SYNTHETIC FIBERS FOR ARTIFICIAL HAIR AND PRODUCTION THEREOF

Inventors: Masao Sone; Mitsutoshi Okazaki; Yasuomi Ueyama, all of Okayama, Japan

Assignees: Japan Exlan Company Limited, Osaka, Japan;

Filed: Apr. 15, 1971

Appl. No.: 134,313

Foreign Application Priority Data
Apr. 18, 1970 Japan.............................................. 45-33217

U.S. Cl. ................. 161/181, 161/172, 161/177
Int. Cl. ......................... D02g 3/00
Field of Search ................. 161/172, 177, 181

REFERENCES CITED

3,492,195 1/1970 Spangler
3,016,599 1/1962 Perry
1,964,659 6/1934 Brumberger

Primary Examiner—Alfred L. Leavitt
Assistant Examiner—Robert A. Dawson
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

ABSTRACT

Synthetic fibers for artificial hair are provided which have a bending rigidity EI of 2 – 9.5 dyne. cm², a drape index Y of $0.04 \times 10^{-8} - 0.24 \times 10^{-8}$ cm⁻³ and a product value of EI times Y of $0.28 \times 10^{-8} - 1.8 \times 10^{-8}$. Such fibers have good esthetic appearance and handle as well as excellent hair-like feel and visual pliability.

7 Claims, 2 Drawing Figures
FIG. 1

FIG. 2

INVENTORS
MASAO SONE
MITSUTOSHI OKAZAKI
YASUOMI UEYAMA

BY
Wendt, Riedel & Snell
ATTORNEYS
SYNTHETIC FIBERS FOR ARTIFICIAL HAIR AND PRODUCTION THEREOF

The present invention relates to synthetic fibers for artificial hair and their production, and more particularly the invention relates to synthetic fibers for artificial hair having quite beautiful esthetic appearance and hand together with excellent hair-like feeling of touch and visual pliability, said synthetic fibers having been provided with specific bending rigidity (EI) and drape index (Y) defined hereinafter by controlling simultaneously the fineness of the synthetic fibers on consideration of the specific gravity of the polymer forming the synthetic fibers, the sectional shapes of the synthetic fibers, and the modulus of longitudinal elasticity thereof.

Hitherto, natural hair has been used for hair-carrying articles such as a wig and a hair piece because of its pleasant feeling as well as the light and pliant draping property of the hair thereof in appearance and hand at use. Furthermore, as the recent remarkable variety and individualization by the combination of clothing fashion and beauty fashion, the demand for hair-carrying articles such as wigs and hair pieces has markedly increased. On the other hand, however, the supply of natural hair is restricted to resources and in particular it is difficult to obtain with a stable or constant cost sufficient amount of hair for regenerating long, abundant and beautiful appearance and hand.

Thus, the utilization of synthetic fibers for wigs and hair pieces in place of natural hair is considered as a matter of course and in fact, acrylic fibers, nylon fibers, chlorine-containing synthetic fibers, etc., are now used as artificial hair for the purposes.

However, owing to the fundamental properties of the polymer forming synthetic fibers and the restrictions in the sectional shapes and the modulus of longitudinal elasticity of the synthetic fibers by the conditions required for producing thicker fibers than fine ones for clothing, the synthetic fibers conventionally produced for artificial hair have such disadvantages that they are lacking in the hair-like pliability based on softness and elasticity, which is most important in wigs, hair pieces, etc., they are bristly and unpleasantly tough, and also they are greatly inferior to hair in the beautiful appearance and hand thereof at the use of them and hair-like wave pliability and abundant natural wave. Therefore, although wigs, hair pieces, etc., prepared by using synthetic fibers produced as artificial hair may be excellent in the points of cleaning, etc., the commercial values of them are quite inferior in pliability and appearance to wigs, hair pieces, etc., prepared by using hair.

Also, for providing proper pliability or pliability to artificial hair made from synthetic fibers and improving the appearance and hand of the artificial hair, there has been proposed a method in which the surface conditions of synthetic fibers are changed by treating the fibers with a chemical, or a method wherein a mixture of synthetic fibers having different fineness (deniers) is used. However, because these improvements require a special treatment step or are accompanied with a low production efficiency for fibers, they encounter such troubles that the production cost or the processing cost is increased. Further, the fundamental properties of the synthetic fibers are not improved to become hair-like even by such improvement. Therefore, the abovementioned improvements are not satisfactory.

Accordingly we have studied theoretically and minutely the physical properties of hair for overcoming the aforesaid disadvantages and it has been discovered that when synthetic fibers have a specific value of bending rigidity which stands for the pliability by touch and a specific value of drape index which stands for the visual pliability in the state where the synthetic fibers hang down by their own weight to form natural waves, the synthetic fibers for artificial hair essentially provided with a pliability which is a most remarkable feature of hair and having excellent hair-like touch are obtained and also the artificial hair made from such fibers has a very high commercial value not inferior to hair. Therefore, a primary object of this invention is to provide improved synthetic fibers for artificial hair.

Other object of this invention is to provide synthetic fibers for artificial hair provided with the pliability similar to the touch of hair and the visual pliability shown by hair in a natural state.

Still other object of this invention is to provide synthetic fibers for artificial hair having very beautiful appearance similar to hair by providing a specific bending rigidity (EI) and a specific drape index (Y) to the synthetic fibers.

These and further objects of this invention will become apparent by the following explanation.

The above objects of this invention can be achieved by imparting to synthetic fibers the bending rigidity EI (dyne·cm²) and the drape index Y (cm⁻³) satisfying the following general equation (I):

\[ 2 \leq EI \leq 9.5 \]
\[ 0.04 \times 10^{-5} \leq Y \leq 0.24 \times 10^{-5} \]

\[ 0.28 \times 10^{-5} \leq EIY \leq 1.8 \times 10^{-5} \]  

That is, when the bending rigidity (EI) of synthetic fibers, which represents the pliability by touch, is from 2.0 dyne·cm² to 9.5 dyne·cm², the drape index (Y) of the synthetic fibers, which represents the pliability by vision, is from 0.04 × 10⁻⁵ cm⁻³ to 0.24 × 10⁻⁵ cm⁻³, and also the product of EI and Y is from 0.28 × 10⁻⁵ to 1.8 × 10⁻⁵ (i.e., they are in the area surrounded by the lines connecting points A, B, C, D, E, and F in FIG. 2 of the accompanying drawings), the novel synthetic fibers for artificial hair having a hair-like appearance and hand can be obtained. In particular, when the bending rigidity (EI) of synthetic fibers is from 3.0 dyne·cm² to 8.0 dyne·cm², the drape index (Y) is less than 0.20 × 10⁻⁵ cm⁻³, and the product of EI and Y is more than 0.417 × 10⁻⁵, that is, the bending rigidity EI and the drape index of synthetic fibers satisfy the following general equation (II):

\[ 3.0 \leq EI \leq 8.0 \]
\[ 0.20 \times 10^{-5} \geq Y \]

\[ 0.417 \times 10^{-5} \leq EIY \]

more excellent synthetic fibers for artificial hair having more hair-like pliable appearance and touch are obtained.

When the bending rigidity (EI) of synthetic fibers is no more than 2.0 dyne.cm² and the drape index (Y)
thereof is over $0.24 \times 10^{-4}$, the feeling of the synthetic fibers by touch becomes extraordinarily softer, the visual supple appearance of them becomes unstrained and loosened, and the appearance and hand of such synthetic fibers becomes quite different from that of hair. Therefore, such synthetic fibers are improper as ones for artificial hair.

Also, when a wig is made from synthetic fibers having $E I$ of not less than 9.5 dyne cm.\(^2\) and $Y$ of no more than $0.04 \times 10^{-3}$ cm.\(^{-3}\), the sense of touch becomes briskly and the sense of vision becomes like briskly wires, which greatly reduces the commercial value of the article. Furthermore, synthetic fibers having the product of $E I$ and $Y$ not less than $1.8 \times 10^{-4}$ are extraordinarily thick synthetic fibers having a very low modulus of longitudinal elasticity and weak mechanical strength. Therefore, the synthetic fibers will readily break during the production of them or during the use of the articles made from such synthetic fibers. Moreover, because of the extraordinarily thick and hard feeling or appearance of the synthetic fibers themselves, the appearance or the feeling of the artificial hair made from such synthetic fibers becomes quite different from that of hair and also the sense of touch of such artificial hair becomes hard and wire like. On the other hand, when the product of $E I$ and $Y$ is no more than $0.28 \times 10^{-4}$, the synthetic fibers are hard wire-like fibers, which gives a metal-like hard visual appearance. Thus, it can be readily understood at a glance that the artificial hair made from such synthetic fibers is not similar to hair, which reduces greatly the commercial value of the article.

In general, it is known that the pliability of an article made from synthetic fibers by touch is influenced by the fineness, the modulus of longitudinal elasticity, the sectional shapes of the synthetic fibers constituting the article as well as the construction of curl and filament bundle and the structure of a knitted article or fabrics. However, by the inventors’ investigations, it has been clarified that the feeling or the appearance of synthetic fibers to be used for wigs, hair pieces, boas, furs, high piles, etc., is more dominantly influenced by the fineness, the modulus of longitudinal elasticity and the sectional shapes of synthetic fibers which are fundamental properties of the synthetic fibers than by the construction of curl and filament bundle and the interaction factor among fibers based on the structure of knitted articles or fabrics and in particular, the pliability of synthetic fibers which dominates the most important hand specific to hair by touch is markedly influenced by the bending rigidity defined by the product $E I$ of the modulus of elasticity ($E$) of fibers and the sectional secondary moment ($I$) determined by the fineness and the sectional shape of fibers.

The above-mentioned bending rigidity $E I$ is obtained by the following manner. That is, a stress-strain curve is detected from the bending stress $W$ (dyne) and the bending displacement $X$ (cm.) by using the apparatus taught by R. M. Khayatt and N. H. Chanberlin (Journal of Textile Institute; Vol. 39, 185–197 (1948)) and the bending rigidity $E I$ is then obtained from the initial slope $a$ of the curve by the following equation (III), wherein the slope $a$ is a value determined by the stress-strain curve obtained above and has the relation of $W = aX$:

$$EI = \frac{a}{3} \times P$$

(III)

wherein $P$ means the weight (g.) of the fibers per unit length (cm.), $y$ is the deflection length (cm.) of the free end of the fibers hung down by the weight thereof, $l$ is the length (cm.) of the fibers hung by the weight thereof from the supported point, and $E I$ is the bending rigidity defined before. In addition, $Y$ is calculated by introducing the numerical values of $E I$, $P$ and $l$ obtained by the actual measurement to the above general equation (IV).

$$Y = \frac{y}{l^3}$$

$$y = P \cdot \frac{1}{8} \cdot E I$$

(IV)

Now, as shown in FIG. 1 of the accompanying drawings, the important facts are that the bending rigidity $E I$ be in proportion to the square of the fineness of fibers, while the drape coefficient be in inverse proportion to the fineness of fibers. From these facts, it will be clearly understood that the bending rigidity and the drape index of fibers are difficult to be defined to a proper range by simply varying the fineness of the fibers. Thus, it has been fundamentally cleared by the results of our investigations that the requirement of the fineness of fibers for obtaining the hair-like pliability by touch is against the requirement of the fineness of the fibers for obtaining the hair-like visual pliability, and the feeling or appearance of the conventional artificial hair prepared from synthetic fibers without considering these facts is greatly inferior to that of hair.

FIG. 1 is a view explaining the fineness dependence on the bending rigidity and the drape index used in the present invention.

FIG. 2 is a graph showing the area formed by the bending rigidity and the drape index in this invention.

The present invention provides novel synthetic fibers having a bending rigidity and a drape index defined in a specific range, which have not hitherto been considered in the production of synthetic fibers for artificial hair, as the synthetic fibers for artificial hair provided
with the hair-like pliability by touch and also the hair-like visual pliability in a natural state. As the practical means for obtaining the synthetic fibers having the specific bending rigidity and drape index as defined in the present invention, such method is employed that the fineness of fibers on consideration of the specific gravity of the polymer forming the synthetic fibers, the sectional shapes of the fibers, and the modulus of longitudinal elasticity of the fibers are simultaneously controlled.

In general, in the case of producing most profitably fibers from a specific polymer on consideration of the spinnability and the production capacity of the polymer as well as the strength of fibers, the available ranges of the spinning condition and the stretching and heat-treatment conditions in the production step for the fibers are restricted and hence it is quite difficult to obtain the synthetic fibers having the specific bending rigidity and the drape index defined by the present invention by varying only the conditions for the production of the fibers.

Therefore, a preferable means for obtaining the synthetic fibers for artificial hair of this invention is to provide a means of controlling the sectional shapes and the fineness of the synthetic fibers while harmonizing these factors with the modulus of longitudinal elasticity based on the production conditions of the synthetic fibers on considering the spinnability and the production capacity of the polymer as well as the strength of the synthetic fibers necessary in the after-treatment step for the fibers.

That is, the synthetic fibers for artificial hair having the bending rigidity and the drape index specified in the present invention are obtained by conducting the spinning of polymer having a specific gravity of \( \rho_p \) under the conditions satisfying the following general equation (V):

\[
40.7 \leq abE \leq 193.5
\]

\[
0.02 \times 10^{-3} \leq \left( \frac{\rho_p}{abE} \right) \leq 0.12 \times 10^{-3}
\]

\[
2.85 \times 10^{-5} \leq abp_p \leq 18.3 \times 10^{-9}
\]

(V)

wherein \( a \) is the longest length (\( \mu \)) of the straight line in the cross section of fiber passing from a point of the periphery to the point at the opposite side through the center of gravity thereof, \( b \) is the longest length (\( \mu \)) of the straight line in the cross section of the fiber at a right angle to the line (a) between the points at the periphery of the cross section, and \( E \) is a modulus of longitudinal elasticity (dyne/cm²) of fibers at the production of the synthetic fibers from the polymer.

As mentioned above, the synthetic fibers for artificial hair provided by the hair-like pliability by touch and also the hair-like visual pliability of this invention can be produced from the synthetic fibers while harmonizing the sectional shapes of the fibers with the modulus of longitudinal elasticity (E) but as the means for obtaining the synthetic fibers for artificial hair having the properties satisfying the purposes of this invention from a specific polymer, a method may be employed in which the specific gravity of the fibers produced from the polymer is positively varied.

That is, the specific gravity of synthetic fibers may be varied by adding one or more additives having a different specific gravity from that of a polymer from which the synthetic fibers are produced to a melt of the polymer or a solution of the polymer at the production of the fibers or by introducing an additive capable of varying the specific gravity of synthetic fibers to the synthetic fibers during the spinning of said fibers.

As the additives to be introduced into the synthetic fibers for such purposes, any inorganic materials or organic materials having a different specific gravity from the polymer of the fibers may be employed.

Also, the specific gravity of synthetic fibers may be varied by using a mixture of polymers, each having a different specific gravity each other or by arranging in layers different polymers along the lengthwise direction of the fibers. In particular, as the additives used for the purpose, the whole well-known fiber-modifying agents such as those for improving the antistatic property of the fibers, improving the hygroscopic property thereof, providing the flame-retarding property to the fibers, improving the dyeing property of the fibers, and improving the luster of the fibers can be preferably used. Moreover, by using an additive capable of providing the properties required by the synthetic fibers for artificial hair among the above-mentioned additives, such as an antistatic agent, a flame retarding agent, a luster-improving agent, etc., the synthetic fibers of this invention can be further provided with the additional valuable properties besides the aforesaid properties satisfying the purposes of this invention, which can further increase the commercial value of the synthetic fibers for artificial hair.

Moreover, the present invention can provide the synthetic fibers for artificial hair having the quite high additional values by incorporating proper additives in the synthetic fibers and hence in the case of producing the additive-containing synthetic fibers satisfying the bending rigidity and the drape index specified by the present invention, the purposes of this invention can be attained with more satisfactory results.

Now, in order to obtain the synthetic fibers for artificial hair containing the above-mentioned additives, it is necessary to conduct the spinning of a melt or a solution of a polymer containing the additives under the conditions satisfying the following general equation (VI):

\[
40.7 \leq abE \leq 193.5
\]

\[
0.02 \times 10^{-7} \leq \left( \frac{\rho_p}{bE} \right) \leq 0.12 \times 10^{-7}
\]

(VI)

\[
2.85 \times 10^{-7} \leq ab \left( \frac{\rho_p}{bE} \right) \leq 18.3 \times 10^{-7}
\]

(VI)

wherein \( a \) is the longest length (\( \mu \)) of the straight line in the cross section of a fiber passing from a point at the periphery to a point at the opposite side thereof passing through the center of gravity thereof, \( b \) is the longest length (\( \mu \)) of the straight line in the cross section of the fiber at a right angle to the line (a) and present between two points at the periphery, \( E \) is the modulus of
3,790,434

For producing the synthetic fibers for artificial hair of this invention by using the polymer as mentioned above, any well-known spinning manner of producing fibers from polymer, such as a melt spinning method, a dry spinning method, an emulsion spinning method, etc., may be employed and if necessary, well-known after treatments such as water washing, stretching, drying, and heat-treatment may be applied.

As mentioned above, the synthetic fibers for artificial hair of this invention are produced by applying a known spinning technique to the polymer for forming the fibers and the particularly important matter in case of producing the synthetic fibers for artificial hair of this invention is the point of selecting such spinnerettes as giving the sectional shape of fibers satisfying the aforesaid general equation (V) or (VI) while harmonizing the shape with the bending modulus of longitudinal elasticity E determined by the known conditions for producing the synthetic fibers from the polymer and in compliance with the spinning method to be employed, a spinnerette having a spinning hole of a circle, a triangle, a Y-form, a square, a rectangle, and ellipse, a star-form, or other polygonal form may be employed. Furthermore, the spinnerettes having such structure that two or more polymer melts or polymer solutions can be spun as a composite form or a mixed form may also be employed in this invention.

In addition, the fineness of a single fiber was measured by the method described in Method D of British Standards 1961-1961, the specific gravity of the fibers was measured by the method described in ASTM D-1505-67, and the shape factor e expressed by b/a was calculated from a and b obtained from the enlarged photograph of the cross section of a fiber in this specification.

The invention will then be explained more practically by the following comparative example and the examples but the scope of this invention shall not be limited by them. In addition, all percentage and parts in the reference example and the examples, unless otherwise indicated, are by weight.

COMPARATIVE EXAMPLE

From three kinds of commercially available wigs made from synthetic fibers, the bending rigidity EI and the shape index Y of the synthetic fibers were obtained by utilizing the general equation (III) and (IV) mentioned before and also by a panel of members composed of two wig makers and three experts engaging in the barber and beauty parlor business, the whole hair-like appearances of the wigs from the pliability thereof by touch and the visual pliability thereof at use were evaluated, the results of which are shown in Table 1.

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Polymer</th>
<th>(G)</th>
<th>(d)</th>
<th>e</th>
<th>a(μ)</th>
<th>EI</th>
<th>Y</th>
<th>Eval.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nylon-6</td>
<td>1.14</td>
<td>58</td>
<td>1.0</td>
<td>85</td>
<td>3.2</td>
<td>0.31×10⁻³</td>
<td>Bad.</td>
</tr>
<tr>
<td>2</td>
<td>Polynitrile chloride</td>
<td>1.39</td>
<td>45</td>
<td>0.86</td>
<td>73</td>
<td>10.0</td>
<td>0.06×10⁻³</td>
<td>Bad.</td>
</tr>
<tr>
<td>3</td>
<td>An-type polymer</td>
<td>1.18</td>
<td>58</td>
<td>0.85</td>
<td>90</td>
<td>13.5</td>
<td>0.06×10⁻³</td>
<td>Bad.</td>
</tr>
</tbody>
</table>

| (G): Specific gravity. (d): Fineness of fibers. AN-type polymer: A copolymer of 90% acrylonitrile and 10% methyl acrylate. |
In addition, the unit of EI in the above table was dyne.cm. and that of Y was cm. As clear from the evaluations shown in Table 1, the commercially available wigs have the synthetic fibers in which the values EI and Y were outside of the ranges defined in this invention, were very inferior in the hair-like appearance and thus had very low commercial values.

EXAMPLE 1

A spinning solution prepared by dissolving 12 parts of an acrylonitrile polymer consisting of 90 percent acrylonitrile and 10 percent methyl acrylate in 88 parts of 44 percent aqueous solution of sodium thiocyanate was spun into a coagulating bath containing 12 percent aqueous solution of sodium thiocyanate at temperatures of −2°C. by using spinnerettes each having a rectangular spinning hole of a spinning hole area of 0.06 mm.² or 0.08 mm.² and a short side/long side ratio of one-tenth to coagulate the spun fibers, which were washed with water, stretched in boiling water to 8 times the original length, and further subjected to heat treatments, whereby three kinds of fibers having different fineness of single fiber and shape factor e were obtained.

From the three kinds of the synthetic fibers thus obtained, the values EI and Y were measured and also the evaluations of the hair-like appearances thereof were conducted by the five experts as in Comparative Example shown above, the results of which are shown in Table 2.

<table>
<thead>
<tr>
<th>Fiber (d)*</th>
<th>(C)**</th>
<th>e</th>
<th>a(μ)</th>
<th>E</th>
<th>EI</th>
<th>Y</th>
<th>Evaln.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>round</td>
<td>1.0</td>
<td>66</td>
<td>1.94 x 10²</td>
<td>1.8</td>
<td>0.27 x 10⁻³</td>
<td>Bad.</td>
</tr>
<tr>
<td>8</td>
<td>round</td>
<td>1.0</td>
<td>104</td>
<td>0.99 x 10²</td>
<td>5.8</td>
<td>0.21 x 10⁻³</td>
<td>Good.</td>
</tr>
<tr>
<td>9</td>
<td>ellipse</td>
<td>0.95</td>
<td>116</td>
<td>1.03 x 10²</td>
<td>7.8</td>
<td>0.18 x 10⁻³</td>
<td>Very good.</td>
</tr>
<tr>
<td>10</td>
<td>round</td>
<td>1.0</td>
<td>98</td>
<td>1.31 x 10²</td>
<td>6.0</td>
<td>0.18 x 10⁻³</td>
<td>Very good.</td>
</tr>
<tr>
<td>11</td>
<td>ellipse</td>
<td>0.62</td>
<td>166</td>
<td>1.26 x 10²</td>
<td>8.0</td>
<td>0.24 x 10⁻³</td>
<td>Bad.</td>
</tr>
</tbody>
</table>


In addition, the units of E, EI and Y were dyne/cm², dyne/cm³, and cm.⁻³, respectively.

As shown in the above table, the synthetic fibers 8, 9 and 10 having the bending rigidity and the drape index in the ranges defined in this invention were evaluated to have a hair-like pliable feeling, while the synthetic fibers 7 and 11 having the bending rigidity and the drape index in the ranges outside the values of this invention were evaluated to be undesirable in hair-like pliability.

EXAMPLE 2

According to an ordinary melt spinning method, synthetic fibers were produced from tips of nylon-6 by using five kinds of spinnerettes with 0.4 to 1.0 mm.² hole area, two kinds of which have a rectangular spinning hole of one-fourth or one-eighth in the short side/long side ratio and three kinds of which have a circular spinning hole and then the fibers were subjected to orientative stretching of 3–4 times. Thus, five kinds of synthetic fibers for wig hair were obtained.

From the five kinds of the synthetic fibers thus prepared, the physical properties were measured and the feelings or appearances of them were evaluated by the five experts as in Comparative Example, the results of which are shown in Table 3.

<table>
<thead>
<tr>
<th>Fiber (d)*</th>
<th>(C)**</th>
<th>e</th>
<th>a(μ)</th>
<th>E</th>
<th>EI</th>
<th>Y</th>
<th>Evaln.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>round</td>
<td>1.0</td>
<td>66</td>
<td>1.94 x 10²</td>
<td>1.8</td>
<td>0.27 x 10⁻³</td>
<td>Bad.</td>
</tr>
<tr>
<td>8</td>
<td>round</td>
<td>1.0</td>
<td>104</td>
<td>0.99 x 10²</td>
<td>5.8</td>
<td>0.21 x 10⁻³</td>
<td>Good.</td>
</tr>
<tr>
<td>9</td>
<td>ellipse</td>
<td>0.95</td>
<td>116</td>
<td>1.03 x 10²</td>
<td>7.8</td>
<td>0.18 x 10⁻³</td>
<td>Very good.</td>
</tr>
<tr>
<td>10</td>
<td>round</td>
<td>1.0</td>
<td>98</td>
<td>1.31 x 10²</td>
<td>6.0</td>
<td>0.18 x 10⁻³</td>
<td>Very good.</td>
</tr>
<tr>
<td>11</td>
<td>ellipse</td>
<td>0.62</td>
<td>166</td>
<td>1.26 x 10²</td>
<td>8.0</td>
<td>0.24 x 10⁻³</td>
<td>Bad.</td>
</tr>
</tbody>
</table>


In addition, the units of E, EI and Y were dyne/cm², dyne/cm³, and cm.⁻³ respectively.

As shown in the above table, the synthetic fibers 8, 9 and 10 having the bending rigidity and the drape index in the ranges defined in this invention were evaluated to have a hair-like pliable feeling, while the synthetic fibers 7 and 11 having the bending rigidity and the drape index in the ranges outside the values of this invention were evaluated to be undesirable in hair-like pliability.

EXAMPLE 3

Four kinds of synthetic fibers for artificial hair were produced by the following manners:

1. A spinning solution prepared by dissolving a copolymer of 92 percent acrylonitrile and 8 percent methyl acrylate in dimethylformamide was dry-spun in hot air of 200°C. at a spinning temperature of 106°C. by using spinnerettes each having a circular spinning hole of 0.2 mm.² in sectional area and after water washing, the fibers were subjected to the orientative stretching of three times to provide the synthetic fibers for artificial hair.

2. A spinning solution prepared by dissolving a polymer consisting of 90 percent acrylonitrile and 10 percent methyl acrylate in dimethylformamide was wet-spun into a coagulation bath of ethyleneglycol at 20°C. at a spinning temperature of 50°C. by using spinnerettes each having a circular spinning hole of 0.15 mm.² in sectional area thereof and then the fibers were subjected to the orientative stretching of six times to provide the synthetic fibers for artificial hair.

3. A spinning solution prepared by dissolving a mixture of 75 parts of a polymer consisting of 90 percent acrylonitrile and 10 percent methyl acrylate and 25 parts of a vinyl chloride-vinylidene chloride copolymer in dimethylformamide was wet-spun into an ethyleneglycol-type coagulation bath maintained at 20°C. at a spinning temperature of 50°C. by using spinnerettes each having a circular spinning hole of 0.24 mm.² in sectional area and then the fibers were subjected to the orientative stretching of 6 times to provide the synthetic fibers for artificial hair.

4. A spinning solution prepared by dissolving a polymer consisting of 60 percent acrylonitrile and 40 percent vinyl chloride in acetonitrile was subjected to an ordinary dry spinning process by using spinnerettes each having a circular spinning hole of 0.2 mm.² in sectional area of the hole and then the filaments thus formed were subjected to the orientative stretching of 5 times to provide the synthetic fibers for artificial hair.

From the four kinds of the synthetic fibers for artificial hair thus obtained, the physical properties were
measured and the appearances were evaluated by the five experts as in Reference Example, the results of which are shown in Table 4.

**TABLE 4**

<table>
<thead>
<tr>
<th>Fiber (G)</th>
<th>(d)</th>
<th>(C)</th>
<th>e (μm)</th>
<th>E</th>
<th>El</th>
<th>Y</th>
<th>Evaln.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 1.18 35 dog bone</td>
<td>0.53</td>
<td>89</td>
<td>7.1</td>
<td>3.0</td>
<td>0.16</td>
<td>Very</td>
<td>good</td>
</tr>
<tr>
<td>13 1.18 19 hair</td>
<td>0.97</td>
<td>48</td>
<td>8.26</td>
<td>2.0</td>
<td>0.13</td>
<td>Bad.</td>
<td></td>
</tr>
<tr>
<td>14 1.28 78 beec</td>
<td>0.60</td>
<td>120</td>
<td>4.14</td>
<td>9.0</td>
<td>0.12</td>
<td>Good.</td>
<td></td>
</tr>
<tr>
<td>15 1.28 48 ellipse</td>
<td>0.63</td>
<td>92</td>
<td>6.46</td>
<td>5.5</td>
<td>0.12</td>
<td>Very</td>
<td>good</td>
</tr>
</tbody>
</table>

(G): Specific gravity.
(d): Fineness of fiber.
(C): Sectional shape of fiber.

In addition, the units of E, El and Y were dyne/cm², dyne cm, and cm⁻² respectively.

As clear from Table 4, only the synthetic fibers 12, 14 and 15 of this invention were evaluated as having excellent hair-like pliability.

**EXAMPLE 4**

To two kinds of the spinning solutions prepared by dissolving respectively a polymer A consisting of 90 percent acrylonitrile and 10 percent methyl acrylate and a polymer B consisting of 82 percent acrylonitrile, 8 percent methyl acrylate, and 10 percent vinylidene chloride in concentrated aqueous solutions of sodium thiocyanate were added the compounds shown in Table 5 and then each of the solutions was subjected to the wet spinning according to the manner shown in Example 1 by using spinnerettes each having a rectangular or circular spinning hole of 0.10 mm.² or 0.14 mm.² in the spinning hole area and of one-tenth in the short side/long side ratio and then the filaments thus obtained were subjected to the heat stretching of 8 or 10 times, and a heat treatment to provide seven kinds of synthetic fibers for artificial hair.

From the seven kinds of the fibers thus prepared, the

pared with hair, whereas the wigs prepared from the fibers 17 – 22 of this invention were evaluated to have the pliability quite similar to that of hair and have a very high commercial value.

Also, it has been confirmed that the fibers 17, 18, 19 and 21 of this invention had a very excellent flame retarding property and self distinguishing property as well as delustered effect. Further, because the fibers 20 had an antistatic property besides the above mentioned properties, the snythetic fibers could provide a very valuable wig capable of completely preventing the formation of static troubles in combing the hair of the wig.

In addition, in Table 5, TBCF stands for tris-(1-bromo-3-chloroisopropyl)phosphate, TDPF stands for tris-(2,3-dibromopropyl)phosphate, GMS stands for glyceryl monostearate, and AO stands for antimony trioxide.

What we claim is:

1. A synthetic fiber for artificial hair having a hair-like appearance and hand, said fiber having a bending rigidity EI (dyne cm²) and a drape index Y (cm⁻²) satisfying the equations

\[ 2.0 \leq EI \leq 9.5 \]
\[ 0.04 \times 10^{-5} \leq Y \leq 0.24 \times 10^{-5} \]
\[ 0.28 \times 10^{-5} \leq EI \cdot Y \leq 1.8 \times 10^{-5} \]

and wherein the longest length a of the straight line in the cross section of the fiber passing from a point on the periphery of the fiber to a point on the opposite side of the fiber through the center of gravity thereof is between 60 and 115 microns, and bia is in the range of from one to one-fifth, b being the longest length of the straight line in the cross section of the fiber at a right angle to the line a between the points at the periphery of the cross section of the fiber.

2. The fiber as claimed in claim 1 wherein the sectional shape of the synthetic fiber is an ellipse.

3. The fiber as claimed in claim 1 wherein said fiber is made of a fiber-forming polymer selected from the

**GROUP A**

- Polyesters
- Vinyl polymers
- Acrylic polymers
- Polymers consisting of polyacrylonitrile and a copolymer of more than 80 percent by weight acrylonitrile and one or more other vinyl monomers.

4. The fiber as claimed in claim 3, wherein the acrylic polymer is selected from the group consisting of polyacrylonitrile and acrylate having the drape index defined in the present invention was evaluated to show hard feeling or appearance as compared to

5. The fiber as claimed in claim 1, containing one or more additives selected from the group consisting of an

**TABLE 5**

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Polymer</th>
<th>Additive</th>
<th>e (μm)</th>
<th>El</th>
<th>Y</th>
<th>Evaln.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>A</td>
<td>TBCF</td>
<td>9</td>
<td>1.23</td>
<td>0.35</td>
<td>10.0</td>
</tr>
<tr>
<td>17</td>
<td>A</td>
<td>TBCF</td>
<td>31</td>
<td>1.33</td>
<td>0.83</td>
<td>4.3</td>
</tr>
<tr>
<td>18</td>
<td>B</td>
<td>TDPF</td>
<td>37</td>
<td>1.38</td>
<td>0.81</td>
<td>8.0</td>
</tr>
<tr>
<td>19</td>
<td>B</td>
<td>TBCF</td>
<td>33</td>
<td>1.38</td>
<td>0.55</td>
<td>7.0</td>
</tr>
<tr>
<td>20</td>
<td>A</td>
<td>GMS+TBCF</td>
<td>0.35</td>
<td>1.36</td>
<td>0.68</td>
<td>5.1</td>
</tr>
<tr>
<td>21</td>
<td>A</td>
<td>AO+TBCF</td>
<td>4.5+27</td>
<td>1.37</td>
<td>1.0</td>
<td>3.8</td>
</tr>
<tr>
<td>22</td>
<td>B</td>
<td>AO</td>
<td>11</td>
<td>1.33</td>
<td>0.75</td>
<td>6.5</td>
</tr>
</tbody>
</table>

*: Amount of additive (per polymer) in fiber.
**: Apparent specific gravity of fiber.
(d): Fineness of fiber.
3,790,434

antistatic agent, a flame-retarding agent and a luster-improving agent having a specific gravity differing from that of the synthetic polymer which constitutes the fiber.

6. The fiber as claimed in claim 1 wherein the fiber consists of an acrylic polymer composition containing one or more additives selected from the group consisting of an antistatic agent, a flame-retarding agent and a luster-improving agent having a specific gravity differing from that of the synthetic polymer which constitutes the fiber.

7. A synthetic fiber for artificial hair having hair-like pliable appearance, said fiber having a bending rigidity $EI$ (dyne cm.²) and a drape index $Y$ (cm.⁻²) satisfying the equations

\[
3.0 \leq EI \leq 8.0 \\
0.20 \times 10^{-5} \leq Y \\
0.417 \times 10^{-5} \leq EI \cdot Y
\]

and wherein the longest length $a$ of the straight line in the cross section of the fiber passing from a point on the periphery of the fiber to a point on the opposite side of the fiber through the center of gravity thereof is between 60 and 115 microns, and $b/a$ is in the range of from one to one-fifth, $b$ being the longest length of the straight line in the cross section of the fiber at a right angle to the line $a$ between the points at the periphery of the cross section of the fiber.

* * * * *