of the individual fiber and the core is the remaining 40 percent. The sheath acts as the thermal binding agent forming the outer surface of the binder fiber and has a melting temperature of 110° C and the core has a melting temperature of 130° C. Such a core/sheath bi-component binder fiber is available from Huvis Corporation in Korea. In one embodiment, core/sheath bi-component binder fiber comprises between 50 and 65 percent by weight of the fiber blend in the nonwoven barrier.

[0100] Other multi-component multi-binding fibers that may also be employed include those fibers of co-extruded polymers in combinations containing at least two of the following polymers: polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6,6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic polymers that have sufficiently low melting points, whether inherent or modified, or any natural cellulosic fibers (cotton, flax, ramie, jute, kenaf, hemp, and the like) or protein fibers (wool, cashmere, camel hair, mohair, other animal hair, silk, and the like) coated or joined together with any of the aforementioned thermoplastic polymers. The term "sufficiently low" has the same meaning as set forth above for the single-component fibers.

[0101] These multi-component multi-binding fibers must contain more than one component comprised of a lower-melt binding agent and a higher melt point component that remains intact after exposure to heat in the thermal bonding stage, similar to the multi-component, multi-binding fibers described hereinabove. The binding agent may be any synthetic fiber with a melting temperature within the aforementioned range that does act as a contributory fuel source for an open flame. The remaining core portion may be any synthetic or natural fiber with a melting temperature no less than 115° C, does not act as a contributory fuel source for an open flame, and has fiber-to-fiber cohesion sufficient to maintain fiber web integrity and hold entanglement among fibers after needling.

[0102] A fiber must have a minimum Limiting Oxygen Index (LOI) of at least 21 to be considered a non-contributory fuel source. LOI is a relative measure of flammability that is determined by igniting a sample in an oxygen/nitrogen atmosphere and then adjusting the oxygen content to the minimum amount required to sustain steady burning. The higher the value, the less flammable a material is considered. The limiting oxygen index (LOI), also called the critical

oxygen index (COI) or oxygen index (OI), is defined as:

$$\text{LOI} = \frac{[\text{O}_2 (\text{conc})]}{[\text{O}_2 (\text{conc})] + [\text{N}_2]}$$

where $[\text{O}_2 (\text{conc})]$ and $[\text{N}_2]$ are the minimum oxygen concentration in the inflow gases required to pass the "minimum burning length" criterion and the nitrogen concentration in the inflow gases respectively. If the inflow gases are maintained at constant pressure then the denominator of the equation is constant since any reduction in the partial pressure (concentration) of oxygen is balanced by a corresponding increase in the partial pressure (concentration) of nitrogen. Limiting oxygen index is more commonly reported as a percentage rather than fraction.

[0103] Since air comprises 20.95% oxygen by volume, any material with a limiting oxygen index less than this will burn easily in air. Conversely, the burning behavior and tendency to propagate flame for a polymer with a limiting oxygen index greater than 20.95 will be reduced or even zero after removal of the igniting source. Self-sustaining combustion is not possible if $\text{LOI} > 100$, such values are not physically meaningful. Examples of the LOI of various compounds are set forth below in Table

TABLE 9

LIMITING OXYGEN INDEX (LOI) OF VARIOUS COMPOUNDS

Polyolefin	18
Cotton	18
Wool	25
Polyamide	22
Polyesters	21
Polyphenylene Sulfide (PPS)	34
Para-aramid	28
Meta-aramid	30
Polyacrylonitrile (PAN)	55
Polytetrafluoroethylene (PTFE)	95
Fiberglass	100
Amorphous silica	100

[0104] Some examples of binder fibers commercially available include the following specialty single polymer fibers, all of which are available from Fiber Innovations Technology (FIT) of Johnson City, Tennessee, the product code of each being provided in parentheses: PETG binder fiber (undrawn) (T-135), PETG binder fiber (drawn) (T-137), PCT (T-180), FR (flame resistant) PET (T-190) and FR PET for yarn spinning (T-191). Other examples of binder fibers include the following concentric sheath/core bi-component fibers, also available from FIT and having the product code set forth in parentheses: 110°C "melt" CoPET/PET (T-201), 185°C melt CoPET/PET (T-202), Dawn Grey version of T-201 (T-203), Black version of T-202 (T-204), 130°C melt CoPET/PET (T-207), 150°C melt high crystallinity CoPET/PET (T-215), Black version of T-215 (T-225), PCT/PP (T-230), PCT/PET (T-231), PETG/PET (T-235), 185°C, high Tg coPET/PET (T-236), HDPE/PET (T-250), HDPE/PP (FDA food contact) (T-251), LLDPE/PET (T-252), PP/PET (T-260), Nylon 6/nylon 6,6 (T-270), and Black version of T-270 (T-271). Polyethylene terephthalate (PET) is particularly useful but a wide variety of binder fiber types exist.

[0105] Still other binder fibers available from FIT include PET (polyester), coPET, Tm = 110°C, coPET, Tm=125°C, coPET, Tm = 180°C, coPET, Tm = 200°C, PLA (polylactic acid), Tm = 130°C, PLA, Tm =150°C, PLA, Tm = 170°C, PTT (polytrimethylene terephthalate) available under the tradename Corterra™, PCT (polycyclohexanediol terephthalate), PETG (PET glycol), HDPE (high density polyethylene, LLDPE linear low density polyethylene, PP (polypropylene, PE/PP copolymer, PMP (polymethyl pentene), nylon 6, nylon 6,6, nylon 11 and nylon 12.

[0106] In addition to the above, polyester binder fibers may be used in some instances. Examples of polyester binder fibers include those available from Wellman, Inc. of Fort Mill, South Carolina, under various type names such as 209, H1305, H1295, H1432, M1440, M1429, M1427, M1425, M1428, and M1431.

[0107] In addition to the required amorphous silica fiber and the required binder fiber, the nonwoven fabric composition may comprise up to 70 percent by weight of other fibers, *i.e.*, complimentary fibers, considered to be a non-contributory

fuel source. Any embodiment comprised of a thermal-only binder fiber, such as a single component binder fiber containing a low melt polymer, requires the addition of at least 15 percent by weight of a higher cohesion fiber to provide mechanical fiber interlock after thermal bonding. One embodiment comprises between 35 and 50 percent by weight of the amorphous silica, between 50 and 65 percent by weight of the binder fiber, wherein the binder fibers is of a core/sheath bi-component configuration comprised of a polyethylene terephthalate (PET) core and a lower melt temperature PET sheath, and between 5 and 10 percent by weight of a complimentary fiber such as a solution dyed (pigmented) PET fiber for color in the single layer nonwoven fire and heat barrier fabric.

[0108] It may also be possible to include up to 15 percent by weight and, in one embodiment up to 10 percent by weight, and in another embodiment, up to 5 percent by weight of complimentary fibers that are not considered to be a "non-contributory" fuel source (as defined hereinabove), *i.e.*, having a LOI of less than 21. However, any such fibers employed will have limited application in the production of flame resistant fabrics or fabrics resistant to fire and heat.

[0109] The method of producing the single layer nonwoven fabric through slight mechanical entanglement of a web of the fibers and further thermal bonding to reduce physical property directional bias, maintain fuller length of individual fibers, encapsulate and contain individual fibers, and to reduce density per area of the nonwoven fabric without significantly diminishing the integrity of the fabric is also disclosed.

[0110] The nonwoven fabric may be constructed as follows. The various combinations of fibers that can be employed may be weighed and dry or wet formed into a fiber web. The web may be formed by any of several different methods:

1. Web forming by the dry laying, carding method.

Bales of each fiber type are fed into the process where the clumps and bundles of fibers are separated (opened). The opened fibers of each type are weighed in process and are fed together into a blended web laydown calculated by percent fiber type weight of the total. This web laydown is then fed into a card which uses rotating cylinders with fine teeth to orient the fibers into parallel arrays. This carded web is then transferred directly to the bonding process or is crosslapped onto a conveyor moving at a right angle allowing layering of carded web to increase web width, web weight and/or cross-directional strength before moving on to the bonding process.

2) Web forming by air laying method.

Bales of each fiber type are fed into the process where the clumps and bundles of fibers are separated (opened). The opened fibers of each type are weighed in process and are fed together into a blended web laydown calculated by percent fiber type weight of the total. This web laydown is formed by suspending the fibers in the air and then collecting them as a batt on a screen that separates the fibers from the air. This web is then transferred directly to the bonding process or is crosslapped onto a conveyor moving at a right angle allowing layering of carded web to increase web width and/or web weight before moving on to the bonding process.

[0111] A useful method of web formation is the dry-laid carded process.

[0112] The useful fabric formation is mechanical fiber entanglement by needlepunching the web and then thermal bonding through the application of heat above the melting temperature of the binder, but below the melting temperature of the structural fibers that mechanically bind the fabric through entanglement.

[0113] It is also possible to hydroentangle the fibers through the use of high pressure water jets, although the water jets tend to be more damaging to the more delicate amorphous silica fibers than the needlepunching.

[0114] Although one embodiment is a nonwoven fabric with mechanically entangled fibers that are then heat bonded, it is also possible to blend the fibers in a woven configuration and then thermally bond. For woven fabrics, it is possible to employ amorphous silica fibers in the machine direction or the cross machine direction, alternating with one or more of the FR or the binder fibers. Alternatively, the fibers can be alternated in the machine direction and woven with either an amorphous or an FR or a binder fiber in the cross machine direction. As a percentage, can comprise the compositions stated above for the blend of amorphous silica and FR fibers as well as amorphous silica and binder fibers. The particular weave construction for open weave fabrics and all ranges of end counts in both the machine and cross machine directions are included.

[0115] The blend in the woven is possible through various yarn structures ("types"= fiber types for blend):

1) Single Yarns:

- a) Blending multiple types of staple fiber before spinning them into a continuous yarn.
- b) Blending multiple types of continuous filaments before twisting or entangling them together into a continuous yarn.

2) Ply/Cord Yarns:

- a) Twisting together two or more single yarns of different types into a resultant ply yarn.
- b) Twisting together two or more ply yarns of different types into a resultant cord yarn.

3) Core-Spun/Wrapped Yarns:

- a) A central core of a continuous yarn or filament around which another type fiber is wrapped or twisted, resulting in a continuous yarn with one fiber type as the core and another type making up the exterior layer.

[0116] The blend in the woven is also possible through woven construction of yarns of different fiber types:

- 1) The warp yarns may be of one type and the weft yarns of another type.
- 2) Yarns of different fiber types may be combined in the warp at some interval.
- 3) Yarns of different fiber types may be combined in the weft at some interval.
- 4) Yarns of different fiber types may be combined in both the warp and the weft directions.

[0117] A fabric useful in protecting items, or products, such as mattresses, from fire and the related heat; a process for producing the fabric; and a process for protecting materials in a product by using the fire and heat barrier fabric are described. One such process for protecting materials in a product using the fire and heat barrier is by ultrasonically bonding or ultrasonically welding the barrier fabric directly to at least one component that is also present in the product. Such a component comprises a material that is susceptible to damage due to fire and heat, occasioned by exposure to open flames and therefore, requires barrier protection. Ultrasonic bonding is well known in the art, but the ability directly incorporate a fire and heat barrier into a sub-assembly is novel. Ultrasonic bonding uses ultrasonic energy to join layers of thermoplastic materials. High speed ultrasonic vibrations result in welds between thermoplastics fusing the materials together. This fusing, or welding, requires similar thermoplastic materials to form the bond.

[0118] As an example, many traditional mattress constructions are covered by a surface assembly of a high-loft fiber batt between an outside layer of ticking fabric and an inner layer of a lightweight fabric (typically spunbond) to hold the backstitch of the needle-and-thread quilted assembly. The quilted assembly forms a surface that is both soft and visually appealing due to the lofty quilted pattern. Because the high-loft fiber batt is conventionally PET, and because both the outer ticking layer and the inner structural layer are available in PET or a majority-blend PET, these and similar assemblies, or products, e.g., furnishings, transportation seats and surfaces, bed clothing and the like, are sometimes quilted by ultrasonic bonding means, rather than by the traditional needle-and-thread sew quilting.

[0119] Using ultrasonic bonding for the production of quilted assemblies typically has advantages over the sewing method because of the higher throughput speeds possible, fewer raw materials (no thread) required, less mechanical wear (no needle breaks; fewer moving parts), and is capable of forming a bond between the layers comparable, or better, than the sewn seams of traditional quilting.

[0120] Many materials and material blends capable of forming an adequate flame and thermal barrier are not thermoplastic, and those that are vary significantly from the other thermoplastic components used in the end product. Therefore, as products are increasingly required to meet new open flame requirements, the possibility to utilize ultrasonic bonding to quilt is lost.

[0121] The blends and resultant fabrics are such that they allow for the ultrasonically bonded quilting of an assembly containing a flame and thermal barrier. Within the described range of blends, those blends comprising at least 40 percent by weight PET, or other suitable thermoplastic, are suitable for ultrasonic bonding to other materials containing a minimum of 40 percent of the same or similar thermoplastic. One embodiment is for the flame and thermal barrier fabric to comprise a minimum of 50 percent PET by weight, and the other layers of the assembly contain at least 50 percent by weight of PET or similar thermoplastic.

[0122] Assemblies for mattress construction may be produced in any number of configurations (no inner layer is necessary) such as the following:

- 1. The flame and thermal barrier fabric may be ultrasonically bonded to the outer ticking layer at points across the full width and along the length of the assembly.
- 2. The flame and thermal barrier fabric may be ultrasonically bonded to the outer ticking layer at points only along the assembly edges.
- 3. For additional softness or depth of quilted pattern along the planar surface, termed "pop" in the mattress industry, layer(s) of high-loft batt may be added between the flame and thermal barrier fabric and the ticking before bonding as described in 1, hereinabove.

4. For additional softness along the planar surface, layer(s) of high-loft batt may be added between the flame and thermal barrier fabric and the ticking before bonding as described in 2, hereinabove.

5. The configurations outlined in items 2 and 4, hereinabove allow for improved flame and thermal shielding because the body of the barrier fabric contains no bond points. The nature of ultrasonic bonding requires pressure between the horn and anvil. This results in compression of the layers at each bonding point and these compressed points typically result in greater thermal transfer through the materials and possibly weaken the char strength of the materials when exposed to open flame. If the smooth surface resultant from assembly configurations 2 and 4 is not desired, it is taught here that high-loft batt or other loft fabric may be ultrasonically bonded directly to the outside ticking layer in the manner described in 1 and 3, before the flame and thermal barrier fabric is subsequently ultrasonically bonded at points along the assembly edge as the inner layer.

6. Variations of configuration 3 offering the same or similar effect are possible by layering the flame and thermal barrier fabric directly to the ticking layer and the high-loft batt is layered to the inside before ultrasonically bonding as described in 1, hereinabove.

7. Variations of configuration 4 offering the same or similar effect are possible by layering the flame and thermal barrier fabric directly to the ticking layer and the high-loft batt is layered to the inside before ultrasonically bonding as described in 2, hereinabove.

[0123] Another product used in mattress construction, is the border fabric, or side fabric material. As an example, satisfactory border assemblies for mattresses and/or box springs may be produced in any of the above configurations using full width roll-good materials up to approximately 120-inches in width (theoretically the width is unlimited because the ultrasonic horns and anvils may be arranged in a modular format, but practically, the width is limited to currently available widths of roll-good ticking and high-loft batt as well as currently available supporting equipment). The body quilt pattern is ultrasonically bonded using a series of wide horns applied across the width of a patterned cylinder anvil. The typical width of a border assembly ranges from 22.86cm (9 inches) to 35.56cm (14 inches) (or more). These individual widths may be ultrasonically slit and the edges ultrasonically sealed with a stitch pattern (or other pattern) using an in-line or off-line series of horns and slitter/sealing anvils.

[0124] Fabrics are particularly useful for mattress borders because the need for comfort is not present, as it is in the tops and bottoms of mattresses, the panels, which will incorporate batting to give the panel softness and loft. Accordingly, in the borders, the FR fabric is readily assembled to the ticking, as by ultrasonic welding, to form that product, which can be thought of a sub-assembly of the complete product, the mattress.

[0125] An example process setup for ultrasonic sealing would employ 1.1kW power supplies to 22.86 cm (9-inch) horns in series across the width of a cylinder anvil patterned to the quilting design desired in the body of the assembly. After the layers are fed from and unwound into this portion of the process, additional layers may be introduced if desired before flowing through a series of one inch diameter horns spaced at the desired widths of the border assemblies to be simultaneously slit and sealed (if desired) using a 1.1kW power supply to each horn. Process variables such as pressure, speed, amplitude, power boosters and loadings differ based on the types of materials used and the mass.

[0126] In order to demonstrate the effectiveness of fabrics, a number of fabric samples were subjected to open flame testing to determine their respective resistances to fire and related heat and in turn, ability to provide protection to the item. It should be appreciated that testing of the protected item is often times specific to the end-use application of the protected item and the test includes that item as a whole rather than testing of the individual components that make up that item. Testing of the fabric as a component to predict or correlate results in the finished item usually differs between manufacturers of the item. Preliminary testing was conducted with a variety of barrier fabrics comprising a range of amorphous silica to binder fiber ratios. As a result of this screening, it was determined that for use in mattresses, a 40 percent amorphous silica content was a useful amount, as it balanced costs against needed barrier protection. Nonetheless, greater or lesser amounts of amorphous silica may well have use in other environments (products) where barrier property requirements may differ as will permissible costs to product the fabric. Such other uses are discussed hereinbelow.

[0127] For development of the fire and thermal barrier fabrics for use in the mattress industry, a proprietary test at an independent test lab was employed to establish a performance baseline and track progress versus that baseline. Although the specifics of the test are held confidential by the independent lab, it can be revealed that the test is based on an open flame in contact with the face of the fabric for a set period of time. After the open flame is removed, the fabric is allowed to continue to burn until it fully extinguishes itself. The maximum temperature is measured on the side opposite the flame over the length of the test. The mass of the sample is measured before and after exposure to the flame to calculate mass loss. The strength of the fabric at the point of exposure may be tested to determine retained strength or char strength (depending on the application, this could be tensile, puncture, inspection for cracking or other). Test results are

EP 1 861 524 B1

reported in Table 10 that follows:

TABLE 10

	OPEN FLAME TESTING OF FR FABRICS						
			Mass per Unit Area				
	Example No.	(g/m ²)	(oz per square yard)	Blend % by Weight	(°C)	Max Temp (°F)	% Mass Loss
5	54	227	6.7	Incumbent Market Product -- FR coated sutchbond	310	590	5.4
10	55	305	9.0	Incumbent Market Product -- FR coated woven	255	491	1.7
15	56	176	5.2	Incumbent Market Product -- FR coated spunlace	286	546	5.3
	57	200	5.9	50% lyocell / 50% PET binder	442	827	49.7
20	58	190	5.6	50% lyocell / 50% PET binder plus FR coating	211	411	5.8
	59	237	7.0	50% PET / 50% lyocell plus FR croating	489	913	30.4
25	60	397	11.7	100% modacrylic plus FR coating	509	948	17.9
	61	295	8.7	20% proprietary "Fiber C" / 80% PET binder plus FR coating	284	544	25.9
30	62	234	6.9	20% proprietary "Fiber C" / 80% PET plus FR coating	261	501	2.5
35	63	468	13.8	100% PET plus fiberglass scrim plus FR coating	≥538	≥1000	3.2
	64	210	6.2	40% amorphous silica / 60% PET binder	236	457	3.2
40	65	193	5.7	40% amorphous silica / 60% PET binder	228	443	3.4
	66	166	4.9	40% amorphous silica / 60% PET binder	274	526	9.1
45	67	159	4.7	40% amorphous silica / 60% PET binder	277	530	7.7
50	68	359	10.6	40% amorphous silica / 60% PET binder	175	347	2.0
	69	292	8.6	40% amorphous silica / 60% PET binder	171	339	1.1
55							

(continued)

OPEN FLAME TESTING OF FR FABRICS							
Example No.	(g/m ²)	Mass per Unit Area (oz per square yard)	Blend % by Weight	(°C)	Max Temp (°F)	% Mass Loss	
70	237	7.0	40% amorphous silica / 60% PET binder	188	371	2.4	
71	234	6.9	45% amorphous silica / 45% proprietary "Fiber C" / 10% PET binder	190	374	3.0	
72	651	19.2	40% amorphous silica / 55% PET binder / 5% PET	107	224	0.5	
73	420	12.4	40% amorphous silica / 52% PET binder / 8% PP	288	551	13.4	
74	566	16.7	40% amorphous silica / 60% PET binder	182	360	3.7	

[0128] Although the specifics of the test are proprietary, the results shared demonstrate the performance of amorphous silica blends, as compared to other flame and thermal barriers when exposed to open flame. The "mass per unit area", "maximum temperature" and "percent mass loss" values are averages of six tested specimens for each blend or product. The testing performed by the independent lab established a baseline of performance for products currently in use as flame and thermal barrier fabrics in mattress industry ("Incumbent Market Product", Examples No. 54-56). Without representing that the results of this test directly correlate to the performance of a bedding set tested per the earlier described TB603 California open flame standard, nevertheless, the results are an indicator of the ability of a component fabric to withstand exposure to an open flame without excessive mass loss or excessive thermal transfer through the fabric.

[0129] What is, or is not, "excessive" may differ between mattress manufacturers, but tests of this kind allow for direct comparison of candidate fabrics against established component fabrics that have been extensively tested in the finished bedding sets. The fabrics tested include 10 examples (Nos. 54-63) of fabrics outside the present invention, followed by 11 examples (Nos. 64-74) of fabrics. With reference to the data in Table 10, it can be seen that the use of barrier fabrics comprising 40 percent of amorphous silica, provided acceptable protection, as compared to the incumbent products. It should be noted that while Examples 66 and 67 did show higher percent mass loss, this was attributable to the lower mass per unit area (4.9 and 4.7) compared to the other fabrics. Also, Example 73 showed both a greater maximum temperature and mass loss, which was due to the presence of the 8 percent PP fiber, a complimentary fiber which may be a fuel source, i.e., not a "non-contributory" fuel source, added to provide a colored, or pigmented, fabric.

[0130] In view of the foregoing disclosure, it is to be appreciated that possible end uses for the FR fabrics in various items include the following:

1. Bedding - barrier beneath ticking or exposed on the bottom of one-sided mattresses or on the top and/or bottom of the box springs. Borders, as discussed above, are also products that benefit by the presence of the barrier.
2. Furniture - barrier beneath upholstery of furniture or exposed on the underside of furniture or other unseen areas.
3. Transportation - barrier beneath upholstery of seating or exposed on the underside of the seating or other unseen areas. Barrier behind wall covering materials or attached to the backside of or within layers of curtains or drapes. Lining for engine and cargo bays or areas that need shielding from extreme heats.
4. Bed clothing - layered within blankets, comforters, pillows and the like.
5. Apparel - layered within personal protective apparel to protect against flames and heat. Uses include firemen, military, astronauts, industry, laboratories and the like, in items such as coats, pants, gloves, boots and the like.
6. Auto - inner lining of engine bays, pipe wrap, barrier within seats and behind carpeting and upholstered surfaces.

7. Construction/Home/Industry - house wrap, inner wall protective layer, fire blankets, linings of storage areas for combustibles, welding drapes, lining of landfills and the like emitting potentially flammable gases, hot gas filtration, backing of scatter rugs and carpets, kitchen pot holders and gloves and the like.

[0131] Thus, it should be evident that the use of amorphous silica fibers is highly effective in providing FR blends and fabrics. Amorphous silica fibers with at least one other flame resistant fiber, or a binder fiber can be combined. The fiber blends of the present invention can be utilized to manufacture flame resistant fabrics for a variety of purposes including, but not limited to barrier fabrics for upholstery, bedding and bed clothing applications. Moreover, the fabrics are not limited to non-woven types.

[0132] Based upon the foregoing disclosure, it should now be apparent that the fiber blends described herein are novel and will provide barrier fabrics and flame resistant fabrics, as set forth herein. Thus, the scope of the invention shall include all modifications and variations that may fall within the scope of the attached claims.

Claims

1. A flame resistant (FR) fiber blend comprising:

amorphous silica fibers comprising a mixture of 94 to 97% by weight SiO_2 , 3 to 4% by weight Al_2O_3 , 0.1 to 0.3% by weight Na_2O , 0.03 to 1.3 % by weight CoO , and 0.01 to 1.2 % by weight SO_3 ; and at least one fiber selected from the group consisting of FR fibers, binder fibers and mixtures thereof.

2. The fiber blend of claim 1, wherein said FR fibers are selected from the group consisting of modacrylics, polyester with phosphalene, melamines, meta-aramids, para-aramids, polybenzimidazole, polyimides, polyamideimides, partially oxidized polyacrylonitriles, novoloids, poly(p-phenylene benzobisoxazoles, poly(p-phenylenebenzothiazoles), polyphenylene sulfides, flame resistant viscose rayons, viscose rayon containing aluminosilicate-modified silica, cellulose, polyetherketones, polyketones, polyetherimides, natural or synthetic fibers coated with an FR resin, or mixtures thereof.

3. The fiber blend of claim 1, wherein the blend comprises at least about 5 weight percent amorphous silica fibers, based upon the total weight of fibers in the blend.

4. The fiber blend of claim 3, wherein the blend comprises from 5 to 65 weight percent amorphous silica fibers and from 35 to 95 weight percent of said FR fibers.

5. The fiber blend of claim 2, comprising Amorphous silica fibers, modacrylic fibers, and FR rayon fibers.

6. The fiber blend of claim 2, comprising amorphous silica fibers, modacrylic fibers, and viscose rayon fibers.

7. The fiber blend of claim 2, comprising amorphous silica fibers, modacrylic fibers, and cellulosic fibers.

8. The fiber blend of claim 2, comprising amorphous silica fibers and FR rayon fibers.

9. The fiber blend of claim 2, comprising amorphous silica fibers, modacrylic fibers, viscose rayon fibers, and FR polypropylene fibers.

10. The fiber blend of claim 1, wherein said binder fibers are selected from the group consisting of single component, multi-component, multi-binding fibers and complimentary fibers, said fibers having a melting temperature of not less than 107°C.

11. The fiber blend of claim 10, wherein said single-component, multi-component and multi-binding fibers and complimentary fibers, provide thermal bonding properties and wherein said multi-component, multi-binding fibers and complimentary fibers additionally provide mechanical properties.

12. The fiber blend of claim 10, wherein said blend comprises at least 15 weight percent amorphous silica fibers, based upon the total weight of fibers in the blend.

13. The fiber blend of claim 12, wherein said blend comprises from 15 to 80 weight percent amorphous silica fibers;

from 15 to 85 weight percent of said binder fibers and up to 70 weight percent of complimentary fibers, with a reduction of the other two fibers to total 100 percent by weight, without falling below the above-stated minimum amounts.

- 5 14. The fiber blend of claim 13, wherein said blend comprises from 15 to 80 weight percent amorphous silica fibers; from 15 to 85 weight percent of said single-component binder fibers and at least 15 weight percent of said complimentary fibers.
- 10 15. The fiber blend of claim 11, wherein said single component binder fibers are selected from the group consisting of low-melt polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6, 6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic fibers selected to have the lowest melting point of the polymers present.
- 15 16. The fiber blend of claim 11, wherein said multiple component binder fibers comprise those fibers of co-extruded polymers in combinations containing at least two polymers selected from the group consisting of polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6, 6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic fibers selected to have the lowest melting point of the polymers present.
- 20 17. The fiber blend of claim 11, wherein said multiple component, multi-binding binder fibers are selected from the group consisting of sheath/core, eccentric sheath/core, side-by-side or bilateral, pie wedge, hollow pie wedge, islands-in-the-sea or matrix constructions and mixtures thereof, which retain core fibers of substantially original Length after thermal bonding.
- 25 18. The fiber blend of claim 17, wherein said multiple component binder fibers comprise those fibers of co-extruded polymers in combinations containing at least two polymers selected from the group consisting of polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6, 6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic fibers selected to have the lowest melting point of the polymers present; said multiple component, multi-binding fibers containing at least one component comprised of a lower melt polymer and a higher melt point polymer that remains intact after exposure to heat sufficient to melt said lower melt polymer.
- 30 19. The fiber blend of claim 18, wherein said multiple component, multi-binding fibers comprise a core/sheath bi-component configuration comprised of a polyethylene terephthalate (PET) core and a lower melt temperature PET sheath whereas the sheath is 60 percent by weight of the individual fiber and the core is the remaining 40 percent.
- 35 20. The fiber blend of claim 11, wherein said complimentary fibers comprise those fibers of co-extruded polymers in combinations containing at least two polymers selected from the group consisting of polyethylene terephthalate, polypropylene, polyethylene, low-density polyethylene, linear low-density polyethylene, polylactic acid, polytrimethylene terephthalate, polycyclohexanediol terephthalate, polyethylene terephthalate glycol, nylon 6, nylon 6, 6, nylon 11, nylon 12, polymethyl pentene and other thermoplastic fibers selected to have the lowest melting point of the polymers present, as well as natural cellulosic fibers and protein fibers, coated or joined together with any of the aforementioned polymers; said multiple component, multi-binding fibers containing at least one component comprised of a lower melt polymer and a higher melt point polymer that remains intact after exposure to heat sufficient to melt said lower melt polymer.
- 40
- 45
- 50

Patentansprüche

1. Flammfeste (FR) Fasermischung, umfassend:

55 amorphe Silikatfasern, umfassend eine Mischung von 94 bis 97 Gew.-% SiO_2 , 3 bis 4 Gew.-% Al_2O_3 , 0,1 bis 0,3 Gew.-% Na_2O , 0,03 bis 1,3 Gew.-% CoO und 0,01 bis 1,2 Gew.-% SO_3 ; und wenigstens eine Faser ausgewählt aus der Gruppe bestehend aus FR-Fasern, Bindefasern und Mischungen davon.

2. Fasermischung nach Anspruch 1, wobei die FR-Fasern ausgewählt sind aus der Gruppe bestehend aus Modacrylen, Polyester mit Phosphalen, Melaminen, Meta-Aramid, Para-Aramid, Polybenzimidazolen, Polyimiden, Polyamidimiden, teilweise oxidierten Polyacrylnitrilen, Novoloiden, Poly(p-Phenyl-Benzobisoxazolen), Poly(p-Phenyl-Benzothiazolen), Polyphenylsulfiden, flammfesten Viskose-Rayonen, Viskose-Rayon, in dem Aluminosilikat-modifizierte Silikate enthalten sind, Zellulosen, Polyetherketonen, Polyketonen, Polyetherimiden, natürlichen oder synthetischen Fasern, die mit einem FR-Harz beschichtet sind, oder Mischungen davon.
5
3. Fasermischung nach Anspruch 1, wobei die Mischung wenigstens ungefähr 5 Gewichtsprozent amorphe Silikatfasern basierend auf dem Gesamtgewicht der Fasern in der Mischung umfasst.
10
4. Fasermischung nach Anspruch 3, wobei die Mischung von 5 bis 65 Gewichtsprozent amorphe Silikatfasern und von 35 bis 95 Gewichtsprozent von den FR-Fasern umfasst.
5. Fasermischung nach Anspruch 2, umfassend amorphe Silikatfasern, Modacrylfasern und FR-Rayonfasern.
15
6. Fasermischung nach Anspruch 2, umfassend amorphe Silikatfasern, Modacrylfasern und Viskoserayonfasern.
7. Fasermischung nach Anspruch 2, umfassend amorphe Silikatfasern, Modacrylfasern und zellulosefaserige Fasern.
8. Fasermischung nach Anspruch 2, umfassend amorphe Silikatfasern und FR-Rayonfasern.
20
9. Fasermischung nach Anspruch 2, umfassend amorphe Silikatfasern, Modacrylfasern, Viskoserayonfasern und FR-Polypropylenfasern.
10. Fasermischung nach Anspruch 1, wobei die Bindefasern ausgewählt sind aus der Gruppe bestehend aus Einzelkomponenten-, Vielkomponenten-, Vielbindungsfasern und Komplementärfasern, wobei die Fasern eine Schmelztemperatur von nicht weniger als 107°C haben.
25
11. Fasermischung nach Anspruch 10, wobei die Einzelkomponenten-, Vielkomponenten- und Vielbindungsfasern und Komplementärfasern thermische Bindungseigenschaften bereitstellen und, wobei die Vielkomponenten-, Vielbindungsfasern und Komplementärfasern zusätzlich mechanische Eigenschaften bereitstellen.
30
12. Fasermischung nach Anspruch 10, wobei die Mischung wenigstens 15 Gewichtsprozent amorphe Silikatfasern basierend auf dem Gesamtgewicht der Fasern in der Mischung umfasst.
35
13. Fasermischung nach Anspruch 12, wobei die Mischung von 15 bis 80 Gewichtsprozent amorphe Silikatfasern; von 15 bis 85 Gewichtsprozent von den Bindefasern und bis zu 70 Gewichtsprozent von Komplementärfasern umfasst, mit einer Reduzierung der anderen zwei Fasern zu totalen 100 Gewichtsprozent ohne unter die oben genannten Minimalmengen zu fallen.
40
14. Fasermischung nach Anspruch 13, wobei die Mischung von 15 bis 80 Gewichtsprozent amorphe Silikatfasern; von 15 bis 85 Gewichtsprozent von den Einzelkomponenten-Bindefasern und wenigstens 15 Gewichtsprozent von den Komplementärfasern umfasst.
15. Fasermischung nach Anspruch 11, wobei die Einzelkomponenten-Bindefasern ausgewählt sind aus der Gruppe bestehend aus Polyethylen-Terephthalat mit niedrigem Schmelzpunkt, Polypropylen, Polyethylen, Polyethylen von geringer Dichte, linearem Polyethylen von niedriger Dichte, Polyactid, Polytrimethylen-Terephthalat, Polycyclohexandiol-Terephthalat, Polyethylen-Terephthalatglykol, Nylon 6, Nylon 6, 6, Nylon 11, Nylon 12, Polymethylpenten und anderen thermoplastischen Fasern, die ausgewählt sind, den niedrigsten Schmelzpunkt der vorliegenden Polymere zu haben.
45
50
16. Fasermischung nach Anspruch 11, wobei die Vielkomponenten-Bindefasern solche Fasern von ko-extrudierten Polymeren in Kombinationen umfassen, beinhaltend wenigstens zwei Polymere, die ausgewählt sind aus der Gruppe bestehend aus Polyethylen-Terephthalat, Polypropylen, Polyethylen, Polyethylen von geringer Dichte, linearem Polyethylen von niedriger Dichte, Polyactid, Polytrimethylen-Terephthalat, Polycyclohexandiol-Terephthalat, Polyethylen-Terephthalatglykol, Nylon 6, Nylon 6, 6, Nylon 11, Nylon 12, Polymethylpenten und anderen thermoplastischen Fasern, die ausgewählt sind, den niedrigsten Schmelzpunkt der vorliegenden Polymere zu haben.
55

17. Fasermischung nach Anspruch 11, wobei die Vielkomponenten-, Vielbindungsbindefasern ausgewählt sind aus der Gruppe bestehend aus Mantel/Kern-, exzentrischen Mantel/Kern-, Seite-an-Seite- oder bilateralen, Tortenkeil-, hohlen Tortenkeil-, Inseln-im-Meer- oder Matrixkonstruktionen und Mischungen davon, welche Kernfasern auf im Wesentlichen ursprünglicher Länge nach dem thermischen Binden halten.

18. Fasermischung nach Anspruch 17, wobei die Vielkomponenten-Bindefasern solche Fasern von ko-extrudierten Polymeren in Kombinationen umfassen, beinhaltend wenigstens zwei Polymere, die ausgewählt sind aus der Gruppe bestehend aus Polyethylen-Terephthalat, Polypropylen, Polyethylen, Polyethylen von geringer Dichte, linearem Polyethylen von niedriger Dichte, Polyactid, Polytrimethylen-Terephthalat, Polycyclohexandiol-Terephthalat, Polyethylen-Terephthalatglykol, Nylon 6, Nylon 6, 6, Nylon 11, Nylon 12, Polymethylpenten und anderen thermoplastischen Fasern, die ausgewählt sind, den niedrigsten Schmelzpunkt der vorliegenden Polymere zu haben; wobei die Vielkomponenten-, Vielbindungsfasern wenigstens eine Komponente umfassend ein Niederschmelzpolymer und ein Polymer mit höherem Schmelzpunkt beinhalten, das nach einer Wärmeaussetzung, die zum Schmelzen des Niederschmelzpolymers ausreicht, intakt bleibt.

19. Fasermischung nach Anspruch 18, wobei die Vielkomponenten-, Vielbindungsbindefasern eine Kern/Mantel-Bi-Komponentenkonfiguration umfassen, die einen Polyethylen-Terephthalat-Kern (PET) und einen PET-Mantel mit niedrigem Schmelzpunkt umfasst, wobei der Mantel 60 Gewichtsprozent der individuellen Faser beträgt und der Kern die verbleibenden 40 % beträgt.

20. Fasermischung nach Anspruch 11, wobei die Komplementärfasern solche Fasern von ko-extrudierten Polymeren in Kombinationen umfassen, beinhaltend wenigstens zwei Polymere, die ausgewählt sind aus der Gruppe bestehend aus Polyethylen-Terephthalat, Polypropylen, Polyethylen, Polyethylen von geringer Dichte, linearem Polyethylen von niedriger Dichte, Polyactid, Polytrimethylen-Terephthalat, Polycyclohexandiol-Terephthalat, Polyethylen-Terephthalatglykol, Nylon 6, Nylon 6, 6, Nylon 11, Nylon 12, Polymethylpenten und anderen thermoplastischen Fasern, die ausgewählt sind, den niedrigsten Schmelzpunkt der vorliegenden Polymere zu haben, als auch natürliche zellulose Fasern und Proteinfasern, die beschichtet oder zusammen mit jedem der zuvor genannten Polymere verbunden sind; wobei die Vielkomponenten-, Vielbindungsfasern wenigstens eine Komponente umfassend ein Niederschmelzpolymer und ein Polymer mit höherem Schmelzpunkt beinhalten, das nach einer Wärmeaussetzung, die zum Schmelzen des Niederschmelzpolymers ausreicht, intakt bleibt.

Revendications

1. Mélange de fibres résistantes au feu (FR) comprenant :

des fibres de silice amorphe comprenant un mélange de 94 à 97 % en poids de SiO_2 , de 3 à 4 % en poids de Al_2O_3 , de 0,1 à 0,3 % en poids de Na_2O , de 0,03 à 1,3 % en poids de CoO et de 0,01 à 1,2 % en poids de SO_3 ; et

au moins une fibre choisie dans le groupe constitué par les fibres FR, les fibres de liant et les mélanges de celles-ci.

2. Mélange de fibres selon la revendication 1, dans lequel lesdites fibres FR sont choisies dans le groupe constitué par les composés modacryliques, un polyester avec du phosphalène, les mélamines, les méta-aramides, les para-aramides, le polbenzimidazole, les polyimides, les polyamideimides, les polyacrylonitriles partiellement oxydés, les composés novoloïdes, les poly(p-phénylène benzobisoxazoles), les poly(p-phénylène benzothiazoles), les poly(sulfures de phénylène), les rayonnées de viscose résistantes au feu, la rayonne de viscose contenant de la silice modifiée par un aluminosilicate, les composés celluloseux, les polyéthercétone, les polycétone, les polyétherimides, les fibres naturelles ou synthétiques revêtues d'une résine FR ou les mélanges de ceux-ci.

3. Mélange de fibres selon la revendication 1, dans lequel le mélange comprend au moins environ 5 pour cent en poids de fibres de silice amorphe, par rapport au poids total des fibres dans le mélange.

4. Mélange de fibres selon la revendication 3, dans lequel le mélange comprend de 5 à 65 pour cent en poids de fibres de silice amorphe et de 35 à 95 pour cent en poids desdites fibres FR.

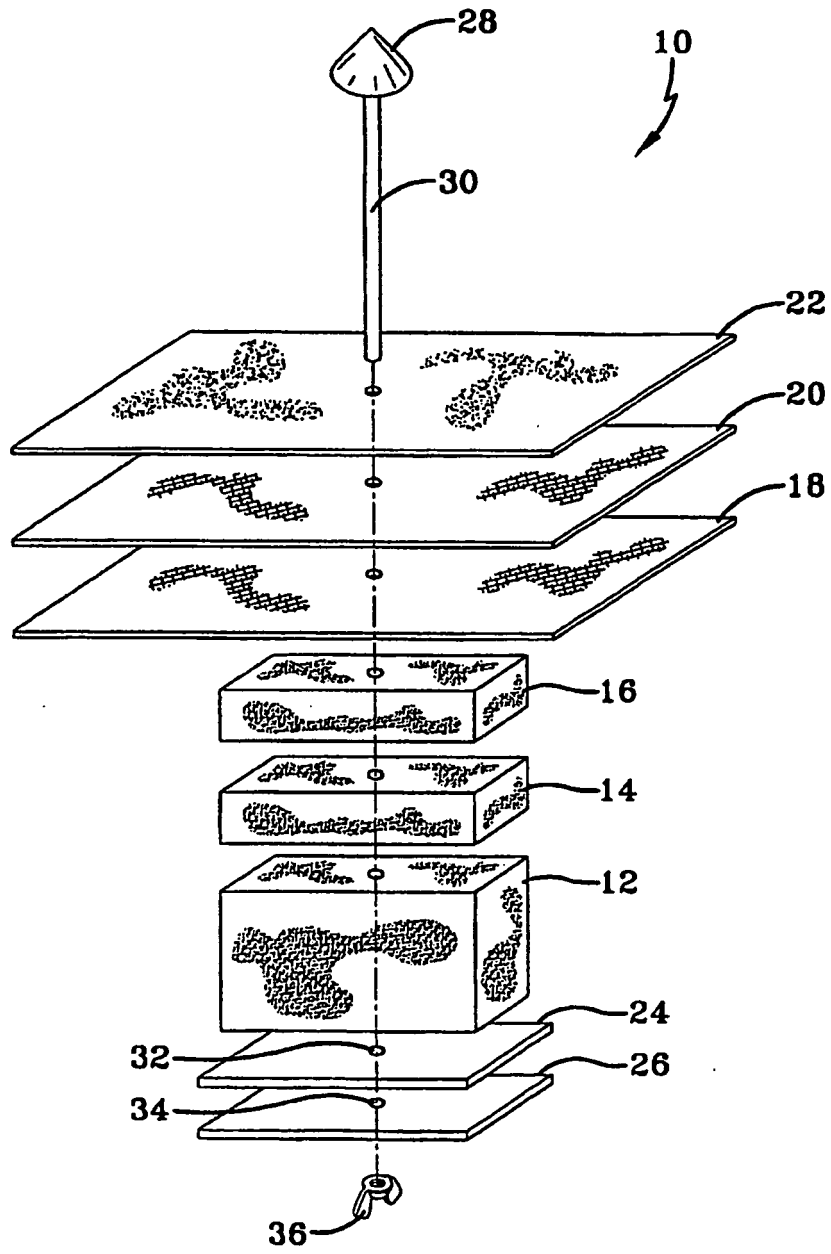
5. Mélange de fibres selon la revendication 2, comprenant des fibres de silice amorphe, des fibres modacryliques et des fibres de rayonne FR.

6. Mélange de fibres selon la revendication 2, comprenant des fibres de silice amorphe, des fibres modacryliques et des fibres de rayonne de viscose.
- 5 7. Mélange de fibres selon la revendication 2, comprenant des fibres de silice amorphe, des fibres modacryliques et des fibres cellulosiques.
8. Mélange de fibres selon la revendication 2, comprenant des fibres de silice amorphe et des fibres de rayonne FR.
- 10 9. Mélange de fibres selon la revendication 2, comprenant des fibres de silice amorphe, des fibres modacryliques, des fibres de rayonne de viscose et des fibres de polypropylène FR.
- 15 10. Mélange de fibres selon la revendication 1, dans lequel lesdites fibres de liant sont choisies dans le groupe constitué par les fibres à un seul composant, à plusieurs composants, à liaisons multiples et les fibres complémentaires, lesdites fibres ayant une température de fusion non inférieure à 107°C.
- 20 11. Mélange de fibres selon la revendication 10, dans lequel lesdites fibres à un seul composant, à plusieurs composants et à liaisons multiples et les fibres complémentaires fournissent des propriétés de liaison thermique et dans lequel lesdites fibres à plusieurs composants, à liaisons multiples et les fibres complémentaires fournissent de plus des propriétés mécaniques.
- 25 12. Mélange de fibres selon la revendication 10, dans lequel ledit mélange comprend au moins 15 pour cent en poids de fibres de silice amorphe, par rapport au poids total des fibres dans le mélange.
- 30 13. Mélange de fibres selon la revendication 12, dans lequel ledit mélange comprend de 15 à 80 pour cent en poids de fibres de silice amorphe ; de 15 à 85 pour cent en poids desdites fibres de liant et jusqu'à 70 pour cent en poids de fibres complémentaires, avec une réduction des deux autres fibres jusqu'à un total de 100 pour cent en poids, sans tomber en deçà des quantités minimales indiquées ci-dessus.
- 35 14. Mélange de fibres selon la revendication 13, dans lequel ledit mélange comprend de 15 à 80 pour cent en poids de fibres de silice amorphe ; de 15 à 85 pour cent en poids desdites fibres de liant à un seul composant et au moins 15 pour cent en poids desdites fibres complémentaires.
- 40 15. Mélange de fibres selon la revendication 11, dans lequel lesdites fibres de liant à un seul composant sont choisies dans le groupe constitué par le poly(téréphtalate d'éthylène) à bas point de fusion, le polypropylène, le polyéthylène, le polyéthylène basse densité, le polyéthylène linéaire basse densité, le poly(acide lactique), le poly(téréphtalate de triméthylène), le poly(téréphtalate de cyclohexanediol), le téréphtalate de polyéthylène glycol, le nylon 6, le nylon 6,6, le nylon 11, le nylon 12, le polyméthylpentène et d'autres fibres thermoplastiques choisies de façon à posséder le point de fusion le plus bas des polymères présents.
- 45 16. Mélange de fibres selon la revendication 11, dans lequel lesdites fibres de liant à plusieurs composants comprennent les fibres de polymères co-extrudés en combinaison contenant au moins deux polymères choisis dans le groupe constitué par le poly(téréphtalate d'éthylène), le polypropylène, le polyéthylène, le polyéthylène basse densité, le polyéthylène linéaire basse densité, le poly(acide lactique), le poly(téréphtalate de triméthylène), le poly(téréphtalate de cyclohexanediol), le téréphtalate de polyéthylène glycol, le nylon 6, le nylon 6,6, le nylon 11, le nylon 12, le polyméthylpentène et d'autres fibres thermoplastiques choisies de façon à posséder le point de fusion le plus bas des polymères présents.
- 50 17. Mélange de fibres selon la revendication 11, dans lequel lesdites fibres de liant à plusieurs composants, à liaisons multiples sont choisies dans le groupe constitué par les constructions à enveloppe et noyau, à enveloppe et noyau excentriques, côte-a-côte ou bilatérales, en portions, en portions creuses, à îlots dans la mer ou de matrice et les mélanges de celles-ci, qui maintiennent les fibres de noyau à une longueur essentiellement d'origine après une liaison thermique.
- 55 18. Mélange de fibres selon la revendication 17, dans lequel lesdites fibres de liant à plusieurs composants comprennent les fibres de polymères co-extrudés en combinaison contenant au moins deux polymères choisis dans le groupe constitué par le poly(téréphtalate d'éthylène), le polypropylène, le polyéthylène, le polyéthylène basse densité, le polyéthylène linéaire basse densité, le poly(acide lactique), le poly(téréphtalate de triméthylène), le poly(téréphtalate de cyclohexanediol), le téréphtalate de polyéthylène glycol, le nylon 6, le nylon 6,6, le nylon 11, le nylon 12, le

polyméthylpentène et d'autres fibres thermoplastiques choisies de façon à posséder le point de fusion le plus bas des polymères présents ; lesdites fibres à plusieurs composants à liaisons multiples contenant au moins un composant constitué d'un polymère de point de fusion plus bas et d'un polymère de point de fusion plus élevé qui reste intact après une exposition à une chaleur suffisante pour faire fondre ledit polymère de point de fusion plus bas.

5
19. Mélange de fibres selon la revendication 18, dans lequel lesdites fibres de liant à plusieurs composants, à liaisons multiples comprennent une configuration à deux composants à enveloppe et noyau, constituée d'un noyau de poly (téréphtalate d'éthylène) (PET) et d'une enveloppe de PET de point de fusion plus bas, dans lequel l'enveloppe constitue 60 pour cent en poids de la fibre individuelle et le noyau constitue les 40 pour cent restants.

10
20. Mélange de fibres selon la revendication 11, dans lequel lesdites fibres complémentaires comprennent les fibres de polymères co-extrudés en combinaison contenant au moins deux polymères choisis dans le groupe constitué par le poly(téréphtalate d'éthylène), le polypropylène, le polyéthylène, le polyéthylène basse densité, le polyéthylène linéaire basse densité, le poly(acide lactique), le poly(téréphtalate de triméthylène), le poly(téréphtalate de cyclohexanediol), le téréphtalate de polyéthylène glycol, le nylon 6, le nylon 6,6, le nylon 11, le nylon 12, le polyméthylpentène et d'autres fibres thermoplastiques choisies de façon à posséder le point de fusion le plus bas des polymères présents, ainsi que les fibres cellulosiques naturelles et les fibres de protéine, revêtues ou liées les unes aux autres avec l'un quelconque des polymères mentionnés précédemment ; lesdites fibres à plusieurs composants à liaisons multiples contenant au moins un composant constitué d'un polymère de point de fusion plus bas et d'un polymère de point de fusion plus élevé qui reste intact après une exposition à une chaleur suffisante pour faire fondre ledit polymère de point de fusion plus bas.



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2002316009 A [0012]
- JP 2001262453 A [0012]
- RU 2165393 [0024] [0031] [0035]