

**Claims**

1. An impregnated natural fiber comprising:  
a cuticle and an interior lumen, the cuticle circumscribing the interior lumen; and  
insoluble particulates possessing a preselected property embedded in the fiber,  
5 wherein said particulates comprise from 0.1% to 30% w/w of the impregnated fiber  
and said embedded particulates impart their preselected property to the fiber when embedded  
therein, and where the particulates are embedded on both the cuticle and within the lumen of  
the fiber.
- 10 2. The impregnated fiber of claim 1, wherein the impregnated fiber exhibits a tensile  
strength in excess of 36 g/tex.
3. The impregnated fiber of claim 1 or 2, wherein the impregnated fiber exhibits an increase  
15 in tensile strength after impregnation that is at least 15% greater than the average tensile  
strength of untreated fibers drawn from the same fiber source as the fiber of the impregnated  
fiber.
4. The impregnated fiber as in any one of claims 1-3, wherein the impregnated fiber exhibits  
a micronaire value in excess of 4.85.
- 20 5. The impregnated fiber as in any one of claims 1-3, wherein the impregnated fiber exhibits  
a micronaire value after impregnation at least 20% greater than the average micronaire value  
of untreated fibers drawn from the same fiber source as the fiber of the impregnated fiber.
- 25 6. The impregnated fiber as in any one of claims 1-5, wherein the yarn formed from the  
impregnated fiber still exhibits the preselected property after 100 home washings or 50  
industrial washings.
- 7 The impregnated fiber as in any one of claims 1-6, wherein the impregnated fiber and  
yarn made therefrom still exhibit the preselected property after the fiber has been bleached  
30 and optically whitened.
8. The impregnated fiber as in any one of claims 1-7, wherein the fibers and yarn made  
therefrom still retain particulate material in their lumens after bleaching and optical whitening

while the number of particulates from an exterior face of the cuticle of the fiber have been reduced by at least 95%

- 5        9. The impregnated fiber as in any one of claims 1-8, wherein the impregnated particulates comprise at least 0.5-20 wt.% of the impregnated fiber.
- 10       10. The impregnated fiber as in any one of claims 1-9, wherein the insoluble particulates are nano-sized particulates between 0.1 and 0.5 microns.
- 10       11. The impregnated fiber as in any one of claims 1-10, wherein the impregnation of the fiber is effected by acoustic cavitation.
- 15       12. The impregnated fiber as in any one of claims 1-11, wherein the impregnated fiber absorbs water at a rate and amount greater than a non-impregnated fiber.
- 15       13. The impregnated fiber as in any one of claims 1-12, wherein the impregnated fiber absorbs water uniformly over the length of the fiber.
- 20       14. The impregnated fiber as in any one of claims 1-13 wherein pores are formed in the fiber cuticle during impregnation of the fiber.
- 25       15. The impregnated fiber as in any one of claims 1-14, wherein the fiber is a cellulose fiber.
- 25       16. The impregnated fiber as in any one of claims 1-15, wherein the insoluble particulates are preselected to impart non-ignition or retarded ignition properties to the fiber and are chosen from the group consisting of Huntite ( $\text{Mg}_3\text{Ca}(\text{CO}_3)_4$ ), magnesium hydroxide, alumina trihydrate and combinations thereof.
- 30       17. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart antimicrobial properties, including antibacterial and/or antifungal, and/or antiviral properties, to the fiber and are chosen from the group consisting of silver oxides, copper oxides, magnesium oxide, zinc oxide, zeolites, ceramic compounds and combinations thereof.

18. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart pesticidal properties to the fiber, and are chosen from the group consisting of diatomaceous earth, copper oxides, silver oxides, zinc oxide, and combinations thereof.

5

19. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart waterproofing properties to the fiber, and are chosen from the group consisting of ground silica, nano-silica, polysiloxanes and combinations thereof.

10

20. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart UV inhibiting properties to the fiber, and are chosen from the group consisting of zinc oxide, titanium dioxide and combinations thereof.

15

21. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart medicinal properties to the fiber for transdermal medicinal transport or dermal treatment, and are chosen from the group consisting of copper oxides, silver oxides, encapsulated nano-spheres containing various pharmaceuticals and combinations thereof.

20

22. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart cosmetic properties to the fiber for dermal treatment, and are selected from a group consisting of copper oxides, silver oxides, benzoyl peroxide and combinations thereof.

25

23. The impregnated fiber as in any one of claims 1-15 wherein the insoluble particulates are preselected to impart the ability to conduct electricity to the fiber, and are chosen from the group consisting of graphene powder and single walled nano-carbon tubes and combinations thereof.

30

24. Yarn woven from a plurality of impregnated fibers, said impregnated fibers comprised as in any one of claims 1-15.

35

25. An article comprising the impregnated fibers as in any one of claims 1-23, the article selected from a group consisting of the following classes of articles: wearing apparel; medical and hospital supplies, uniforms, curtains, scrubs, sheets, pillowcases, blankets, slippers, patient gowns, towels and any textile or product made from a textile used in a healthcare

environment, an elderly care facility, a public or private institution, or as a domestic product used in the home.

5 26. An article comprising yarn woven from the impregnated fibers as in any one of claims 1-23, said article selected from a group consisting of the following classes of articles: wearing apparel; medical and hospital supplies, uniforms, curtains, scrubs, sheets, pillowcases, blankets, slippers, patient gowns, towels and any textile or product made from a textile used in a healthcare environment, an elderly care facility, a public or private institution, or as a domestic product used in the home.

10 27. An article comprising a non-woven textile which is comprised of the impregnated fibers as in any one of claims 1-23, said article selected from a group consisting of the following classes of articles: wearing apparel; medical and hospital supplies uniforms, curtains, scrubs, sheets, pillowcases, blankets, slippers, patient gowns, towels and any textile or product made  
15 from a textile used in a healthcare environment, an elderly care facility, a public or private institution, or as a domestic product used in the home.

28. A system for producing sliver fibers impregnated with insoluble particulates, said system comprising:  
20 a conveyor for conveying at least one sliver fiber ribbon;  
a dispenser for containing a paste which comprises: i) at least one insoluble particulate material possessing at least one preselected property, ii) a thickening agent and iii) water, the paste from the dispenser dispensed on the at least one sliver fiber ribbon; and  
a sonotrode in ultrasonic communication with a transducer for generating  
25 ultrasonic waves which are transmitted through said dispensed paste to the at least one sliver fiber ribbon, the ultrasonic waves embedding, the at least one insoluble particulate material in the at least one sliver fiber.

29. The system of claim 28, further comprising a wetting bath positioned upstream from the  
30 sonotrode for containing a deaerating solution through which the at least one sliver fiber ribbon is conveyed and wetted.

30. The system as in any one of claims 28-29, wherein the sonotrode is a bore sonotrode having a plurality of bores.

31. The system as in anyone of claims 28-30 wherein the plurality of bores each has a diameter of from 4mm to 20mm and a length of from 40mm to 80mm.

5 32. The system as in any one of claims 28-30 wherein the plurality of bores each has a diameter from 6mm to 15mm and a length of from 50mm to 70mm.

33. The system as in any one of claims 28-32, further comprising a constraining device configured for constraining or folding the at least one sliver fiber ribbon.

10 34. The system of claim 33, wherein the constraining device comprises a series of constraining rings upstream from the sonotrode, each of said rings being essentially circular and having a diameter smaller than the adjacent ring in the series upstream from it.

15 35. The system of claim 33, wherein the ring of the constraining device closest to the sonotrode and upstream from it has an oval shape.

36. The system as in any one of claims 28-35, further comprising an releasing device configured for releasing the constrained or folded at least one sliver fiber ribbon.

20 37. The system as in claim 36, wherein the releasing device comprises a series of rings downstream from the sonotrode, each ring being essentially circular and having a diameter larger than the adjacent ring in the series of rings further downstream from the sonotrode .

25 38. The system as in any one of claims 28-37, wherein said conveyor comprises a series of non-continuous spaced apart conveyors.

30 39. The system as in any one of claims 28-38, further comprising a first pair of squeeze rollers wherein the at least one sliver fiber ribbon after being squeezed by the first pair of squeeze rollers has enough integral strength to be pulled by a second pair of squeeze rollers over regions where the conveyor is absent.

35 40. The system as in any one of claim 28-39, wherein the at least one insoluble particulate material is selected from a material which comprises at least one of an element, a compound, a composition and any combination of the above.

41. The system as in any one of claims 28-40, further comprising a first container wherein the at least one sliver fiber ribbon is bleached.

5 42. The system as in any one of claims 28-41, further comprising a second container wherein the at least one sliver fiber ribbon is optically whitened.

43. The system as in any one of claims 28-42, further comprising at least one water spraying or rinsing apparatus for removal of residual thickening agent from the sliver fiber ribbons.

10 44. The system as in any one of claims 28-43, wherein the at least one sliver fiber ribbon is comprised of fibers as described in any one of claims 1-27.

45. The system as in any one of claims 28-44, wherein the at least one sliver fiber ribbon is comprised of cellulose fibers.

15 46. The system as in any one of claims 28-45, wherein the paste is comprised of insoluble particulate material having a 27-33 weight % of the paste, a thickening agent having a 20-36 weight % of the paste, and water having a 31-53 weight % of the paste.

20 47. The system as in any one of claims 28-46, wherein the thickening agent is selected from a group consisting of nanocellulose, fumed silica, guar gum, alginate acid and salts thereof, agar, locust bean gum, pectin, and gelatin.

48. The system as in any one of claims 28-46, wherein the thickening agent is nanocellulose.

25 49. The system as in any one of claims 28-48 wherein the paste has a viscosity of from 650 to 1000 centipoise at room temperature.

30 50. The system as in any one of claims 28-48 wherein the paste has a viscosity of from 740 to 806 centipoise at room temperature when the insoluble particulate material of the paste is in the range of from 27-33% weight.

35 51. A method for impregnating sliver fibers with insoluble particulates, comprising the steps of:

a. obtaining a paste comprising:

i. at least one insoluble particulate material having a preselected desired property;

ii. water; and,

iii a thickening agent;

5 b. providing at least one ribbon of sliver fibers;

c. dispensing the paste on the at least one sliver fiber ribbon; and

d. conveying the paste-coated at least one sliver fiber ribbon through a sonotrode and so that ultrasonic waves are transmitted through the at least one sliver fiber ribbon so that the at least one insoluble particulate material in the paste on the at least one sliver fiber ribbon is  
10 embedded in the ribbon, thereby imparting the desired property of the at least one particulate material to the sliver fibers.

52. The method of claim 51, wherein the sonotrode is a bore sonotrode having a plurality of bores.  
15

53. The method as in any one of claims 51-52, further comprising a step of constraining or folding the at least one sliver fiber ribbon so that it is compressed so that the fibers of the ribbon cannot separate and disperse.

20 54. The method as in any one of claims 51- 53, further comprising a step of releasing or unfolding the constraining or folded at least one sliver fiber ribbon.

55. The method as in any one of claims 51-54, further comprising a step of contacting a deaerating solution to the at least one sliver fiber ribbon prior to said step of dispensing.

25 56. The method as in any one of claims 51-55, further comprising a step of washing the at least one sliver fiber ribbon to remove excess paste from the ribbon.

57. The method as in any one of claims 51-56, wherein the sonotrode is operated between  
30 about 500W to about 3000 W and between about 15 kHz to about 30 kHz.

58. The method as in any one of claims 51-56, wherein the sonotrode is operated between about 1000W to about 2000W and between about 15kHz to about 25 kHz.

59. The method as in any one of claims 51-58, further comprising a step of bleaching and/or optically whitening the at least one impregnated sliver fiber ribbon.

5 60. The method as in any one of claims 51-59, wherein the at least one insoluble particulate material is selected from an element, a compound, a composition and any combination of the above.

61. The method as in any one of claims 51-60 wherein the resultant impregnated fiber sliver  
10 can be used directly for producing yarn without a second carding operation.