**ABSTRACT**

A flame retardant flexible substrate comprising at least one flexible substrate and at least one flame retardant composition, wherein the flame retardant composition partially covers at least one face of the flexible substrate and wherein the flame retardant composition is present in the form of a regular or irregular pattern.

**DESCRIPTION** (OCR text may contain errors)

**TITLE**

Patterned flame retardant flexible substrates and process of manufacture thereof

**FIELD OF THE INVENTION**

The present invention relates to flexible substrates having flame retardant properties, as well as to a production process to obtain the said flexible substrates having flame retardant properties.

**BACKGROUND OF THE INVENTION**

In the construction industry, different fabrics that are water-permeable, yet water-proof are in high demand for applications such as roof liners, house wraps, air and/or water intrusion barriers, floor coverings and floor underlay.

Mainly, these fabrics provide for a barrier to liquid water, which, should it enter into the structure of the building, can damage the structure of the said building. At the same time, these fabrics serve as breathable layers which allow water vapour to permeate across the fabric to evacuate excess humidity.

Synthetic fabrics, and particularly flash-spun polyolefin fabrics, are known to provide the aforementioned combination of properties and are therefore used extensively in buildings, for example as roof linings.

Regional and national building standards, designed to ensure the safety of the building materials used in the construction industry, require that the aforementioned fabrics used in buildings meet certain criteria, especially when they are in contact with a heat source such as for example fire, intense heat radiation or electrical arcs.

In particular, when under intense heat stress such as fires, the fabric material used in roof liners, for example, should not form burning droplets of molten material that could help spread the fire, nor should it form dense, toxic fumes or smoke that could cause health problems or other discomfort in humans.

Methods that improve the flame retardancy of synthetic fabrics and which are known in the art are methods where a halogenated flame retardant composition such as a brominated diphenyl ether or another brominated aromatic compound is applied to a fabric to coat the surface of the fabric. However, fabrics coated with halogenated flame retardants will be heavily coated and produce corrosive and toxic fumes when on fire, something which is highly undesirable in closed systems, while these fabrics are in contact with a heat source such as for example fire, intense heat radiation or electrical arcs.

What is claimed is: 1. A flame retardant flexible substrate comprising at least one flexible substrate and at least one flame retardant composition, wherein the flame retardant composition partially covers at least one face of the at least one flexible substrate, and wherein the at least one flame retardant composition is present in the form of a regular or irregular pattern.

2. The flame retardant flexible substrate according to claim 1, wherein the regular or irregular pattern comprises a plurality of individual elements in which the distance between adjacent elements is of from 0.1 mm to 20 mm.

3. The flame retardant flexible substrate according to claim 1 or 2, wherein the amount of the at least one flame retardant composition is from 2 weight percent to 100 weight percent, based on the areal weight of the flexible substrate.

4. The flame retardant flexible substrate according to any one of claims 1 to 3, wherein the at least one flame retardant composition covers the at least one face of the flexible substrate of from 15 percent to 95 percent, by area of the at least one face of the flexible substrate.

5. The flame retardant flexible substrate according to any one of claims 1 to 4, wherein the distance between adjacent elements of the regular or irregular pattern is from 0.1 mm to 20 mm, and wherein the at least one flame retardant composition covers the at least one face of the flexible substrate of from 20 percent to 80 percent, by area of the at least one face of the flexible substrate.

6. The flame retardant flexible substrate according to any one of claims 1 to 5, wherein the at least one flame retardant composition covers one face of the flexible substrate only, while the opposite face of the flexible substrate remains essentially free of the at least one flame retardant composition.

7. The flame retardant flexible substrate according to any one of claims 1 to 6, wherein the at least one flame retardant composition is selected from a group consisting of a phosphorus based composition, boron based composition, inorganic salt based composition, organometallic salt based composition, organic salt based composition, and polyether based composition.
Furthermore, the organic solvents present in flame retardant compositions which are supposed to facilitate the spreading of flame retardant composition can change the breathability of the fabric, because the organic solvent can penetrate into the void spaces of the fabric and draw the flame retardants present in the formulations into the pores. After solvent vaporization, the flame retardants present in the formulations clog the pores of the fabric, reducing the breathability of the fabric.

Furthermore, water-soluble flame retardant additives present in the coating can negatively impact water repellence. The hydrophilicity of these additives present in the coating influence the surface tension of the textile and in a way that will negatively impact water repellence and make the treated fabric loose its waterproof characteristics, because the pores of the fabrics become more wettable and therefore draw in more water by the capillary effect.

Last but not least, non-halogenated flame retardant compositions and their active ingredients are expensive, and there is a significant economical advantage in applying only the necessary and sufficient amount of flame retardant composition to the fabrics that are to be fireproofed.

Therefore, there exists a need to provide flexible substrates having improved or equal flame retardant properties when compared to existing solutions, but which at the same time fulfil regional fire retardancy standards and offer excellent breathability standards.

SUMMARY OF THE INVENTION

The present invention provides for a flame retardant flexible substrate comprising at least one flexible substrate and at least one flame retardant composition, wherein the flame retardant composition partially covers at least one face of the flexible substrate, and wherein the flame retardant composition is present in the form of a regular or irregular pattern.

The present invention further provides a production process for a flame retardant flexible substrate, comprising the steps of:

a. providing at least one flexible substrate, b. applying at least one flame retardant composition in the form of a regular or irregular pattern onto at least one face of the at least one flexible substrate.

DETAILED DESCRIPTION

The features and advantages of the present disclosure will be more readily understood, by those of ordinary skill in the art, from reading the following detailed description.

It is to be appreciated that certain features of the disclosure, which are, for clarity, described above and below in the context of separate embodiments, may also be provided in combination in a single embodiment.

Conversely, various features of the disclosure that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any sub-combination. In addition, references in the singular may also include the plural (for example, "a" and "an" may refer to one, or one or more) unless the context specifically states otherwise.

The term "fibre" as used herein refers to staple fibres, stretch broken fibres, fibrils and pulp as well as continuous filaments, both natural and/or synthetic.

The term "nonwoven fabric" as used herein refers to any fabric comprising a structure of individual fibres that are positioned in a random manner to form a planar material without an identifiable pattern, as opposed to a knitted or woven fabric. Non-limiting examples of nonwoven fabrics are meltblown fabrics, spunbond nonwoven webs, staple-based fabrics including carded and air-laid fabrics, spunlaced fabrics, flashspun fabrics such as the fabrics commercially available from E. I. du Pont...
de Nemours and Company under the trademark Tyvek®, as well as any combinations of the above.

The term "woven fabric" as used herein refers to a fabric having at least one weft and at least one warp that are positioned in an periodic manner to form a planar material with an identifiable pattern, as opposed to nonwoven fabric.

The term "roof liner" as used herein refers to a single layered or multilayered fabric that can be fixed directly or indirectly to a structural component of a roofing element or ceiling in order to form a selective barrier to liquids and gases.

The term "wall covering" and "house wraps" as used herein refers to a single layered or multilayered fabric that can be fixed directly or indirectly to a structural component of a wall element in order to form a selective barrier to liquids and gases.

The term "(meth) acrylic" as used herein refers to both acrylic and methacrylic.

The terms "fireproofing" and "flameproofing" are used interchangeably, and are used herein to refer to an object, which compared to an object that is not subjected to fireproofing or flameproofing, will exhibit improved properties when under thermal stress, such as for example lower flammability, lower smoke generation and/or reduction of burning droplets.

The term "hydrostatic head" as used herein refers to the resistance to water penetration, as measured according standard EN 2081 1, in centimetres.

The term "MVTR" refers to the moisture vapour transition rate as measured according to EN ISO 12572 (climate C with the wet-cup method).

The term "trace amount" refers to less than 1000 ppm.

The terms "areal density" and "areal weight" are used interchangeably, and are used herein to refer to the weight of a fabric per unit area. The flame retardant flexible substrates of the present invention, and in particular the fabrics and the nonwoven fabrics, are useful in building and construction applications such as, for example, roof liners, underlays, wall coverings, as water control layer, vapour control layer and air control layer and acoustic liners, as well as in graphic and packaging applications, banner applications, cargo and car cover applications, light reflector applications, garment applications and in personal protection applications. Therefore the present invention is also directed to the use of the flame retardant flexible substrates in the above applications.

The flame retardant flexible substrate of the present invention comprises at least one flexible substrate and at least one flame retardant composition, wherein the flame retardant composition partially covers at least one face of the flexible substrate, and wherein the flame retardant composition is present in the form of a regular or irregular pattern.

The at least one flexible substrate being partially covered by at least one flame retardant composition present in the form of an regular or irregular pattern according to the present invention may be chosen from any self-supporting flexible substrate.

Suitable self-supporting flexible substrates may be chosen, for example, from the group consisting of nonwoven, woven or knitted fabrics, micro-porous films, paper, carton, cardboard, polymeric films, wood panels, felted materials, fleece, carpet backing, or a combination of two or more flexible substrates, such as laminates, for example, SMS (Spunbonded/Meltblown/Spunbonded) laminates.

Preferably, the flexible substrate is a porous flexible substrate.

Porous flexible substrates include flexible substrates which became porous due to their preparation process, but also include flexible substrates which became porous due to a treatment after the preparation, for example, due to a perforation process, and combinations of both.

Porous flexible substrates may be chosen among a nonwoven or woven fabric comprising one or more natural or synthetic (man-made) fibres or filaments. The natural fibres or filaments of the non-woven or woven fabric can be chosen among cellulose, cotton, wool, silk, sisal, linen, flax, jute, kenaf, hemp, coconut, wheat, rice, and/or mixtures thereof.

The synthetic (man-made) fibres or filaments of the non-woven or woven fabric can be chosen among polyamides, polyaramids, polyesters, polyimide, polyolefins, and/or hybrids and mixtures thereof.

In the case where the flexible substrate is a woven fabric comprising one or more synthetic (man-made) fibres or filaments, it is preferably a fabric comprising polyamide fibres or
filaments, in particular aromatic polyamide fibres or filaments, such as for example para- or meta-aramid fibres or filaments.

More preferably, the flexible substrate may be chosen among nonwoven fabrics.

Suitable nonwoven fabrics can preferably be chosen among polymeric nonwoven fabrics, more preferably among polyolefinic nonwoven fabrics, aromatic polyamide nonwoven fabrics, polyester nonwoven fabrics, or mixed polyolefinic/polyester nonwoven fabrics.

Polyolefinic nonwoven fabrics can preferably be chosen among polyethylene nonwoven fabrics, polypropylene nonwoven fabrics or mixed polyethylene/polypropylene nonwoven fabrics.

Polyester nonwoven fabrics can preferably be chosen among polyethylene terephthalate (PET) nonwoven fabrics, polyhydroxalkanoate nonwoven fabrics (PHA) such as polylactic acid, or mixed PET/PHA nonwoven fabrics.

Most preferably, the flexible substrate of the invention is a polyethylene flash-spun fabric, as commercially available, for example, under the trade name Tyvek® from DuPont de Nemours & Company.

The flexible substrate may further comprise a metallic layer on at least one face of the flexible substrate, which can be deposited by sputtering or evaporative deposition, to increase the thermal insulation properties of the flexible substrate. Suitable metals that may be used are for example silver, gold, copper or aluminium. The flexible substrate may be a combination of two or more flexible substrates. It may be, for example, a laminate combining two or more flexible substrates, preferably of at least two different types of woven or nonwoven fabrics. Examples of those laminates are laminates of polyethylene nonwoven and polypropylene nonwoven, available from E. I. du Pont de Nemours and Company under the trademark Tyvek®.

The flexible substrate preferably has a moisture vapour transmission rate (MVTR) of at least 100, more preferably of 100 to 5000 g/m²/day. For example, polyolefinic flash-spin nonwovens, commercially available under the trademark Tyvek® from E.I. du Pont de Nemours and Company, having an areal weight of 40 g/m² and 115 g/m² have, for example, a MVTR of 4134 and 830 g/m²/day respectively, when measured according to DIN EN ISO 12572 (climate C with the wet-cup method).

It is believed that the porosity of the flexible porous substrate, for example, of the polyethylene flash-spin nonwoven enables the moisture vapour to freely diffuse through the void spaces within the fabric, but that liquid water cannot penetrate the void spaces, thus resulting in a waterproof, yet breathable material.

The at least one flame retardant composition partially covering at least one face of the flexible substrate and being present in the form of a regular or irregular pattern may be chosen among any effective flame retardant compositions known in the art, such as for example, phosphorus based compositions, boron based compositions, inorganic salt compositions, organometallic salt compositions, halogenated flame retardant compositions, fluoropolymer compositions, nitrogen-based compositions, filler compositions, silicon based compositions, and/or combinations thereof.

Suitable phosphorus based compositions may be chosen among compositions comprising phosphates such as for example ammonium phosphates, pentaerythritol phosphates, oligomeric phosphate esters, ammonium polyphosphates, melamine phosphates (e.g. melamine pyrophosphate and/or melamine orthophosphate) or aliphatic organophosphorous compounds such as triethylphosphate,

tributylphosphate, tributoxyethyl phosphate, tricetylphosphate and triphenylphosphate; compositions comprising phosphites such as for example diphenyl phosphate, dibutyl phosphate or 9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide (DOPO); compositions comprising phosphonates such as, for example, diethyl-N,N-bis(2-hydroxyethyl) aminomethyl phosphonate, dimethyl methylphosphonate,

trimethylolpropane methylphosphonate or cyclic phosphonate esters; compositions comprising phosphazenes; compositions comprising phosphine oxides; compositions comprising phosphonitriles; compositions comprising phosphonic acid amide; and/or combinations thereof. Furthermore, phosphate compounds available in commerce from Albemarle under the tradename Antiblaze®, cyclic phosphonate esters available in commerce from Rhodia under the tradename Amgard® CU and Amgard® 1045, aromatic phosphate esters from Albemarle (NCendX®), oligomeric phosphorous compounds;

oligomeric phosphate esters from Akzo Nobel (Fyro 51, Fyro 99) and from ICL Industrial Products (Fyroflex® Sol-DP), resorcinol bis(diphenyl phosphate), bis-phenol A-bis(diphenyl phosphate) can be used.

Suitable boron based compositions may be chosen among compositions comprising boric acid or trimethylxyboroxine.
Suitable inorganic salt compositions may be chosen among compositions comprising metal hydroxides such as aluminium trihydroxide, magnesium hydroxide, brucite, hydromagnesite, aluminium phosphinates, mixed metal hydroxides or mixed metal hydroxycarbonates; compositions comprising metal oxides such as magnesium oxide; antimony trioxide; compositions comprising metal carbonates such as calcium carbonate; compositions comprising metal borates such as barium metaborate; zinc borate, zinc metaborate; compositions comprising metal stannates such as zinc hydroxystannate, zinc stannate; compositions comprising metal sulphates; and/or combinations thereof.

Suitable organo-metallic salt compositions may be chosen among compositions comprising metal sulfonates, compositions comprising metal tetraborates; and/or combinations thereof. Suitable silicon based compositions may be chosen among compositions comprising siloxanes, silicones, silica and/or silicate derivatives; and/or combinations thereof.

Suitable halogenated flame retardant compositions may be chosen, too, even if not preferred, among compositions comprising polybrominated diphenyl ethers, polybrominated biphenyl, brominated cyclohydrocarbons, tetrabromo bisphenol A, hexabromodiphényl ether, decabromo diphenyl ether; and/or combinations thereof.

Suitable fluoropolymer compositions may be chosen among compositions comprising polymers or copolymers of tetrafluoroethylene, hexafluoropropylene, vinylidene fluoride or perfluoromethylvinylether for example.

Suitable filler based compositions may be chosen among compositions comprising glass, fumed silica, fly ash, glass fibre, expandable graphite, carbon nanotube, blends of vitreous materials that act as a flame retardant barrier, nanoparticles such as polyhedral oligomeric silsesquioxanes, nanosilica reinforced acrylate, nanoclay;

alone or in combination with binders such as urea-, phenol- or melamine- formaldehyde resins (UF, PF, and MF resins), modified acrylic or polyester resins; and/or combinations thereof.

Suitable nitrogen-based compositions may be chosen among, for example, compositions comprising melamine, melamine cyanurate, other melamine salts, alkylamine-derivatives, alkoxyamine-derivatives and/or guanidine compounds. Nitrogen compounds containing hindered amine such Flamestab® NOR 116 from BASF and Hostavin® NOW from Clariant may also be used.

Phosphorus based flame retardant compositions are preferred. They may be used in combination with other flame retardant compositions.

The amount of flame retardant composition necessary for fireproofing the flexible substrate is dependent on the areal weight of the substrate as well as the chemical nature of the substrate.

In general, the amount of flame retardant composition covering the at least one face of the flexible substrate may be of from 2 weight percent to 100 weight percent, based on the areal weight of the substrate. Preferably, the amount of composition may be of from 4 weight percent to 50 weight percent, and more preferably from 5 weight percent to 25 weight percent, based on the areal weight of the fabric.

In the case where the fabric is a polyolefin-based nonwoven fabric, the amount of composition coated thereon can be from 2 weight percent to 100 weight percent, preferably of from 4 weight percent to 50 weight percent, and more preferably from 5 weight percent to 40 weight percent, based on the areal weight of the fabric. The flame retardant flexible substrate according to the present invention comprises at least one flame retardant composition present in the form of a regular or irregular pattern. The regular or irregular pattern comprises a plurality of individual elements wherein the distance between adjacent elements is not in excess of 25 mm, for example, from 0.1 mm to 25 mm, preferably of from 0.1 mm to 20 mm, more preferably of from 0.1 mm to 15 mm, most preferably of from 0.5 to 8 mm.

Irregular patterns can be chosen from patterns comprising a plurality of individual elements, such as wood grain pattern, meandering patterns, labyrinthic patterns, blot patterns, other complex shapes and/or groups thereof, and the distance between adjacent elements or groups of elements is irregular (i.e. is anisotropic), or regular (i.e. is isotropic), and is not in excess of 25 mm, for example, of from 0.1 to 25 mm, preferably of from 0.1 mm to 20 mm, more preferably of from 0.1 to 15 mm, most preferably of from 0.5 to 8 mm.

Regular patterns can be chosen from patterns comprising a plurality of individual elements such as curved or straight lines, dots, circles, squares, lozenges, polygons, other complex shapes and/or groups thereof, and the distance between adjacent elements or groups of elements is irregular (i.e. is anisotropic), or regular (i.e. is isotropic), and is not in excess of 25 mm, for example, of from 0.1 to 25 mm, preferably of from 0.1 mm to 20 mm, more preferably of from 0.1 to 15 mm, most preferably of from 0.5 to 8 mm. The term "distance between adjacent elements" refers to the shortest distance between two points
located on the outlines of two adjacent individual elements of the same pattern.

Stated alternatively, for any element of a pattern according to the present invention, a circle having its centre on the edge of the pattern element and having a radius of the "distance between adjacent elements" will intersect with at least one other individual element of the pattern.

In another embodiment, the flame retardant composition may be present in the form of a regular or irregular pattern having a regular or irregular pattern negatively superposed on it.

By negatively superposed, it is meant that for a first pattern which is superposed with a second pattern, where the two patterns intersect or where only the second pattern is present, no flame retardant composition is present on the flame retardant flexible substrate.

The flame retardant flexible substrate of the present invention comprises at least one flame retardant composition, wherein the flame retardant composition partially covers at least one face of the flexible substrate.

The at least one flame retardant composition may be present on the at least one face of the flexible substrate covering from 15 percent to 95 percent, preferably from 20 to 80 percent, more preferably from 25 percent to 75 percent and most preferably from 25 percent to 50 percent of the surface area of the at least one face of the flexible substrate.

In a preferred embodiment, the at least one flame retardant composition is present in the form of a regular or irregular pattern comprising a plurality of individual elements wherein the distance between adjacent elements is not in excess of 25 mm and the flame retardant composition covers from 15 to 95 percent of the surface area of the at least one face of the flexible substrate. For example, the distance between adjacent elements of the regular or irregular pattern may be from 0.1 mm to 25 mm, preferably from 0.1 mm to 20 mm, more preferably from 0.1 mm to 15 mm and most preferably from 0.5 mm to 8 mm.

According to one embodiment the distance between adjacent elements of the regular or irregular pattern may be from 0.1 mm to 25 mm, with the pattern covering from 15 percent to 95 percent of the surface area of the at least one face of the flexible substrate, preferably the distance between adjacent elements of the regular or irregular pattern may be from 0.1 mm to 20 mm with the pattern covering from 20 percent to 80 percent of the surface area of the flexible substrate, more preferably the the distance between adjacent elements of the regular or irregular pattern may be from 0.1 mm to 15 mm with the pattern covering from 25 percent to 75 percent of the surface area of the at least one face of the flexible substrate, and most preferably the distance between adjacent elements of the regular or irregular pattern may be from 0.5 mm to 8 mm with the pattern covering from 25 percent to 50 percent of the surface area of the at least one face of the flexible substrate.

According to a preferred embodiment, the at least one flame retardant composition may cover one face of the flexible substrate only, while the opposite face of the flexible substrate remains essentially free of flame retardant composition.

When the at least one flame retardant composition covers one face of the flexible substrate only, while the opposite face of the flexible substrate remains free of the composition, the initial MVTR of the flexible substrate can be maintained or be minimally reduced, while at the same time conferring excellent flame retardancy to the flexible substrate.

The thickness of the at least one flame retardant composition present in the form of an regular or irregular pattern on the flexible substrate may range of from 0.1 to 200 µm.

The present invention further relates to a production process for the above flame retardant flexible substrate, comprising the steps of providing at least one flexible substrate and applying an at least one flame retardant composition in the form of an regular or irregular pattern onto an at least one face of the at least one flexible substrate.

The application of the at least one flame retardant composition may be carried out by using coating or printing methods known in the art, such as for example, spray coating, flood coating, knife coating, doctor blade coating, Meyer bar coating, dip coating, gravure coating, flexographic printing, screen printing, gravure printing and/or combinations thereof.

Preferably, the application of the at least one flame retardant composition may be carried out by printing, in particular by screen printing, flexographic printing and/or gravure printing. Most preferably, the application of the at least one flame retardant composition is carried out by gravure printing.

The application of the at least one flame retardant composition may be carried out with a composition having a viscosity of, for example, less than 25,000 mPas at 25°C. Preferably, the composition may have a viscosity of 10 mPas to 25000 mPas and more preferably of from 200mPas to 15000 mPas at 25°C.

A flame retardant composition having a viscosity as above remains at the external surface of the flexible substrate, in particular when the flexible substrate is a fabric, and is thereby prevented from wicking or penetrating into the void spaces of the flexible substrate and subsequently clogging the void spaces and reducing the MVTR.
Preferably the at least one flame retardant composition is a curable composition.

In the case where the at least one flame retardant composition can be cured, the curing may be carried out by any suitable curing method known in the art, such as thermal, chemical, and/or radiation curing.

Thermal curing can be carried out at temperatures of, e.g., 60 °C to 160 °C. Curing temperatures may depend on the curing chemistry and/or on the melting point of the flexible substrate to be coated. In the case where the flexible substrate is a polyolefin-based nonwoven fabric, curing temperature should not exceed 100 °C to 130 °C, depending on the specific polyolefin.

Preferably, the curing can be carried out by radiation curing, for example, by using visible light, ultraviolet radiation and/or ionising radiation such as gamma rays, X-rays or electron beam.

More preferably, curing is carried out by radiation curing with UV radiation and/or electron beam. In the case of electron beam curing the curing may be carried out with an electron beam source delivering a radiation dose of 0.1 to 15 MRad, more preferably of 2 to 5 MRad.

In case of UV curing the curing may be carried out with a UV lamp having a capacity of, for example 60 to 240 W/cm.

The flame retardant composition, in particular the curable flame retardant composition may comprise additional components such as reactive diluents, curing initiators or catalysts, colorants (dyes and/or pigments), additives conventionally used in coating compositions, for example, flow control agents, levelling agents, anti-settling agents, thickeners, surfactants, adhesion promoters, stabilizing agents, antioxidants, UV-absorbers, and/or mixtures thereof. The amount of colorants and additives usually does not exceed 10% by weight.

The flame retardant composition, in particular the curable composition may also contain water and/or organic solvents. However, the composition is preferably essentially free of solvents i.e. the composition may contain only trace amounts of solvents such as water and/or volatile organic components such as glycol, ethyl acetate, acetone or n-alkanes. The process according to the present invention is preferably carried out as a continuous process, in which the application of the at least one flame retardant composition to the flexible substrate and curing thereof takes place in-line, in the case where the composition is a curable composition.

The following examples are intended to illustrate the invention in greater detail. All parts and percentages are on a weight basis unless otherwise indicated.

EXAMPLES

Flame propagation tests on nonwoven materials

Vertical flame propagation testing was performed according to the general procedures of ISO EN 1 1925-2 "Ignitability/Flame Propagation" Test. A 2 cm long propane/air ignition flame was applied at 45 degrees for 15 seconds to the bottom of a 9 cm (wide) x 25 cm (high) sample of nonwoven material held in place vertically by a metal frame. The ignition flame was then removed and the burning sample observed for a further 5 seconds at which time the vertical height of the upper tip of the flame from the original point of appliction of the ignition flame was measured and reported in centimeters. If the sample does not ignite or ignites and extinguishes before 20 seconds have elapsed, the samples is recorded as "self-extinguising". A material is deemed to pass this test with "Class E" performance when each of six samples tested is either self-extinguishing or has a maximum flame height during the 20 seconds of less than 15 cm. To further quantify burning behaviour, the test was performed as described above applying the the flame to the coated side of several samples of each material, but a flame height was recorded also on samples which were self-extinguished at 20 seconds, this being the highest flame height seen at any time during the test. This allowed an "average flame height" to be calculated as the simple arithmetic mean of all the results from samples of that material. Another measure used for some materials was to take note during the testing of each sample of whether drops of burning polymer from the sample ignited a piece of filter paper placed directly below the sample and the proportion of samples of that material showing this behaviour was reported. General printing method

Screen printing was found to be a practical method to apply flame retardant coating compositions to nonwoven substrates in a variety of patterns and coat-weights to demonstrate the effectiveness of patterns according to this invention, but any suitable printing technique may be used to produce such patterns. For convenience, a UV curable coating composition was used, consisting of a blend of a UV-curable acrylated polyester, reactive diluant acrylates, a suitable system of photoinitiators and a suitable flame retardant additive, such that when this was applied pattern-wise in sufficient quantity to a flash spun polyethylene sheet, the resulting coated sheet could pass the EN ISO 1 1925-2 flame propagation test with a "Class E" rating. This flame retardant coating composition was applied in a variety of patterns described in the examples below, to samples of
Tyvek® 1073D, a flash spun polyethylene nonwoven commercially available from E. I. du Pont de Nemours and Company, having an areal density of 75 g/m². Each sample was printed with the flame retardant coating composition in the chosen pattern by manual screen printing using a screen of suitable mesh size and a 95 Shore D hardness, square-edged squeegee, and the printed sample was immediately passed under a mercury vapour UV lamp at such a speed as to provide a UV dose sufficient to cure the formulation to form a solid coating. Each sample was also weighed before and after printing so that the areal density of the flame retardant coating composition applied to that sheet could be easily calculated in g/m². The amount of coating applied in the printed areas was controlled by the choice of screen mesh size used to make that print. Several samples of each pattern were produced in this way and the resulting flame propagation properties were tested by the method described above. Comparative Example 1

Tyvek® 1073D, a flash spun polyethylene nonwoven, commercially available from E. I. du Pont de Nemours and Company, having an areal density of 75 g/m² was tested without further treatment. Example 2

According to the method described above, a T48 screen was used to print the flame retardant coating composition as regular pattern of squares, each square being 12 mm x 12 mm and spaced 24 mm from its neighbours such that the printed pattern covered one ninth (approximately 11%) of the surface area of the sheet.

Example 3

According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 6 mm x 6 mm and spaced 12 mm from its neighbours such that the printed pattern covered one ninth (approximately 11%) of the surface area of the sheet. Example 4

According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 3 mm x 3 mm and spaced 6 mm from its neighbours such that the printed pattern covered one ninth (approximately 11%) of the surface area of the sheet.

Example 5

According to the method described above, a T140 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 12 mm x 12 mm and spaced 12 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 6

According to the method described above, a T140 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 6 mm x 6 mm and spaced 6 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 7

According to the method described above, a T140 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 3 mm x 3 mm and spaced 3 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.
Table 1 shows for the above examples the amount of curable composition in g/m² printed onto the Tyvek® 1073D substrate, the characteristics of the printed pattern and the performance of such samples in the EN ISO 1 1925-2 flame propagation test. Printing the flame retardant coating over 25% of the area of the sheet provides a material which is capable of passing the EN ISO 1 1925-2 Class E test, while a similar total amount of flame retardant coating concentrated on only 11% of the surface area of the sheet provides only a modest improvement in burning behaviour and is insufficient to pass the Class E test.

Example 8

According to the method described above, a T81 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 12 mm x 12 mm and spaced 12 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 9

According to the method described above, a T81 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 6 mm x 6 mm and spaced 6 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet. Example 10

According to the method described above, a T81 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 3 mm x 3 mm and spaced 3 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 11

According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 12 mm x 12 mm and spaced 12 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet. Example 12

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</thead>
<tbody>
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<td>Substrate area density (g/m²)</td>
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<td>75</td>
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<td>75</td>
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<td>4.9</td>
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<td>Surface area printed (%)</td>
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<td>24</td>
<td>24</td>
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<td>24</td>
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<tr>
<td>Minimum distance between adjacent pattern elements (mm)</td>
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<td>13.3</td>
<td>13.8</td>
<td>12.8</td>
<td>12.8</td>
<td>12.8</td>
<td>12.8</td>
<td>12.8</td>
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<tr>
<td>Average maximum flame height (cm)</td>
<td>7 of 17</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
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<tr>
<td>Number of samples/width flame height &gt; 10 cm</td>
<td>7 of 17</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
<td>5 of 16</td>
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</tr>
<tr>
<td>Number of samples producing burning droplets</td>
<td>12 of 17</td>
<td>8 of 16</td>
<td>8 of 16</td>
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<td>Flame propagation test EN ISO 11925-2 Class E</td>
<td>Failed</td>
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<td>Failed</td>
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</table>

Table 1
According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 6 mm x 6 mm and spaced 6 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 13

According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 3 mm x 3 mm and spaced 3 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.

Example 14

According to the method described above, a T48 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 1.5 mm x 1.5 mm and spaced 1.5 mm from its neighbours such that the printed pattern covered one quarter (25%) of the surface area of the sheet.
flame height > 15 cm for a small number of samples does not fail Class E if six consecutive samples tested have maximum flame height < 15 cm

Table 2 shows for the above examples the amount of curable composition in g/m² printed onto the Tyvek® 1073D substrate, the characteristics of the printed pattern and the performance of such samples in the EN ISO 1 1925-2 flame propagation test. Printing the flame retardant coating over 25% of the area of the sheet provides a material which is capable of passing the EN ISO 1 1925- Class E test. A further improvement in burning behavior is observed when the minimum distance between adjacent elements of the printed pattern is reduced, as demonstrated by a tendency to produce fewer burning droplets and a lower average flame height.

Example 15

According to the method described above, a T140 screen was used to print the flame retardant coating composition as
regular pattern of squares, each square being 12 mm x 12 mm and spaced 5 mm from its neighbours such that the printed pattern covered approximately one half (50%) of the surface area of the sheet.

Example 16

According to the method described above, a T140 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 6 mm x 6 mm and spaced 2.5 mm from its neighbours such that the printed pattern covered approximately one half (50%) of the surface area of the sheet.

Example 17

According to the method described above, a T140 screen was used to print the flame retardant coating composition as a regular pattern of squares, each square being 3 mm x 3 mm and spaced 1.25 mm from its neighbours such that the printed pattern covered approximately one half (50%) of the surface area of the sheet.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>Example 15</th>
<th>Example 16</th>
<th>Example 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate areal density (g/m²)</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>FR Coating amount (g/m²)</td>
<td>9.0</td>
<td>7.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Surface area printed (%)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Minimum distance between adjacent pattern elements (mm)</td>
<td>5</td>
<td>2.5</td>
<td>1.25</td>
</tr>
<tr>
<td>Average maximum flame height (cm)</td>
<td>9.1</td>
<td>9.4</td>
<td>7.7</td>
</tr>
<tr>
<td>Number of samples with flame height &gt; 15 cm</td>
<td>1 of 15</td>
<td>2 of 16</td>
<td>0 of 16</td>
</tr>
<tr>
<td>Number of samples producing burning droplets</td>
<td>5 of 15</td>
<td>5 of 16</td>
<td>0 of 16</td>
</tr>
<tr>
<td>Flame propagation test EN ISO 11925-2 Class E</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

flame height > 15 cm for a small number of samples does not fail Class E if six consecutive samples tested have maximum flame height < 15 cm

Table 3 shows for the above examples the amount of curable composition in g/m² printed onto the Tyvek® 1073D substrate, the characteristics of the printed pattern and the performance of such samples in the EN ISO 1925-2 flame propagation test. Printing the flame retardant coating over 50% of the area of the sheet in a pattern according to this invention provides a material which is capable of passing the EN ISO 1925-2 Class E test. These examples also demonstrate that Class E rating can be achieved using a lower amount of costly flame retardant coating if the minimum distance between adjacent elements of the printed pattern is reduced. Example 18

According to the method described above, a T100 screen was used to print the flame retardant coating composition as an anisotropic labyrinth pattern having adjacent elements spaced between 6 mm and 12 mm apart such that the printed pattern covered approximately 40% of the surface area of the sheet.

Example 19

According to the method described above, a T100 screen was used to print the flame retardant coating composition as an anisotropic labyrinth pattern having adjacent elements spaced between 2 mm and 5 mm apart such that the printed pattern covered approximately 40% of the surface area of the sheet.

Example 20

According to the method described above, a T100 screen was used to print the flame retardant coating composition as an anisotropic labyrinth pattern having adjacent elements spaced between 1 mm and 2 mm apart such that the printed pattern covered approximately 40% of the surface area of the sheet.

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>Example 18</th>
<th>Example 19</th>
<th>Example 20</th>
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<tbody>
<tr>
<td>Substrate areal density (g/m²)</td>
<td>75</td>
<td>75</td>
<td>75</td>
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<tr>
<td>FR Coating amount (g/m²)</td>
<td>6.0</td>
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<td>5.7</td>
</tr>
<tr>
<td>Surface area printed (%)</td>
<td>40</td>
<td>40</td>
<td>40</td>
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<tr>
<td>Minimum distance between adjacent pattern elements (mm)</td>
<td>6 - 12</td>
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<tr>
<td>Average maximum flame height (cm)</td>
<td>10.6</td>
<td>8.2</td>
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<tr>
<td>Number of samples with flame height &gt; 15 cm</td>
<td>1 of 15</td>
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<tr>
<td>Number of samples producing burning droplets</td>
<td>4 of 15</td>
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<tr>
<td>Flame propagation test EN ISO 11925-2 Class E</td>
<td>Pass</td>
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</table>
flame height > 15 cm for a small number of samples does not fail Class E if six consecutive samples tested have flame height < 15 cm

Table 4 shows for the above examples the amount of curable composition in g/m² printed onto the Tyvek® 1073D substrate, the characteristics of the printed pattern and the performance of such samples in the EN ISO 1 1925-2 flame propagation test. Printing the flame retardant coating over 40% of the area of the sheet in an anisotropic labyrinth pattern according to this invention provides a material which is capable of passing the EN ISO 1 1925-2 Class E test. These examples also demonstrate that performance measured as the average flame height improves if the minimum distance between adjacent elements of the printed pattern is reduced.

**PATENT CITATIONS**

<table>
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<th>Publication date</th>
<th>Applicant</th>
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<tr>
<td>EP0111076A2 *</td>
<td>Sep 26, 1983</td>
<td>Jun 20, 1984</td>
<td>Blücher Hubert von</td>
<td>Flame-resistant flexible material</td>
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* Cited by examiner

**NON-PATENT CITATIONS**

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**CLASSIFICATIONS**

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**LEGAL EVENTS**

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