CLAIMS

1. A composite material comprising:

a structural matrix; and

a plurality of substantially-delignified, cellulose-based fibers disposed within the structural matrix, each cellulose-based fiber being chemically-extracted intact from a matrix of lignin and hemicellulose in a respective piece of natural plant material.

2. The material of claim 1, wherein the structural matrix comprises a polymer or concrete.

3. A composite material comprising:

a plurality of substantially-delignified, cellulose-based fibers, each cellulose-based fiber being chemically-extracted intact from a matrix of lignin and hemicellulose in a respective piece of natural plant material; and

a polymer infiltrating each cellulose-based fiber.

4. An engineered plant material comprising:

one or more substantially-delignified, cellulose-based fibers chemically-extracted intact from a matrix of lignin and hemicellulose in a piece of natural plant material.

5. The material of any one of claims 2 and 3, wherein the polymer comprises epoxy resin, polyvinyl alcohol (PVA), polyethylene glycol (PEO), polyamide (PA), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polytrimethylene terephthalate (PTT), polyacrylonitrile (PAN), polycaprolactam (PA6), poly(m-phenylene isophthalamide) (PMIA), poly-p-phenylene terephthalamide (PPTA), polyurethane (PU), polycarbonate (PC), polypropylene (PP), high-density polyethylene (HDPE), polystyrene (PS), polycaprolactone (PCL), polybutylene succinate (PBS), polybutylene adipate terephthalate (PBAT), poly(butylene succinate-co-butylene adipate) (PBSA), polyhydroxybutyrate (PHB), poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), poly(glycolic acid) (PGA), polypyrrole (PPy), polythiophene (PTh), polyvinylidene fluoride (PVDF), polyvinyl fluoride (PVF), ethylene vinyl alcohol

(EVOH), poly(vinylidene chloride) (PVDC), polyxylylene adipamide (MXD6), polyethylene (PE), polyvinyl chloride (PVC), poly(methyl methacrylate) (PMMA), acrylonitrile butadiene styrene (ABS), polyimide (PI), polyethylenimine (PEI), polylactic acid (PLA), octadecyltrichlorosilane (OTS), polyoctahedral silsesquioxane (POSS), paramethylstyrene (PMS), polydimethylsiloxane (PDMS), poly(ethylene naphthalate (PEN), a graft copolymer of acrylonitrile-butadiene-styrene-methylmethacrylate (ABSM), dodecyltrimethoxysilane (DTMS), rosin, chitin, chitosan, protain, plant oil, carboxymethyl cellulose, cellulose acetate, starch, agar, alginic acid, or any combination of the foregoing.

6. The material of claim 2, wherein the concrete comprises Portland cement, agro-concrete, magnesium carbonate ($MgCO_3$), magnesium hydroxide ($Mg(OH)_2$), or any combination of the foregoing.

7. The material of any one of claims 1-3, wherein a content of the plurality of the cellulose-based fibers within the composite material is at least 0.1 wt%.

8. The material of any one of claims 1-4, wherein the natural plant material comprises grass, bamboo, reed, sugarcane, maize, wheat, rice, jute, hemp, kenaf, ramie, banana, corn, wheat, rice, roselle, rattan, sorghum, sisal, palm, henequen, manila, pineapple, curaua, yucca, cabuya, screw pine, abaca, gladiolus, or agave.

9. The material of any one of claims 1-4, wherein each cellulose-based fiber has a length of at least 5 cm and a maximum cross-sectional dimension in a plane perpendicular to a direction of the length of at least 5 μm.

10. The material of claim 9, wherein the length of each cellulose-based fiber is between 5 cm and 200 cm, inclusive.

11. The material of claim 9, wherein the maximum cross-sectional dimension of each cellulose-based fiber is between 5 μm and 1 mm, inclusive.

12. The material of claim 9, wherein the maximum cross-sectional dimension of each cellulose-based fiber is at least 100 μm.

13. The material of any one of claims 1-4, wherein each cellulose-based fiber has a specific strength of at least 0.5 GPa·cm^3/g, a crystallinity of at least 40%, a tensile strength of at least 0.5 GPa, a Young's modulus of at least 20 GPa, a density of at least 0.8 g/cm^3, or any combination the foregoing.

14. The material of any one of claims 1-4, wherein each cellulose-based fiber has a cellulose content of at least 70 wt%, a hemicellulose content less than or equal to 10 wt%, a lignin content less than or equal to 10 wt%, or any combination of the foregoing.

15. The material of any one of claims 1-4, wherein each cellulose-based fiber has a moisture content less than or equal to 10 wt%.

16. The material of any one of claims 1-4, wherein provided on or within each cellulose-base fiber is a conductive additive, a magnetic additive, a piezoelectric material, a stimuli-responsive material, a catalytic material, or any combination of the foregoing.

17. A method comprising:

(a) subjecting a piece of natural plant material to one or more chemical treatments so as to remove substantially all lignin therefrom, at least one of the one or more chemical treatments comprising partial or full immersion in one or more chemical solutions; and

(b) after (a), extracting from the chemically-treated piece a plurality of substantially-delignified, cellulose-based fibers separated from each other.

18. The method of claim 17, wherein (b) comprises agitating the chemically-treated piece in solution.

19. The method of claim 17, wherein the one or more chemical solutions comprise an alkaline solution.

20. The method of claim 17, further comprising:

(c) after (b), drying the cellulose-based fibers such that evaporation of water from each cellulose-based fiber causes densification thereof,

wherein, after (c), each cellulose-based fiber has a moisture content of 10 wt% or less.

21. The method of claim 17, wherein (a) comprises:

(a1) immersing at least a first portion of the piece of natural plant material within a first solution to remove some of the lignin in the immersed first portion; and

(a2) after (a1), immersing at least the first portion within a second solution to remove remaining lignin in the immersed first portion.

22. The method of claim 21, wherein:

(i) the first solution comprises peroxyformic acid (CH_2O_3), and the second solution comprises sodium hydroxide (NaOH) or potassium hydroxide (KOH); or

(ii) the first solution comprises a mixture of potassium hydroxide (KOH) and sodium sulfite (Na_2SO_3), a mixture of potassium hydroxide (KOH) and sodium sulfide (Na_2S), a mixture of sodium hydroxide (NaOH) and sodium sulfite (Na_2SO_3), or a mixture of sodium hydroxide (NaOH) and sodium sulfide (Na_2S), and the second solution comprises a mixture of hydrogen peroxide (H_2O_2) and acetic acid ($C_2H_4O_2$), or a mixture of hydrogen peroxide (H_2O_2) and formic acid (CH_2O_2).

23. The method of claim 17, further comprising:

infiltrating a polymer into each cellulose-based fiber to form a composite material; or

embedding each cellulose-based fiber within a structural matrix to form a composite material, wherein the structural matrix comprises a polymer or concrete.

.

24. The method of claim 17, wherein the natural plant material comprises grass, bamboo, reed, sugarcane, maize, wheat, rice, jute, hemp, kenaf, ramie, banana, corn, wheat, rice, roselle, rattan, sorghum, sisal, palm, henequen, manila, pineapple, curaua, yucca, cabuya, screw pine, abaca, gladiolus, or agave.

25. The method of claim 17, wherein, after (c), each cellulose-based fiber has a length of at least 5 cm and a maximum cross-sectional dimension in a plane perpendicular to a direction of the length of at least 5 μm.