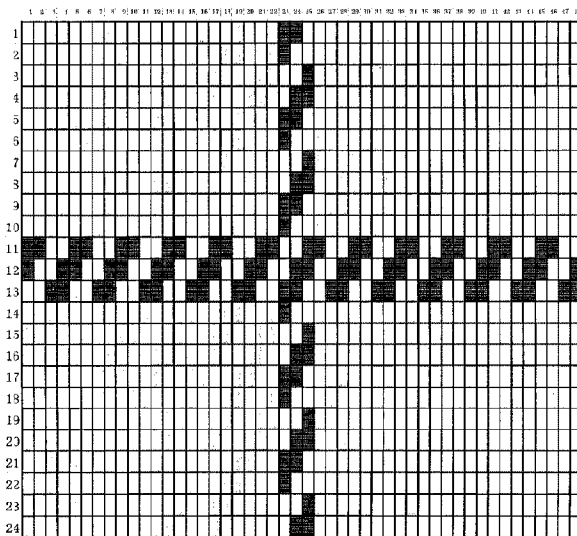
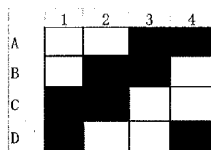




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(54) Titre : FIBRE/TESSU/VETEMENT IGNIFUGEANT  
(54) Title: FLAME-RETARDANT YARN/FABRIC/CLOTHING



(57) Abrégé/Abstract:

The present invention provides a flame-retardant yarn/fabric/clothing, containing the following three types of fibers in percentage by weight percent based on their total weight: modacrylic: 20% to 80%; cellulose: 10% to 50%; and polyimide: 1% to 50%. A vertical burning test is carried out in accordance with GB/T 5455-2014 to test the flame retardance of the flame-retardant yarn, fabric or clothing in the present invention, and the measured char length is lower than 150 mm, 100 or 50 mm. The char length is reduced to different extents, and thus different flame retardance requirements are met.

**ABSTRACT**

The present invention provides a flame-retardant yarn/fabric/clothing, containing the following three types of fibers in percentage by weight percent based on their total weight: modacrylic: 20% to 80%; cellulose: 10% to 50%; and polyimide: 1% to 50%. A vertical burning test is carried out in accordance with GB/T 5455-2014 to test the flame retardance of the flame-retardant yarn, fabric or clothing in the present invention, and the measured char length is lower than 150 mm, 100 or 50 mm. The char length is reduced to different extents, and thus different flame retardance requirements are met.

CWCAS-468

**FLAME-RETARDANT YARN/FABRIC/CLOTHING****TECHNICAL FIELD**

The present invention relates to the field of labor protection, and in particular, to a flame-retardant yarn/fabric/clothing.

**BACKGROUND**

Regarding modacrylic, cellulose fibers and polyimide in the prior art, the three types of fibers are totally different in physical and chemical properties and may be produced by different manufactures, so it is quite difficult to completely understand and master their properties to carry out proper blending processing. There is a modacrylic/lyocell (one of the cellulose fibers)/aromatic polyamide product available in the U.S. market. The company providing this product owns the patent on modacrylic/cotton/aromatic polyamide which, however, actually has not been put into mass production. Modacrylic may produce a flame-retardant gas as a barrier for oxygen during combustion, allowing a blend to be flame-retardant as a whole, and meanwhile, a certain amount of acid vapor may be produced. Due to weak acid resistance of aromatic polyamide, it is possible that the char length of a fabric is not ideal enough or unstable. Polyimide fibers are expensive and have been extensively used in the aerospace field with high radiation resistance, good acid-base resistance and excellent heat resistance and heat insulation property. In recent years, the polyimide fibers have been well developed, and begin to gradually step into the civil field.

**SUMMARY OF THE INVENTION**

The technical problem to be solved by the present invention is to blend modacrylic, cellulose and polyimide in a certain ratio, allowing a smaller char length of a fabric after vertical burning, which is applicable to a flame-retardant yarn/fabric/clothing.

A flame-retardant yarn contains the following three types of fibers in percentage by weight based on their total weight:

CWCAS-468

modacrylic: 20% to 80%;  
cellulose: 10% to 50%; and  
polyimide: 1% to 50%.

The flame-retardant yarn in the present invention, contains the following three types of fibers in percentage by weight based on their total weight:

modacrylic: 25% to 75%;  
cellulose: 15% to 45%; and  
polyimide: 2% to 45%.

The flame-retardant yarn in the present invention contains anti-static staple fibers or filaments.

The flame-retardant yarn in the present invention contains anti-static staple fibers.

In the flame-retardant yarn in the present invention, an anti-static component of the anti-static staple fibers is carbon or a metal.

In the flame-retardant yarn in the present invention, the anti-static component is carbon.

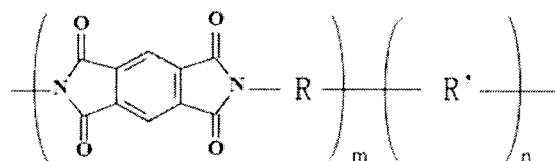
In the flame-retardant yarn in the present invention, the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer. When the weight of the vinyl chloride or the modacrylic or the total weight of both in the modacrylic accounts for 40-60% of that of the modacrylic, a better flame retardance may be achieved. In addition, dyeing groups containing sulfonic groups account for 0.5% to 1%. The modacrylic also includes a modacrylic containing one or more antimony oxides selected from a group consisting of antimony trioxide, antimony tetroxide and antimony pentoxide, and a better flame retardance may be achieved when the content of the antimony oxide(s) accounts for above 2.5% of the weight of the modacrylic.

The limit oxygen index (LOI) of the modacrylic ranges from 28 to 33 (the LOI is the percentage of the minimum content of oxygen needed to support combustion; generally,

CWCAS-468

air contains about 20% of oxygen; materials having the LOI lower than 20 are inflammable, while those having the LOI above 26 are flame-retardant materials and those having the LOI above 40 are incombustible materials). The modacrylic, after being set alight, may give off a flame-retardant gas heavier than air to prevent contact between an inflammable material and oxygen, thereby improving the flame retardance of surrounding articles. This fiber is high in flame retardance, but low in temperature tolerance and dimensional stability. When the content of the modacrylic accounts for 20%-80% of the blend, a significant effect may be achieved. If the content of the modacrylic is lower than 20%, the flame-retardant gas produced is insufficient, leading to a failure in ensuring the overall flame retardance of the blend. If the content of the modacrylic is more than 80%, the blend is low in heat resistance, and may have an increased char length because the burning part may be torn apart due to thermal contraction during vertical burning. With an excessive increase of the modacrylic, the amount of the cheap cellulose fibers added is reduced consequently, which is unfavorable for cost control. When the content of the modacrylic accounts for 25-75% of the blend, a better flame retardance may be achieved.

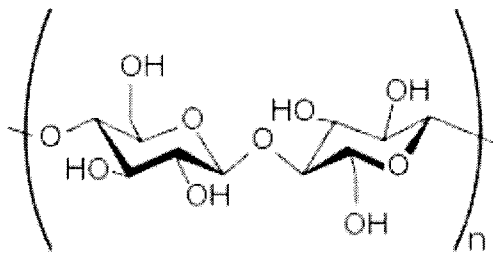
In the flame-retardant yarn in the present invention, the polyimide is expressed by a molecular structural formula below:



wherein bis(-CO-N-CO-) is a core structure in a mass ratio above 50%. The polyimide decomposes at a temperature above 500 DEG C, has the characteristics of acid and base resistance, high flame retardance, high LOI above 36, good heat insulation property, and good thermal stability, and has extensive application in the aerospace field due to high radiation resistance.

In the flame-retardant yarn in the present invention, the cellulose is expressed by a molecular structural formula below:

CWCAS-468



The cellulose in the present invention consists of D-glucopyranosyl groups (anhydroglucoses) with a simple molecular formula  $(C_6H_{10}O_5)_n$ , and may be in following specific forms: cotton, flax, viscose or rayon, lyocell, bamboo fiber, wood fiber, and other fibers derived from plant celluloses. The cellulose has the characteristics of good water absorbability and friendliness to human body, and is an inflammable fiber with the LOI of 17 to 19.

The flame-retardant yarn in the present invention further contains various types of fibers having no influence on the effect of the present invention, such as terylene, nylon 66, meta-aramid, aramid, polyoxadiazole, acrylic, wool, cony hair, silk, carbon-containing anti-static components, and metallic anti-static components.

A flame-retardant fabric contains the following three types of fibers in percentage by weight based on their total weight:

modacrylic: 20% to 80%;

cellulose: 10% to 50%; and

polyimide: 1% to 50%.

The flame-retardant fabric in the present invention contains the following three types of fibers in percentage by weight based on the weight of the fabric:

modacrylic: 25% to 75%;

cellulose: 15% to 45%; and

polyimide: 2% to 45%.

CWCAS-468

The flame-retardant fabric in the present invention has a char length of less than 150 mm measured in accordance with GB/T 5455-2014.

The flame-retardant fabric in the present invention has a char length of less than 100 mm measured in accordance with GB/T 5455-2014.

The flame-retardant fabric in the present invention has a char length of less than 50 mm measured in accordance with GB/T 5455-2014.

The flame-retardant fabric in the present invention contains an anti-static component.

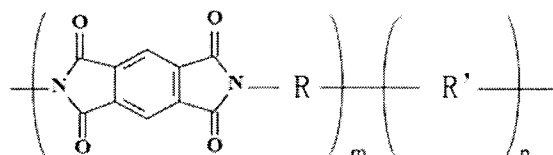
In the flame-retardant fabric in the present invention, the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer. When the weight of the vinyl chloride or the modacrylic or the total weight of both in the modacrylic accounts for 40-60% of that of the modacrylic, a better flame retardance may be achieved. In addition, dyeing groups containing sulfonic groups account for 0.5% to 1%. The modacrylic also includes a modacrylic containing one or more antimony oxides selected from a group consisting of antimony trioxide, antimony tetroxide and antimony pentoxide, and a better flame retardance may be achieved when the content of the antimony oxide(s) accounts for above 2.5% of the weight of the modacrylic.

The LOI of the modacrylic ranges from 28 to 33. The modacrylic, after being set alight, may give off a flame-retardant gas heavier than air to prevent contact between an inflammable material and oxygen, thereby improving the flame retardance of surrounding articles. This fiber is high in flame retardance, but low in temperature tolerance and dimensional stability. When the content of the modacrylic accounts for 20%-80% of the blend, a significant effect may be achieved. If the content of the modacrylic is lower than 20%, the flame-retardant gas produced is insufficient, leading to a failure in ensuring the overall flame retardance of the blend. If the content of the modacrylic is more than 80%, the blend is low in heat resistance, and may have an increased char length because the burning part may be torn apart due to thermal contraction during vertical burning. With an

CWCAS-468

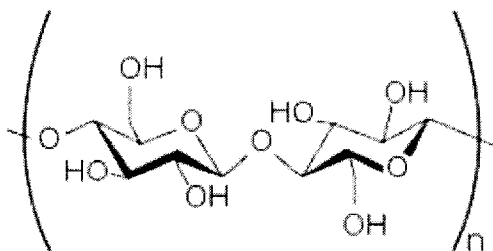
excessive increase of the modacrylic, the amount of the cheap cellulose fibers added is reduced consequently, which is unfavorable for cost control. When the content of the modacrylic accounts for 25-75% of the blend, a better flame retardance may be achieved.

In the flame-retardant yarn in the present invention, the polyimide is expressed by a molecular structural formula below:



wherein bis(-CO-N-CO-) is a core structure in a mass ratio above 50%. The polyimide decomposes at a temperature above 500 DEG C, has the characteristics of acid and base resistance, high flame retardance, high LOI above 36, good heat insulation property, and good thermal stability, and has extensive application in the aerospace field due to high radiation resistance.

In the flame-retardant fabric in the present invention, the cellulose is expressed by a molecular structural formula below:



The cellulose in the present invention consists of D-glucopyranosyl groups (anhydroglucoses) with a simple molecular formula  $(C_6H_{10}O_5)_n$ , and may be in following specific forms: cotton, flax, viscose or rayon, lyocell, bamboo fiber, wood fiber, and other fibers derived from plant celluloses. The cellulose has the characteristics of good water absorbability and friendliness to human body, and is an inflammable fiber with the LOI of 17 to 19.

CWCAS-468

The flame-retardant fabric in the present invention further contains various types of fibers having no influence on the effect of the present invention, such as terylene, nylon 66, meta-aramid, aramid, polyoxadiazole, acrylic, wool, cony hair, silk, carbon-containing anti-static components, and metallic anti-static components.

A flame-retardant clothing contains the following three types of fibers in percentage by weight based on their total weight:

modacrylic: 20% to 80%;

cellulose: 10% to 50%; and

polyimide: 1% to 50%.

The flame-retardant clothing in the present invention contains the clothing three types of fibers in percentage by weight based on the weight of the clothing:

modacrylic: 25% to 75%;

cellulose: 15% to 45%; and

polyimide: 2% to 45%.

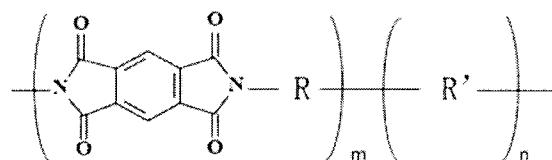
In the flame-retardant clothing in the present invention, the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer. When the weight of the vinyl chloride or the modacrylic or the total weight of both in the modacrylic accounts for 40-60% of that of the modacrylic, a better flame retardance may be achieved. In addition, dyeing groups containing sulfonic groups account for 0.5% to 1%. The modacrylic also includes a modacrylic containing one or more antimony oxides selected from a group consisting of antimony trioxide, antimony tetroxide and antimony pentoxide, and a better flame retardance may be achieved when the content of the antimony oxide(s) accounts for above 2.5% of the weight of the modacrylic.

The LOI of the modacrylic ranges from 28 to 33. The modacrylic, after being set alight, may give off a flame-retardant gas heavier than air to prevent contact between an inflammable material and oxygen, thereby improving the flame retardance of surrounding articles. This fiber is high in flame retardance, but low in temperature tolerance and

CWCAS-468

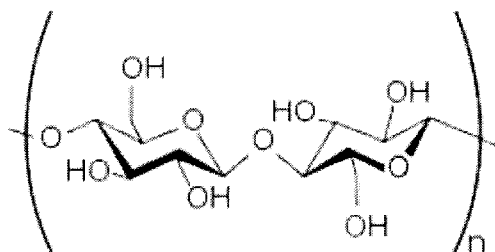
dimensional stability. When the content of the modacrylic accounts for 20%-80% of the blend, a significant effect may be achieved. If the content of the modacrylic is lower than 20%, the flame-retardant gas produced is insufficient, leading to a failure in ensuring the overall flame retardance of the blend. If the content of the modacrylic is more than 80%, the blend is low in heat resistance, and may have an increased char length because the burning part may be torn apart due to thermal contraction during vertical burning. With an excessive increase of the modacrylic, the amount of the cheap cellulose fibers added is reduced consequently, which is unfavorable for cost control. When the content of the modacrylic accounts for 25-75% of the blend, a better flame retardance may be achieved.

In the flame-retardant clothing in the present invention, the polyimide is expressed by a molecular structural formula below:



wherein bis(-CO-N-CO-) is a core structure in a mass ratio above 50%. The polyimide decomposes at a temperature above 500 DEG C, has the characteristics of acid and base resistance, high flame retardance, high LOI above 36, good heat insulation property, and good thermal stability, and has extensive application in the aerospace field due to high radiation resistance.

In the flame-retardant clothing in the present invention, the cellulose is expressed by a molecular structural formula below:



CWCAS-468

The cellulose in the present invention consists of D-glucopyranosyl groups (anhydroglucoses) with a simple molecular formula  $(C_6H_{10}O_5)_n$ , and may be in following specific forms: cotton, flax, viscose or rayon, lyocell, bamboo fiber, wood fiber, and other fibers derived from plant celluloses. The cellulose has the characteristics of good water absorbability and friendliness to human body, and is an inflammable fiber with the LOI of 17 to 19.

The flame-retardant fabric in the present invention further contains various types of fibers having no influence on the effect of the present invention, such as terylene, nylon 66, meta-aramid, aramid, polyoxadiazole, acrylic, wool, cony hair, silk, carbon-containing anti-static components, and metallic anti-static components.

The flame-retardant clothing in the present invention further contains various types of fibers having no influence on the effect of the present invention, such as terylene, nylon 66, meta-aramid, aramid, polyoxadiazole, acrylic, wool, cony hair, silk, carbon-containing anti-static components, and metallic anti-static components.

The flame-retardant yarn, fabric or clothing in the present invention differs from the prior art in that:

For the flame-retardant yarn, fabric or clothing in the present invention, the three types of fibers are blended to form a blend, wherein the modacrylic, which is low in heat resistance, is a gas-phase flame-retardant material and may be blended with the inflammable cellulose fibers, such as cotton, flax, viscose or rayon, lyocell, bamboo fiber, wood fiber, and other fibers derived from plant celluloses like these. The blend has flame retardance as a whole. The modacrylic, when burning, may give off a flame-retardant gas to fully prevent contact between the cellulose fibers and oxygen, and the combustion of the cellulose fibers may promote charring of the modacrylic to prevent further combustion of the modacrylic, thereby forming a mechanism of continuous combustion suppression. Once the source of ignition is removed, combustion ends fast, thus achieving the purpose of automatic fire extinguishment. As the cellulose may improve the overall moisture absorbability and comfort of the blend, the skin-friendliness of the yarn, fabric or clothing produced from the

CWCAS-468

blend is greatly improved. Furthermore, the polyimide has excellent heat resistance and extremely high flame retardance with extensive application in the fields of aerospace and electronics, and can still maintain such properties after being made into fibers; besides, after the polyimide is blended with the modacrylic and the cellulose fibers, the thermal stability, dimensional stability and heat insulation property of the blend may be improved. The fabric produced from the blend may be quickly charred with high flame retardance. The polyimide fiber high in heat resistance serves as a flexible stiffener in the charred film such that the charred film is not prone to breakage and further combustion of the fabric is prevented more effectively, thus achieving the purpose of reducing the char length.

Vertical burning tests are carried out in accordance with GB/T 5455-2014 to test the flame retardance of fabric woven using the flame-retardant yarns provided in the present invention and the fabric or clothing provided in the present invention, wherein the measured char length is lower than 150 mm, 100 or 50 mm. The char length is reduced to different extents, and thus different flame retardance requirements are met.

The flame-retardant yarn, fabric or clothing provided in the present invention will be further described below in conjunction with the accompanying drawings and specific examples.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a weave diagram of 2/2 right-hand diagonal twill in an example of the present invention; and

Fig. 2 is a diagram of 10 mm x 10 mm fabric checks formed by 48 warps and 24 wefts in example 10 of the present invention.

#### **DETAILED DESCRIPTION OF THE INVENTION**

In the present invention, Modacrylic is PROTEX-C fiber from KANEKA CORPORATION, which has the fineness of 1.7 dtex and the length of 38 mm; cotton is combed cotton available on the open market; lyocell is Tencel fiber from Lenzing AG,

## CWCAS-468

which has the fineness of 1.5 dtex and the length of 38 mm; viscose or rayon is common viscose or rayon available on the open market, which has the fineness of 1.5 dtex and the length of 38 mm; polyimide is 2.2 dtex gray fiber from Lianyungang Aoshen company, with the length of 38 mm; and anti-static fiber is 5.5 dtex polyester-based carbon-containing anti-static fiber from Wuxi Textile Research Institute, which has the length of 38 mm and the electrical resistivity of  $10^6$  to  $10^7$   $\Omega/\text{cm}$ .

## Example 1

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 75%;

cellulose (cotton): 10%;

polyimide: 13%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 2

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 48%;

cellulose (cotton): 49%;

polyimide: 1%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 3

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 45%;

cellulose (cotton): 45%;

polyimide: 8%; and

polyester-based carbon-containing anti-static fibers: 2%.

## CWCAS-468

## Example 4

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 48%;

cellulose (cotton): 35%;

polyimide: 15%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 5

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 48%;

cellulose (cotton): 20%;

polyimide: 30%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 6

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 38%;

cellulose (cotton): 10%;

polyimide: 50%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 7

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 25%;

cellulose (cotton): 28%;

polyimide: 45%; and

polyester-based carbon-containing anti-static fibers: 2%.

## CWCAS-468

## Example 8

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 25%;

cellulose (lyocell): 28%;

polyimide: 45%; and

polyester-based carbon-containing anti-static fibers: 2%.

## Example 9

A flame-retardant yarn is composed of materials in percentage by weight as follows:

modacrylic: 48%;

cellulose (viscose or rayon): 35%;

polyimide: 15%; and

polyester-based carbon-containing anti-static fibers: 2%.

Examples 1 to 9 are instances for composition in the present invention, and various compositions within the scope of the present invention shall all fall into the scope of protection of the present invention. For example, the modacrylic may also be 20% or 80%; the polyimide may also be 2%; and the cellulose may also be 50% or 15%.

To make the advantages of the present invention more prominent, comparative tests are carried out.

Besides the examples, para-aramid from Yantai Taihe company is also used, which is 2.2 dtex and 51 mm.

## Comparative example 1

A blend is composed of materials in percentage by weight as follows:

modacrylic: 48%;

cellulose (cotton): 35%;

para-aramid: 15%; and

CWCAS-468

polyester-based carbon-containing anti-static fibers: 2%.

#### Comparative example 2

A yarn is composed of materials in percentage by weight as follows:

modacrylic: 53%;

cellulose (cotton): 45%; and

polyester-based carbon-containing anti-static fibers: 2%.

#### Comparative example 3

A yarn is composed of materials in percentage by weight as follows:

modacrylic: 10%;

cellulose (cotton): 38%;

polyimide: 50%; and

polyester-based carbon-containing anti-static fibers: 2%.

In the examples and the comparative examples of the present invention, the same test parameters are used: 16/1 (cotton count/single yarn), 2/2 right-hand diagonal twill, warp density of 120 warps/inch, weft density of 60 wefts/inch, and the final grams per square meter of the fabrics: 250 g/gsm. The char length is measured in accordance with GB/T 5455-2014.

Notes: 16/1 (cotton count/single yarn) represents that one pound of cotton yarns have 16 840-yard lengths under the commercial moisture regain, which is a unit of measurement for thickness of yarns; and the greater the value, the finer the yarns. /1 represents a single yarn without being stranded.

2/2 right-hand diagonal twill is one of general weaves of woven fabrics with a weave diagram as shown in Fig. 1.

1 to 4 represent four warps, and A to D represent 4 wefts; the colored portions represent that when warps and wefts are interlaced, the warps are in the surface of the fabric, while

CWCAS-468

the wefts are on the reverse side. The uncolored portions represent that the wefts are in the surface of the fabric, while the warps are sunk under the wefts. When the colored portions go towards the upper right by a regular pattern, it is called right-hand diagonal.

The warp density of 120 warps/inch and the weft density of 60 wefts/inch represent the number of the warps and the number of the wefts in each 1 inch which is equal to 25.4 mm. The greater the number, the denser the yarns.

250 g/gsm grams per square meter represents that the weight of one square meter of fabric is 250 g, i.e., the total weight of the warps and the wefts in one square meter of fabric. This parameter is closely related to the warp density and the weft density.

Blends shown in examples 1 to 9 and comparative examples 1 to 3 are fully opened and uniformly blended by means of conventional devices, and then conventionally carded, and spun in a compact Siro spinning mode. Perfect control is carried out on the hairness of the yarns and the uniformity of the yarns such that the results of the comparative tests are not influenced by the spinning quality of the yarns.

The yarns shown in the same example or comparative example are woven using a widely popularized rapier loom in accordance with the above-mentioned warp density and weft density and the above-mentioned weave. Before weaving, the warps are subject to necessary slashing using a compound slashing agent of starch and PVC.

The woven gray fabric is conventionally dyed using a reactive dye through a one bath process. The uncolored fibers are not dyed again. The dyed fabric undergoes conventional after-treatment such as setting, drying and the like. Any after-treatment that may possibly influence the flame retardance of the fabric is avoided.

Vertical burning tests are carried out on the obtained fabrics in accordance with GB/T 5455-2014. The measured char lengths are shown below.

## CWCAS-468

|                       | Char Length mm |                 |
|-----------------------|----------------|-----------------|
|                       | Warp           | Weft            |
| Example 1             | 35             | 55              |
| Example 2             | 124            | 123             |
| Example 3             | 64             | 68              |
| Example 4             | 55             | 53              |
| Example 5             | 42             | 50              |
| Example 6             | 31             | 37              |
| Example 7             | 45             | 51              |
| Example 8             | 28             | 44              |
| Example 9             | 49             | 57              |
| Comparative example 1 | 85             | 92              |
| Comparative example 2 | 165            | 177             |
| Comparative example 3 | 153            | Burning through |

At least the following explicit conclusions can be drawn from the test results.

1. The char length has no inevitable relationship with the type of the inflammable cellulose fibers.

## CWCAS-468

|           | Blending ratio % |           |                  |         |                  |             |                                                      | Char length mm |      |
|-----------|------------------|-----------|------------------|---------|------------------|-------------|------------------------------------------------------|----------------|------|
|           | Modacrylic       | Polyimide | Cellulose Fibers |         |                  | Para-aramid | Polyester-based carbon-containing anti-static fibers | Warp           | Weft |
|           |                  |           | Cotton           | Lyocell | Viscose or rayon |             |                                                      |                |      |
| Example 4 | 48               | 15        | 35               |         |                  |             | 2                                                    | 55             | 53   |
| Example 9 | 48               | 15        |                  |         | 35               |             | 2                                                    | 49             | 57   |
| Example 7 | 25               | 45        | 28               |         |                  |             | 2                                                    | 45             | 51   |
| Example 8 | 25               | 45        |                  | 28      |                  |             | 2                                                    | 28             | 44   |

Example 4 is compared with example 9, and example 7 is compared with example 8. Every two compared examples are the same in types and proportions of other fibers than the types of the cellulose fibers, and have quite close maximum char lengths after burning. Hence, it may be basically regarded that the char length is correlated to test errors, and unrelated to the type of the cellulose.

2. Even though a small quantity of polyimide is blended, it may still greatly impact the char length, leading to reduction of the char length.

CWCAS-468

|                       | Blending ratio % |           |                  |         |                  |             | Char length mm                                       |      |      |
|-----------------------|------------------|-----------|------------------|---------|------------------|-------------|------------------------------------------------------|------|------|
|                       | Modacrylic       | Polyimide | Cellulose Fibers |         |                  | Para-aramid | Polyester-based carbon-containing anti-static fibers | Warp | Weft |
|                       |                  |           | Cotton           | Lyocell | Viscose or rayon |             |                                                      |      |      |
| Example 2             | 48               | 1         | 49               |         |                  |             | 2                                                    | 124  | 123  |
| Comparative example 2 | 53               |           | 45               |         |                  |             | 2                                                    | 165  | 177  |

In example 2, 49% of inflammable cotton and 2% of inflammable polyester-based carbon-containing anti-static fibers, 51% in total, are included; in comparative example 2, the summation of the inflammable fibers is 47%, which is 4% less than that in embodiment 2. However, according to the char lengths measured through actual burning tests, the maximum char length in example 2 is 53 mm less than that in comparative example 2. It thus can be seen that the 1% of polyimide in example 2 has a significant effect on reduction of the char length.

3. The higher the content of polyimide, the smaller the char length.

|           | Blending ratio % |           |                  |         |                  |             | Char length mm                                       |      |      |
|-----------|------------------|-----------|------------------|---------|------------------|-------------|------------------------------------------------------|------|------|
|           | Modacrylic       | Polyimide | Cellulose Fibers |         |                  | Para-aramid | Polyester-based carbon-containing anti-static fibers | Warp | Weft |
|           |                  |           | Cotton           | Lyocell | Viscose or rayon |             |                                                      |      |      |
| Example 3 | 45               | 8         | 45               |         |                  |             | 2                                                    | 64   | 68   |
| Example 1 | 75               | 13        | 10               |         |                  |             | 2                                                    | 35   | 55   |

## CWCAS-468

|           |    |    |    |  |  |  |   |    |    |
|-----------|----|----|----|--|--|--|---|----|----|
| Example 4 | 48 | 15 | 35 |  |  |  | 2 | 55 | 53 |
| Example 5 | 48 | 30 | 20 |  |  |  | 2 | 42 | 50 |
| Example 7 | 25 | 45 | 28 |  |  |  | 2 | 45 | 51 |
| Example 6 | 38 | 50 | 10 |  |  |  | 2 | 31 | 57 |

The worst values of the char length are put in an order basically consistent with that of the contents of the polyimide. It may be estimated that if the content of the polyimide is more than 50%, the char length may be smaller. The test results for example 6 are already able to meet the highest flame-retardant level requirement of less than 50 mm, and therefore, it is unnecessary to increase the content of the expensive polyimide.

4. The content of the modacrylic fibers should not be too low and may not be out of reasonable balance with the content of the inflammable cellulose fibers; otherwise, the entire blend can not maintain the flame retardance.

|                       | Blending ratio % |           |                  |         |                  |             | Char length mm                                       |      |                 |
|-----------------------|------------------|-----------|------------------|---------|------------------|-------------|------------------------------------------------------|------|-----------------|
|                       | Modacrylic       | Polyimide | Cellulose Fibers |         |                  | Para-aramid | Polyester-based carbon-containing anti-static fibers | Warp | Weft            |
|                       |                  |           | Cotton           | Lyocell | Viscose or rayon |             |                                                      |      |                 |
| Example 7             | 25               | 45        | 28               |         |                  |             | 2                                                    | 45   | 51              |
| Comparative example 3 | 10               | 50        | 38               |         |                  |             | 2                                                    | 153  | Burning through |

## CWCAS-468

From example 7, it can be seen that with 25% of modacrylic and 30% in total of inflammable cotton and inflammable polyester-based carbon-containing anti-static fibers, the entire blend can automatically stop burning with outstanding char length data. From example 3, it can be seen that even though the content of the polyimide is up to 50% with 10% of modacrylic and 40% in total of inflammable cotton and inflammable polyester-based carbon-containing anti-static fibers, the blend cannot automatically stop burning, and the test result is burning through, i.e., infinite char length. If the content of the modacrylic is increased to 20% and the content of the inflammable cotton and inflammable polyester-based carbon-containing anti-static fibers is reduced to 30%, the fabric may maintain the characteristic of automatically stopping burning with fine char length data.

5. Under the same circumstance, the polyimide in the same proportion as the para-aramid is more advantageous for reduction of the char length.

|                       | Blending ratio % |           |                  |         |                  |             | Char length mm                                       |      |      |
|-----------------------|------------------|-----------|------------------|---------|------------------|-------------|------------------------------------------------------|------|------|
|                       | Modacrylic       | Polyimide | Cellulose Fibers |         |                  | Para-aramid | Polyester-based carbon-containing anti-static fibers | Warp | Weft |
|                       |                  |           | Cotton           | Lyocell | Viscose or rayon |             |                                                      |      |      |
| Example 4             | 48               | 15        | 35               |         |                  |             | 2                                                    | 55   | 53   |
| Comparative example 1 | 48               |           | 35               |         |                  | 15          | 2                                                    | 85   | 92   |

Under normal circumstances, the tensile strength of the para-aramid is in a range of about 15 to 22 cN/dtex or above, and the tensile strength of the polyimide is above 4 cN/dtex. It is apparent that the para-aramid is much stronger. However, the polyimide may have higher temperature endurance when burning and may decompose at a temperature above 500 DEG C which is almost 100 DEG C higher than that of the para-aramid. The LOI (the minimum percentage content of oxygen needed to support combustion) of the para-aramid is above

## CWCAS-468

28, while that of the polyimide is above 36. After being set alight, the modacrylic may give off hydrochloric acid (HCl) vapor. The para-aramid is worse than the polyimide in acid resistance, and when the char length is tested by using a tearing method, the polyimide, instead, is much stronger than the para-aramid. It can be seen that in the blend system with the modacrylic and cellulose fibers, the polyimide is more suitable than the para-aramid. In the comparative example, no meta-aramid is blended because the meta-aramid is lower than the para-aramid in both tensile strength and heat resistance in spite of identical acid resistance, and also cannot be compared to the polyimide in controlling the char length.

The above descriptions are examples having the same warp and weft blending proportions. The example of a checked weave will be shown below.

## Example 10

Yarn 1 is composed of materials in percentage by weight as follows:

polyimide: 98%; and

polyester-based carbon-containing anti-static fibers: 2%.

Yarn 2 is composed of materials in percentage by weight as follows:

modacrylic: 49%;

cellulose (cotton): 49%; and

polyester-based carbon-containing anti-static fibers: 2%.

Fabric parameters in the example are shown below:

16/1 (cotton count/single yarn), 2/2 right-hand diagonal twill, warp density of 120 warps/inch, weft density of 60 wefts/inch, and the final grams per square meter of the fabrics: 250 g/gsm. The char length is measured in accordance with GB/T 5455-2014.

Notes: 16/1 (cotton count/single yarn) represents that one pound of cotton yarns have 16 840-yard lengths under the commercial moisture regain, which is a unit of measurement for thickness of yarns; and the greater the value, the finer the yarns. /1 represents a single yarn without being stranded.

CWCAS-468

2/2 right-hand diagonal twill is one of general weaves of woven fabrics with a weave diagram as shown in Fig. 1.

Three yarns 1 are woven in the warp and weft of fabric at an equal interval of 10 mm with the yarns 2 being woven therewith. Looping is carried out according to the weave diagram shown in Fig. 2. Forty-eight warps and 24 wefts just form 10 mm x 10 mm fabric checks.

The blending proportions of various fibers in the fabric may be calculated conveniently based on the blending ratio of yarns 1 and yarns 2 and the number of the yarns used:

modacrylic: 44.9%;

cellulose (cotton): 44.9%;

polyimide: 8.2%;  $(3+3)/(48+24)*98\%=8.2\%$ ; and

polyester-based carbon-containing anti-static fibers: 2%.

The yarns are woven using a widely popular rapier loom in accordance with the above-mentioned warp density and weft density and the above-mentioned weave. Before weaving, the warps are subject to necessary slashing using a compound slashing agent of starch and PVC.

The woven gray fabric is conventionally dyed using a reactive dye through a one bath process. The uncolored fibers are not dyed again. The dyed fabric undergoes conventional after-treatment such as setting, drying and the like. Any after-treatment that may possibly influence the flame retardance of the fabric is avoided.

Burning tests are carried out in accordance with GB/T 5455-2014. The measured char lengths are: warp: 60 mm, and weft 65 mm.

Comparison between example 10 and example 3 is shown below.

## CWCAS-468

|               | Blending ratio % |           |                  |         |                     |                 | Char length mm                                                        |      |      |
|---------------|------------------|-----------|------------------|---------|---------------------|-----------------|-----------------------------------------------------------------------|------|------|
|               | Modacrylic       | Polyimide | Cellulose Fibers |         |                     | Para-<br>aramid | Polyester-<br>based<br>carbon-<br>containing<br>anti-static<br>fibers | Warp | Weft |
|               |                  |           | Cotton           | Lyocell | Viscose<br>or rayon |                 |                                                                       |      |      |
| Example<br>3  | 45               | 8         | 45               |         |                     |                 | 2                                                                     | 64   | 68   |
| Example<br>10 | 44.9             | 8.2       | 44.9             |         |                     |                 | 2                                                                     | 60   | 65   |

From the table above, it can be seen that the char lengths are basically identical although the design methods of the fabrics are different. The blending proportions of various fibers in the blend determine the basic level of the char length.

The flame retardance of the flame-retardant clothing provided in the present invention is determined by the flame retardance of the fabric, and therefore, it is unnecessary to show examples and comparative examples of the flame-retardant clothing, which may not impact the scope of the present invention.

The examples described above are merely intended to describe the preferred embodiments of the present invention, and not limit to the scope of the present invention. Various variations and improvements made by those of ordinary skill in the art to the technical solutions of the present invention without departing from the design spirit of the present invention shall all fall into the scope of protection of the present invention defined by the appended claims.

### **Industrial Applicability**

According to the flame-retardant yarn, fabric or clothing provided in the present invention, three types of fibers modacrylic, cellulose and polyimide are blended to form a blend, wherein the modacrylic, when burning, may give off a flame-retardant gas to fully isolate

CWCAS-468

the cellulose fibers from oxygen, and the combustion of the cellulose fibers may promote charring of the modacrylic to prevent further combustion of the modacrylic, thereby forming a mechanism of continuous combustion suppression. Once the source of ignition is removed, combustion ends fast, thus achieving the purpose of automatic fire extinguishment. As the cellulose may improve the overall moisture absorbability and comfort of the blend, the skin-friendliness of the yarn, fabric or clothing produced from the blend is greatly improved. Furthermore, the polyimide has excellent heat resistance and extremely high flame retardance, and after being blended with the modacrylic and the cellulose fibers, may improve the thermal stability, dimensional stability and heat insulation property of the blend. The fabric in the present invention may be quickly charred with high flame retardance. The polyimide fibers high in heat resistance serves as a flexible stiffener in the charred film such that the charred film is not prone to breakage and further combustion of the fabric is prevented more effectively, thus achieving the purpose of reducing the char length. The flame-retardant yarn, fabric or clothing provided in the present invention is significant in flame retardance effect, and thus has good industrial applicability.

WHAT IS CLAIMED IS:

1. A flame-retardant yarn, containing the following three types of fibers in the percentage by weight based on their total weight:

modacrylic: 20% to 80%;

cellulose: 10% to 50%; and

polyimide: 1% to 50%;

wherein the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer; and

wherein the weight of the vinyl chloride or the vinylidene chloride or the weight of both accounts for 40% to 60% of the weight of the modacrylic; the content of the acrylon accounts for 35% to 55%; and dyeing groups containing sulfonic groups account for 0.5% to 1%.

2. The flame-retardant yarn according to claim 1, containing the following three types of fibers in percentage by weight based on their total weight:

modacrylic: 25% to 75%;

cellulose: 15% to 45%;

polyimide: 2% to 45%.

3. The flame-retardant yarn according to claim 2, containing anti-static staple fibers or filaments.

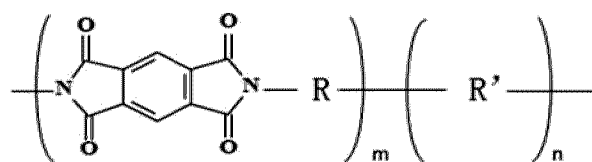
4. The flame-retardant yarn according to claim 3, containing anti-static staple fibers.

5. The flame-retardant yarn according to claim 4, characterized in that an anti-static component of the anti-static staple fibers is carbon or metal.

6. The flame-retardant yarn according to claim 5, characterized in that the anti-static component is carbon.

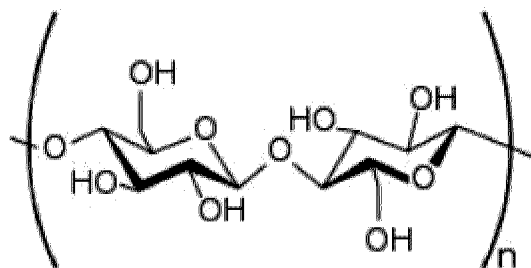
7. The flame-retardant yarn according to claim 1, characterized in that the modacrylic also includes a modacrylic containing one or more antimony oxides selected from a group consisting of antimony trioxide, antimony tetroxide and antimony pentoxide, the content of the antimony oxide(s) accounting for above 2.5% of the weight of the modacrylic.

8. The flame-retardant yarn according to claim 7, characterized in that the polyimide is expressed by a molecular structural formula below:



wherein bis(-CO-N-CO-) is a core structure in a mass ratio above 50%.

9. The flame-retardant yarn according to claim 1, characterized in that: the cellulose is expressed by a molecular structural formula below:



and the cellulose is one or more of cotton, flax, viscose or rayon, lyocell, bamboo fiber and wood fiber.

10. A flame-retardant fabric, containing the following three types of fibers in percentage by weight based on their total weight:

- modacrylic: 20% to 80%;
- cellulose: 10% to 50%; and
- polyimide: 1% to 50%;

wherein the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer; and

wherein the weight of the vinyl chloride or the vinylidene chloride or the weight of both accounts for 40% to 60% of the weight of the modacrylic; the content of the acrylon accounts for 35% to 55%; and dyeing groups containing sulfonic groups account for 0.5% to 1%.

11. The flame-retardant fabric according to claim 10, containing three types of fibers in percentage by weight based on the weight of the fabric:

modacrylic: 25% to 75%;

cellulose: 15% to 45%; and

polyimide: 2% to 45%.

12. The flame-retardant fabric according to claim 10, characterized by a char length of less than 150 mm measured in accordance with GB/T 5455-2014.

13. The flame-retardant fabric according to claim 10, characterized by a char length of less than 100 mm measured in accordance with GB/T 5455-2014.

14. The flame-retardant fabric according to claim 10, characterized by a char length of less than 50 mm measured in accordance with GB/T 5455-2014.

15. The flame-retardant fabric according to claim 10, containing an anti-static component.

16. A flame-retardant clothing, containing the following three types of fibers in percentage by weight based on their total weight:

modacrylic: 20% to 80%;

cellulose: 10% to 50%; and

polyimide: 1% to 50%;

wherein the modacrylic, in which the content of acrylon is 35% to 85%, comprises a vinyl chloride-acrylon copolymer, a vinylidene chloride-acrylon copolymer, or a vinyl chloride-vinylidene chloride-acrylon copolymer; and

wherein the weight of the vinyl chloride or the vinylidene chloride or the weight of both accounts for 40% to 60% of the weight of the modacrylic; the content of the acrylon accounts for 35% to 55%; and dyeing groups containing sulfonic groups account for 0.5% to 1%.

17. The flame-retardant clothing according to claim 16, containing the following three types of fibers in percentage by weight based on the weight of the clothing:

modacrylic: 25% to 75%;

cellulose: 15% to 45%; and

polyimide: 2% to 45%.



