



SOLUTION-DYED NYLON FIBERS

The present invention relates to spinning fibers from thermoplastic polymers. More specifically, the present invention relates to spinning thermoplastic fibers that are colored in the melt, i.e., solution-dyed.

As used herein, certain terms have the meanings ascribed to them.

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"Colorant" means a compound added to impart color to a substrate. Colorants can be, for example, pigments or dyes or mixtures of pigments, dyes, etc.

15 "Spinning efficiency" means the percentage of time that the winder is collecting yarn ("up time") with respect to the total operating time, i.e., $(\text{up time}/\text{total time}) \times 100$.

"Solution-dyed" means that color is added to a fiber-forming material prior to extruding it into a fiber through a spinneret capillary.

It is known that, unaided, nylon fibers are not sufficiently light resistant for certain applications. For these nylon fibers, exposure to light causes the fiber to discolor and/or to lose physical properties. Light stabilizers have been incorporated in the nylon polymer to address this problem.

There are several classes of light stabilizers. As additives, organic stabilizers (such as hindered phenols) are expensive and have limited effectiveness.

Inorganic salts are generally less expensive and more effective than organic stabilizers but suffer from a different set of problems. For example, copper compounds are inexpensive relative to organic stabilizers but form copper deposits in pipes, spin packs, extruders and other equipment because some of the copper ions reduce to elemental copper during the spinning process. This phenomenon is described in U.S. Patent No. 3,929,725 to Davis and U.S. Patent No. 3,947,424 to Tomek. Copper deposits cause spinning difficulties and add significant equipment maintenance expense. Furthermore, the removal of copper deposits generates environmentally undesirable effluent.

45 A class of stabilizers is known as "hindered amine light stabilizers" or by the acronym "HALS". HALS stabilizer additives may be added to the polymer after polymerization in the form of



monomers, low molecular weight additives or incorporated into a polymer backbone. Such stabilizers are typically high cost and low effectiveness compared to copper based stabilizers. In addition, the polymer itself has been modified by polymerizing the amide monomers in the presence of a HALS type of compound. This has been described in WO 95/28443.

It is known to solution-dye nylon fibers. For example, solution-dyed nylon fibers are described in U.S. Patent No. 4,374,641 to Burlone. The problem of light stability is complicated by solution-dyeing. Some colorants actually accelerate the degradation of the host polyamide. Without stabilizing additives, the fiber loses an unacceptable degree of strength during exposure to light or the colorant does not remain "true" to its color. Proper stabilizer selection is made tricky, to say the least. For example, certain pigments are taught to be incompatible with HALS stabilizers. See W. Herbst and K. Hunger, "Industrial Organic Pigments" Verlagsgesellschaft mbH, Federal Republic of Germany, 1993, pp. 467-475

Although WO 95/28443 describes addition of TiO_2 and possibly other colorants, this addition is during the polymerization phase. In the manufacture of a palette of solution-dyed yarns, it is not practical to use polymer that is already colored (not delustered) in polymerization. It should be apparent that the color of the polymer will interfere with the fiber spinner's ability to make a broad spectrum of colors.

In addition, certain colorants or classes of colorants are notoriously difficult to spin and operators experience frustrating breaks during the spinning process. Any method that improves the spinning efficiency of solution-dyed fibers colored with these materials is desirable.

Therefore, there remains a need for an inexpensive method for making a variety of colors in solution-dyed nylon fibers that are stabilized with respect to the polyamide and to the colorant. Such a method should not have any of the disadvantages that are described above.

It is an object of the present invention to provide a process for making a light stabilized solution-dyed fiber.

It is another object of the present invention to provide improved spinning efficiency for traditionally difficult to spin solution-dyed fibers.

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A further object of the present invention is to eliminate or significantly reduce stabilizer build-up in melt spinning lines.

A still further objective of the present invention is to provide a light stabilized solution-dyed fiber.

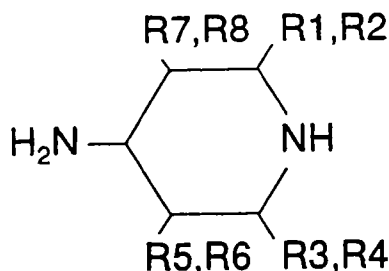
Yet, another object of the present invention is to provide an environmentally-friendly, efficient process for producing solution-dyed nylon fibers.

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These objects are achieved in a process for making stabilized, solution-dyed fiber by melting a polyamide which is amide monomers polymerized in the presence of at least one mono or dicarboxylic acid chain regulator and at least one hindered

15 piperidine compound having the formula:

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where R1, R2, R3 and R4 are not hydrogen, but are any alkyl group having up to about 20 carbon atoms, and R5, R6, R7 and R8 are any alkyl group having up to 20 carbon atoms or hydrogen; and coloring the melted polyamide with a colorant selected from the group consisting of: pigments that are not pure iron oxide pigments; dyes; and mixtures thereof.

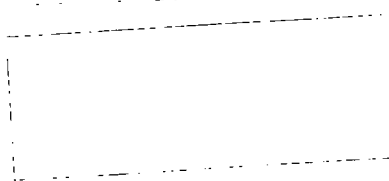
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The colored polyamide is spun into fibers that have about 40% or better retained tenacity after 2125 kJ exposure to xenon arc radiation as per AATCC Test Method 16-1993, "Colorfastness to Light," Option E and that contain no more than about 10 ppm uncomplexed copper.

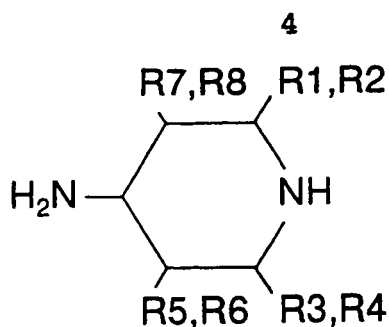
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In another aspect, the present invention includes a light stabilized solution-dyed nylon fiber. The fiber is a polyamide host polymer which is amide monomers polymerized in the presence of at least one mono or dicarboxylic acid chain regulator and at least one hindered piperidine compound having the formula:

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10 where R1, R2, R3 and R4 are not hydrogen, but are any alkyl group having up to about 20 carbon atoms, and R5, R6, R7 and R8 are any alkyl group having up to about 20 carbon atoms or hydrogen; and a non-white colorant dispersed throughout the host polymer. Such fiber is substantially free from copper compounds.

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Related objects and advantages of the present invention will be apparent to those of ordinary skill in the art after reading the following detailed description.

20 FIG. 1 is a bar chart comparing the retained tenacity after xenon light exposure of fibers made according to the invention to other fibers.

FIG. 2 is a bar chart comparing the color change after xenon light exposure of fibers made according to the invention to other fibers.

To promote an understanding of the principles of the present invention, descriptions of specific embodiments of the invention follow and specific language is used to describe the same. It will be understood that no limitation of the scope of the invention is intended by the use of this specific language and that alterations, modifications, equivalents and further applications of the principles of the invention discussed are contemplated as would normally occur to one ordinarily skilled in the art to which the invention pertains.

One aspect of the present invention is a process for making light stabilized solution-dyed fiber. A modified nylon containing a hindered amine light stabilizer (HALS) functionality built into the nylon molecule is used. The result is a surprisingly stable fiber product, even in the presence of strongly pro-degrading pigments. The invention significantly reduces dependence on stabilizer additives for solution-dyed nylon production.

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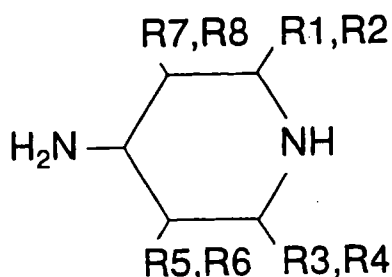
The process of the present invention includes melting a certain polyamide. The melted polyamide is colored with a colorant and spun into fibers. After spinning, the fibers are quenched, and optionally, drawn, textured and taken up according to typical procedures that are well known in the art.

The fibers made by this process are useful in any of the common applications for polyamide fibers. These applications include (but are not limited to) apparel, carpeting, upholstery, etc.

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The certain polyamide used in the present invention is made by hydrolytically polymerizing nylon forming monomers or co-monomers (e.g., those used to make nylons such as nylon 6, nylon 6/6, nylon 12, nylon 6/12, nylon 11, etc.), preferably, ϵ -caprolactam in the presence of water, at least one dicarboxylic acid chain regulator and at least one hindered piperidine derivative. In the description of the invention, nylon 6 and caprolactam are used as specific examples of the invention. While this embodiment of the invention is presently preferred, it should not be considered limiting. The exemplary nylon may be made by polymerizing ϵ -caprolactam in the presence of at least one copolymerizable hindered amine (piperidine) compound of the formula:

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where R1, R2, R3, and R4 are not hydrogen, but are any alkyl group such as methyl, ethyl, propyl, isopropyl, butyl, etc., having up to about 20 carbon atoms. R5, R6, R7, and R8 are any alkyl group having up to about 20 carbon atoms or hydrogen. The R 1-8 may be all the same; they may all be different; or they may be some combination thereof. It is contemplated that the alkyl groups may be substituted alkyl groups. Such substitution is included within the scope of "alkyl."

The hindered piperidine derivative is preferably an amino polyalkylpiperidine. Preferably, the hindered piperidine derivative is a 2,2',6,6'-tetraalkylpiperidine. Exemplary useful hindered piperidine compounds include:

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- 4-amino-2,2',6,6'-tetramethylpiperidine;
4-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
5 3-amino-2,2',6,6'-tetramethylpiperidine;
3-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
2,2',6,6'-tetramethyl-4-piperidinecarboxylic acid;
10 2,2',6,6'-tetramethyl-4-piperidinealkylcarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinearylcboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinealkyl/arylcboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinecarboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinealkylcarboxylic acid;
15 2,2',6,6'-tetramethyl-3-piperidinearylcboxylic acid; and
2,2',6,6'-tetramethyl-34-piperidinealkyl/arylcboxylic
acids.

The hindered amine compound may be mixtures of these as well. To
20 make the polyamide used in the present invention, the hindered
amine compound is added to the starting monomers or to the poly-
merizing reaction mixture. The polymerization is preferably car-
ried out according to a range of conventional conditions for
polymerizing the type of amide monomer, e.g., caprolactam to make
25 nylon 6. The hindered amine compound is added to the starting
monomers at from about 0.03 to about 0.8 mol %, preferably from
about 0.06 to about 0.4 mol % (in relation to 1 mole amide groups
of the polyamide).

30 The hindered amine compound may be used with at least one chain
regulator. Suitable chain regulators are, for example, mono-
carboxylic acids such as acetic acid, propionic acid and benzoic
acid; and dicarboxylic acids.

35 Preferred dicarboxylic acid chain regulators are selected from
the group of C₄-C₁₀ alkane dicarboxylic acids (e.g., adipic acid,
sebacic acid, cyclohexane-1, 4-dicarboxylic acid); benzene and
naphthalene dicarboxylic acids (e.g., isophthalic acid,
terephthalic acid and naphthalene 2,6-dicarboxylic acid); and
40 combinations thereof. Preferably, the dicarboxylic acid chain
regulator is terephthalic acid, sebacic acid or adipic acid. The
preferable amount of dicarboxylic acid used is from 0.06 to 0.6
mole % in relation to 1 mole amide groups.

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Water is preferably used as a polymerization initiator. The amount of water used as an initiator may vary but is typically about 0.4 wt. % based on the weight of the ϵ -caprolactam monomer.

5 When the amide monomer is ϵ -caprolactam, exemplary polymerization conditions are from about 240°C to about 290°C for about 8 to about 12 hours at pressure conditions of from about 1.0 to about 1.9 bar. The pressure is measured in the vapor phase above the polymerization zone.

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The polyamide made in this way is fed to an extruder that may be any extruder used in the art for spinning fibers. Typically, such extruders melt the polyamide over several stages. The melt temperature will depend somewhat on the polyamide used but will

15 generally be in the range from about 240°C to about 290°C.

The melted polyamide is colored with a colorant selected from the group consisting of pigments, dyes, as well as any colored compound with properties in between pigments and dyes and

20 combinations or mixtures of any of these. Especially preferred colorants include those that are considered difficult to spin due to breaks (decreased spinning efficiency). These colorants include transparent iron oxide red, zinc ferrite tan, and titanium dioxide. It should be noted that pure iron oxide pigment (i.e.,
25 iron oxide that is not used with other colorants), which yields a red color, is not included in the list of pigments that are used in the present invention. Other colorants where iron oxide is only one of the colorants in a mixture of pigments, are included in the colorants used in the present invention. In such
30 colorants, iron oxide may typically be included at up to about 1.5% by weight of the colorant.

The colored polyamide is spun into fibers according to techniques known to those of ordinary skill in the art. It is not deemed

35 limiting to use any specific method of spinning. The polyamide may be spun into fibers as a monocomponent filament or as one component of a multicomponent filament. The fiber may have any of the variety of cross-sections made in the art. For example, the fiber may be round, multilobal (e.g., trilobal), deltoid, pentag-
40 onal, etc.

The denier of the fiber will depend on its intended end use and is not considered limited by the invention. The denier may be very fine, e.g., about 0.1 denier per filament or very large,

45 e.g., about 50 denier or more per filament.

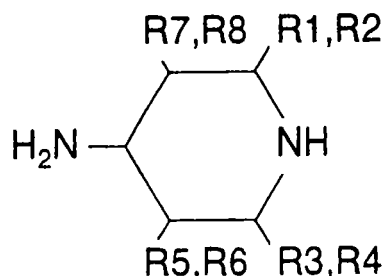
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The present invention surprisingly produces solution-dyed fibers wherein the polyamide and the colorant are both stabilized from degradation by light. With the present invention, it is not considered necessary to use other stabilizers as additives. For example, it is not necessary to use copper salts as stabilizing additives. Copper compounds may be present in the fiber because, for example, some pigments (e.g., phthalocyanine blue) are copper complexes. The present invention results in a fiber having a 40% or better retained tenacity after 2125 kJ exposure to xenon arc radiation per AATCC Test Method 16-1993 "Colorfastness to Light" Option E and even when containing no more than about 10 ppm uncomplexed copper. The elimination of such stabilizing additives reduces equipment maintenance costs and eliminates harmful effluents produced in the removal of stabilizer deposits in spinning equipment.

Even more surprising is the increased spinning efficiency noted with certain difficult to spin colorants. Spinning efficiency is preferably increased by at least about 0.5%. Such increases in spinning efficiency can translate into hundreds of thousands of dollars in reduced annual manufacturing costs. Example 6 below demonstrates some of the improved efficiency observed with the present invention.

Of course, various non-stabilizing additives may be used in one or more of the filaments. These include, without limitation, lubricants, nucleating agents, antioxidants, antistatic agents, etc.

Another aspect of the present invention is a stabilized light solution-dyed nylon fiber that is made from a polyamide host polymer which includes amide monomers polymerized in the presence of at least one mono or dicarboxylic acid chain regulator and at least one hindered piperidine compound having the formula:



where R1, R2, R3 and R4 are not hydrogen, but are any alkyl group having up to about 20 carbon atoms. R5, R6, R7 and R8 are any alkyl group having up to about 20 carbon atoms or hydrogen.

- 5 R1-8 may each be the same group; may each be a different group; or some combination thereof. It is contemplated that the alkyl groups may be substituted and such substitution is included in the scope of "alkyl."
- 10 A non-white colorant is dispersed throughout the host polyamide. This fiber may be made according to the process described above. It may have the characteristics attributed to fibers made by the process.
- 15 This invention will be described by reference to the following detailed examples. The examples are set forth by way of illustration, and are not intended to limit the scope of the invention. All percentages are by weight unless otherwise noted.
- 20 In the following Examples, the following standardized test methods are used:

Xenon Arc Exposure:

- 25 Knit tubes are exposed and tested according to AATCC Test Method 16-1990, Option E: "Water-Cooled Xenon-Arc Lamp, Continuous Light" to 2125 kJ (500 hours) in 425 kJ (100 hour) increments. Ozone and NO_x Exposure:

- 30 Knit tubes are tested according to AATCC Test Method 129-1996, "Colorfastness to Ozone in the Atmosphere Under High Humidities" and AATCC Test Method 164-1992, "Colorfastness to Oxides of Nitrogen in the Atmosphere Under High Humidities". Data is collected at 1, 2, 3, 4, 6 and 8 cycles.

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EXAMPLES 1A - 1I COMPARATIVE

(Solution-Dyed Nylon Fibers - Nylon Host Polymer-No Stabilizer)

- 40 Using a small scale extruder with a 1" diameter screw, solution-dyed 715/14 (yarn denier/no. of filaments) trilobal yarns are spun without any light stabilization using standard unmodified nylon 6 host polymer (BS700F available from BASF Corporation, Mt. Olive, New Jersey) (RV = 2.7 as measured in sulfuric acid). Yarn
- 45 extrusion conditions are:

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Zone 1	240°C
Zone 2	260°C
Zone 3	270°C
Polymer temperature	270 °C
5 Throughput	30 grams/minute
Winder	371 meters/minute take-up
Finish	0.90% finish on yarn

Pigments are added to the nylon 6 host polymer prior to yarn
 10 extrusion as the concentrates described in TABLE 1. Before addition to the host polymer, concentrate chips are first ground with a Wiley Mill and then bag blended with a similarly ground nylon 6 base polymer.

15 TABLE 1

Example	Pigment	Carrier	% Pigment in Carrier	Pigment Loading in Fiber
20 1A	anatase titanium dioxide	nylon 6	30%	0.3%
1B	zinc ferrite tan	nylon 6	25%	0.1%
1C	zinc ferrite tan	nylon 6	25%	1.0%
1D	pigment blue 15:1	nylon 6	25%	0.1%
25 1E	pigment blue 15:1	nylon 6	25%	1.0%
1F	pigment red 149	nylon 6	25%	0.1%
1G	pigment red 149	nylon 6	25%	1.0%
1H	pigment red 179	nylon 6	15%	0.1%
30 1I	pigment red 179	nylon 6	15%	1.0%

The yarn is drawknit at a 3.25 draw ratio on a Lawson-Hemphill HDK knitter to make 220/14 flat-knit tube product.

35 Knit tubes are tested for xenon arc, NO_x and ozone exposure according to the AATCC methods indicated above. The data for xenon arc (UV) exposure are presented in TABLES 3 and 4. The data for NO_x and ozone exposure are presented in TABLE 5.

40 EXAMPLE 2A-2I COMPARATIVE

(Solution-Dyed Nylon Fibers - Nylon 6 Host Polymer-Stabilized with Copper)

45 Examples 2A-2I correspond respectively to Examples 1A-1I except that a copper light stabilizing compound is added to the bag blended concentrate as needed to produce 0.01% in nylon fiber.

Knit tubes are exposed and tested for Xenon arc, NO_x and ozone exposure. The data are presented in TABLES 3-5.

EXAMPLES 3A - 3I INVENTION

5 (Solution-Dyed Nylon Fibers - Modified Nylon Host Polymer)

Examples 3A-3I correspond respectively to Examples 1A-1I except that the nylon host polymer is caprolactam polymerized in the presence of 2,2',6,6'-tetraalkylpiperidine using terephthalic
10 acid as a chain regulator.

Knit tubes are exposed and tested for Xenon arc, NO_x and ozone exposure. The data are presented in TABLES 3-5.

15 EXAMPLES 4B-4G

(Solution-Dyed Nylon Fibers - Modified Nylon Host Polymer-Copper Stabilizer Added)

Examples 4B-4G correspond to Examples 3B-3G except that of a copper compound stabilizer is added to the bag blended pigment concentrate to yield 0.01% in nylon 6.
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Knit tubes are exposed and tested for Xenon arc, NO_x and ozone exposure. The data are presented in TABLES 3-5.

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EXAMPLES 5A-5F and COMPARATIVE

(Pure Iron Oxide Pigment)

Examples 5A-5F are prepared according to Example 1 using the formulations shown in TABLE 2.
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TABLE 2

Example	Polymer	Pigment	Carrier	Pigment in Carrier (%)	Pigment in Fiber (%)	Copper Compound (%)
5A	nylon 6	iron oxide	polyethylene	25	0.1	0
5B	nylon 6	iron oxide	polyethylene	25	1.0	0
5C	nylon 6	iron oxide	polyethylene	25	0.1	0.01
5D	nylon 6	iron oxide	polyethylene	25	1.0	0.01
5E	modified nylon 6*	iron oxide	polyethylene	25	0.1	0
5F	modified nylon 6*	iron oxide	polyethylene	25	1.0	0

* caprolactam polymerized in the presence of 2,2',6,6'-tetraalkylpiperidine using terephthalic acid as a chain regulator.

Knit tubes are exposed and tested for xenon arc, NO_x and ozone exposure. The data are presented in TABLES 3-5.

TABLE 3 - XENON ARC EXPOSURE (RETAINED TENACITY)

Example	Percent Tenacity Retained After UV Exposure				
	425 kJ	850 kJ	1275 kJ	1700 kJ	2125 kJ
1A	90	77	69	59	58
1B	77	36	22	0	0
1C	86	73	59	42	28
1D	91	84	73	66	70
1E	102	93	102	92	90
1F	112	65	44	21	13
1G	77	41	25	10	0
1H	89	81	77	71	64
1I	72	61	49	45	38
2A	99	99	97	95	83
2B	105	94	96	101	93
2C	98	93	98	82	86
2D	89	106	105	96	94
2E	97	98	91	85	86
2F	96	89	93	83	75
2G	102	95	92	82	79
2H	97	85	80	74	75
2I	76	66	57	54	52
3A	109	109	107	102	102

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Percent Tenacity Retained After UV Exposure						
Example	425 kJ	850 kJ	1275 kJ	1700 kJ	2125 kJ	
3B	104	92	96	91	91	
3C	97	84	93	91	91	
3D	98	96	98	94	89	
3E	100	92	93	84	84	
3F	104	100	92	90	89	
3G	85	89	86	80	74	
3H	88	89	83	88	85	
3I	105	98	85	86	84	
4B	109	107	105	103	100	
4C	101	97	90	96	94	
4D	106	103	103	103	93	
4E	94	99	55	87	79	
4F	110	100	99	104	95	
4G	96	100	86	88	77	
5A	102	15	0	0	0	
5B	39	15	0	0	0	
5C	112	99	86	73	64	
5D	88	78	67	49	42	
5E	79	62	51	33	28	
5F	82	45	39	14	15	

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TABLE 4 - XENON ARC EXPOSURE (COLOR CHANGE)

Ex.	0 kJ Exposure				425 kJ Exposure				850 kJ Exposure			
	L*	a*	b*	DE*	L*	a*	b*	DE*	L*	a*	b*	DE*
1A	94.42	-0.31	2.98		94.91	-0.52	2.32	0.85	94.88	-0.59	2.46	0.75
1B	75.75	12.94	33.97		76.17	12.70	33.61	0.60	75.91	12.64	33.55	0.54
1C	56.12	22.01	45.15		56.27	22.09	45.31	0.23	56.35	22.08	45.65	0.55
1D	55.78	-17.20	-34.43		56.13	-16.85	-34.09	0.60	56.17	-16.78	-33.82	0.84
1E	32.01	-10.54	-35.04		32.57	-10.60	-35.20	0.59	32.85	-10.70	-35.28	0.89
1F	57.84	49.74	22.61		57.41	46.79	20.28	3.78	57.22	46.74	20.25	3.87
1G	39.92	56.84	35.19		39.29	55.73	34.14	1.65	38.65	56.07	34.82	1.53
1H	52.89	37.52	9.79		52.50	32.50	6.62	5.95	52.48	32.84	6.61	5.67
1I	30.29	42.74	16.93		30.46	42.74	16.49	0.47	29.64	43.76	17.13	1.23
2A	94.93	-0.45	2.93		92.07	-2.24	1.91	3.52	92.15	-2.27	2.22	3.40
2B	77.47	9.71	30.02		77.73	9.64	30.12	0.29	77.44	9.87	30.53	0.54
2C	57.09	21.41	44.88		57.17	21.49	44.97	0.14	57.13	21.46	45.28	0.41
2D	56.49	-17.21	-33.93		56.87	-16.77	-33.38	0.80	56.92	-16.67	-33.27	0.96
2E	31.00	-9.77	-34.59		31.63	-9.89	-34.56	0.64	31.59	-9.95	-34.86	0.67
2F	55.68	44.90	20.24		55.80	43.97	19.34	1.30	55.91	44.32	19.55	0.93
2G	37.36	51.87	31.75		37.91	52.62	31.85	0.94	37.36	53.72	33.35	2.45
2H	50.20	34.45	8.53		50.17	31.85	6.59	3.24	49.96	32.62	6.76	2.56
2I	29.03	39.76	15.17		29.40	40.27	15.21	0.63	29.58	40.53	15.28	0.95

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Ex.	0 kJ Exposure					425 kJ Exposure					850 kJ Exposure				
	L*	a*	b*	L*	a*	b*	DE*	L*	a*	b*	DE*	L*	a*	b*	DE*
3A	91.97	-2.08	2.05	94.44	-0.51	2.30	2.94	94.22	-0.60	2.58	2.74	94.22	-0.60	2.58	2.74
3B	77.29	11.69	32.28	77.47	11.37	31.86	0.56	77.27	11.35	31.74	0.64	77.27	11.35	31.74	0.64
3C	56.12	22.15	45.46	56.31	22.02	45.39	0.24	56.33	22.18	46.23	0.80	56.33	22.18	46.23	0.80
3D	56.33	-17.20	-33.73	56.86	-16.79	-33.38	0.76	56.76	-16.56	-33.07	1.01	56.76	-16.56	-33.07	1.01
3E	30.32	-9.25	-34.25	30.68	-9.26	-34.39	0.39	30.96	-9.28	-34.47	0.68	30.96	-9.28	-34.47	0.68
3F	57.54	49.99	22.96	56.77	46.77	20.48	4.14	56.54	46.29	20.21	4.72	56.54	46.29	20.21	4.72
3G	39.86	56.62	35.12	39.17	55.31	33.85	1.95	38.41	55.80	34.77	1.70	38.41	55.80	34.77	1.70
3H	52.60	39.27	11.22	51.73	32.76	6.82	7.91	51.83	33.29	6.73	7.52	51.83	33.29	6.73	7.52
3I	29.58	42.36	17.09	29.82	42.25	16.66	0.50	29.94	42.37	16.69	0.54	29.94	42.37	16.69	0.54
4B	76.36	11.26	32.09	76.64	11.11	31.78	0.44	76.13	11.17	31.71	0.45	76.13	11.17	31.71	0.45
4C	54.89	21.23	44.33	55.22	21.22	44.61	0.43	55.26	21.29	45.25	0.99	55.26	21.29	45.25	0.99
4D	54.72	-17.22	-34.50	55.06	-16.86	-34.02	0.69	54.98	-16.78	-33.88	0.80	54.98	-16.78	-33.88	0.80
4E	30.06	-9.13	-34.03	30.34	-9.13	-33.96	0.29	30.74	-9.18	-33.98	0.68	30.74	-9.18	-33.98	0.68
4F	57.86	42.77	18.60	57.84	42.21	18.04	0.79	58.12	42.26	18.02	0.81	58.12	42.26	18.02	0.81
4G	37.86	52.89	32.57	38.04	53.39	32.90	0.63	37.33	54.08	33.85	1.83	37.33	54.08	33.85	1.83
5A	67.39	21.33	35.49	67.65	21.09	35.36	0.38	67.32	21.00	35.55	0.34	67.32	21.00	35.55	0.34
5B	42.56	31.92	39.29	42.79	32.06	39.55	0.37	42.70	32.43	40.51	1.33	42.70	32.43	40.51	1.33
5C	67.82	19.28	33.89	68.19	19.23	34.14	0.45	68.06	19.27	34.38	0.55	68.06	19.27	34.38	0.55
5D	39.80	28.80	35.75	41.25	31.36	37.97	3.69	41.23	31.96	39.14	4.85	41.23	31.96	39.14	4.85
5E	66.49	21.87	36.01	66.74	21.90	36.37	0.44	66.85	21.58	36.18	0.49	66.85	21.58	36.18	0.49
5F	41.97	31.76	38.65	42.43	32.06	39.09	0.70	42.09	32.48	40.07	1.60	42.09	32.48	40.07	1.60

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TABLE 4 - XENON ARC EXPOSURE (COLOR CHANGE)

Ex.	1275 kJ Exposure				1700 kJ Exposure				2125 kJ Exposure			
	L*	a*	b*	DE*	L*	a*	b*	DE*	L*	a*	b*	DE*
1A	94.66	-0.60	2.50	0.61	94.75	-0.50	2.47	0.64	94.28	-0.48	2.65	0.40
1B	75.84	12.53	33.52	0.62	75.93	12.64	33.63	0.49	75.86	12.61	33.74	0.42
1C	56.74	22.05	45.68	0.82	56.79	21.89	45.35	0.71	56.62	21.89	45.38	0.56
1D	56.35	-16.69	-33.73	1.04	56.61	-16.60	-33.63	1.30	56.31	-16.74	-33.57	1.11
1E	33.14	-10.70	-35.39	1.19	33.30	-10.59	-35.50	1.37	32.83	-10.97	-35.75	1.17
1F	57.68	46.00	19.87	4.64	57.85	45.54	19.73	5.09	57.85	45.16	19.74	5.40
1G	38.86	55.11	33.74	2.49	38.97	54.87	33.24	2.93	38.74	54.80	33.46	2.92
1H	52.90	32.91	6.80	5.49	53.23	33.01	6.79	5.43	53.45	33.70	7.62	4.43
1I	30.39	43.00	16.85	0.29	30.68	42.94	16.74	0.48	28.72	41.87	16.64	1.82
2A	92.37	-2.16	2.62	3.09	92.62	-2.07	2.74	2.83	92.29	-2.09	3.14	3.12
2B	77.75	9.75	30.32	0.41	77.74	10.00	30.53	0.65	77.59	9.93	30.45	0.50
2C	57.07	21.38	44.74	0.14	57.37	21.44	44.92	0.28	57.29	21.40	44.78	0.22
2D	56.45	-16.75	-33.58	0.58	56.95	-16.56	-33.45	0.93	56.75	-16.65	-33.44	0.79
2E	31.58	-9.87	-34.80	0.62	32.10	-9.80	-34.85	1.13	31.71	-10.31	-35.24	1.10
2F	56.14	44.33	19.68	0.92	56.43	44.02	19.50	1.37	56.73	44.06	19.74	1.43
2G	37.90	53.31	32.58	1.75	38.07	53.29	32.21	1.65	37.95	53.43	32.49	1.82
2H	50.75	32.20	6.77	2.91	51.08	32.45	6.90	2.73	48.14	32.30	7.31	3.22
2I	29.77	41.51	15.94	2.05	30.13	41.51	15.93	2.20	29.87	42.01	16.18	2.61
3A	94.03	-0.46	2.37	2.64	94.00	-0.38	2.40	2.67	93.80	-0.43	2.52	2.51

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1275 kJ Exposure				1700 kJ Exposure				2125 kJ Exposure				
Ex.	L*	a*	b*	DE*	L*	a*	b*	DE*	L*	a*	b*	DE*
3B	77.50	11.17	31.61	0.87	77.43	11.24	31.69	0.76	77.44	11.19	31.64	0.83
3C	56.39	22.07	45.73	0.39	56.60	22.05	45.60	0.51	56.40	22.03	45.75	0.42
3D	57.00	-16.53	-33.15	1.11	57.09	-16.47	-33.23	1.17	57.04	-16.59	-33.12	1.12
3E	31.03	-9.37	-34.57	0.79	31.25	-9.03	-34.51	0.99	30.84	-9.46	-34.77	0.76
3F	56.60	45.55	19.78	5.54	56.97	45.31	19.72	5.72	57.04	44.95	19.92	5.91
3G	38.75	54.99	33.54	2.53	38.72	54.63	33.11	3.05	38.43	54.31	33.00	3.45
3H	52.44	33.27	6.76	7.48	52.77	33.45	6.82	7.30	52.54	33.70	6.95	7.02
3I	29.85	42.67	16.99	0.42	30.11	42.45	16.78	0.62	29.81	42.90	17.02	0.59
4B	76.73	11.03	31.63	0.63	76.71	11.15	31.91	0.41	76.75	10.95	31.56	0.73
4C	55.33	21.33	44.94	0.76	55.62	21.31	45.01	1.00	55.46	21.32	45.06	0.93
4D	55.19	-16.80	-33.95	0.84	55.35	-16.68	-33.79	1.09	55.28	-16.80	-33.78	1.00
4E	30.92	-9.21	-34.26	0.89	31.04	-9.17	-34.15	0.99	30.76	-9.76	-34.73	1.17
4F	58.37	41.96	17.99	1.14	58.63	41.82	17.93	1.39	58.65	41.69	18.30	1.37
4G	37.79	53.39	32.80	0.55	37.85	53.20	32.40	0.35	37.71	53.07	32.50	0.24
5A	67.31	20.68	35.35	0.67	67.33	20.45	35.25	0.91	67.15	20.36	35.59	1.00
5B	43.03	32.34	40.38	1.26	43.09	32.22	40.42	1.28	42.88	32.36	41.06	1.85
5C	68.28	19.40	34.46	0.74	68.36	19.44	34.52	0.85	68.35	19.59	34.69	1.01
5D	41.51	31.98	39.02	4.87	41.87	32.11	38.97	5.06	41.61	32.43	39.53	5.54
5E	67.09	21.44	36.15	0.75	67.01	21.51	36.12	0.64	66.97	21.52	36.23	0.63
5F	42.74	32.41	39.84	1.56	42.60	32.34	39.68	1.34	42.60	32.68	40.39	2.07

TABLE 5 - NO_x AND OZONE EXPOSURE

Example	Color Change (DE*)											
	Cycles of Ozone Exposure						Cycles of NO _x Exposure					
	1	2	3	4	6	8	1	2	3	4		
1A	1.09	1.60	1.38	0.87	1.56	1.71	1.32	2.32	2.67	2.39		
1B	1.29	0.89	0.80	1.03	1.34	0.72	0.86	1.25	1.32	1.21		
1C	0.36	0.19	0.53	0.72	0.32	0.84	0.13	0.78	0.52	0.97		
1D	0.36	0.50	0.37	0.54	0.38	0.47	0.32	0.35	0.43	0.56		
1E	1.05	0.67	0.51	0.70	1.12	0.46	0.97	0.92	0.53	1.12		
1F	0.62	0.68	0.84	0.87	0.82	0.96	0.59	1.02	0.64	0.34		
1G	0.69	2.34	1.68	1.64	2.58	2.45	1.58	1.88	2.40	2.19		
1H	0.84	1.32	0.78	0.98	1.60	1.36	1.51	0.93	1.08	1.43		
1I	0.15	0.57	0.43	0.92	1.05	0.82	0.55	0.56	1.03	0.66		
2A	1.19	1.49	2.25	1.76	2.54	3.18	1.07	2.04	2.78	2.20		
2B	0.29	0.92	0.62	3.00	0.86	1.20	0.79	0.43	0.82	0.90		
2C	0.89	1.00	0.92	0.98	1.32	0.95	0.46	1.04	0.60	1.15		
2D	1.46	0.26	0.38	0.92	0.56	0.70	1.09	0.69	0.52	0.78		
2E	0.49	0.50	0.63	0.93	0.90	0.35	0.87	0.69	0.82	0.78		
2F	2.24	2.35	2.78	1.69	2.30	2.33	1.75	2.52	2.32	3.21		
2G	2.80	3.01	3.69	3.93	2.95	3.79	3.78	3.46	3.34	3.30		
2H	1.13	1.76	2.34	1.30	2.92	2.09	3.65	3.30	3.52	4.01		
2I	1.75	2.15	2.40	2.40	2.96	3.08	2.81	3.00	3.13	2.30		

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Color Change (DE*)														
	Cycles of Ozone Exposure								Cycles of NOx Exposure					
	0.54	0.69	0.80	1.33	1.41	2.33	1.33	1.27	1.33	0.48	0.51	1.54	1.59	0.86
3A	0.54	0.69	0.80	1.33	1.41	2.33	1.33	1.27	1.33	0.48	0.51	1.54	1.59	0.86
3B	0.21	0.42	1.70	0.79	1.61	1.00	0.48	0.52	0.38	0.38	0.52	0.93	0.39	0.39
3C	0.83	0.23	0.48	0.02	0.35	0.82	0.73	0.52	0.73	0.52	0.77	0.27	0.27	0.27
3D	0.37	0.47	0.39	0.48	0.30	0.36	0.35	0.92	0.41	0.39	1.09	1.59	0.81	0.55
3E	0.41	0.59	0.34	0.39	0.23	0.43	1.06	1.89	1.95	1.09	1.59	0.81	0.55	0.55
3F	1.53	1.48	2.29	1.14	1.53	1.44	1.38	1.38	2.04	1.59	0.81	0.55	0.55	0.55
3G	0.73	1.63	1.84	2.01	2.39	2.41	1.38	1.38	2.04	1.59	0.81	0.55	0.55	0.55
3H	0.68	1.01	1.29	0.63	1.15	0.50	0.58	1.07	1.06	0.81	0.55	0.55	0.55	0.55
3I	0.12	0.48	0.52	0.88	0.77	0.81	0.76	0.46	0.32	0.55	0.55	0.55	0.55	0.55
4B	4.17	4.76	2.95	3.09	3.99	3.66	3.66	4.12	3.65	3.65	3.10	3.10	3.10	3.10
4C	0.33	0.82	0.92	0.58	0.73	0.62	0.93	0.82	0.59	1.28	1.28	1.28	1.28	1.28
4D	0.56	0.50	0.51	0.83	1.13	0.90	0.94	0.68	0.81	0.68	0.68	0.68	0.68	0.68
4E	0.26	0.36	0.19	0.17	0.24	0.46	0.35	0.31	0.27	0.11	0.11	0.11	0.11	0.11
4F	0.98	0.87	1.13	1.14	2.19	3.05	2.16	2.76	1.81	2.73	2.73	2.73	2.73	2.73
4G	1.99	3.07	2.90	3.38	2.95	4.05	3.21	3.49	3.26	3.59	3.59	3.59	3.59	3.59
5A	1.07	1.79	1.04	0.60	1.26	1.25	1.38	1.70	1.85	0.99	0.99	0.99	0.99	0.99
5B	0.36	0.29	0.74	0.53	0.69	0.72	0.50	0.69	1.08	1.03	1.03	1.03	1.03	1.03
5C	1.18	0.94	1.71	0.41	1.05	4.67	4.57	4.12	3.65	4.48	4.48	4.48	4.48	4.48
5D	2.57	2.48	2.83	1.97	2.63	2.52	2.29	2.78	2.59	2.67	2.67	2.67	2.67	2.67
5E	0.11	0.54	0.31	0.98	1.09	0.88	0.53	0.70	1.20	0.48	0.48	0.48	0.48	0.48
5F	0.11	0.40	0.17	0.58	0.51	0.40	0.33	0.37	0.72	0.43	0.43	0.43	0.43	0.43

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As indicated by the retained tenacity data in TABLE 3, yarns made according to the present invention (Examples 3A-3I) are substantially as photostable as the yarns of Examples 2A - 2I which were stabilized by copper compounds. FIG. 1 graphically illustrates the tenacity data presented in TABLE 3. High percent retained tenacity corresponds to low degradation on exposure to xenon light. Lower percent retained tenacity corresponds to increased degradation on exposure to xenon light. Yarns colored with zinc ferrite tan and perylene red (pigment red 149), two strongly pro-degrading pigments, were surprising at least as stable to light exposure as yarns stabilized with copper compounds. Yarns made by the invention and colored with perylene pigments were as light stable as copper stabilized yarns even though perylene pigments have been reported to negate light stabilizing effects of HALS. In some cases, the stability of perylene colored yarns was dramatically improved.

As noted, yarns colored with pure iron oxide yarns are not considered within the scope of the present invention. Iron oxide red is a notoriously prodegrading pigment that is not usually used as a primary component of a colorant formulation. Therefore, while pure iron oxide as a colorant is outside the scope of the present invention, yarns that are colored with blends of iron oxide and some other colorant are within the scope of the present invention. It is not considered limiting of the present invention that pure iron oxide is not within the scope since pure iron oxide is not a commercially important fiber colorant.

As shown in the xenon arc colorfastness data, the present invention provides yarn that is colorfast to light without the presence of copper compounds. The larger the DE* value the more the color has changed, i.e., the less colorfast the color. Exceptionally large color changes indicate unacceptable performance for most commercial applications where the fiber is exposed to UV light.

Another benefit with the present invention is that the elimination of copper compounds as stabilizers permits truer pigment coloration for certain pigments. For example, as shown in TABLE 4, the presence of copper effects perylene red's color before as well as after light exposure. For such pigments, yarns with copper are greener, bluer, and have lower chroma than those without.

EXAMPLE 6

Spinning Efficiency

Example 6A-Invention

- 5 Nylon 6 polyme modified with 2,2', 6,6'-tetraalkylpiperidine using terephthalic acid as the chain regulator is melt colored a light gray. The light gray color is achieved using a concentrate to provide 0.3% by weight TiO_2 , 0.001-0.1% by weight carbon black and 0.0001-0.1% by weight copper phthalocyanine in the spun fiber.
- 10 The spinning efficiency is 97.6%.

Example 6B-Comparative

- Example 6A is followed except that nylon 6 (not modified) is used
- 15 instead of the modified nylon 6. Copper stabilizer is also added. The spinning efficiency is 95.2%.

The present invention improves spinning efficiency for light gray solution-dyed fibers by about 2.4%. Other colors may yield different results.

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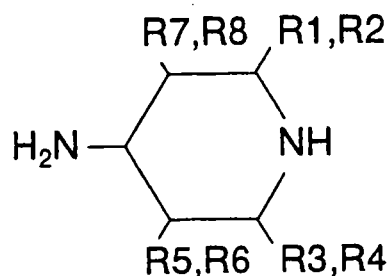
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WHAT IS CLAIMED IS:

1. A process for making stabilized solution-dyed fiber comprising:

melting a polyamide which is amide monomers polymerized in the presence of at least one mono or dicarboxylic acid chain regulator and at least one hindered piperidine compound having the formula:



where R₁, R₂, R₃ and R₄ are not hydrogen, but any alkyl group having up to 20 carbon atoms, and R₅, R₆, R₇ and R₈ may be alkyl substituents such as those present in R₁-R₄ or hydrogen;

coloring the melted polyamide with a colorant selected from the group consisting of:

pigments that are not pure iron oxide pigments;
dyes;
mixtures thereof; and

spinning the colored polyamide into fibers that have about 40% or better retained tenacity after 2125 kJ exposure to xenon arc radiation as per AATCC Test Method 16-1993, "Colorfastness to Light," Option E and no more than about 10 ppm uncomplexed copper.

2. The process of claim 1 wherein at least one hindered piperidine derivative is selected from the group consisting of:

4-amino-2,2',6,6'-tetramethylpiperidine;
4-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
3-amino-2,2',6,6'-tetramethylpiperidine;

- 3-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
2,2',6,6'-tetramethyl-4-piperidinecarboxylic acid;
5 2,2',6,6'-tetramethyl-4-piperidinealkylcarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinearylcarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinealkyl/arylcarboxylic
acid;
2,2',6,6'-tetramethyl-3-piperidinecarboxylic acid;
10 2,2',6,6'-tetramethyl-3-piperidinealkylcarboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinearylcarboxylic acid;
and
2,2',6,6'-tetramethyl-3,4-piperidinealkyl/arylcarboxylic
acids.

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3. The process of claim 1 wherein said chain regulator is a mono
or dicarboxylic acid chain regulator is selected from the
group consisting of:

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terephthalic acid;
adipic acid;
acetic acid;
propionic acid;
benzoic acid;

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isophthalic acid;
sebacic acid;
naphthalene 2,6-dicarboxylic acid; and
combinations thereof.

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4. The process of claim 3 wherein the hindered piperidine deri-
vative is 4-amino-2,2',6,6'-tetramethyl piperidine.

5. The process of claim 1 wherein the hindered piperidine deri-
vative is present at about 0.05 to about 2.0% by weight of
35 the polyamide.

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6. The process of claim 1 wherein the starting monomers are sub-
stantially ϵ -caprolactam monomers and the polyamide is a
modified nylon 6 polymer.

7. The process of claim 2 wherein the starting monomers are sub-
stantially caprolactam monomers and the polyamide is a
modified nylon 6 polymer.

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8. The process of claim 1 wherein said coloring uses colorant
selected from the group consisting of:

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perylene red
perylene maroon;
up to about 1.5 % iron oxide red;
zinc ferrite tan; and
5 mixtures thereof with each other or with other organic or
inorganic colorants.

9. The process of claim 1 wherein the fibers are substantially
free from copper compounds.

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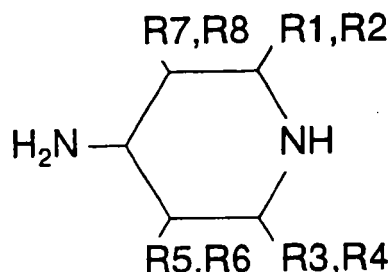
10. The process of claim 1 wherein said spinning is at least ab-
out 0.5% more efficient than spinning solution-dyed fibers
from polyamide which is not polymerized in the presence of a
mono or dicarboxylic acid chain regulator and at least one
15 hindered piperidine derivative and which is colored with the
same colorants.

11. An improved process for spinning solution-dyed nylon fibers
comprising:

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coloring a molten polyamide, which polyamide is ϵ -caprolactam
polymerized in the presence of at least one mono or dicarb-
oxylic acid chain regulator and at least one hindered
piperidine derivative having the formula:

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35 where R1, R2, R3 and R4 are not hydrogen, but any alkyl group
having up to about 20 carbon atoms, and R5, R6, R7 and R8 may
be alkyl substituents such as those present in R1-R4 or hy-
drogen; and

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spinning the colored polyamide into fibers that have about
40% or better retained tenacity after 500 hours exposure to
xenon arc radiation as per AATCC Test Method 16 -1993, "Co-
lorfastness to Light," Option E wherein said spinning is at
least 0.5 % more efficient than spinning solution-dyed fibers
45 colored with the same colorant from a polyamide which is not
polymerized in the presence of said at least one mono or

dicarboxylic acid chain regulator and said at least one hindered piperidine derivative.

12. The process of claim 11 wherein said coloring is accomplished using a colorant selected from the group consisting of:

perylene red
perylene maroon;
up to about 1.5 % iron oxide red;
zinc ferrite tan; and
mixtures thereof with other organic or inorganic colorants.

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13. The process of claim 11 wherein the hindered piperidine derivative compound is 4-amino-2,2',6,6'-tetramethyl piperidine.

14. The process of claim 13 wherein the hindered piperidine derivative compound is present at about 0.05 to about 2.0 % by weight of the polyamide.

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15. The process of claim 14 wherein said colorant is a pigment selected from the group consisting of:

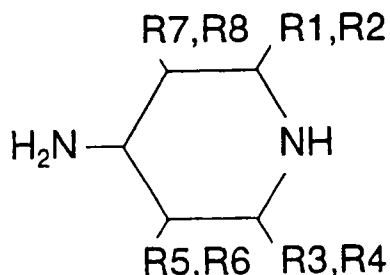
perylene red
perylene maroon;
zinc ferrite tan;
up to about 1.5 % iron oxide red; and
mixtures thereof with other organic or inorganic colorants.

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16. A light stabilized solution-dyed nylon fiber comprising:

a polyamide host polymer which is amide monomers polymerized in the presence of at least one mono or dicarboxylic acid chain regulator and at least one hindered piperidine compound having the formula:

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where R1, R2, R3 and R4 are not hydrogen, but any alkyl group having up to about 20 carbon atoms, and R5, R6, R7 and R8 are alkyl substituents such as those present in R1-R4 or hydrogen; and

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a non-white colorant dispersed throughout said host polymer;
said fiber having less than about 10 ppm uncomplexed copper.

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17. The fiber of claim 16 wherein said amide monomers are at least some ϵ -caprolactam monomers.

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18. The fiber of claim 17 wherein at least one hindered piperidine derivative is selected from the group consisting of:

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4-amino-2,2',6,6'-tetramethylpiperidine;
4-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
4-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
3-amino-2,2',6,6'-tetramethylpiperidine;
3-(aminoalkyl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl)-2,2',6,6'-tetramethylpiperidine;
3-(aminoaryl/alkyl)-2,2',6,6'-tetramethylpiperidine;
2,2',6,6'-tetramethyl-4-piperidinecarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinealkylcarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinearylcarboxylic acid;
2,2',6,6'-tetramethyl-4-piperidinealkyl/arylcarboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinecarboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinealkylcarboxylic acid;
2,2',6,6'-tetramethyl-3-piperidinearylcarboxylic acid;
and
2,2',6,6'-tetramethyl-3,4-piperidinealkyl/arylcarboxylic acids.

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19. The fiber of claim 18 wherein said chain regulator is a mono or dicarboxylic acid chain regulator is selected from the group consisting of:

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terephthalic acid;
adipic acid;
acetic acid;
propionic acid;
benzoic acid;
isophthalic acid;

sebacic acid;
combinations thereof.

20. The fiber of claim 18 wherein the hindered piperidine derivative is 4-amino-2,2',6,6'-tetramethyl piperidine.

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21. The fiber of claim 16 wherein the hindered piperidine derivative is present at about 0.05 to about 2.0% by weight of the polyamide.

- 10 22. The fiber of claim 16 wherein said colorant is selected from the group consisting of:

perylene red
perylene maroon;
15 up to 1.5 % iron oxide red;
zinc ferrite tan; and
mixtures thereof with each other or with other organic or
inorganic colorants.

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