CLAIMS

1. A method comprising:

(a) producing a piece of partially-delignified cellulose-based material by subjecting a piece of naturally-occurring cellulose-based material to one or more chemical treatments so as to remove at least some lignin therefrom while preserving a microstructure of the piece of naturally-occurring cellulose-based material, the microstructure comprising cellulose-based longitudinal cells extending along an extension direction that is substantially parallel to a longitudinal growth direction of the naturally-occurring cellulose-based material;

(b) drying the piece of partially-delignified cellulose-based material so as to remove moisture therefrom, such that lumina of at least some of the cellulose-based longitudinal cells collapse and such that the dried piece has a moisture content less than or equal to 15 wt%;

(c) performing a fluid-shock treatment to the dried piece of partially-delignified cellulose-based material to yield a rehydrated piece of partially-delignified cellulose-based material, the fluid-shock treatment comprising exposing the dried piece to moisture, the rehydrated piece having a moisture content of at least 35 wt%; and

(d) forming the rehydrated piece of partially-delignified cellulose-based material from a substantially flat planar configuration into a non-planar three-dimensional configuration,

wherein the lumina of first cellulose-based longitudinal cells in the rehydrated piece of partially-delignified cellulose-based material that have a cross-sectional size less than a first size are substantially collapsed and lumina of second cellulose-based longitudinal cells in the rehydrated piece of partially-delignified cellulose-based material that have a cross-sectional size greater than the first size are at least partially open.

2. The method of claim 1, wherein a thickness of the piece of naturally-occurring cellulose-based material in a direction perpendicular to the extension direction is 10 mm or less.

3. The method of claim 1, wherein the moisture content of the rehydrated piece during (d) is at least 50 wt%.

4. A method comprising:

(a) producing a piece of partially-delignified cellulose-based material by subjecting a piece of naturally-occurring cellulose-based material to one or more chemical treatments so as to remove at least some lignin therefrom while preserving a microstructure of the piece of naturally-occurring cellulose-based material, the microstructure comprising cellulose-based longitudinal cells extending along an extension direction that is substantially parallel to a longitudinal growth direction of the naturally-occurring cellulose-based material;

(b) after (a), partially drying the piece of partially-delignified cellulose-based material so as to remove some moisture therefrom, such that the partially-delignified cellulose-based material has a moisture content of at least 35 wt% and such that lumina of first cellulose-based longitudinal cells in the partially-delignified cellulose-based material that have a cross-sectional size less than a first size are collapsed and lumina of second cellulose-based longitudinal cells in the partially-delignified cellulose-based material that have a cross-sectional size greater than the first size are at least partially open;

(c) after (b), forming the piece of partially-delignified cellulose-based material from a substantially flat planar configuration into a non-planar three-dimensional configuration; and

(d) further drying the piece of partially-delignified cellulose-based material to remove additional moisture therefrom such that the moisture content of the piece of partially-delignified cellulose-base material is less than or equal to 15 wt%, thereby setting a shape of the piece in the non-planar three-dimensional configuration and forming a rigid monolithic piece of the partially-delignified cellulose-based material.

5. The method of any one of claims 1-4, wherein a thickness of the piece of naturally-occurring cellulose-based material in a direction perpendicular to the extension direction is between 0.1 mm and 10 mm, inclusive.

6. The method of either of claim 1 or claim 4, wherein the forming into the non-planar three-dimensional configuration comprises folding the piece, bending the piece, or any combination thereof.

7. The method of claim 1, further comprising, after the forming into the non-planar three-dimensional configuration:

(e) drying the piece to remove moisture therefrom so as to set a shape of the piece and form a rigid monolithic piece of partially-delignified cellulose-based material in the non-planar three-dimensional configuration,

wherein the rigid monolithic piece has a moisture content less than or equal to 15 wt%.

8. The method of claim 4, further comprising:

forming a protective layer or coating over the rigid monolithic piece, the protective layer or coating being constructed to prevent rehydration of the rigid monolithic piece.

9. The method of claim 1, wherein the exposing to moisture of (c) comprises immersing partially or fully within a fluid, exposing to fluid vapor in a humidified environment, or any combination thereof.

10. The method of claim 4, wherein the moisture content of the partially-dried piece during (c) is at least 50 wt%.

11. The method of either of claim 1 or claim 4, wherein the naturally-occurring cellulose-based material is a hardwood, softwood, bamboo, grass, or reed.

12. The method of either claim 1 or claim 4, wherein the naturally-occurring cellulose-based material comprises a hardwood, the first cellulose-based longitudinal cells comprise fibers or tracheids of the hardwood, and the second cellulose-based longitudinal cells comprise vessels of the hardwood; or

the naturally-occurring cellulose-based material comprises a softwood, and the first and second cellulose-based longitudinal cells comprise tracheids.

13. The method of claim 4, wherein for each lumen of the second cellulose-based longitudinal cells, a cross-sectional size thereof after the partially drying of (b) and before the forming of (c) is less than a cross-sectional size thereof in the naturally-occurring cellulose-based material prior to (a).

14. The method of either claim 1 or claim 4, wherein:

the subjecting to one or more chemical treatments of (a) is such that a lignin content in the naturally-occurring cellulose-based material is reduced by between 0.1% and 99%, inclusive, to produce the piece of partially-delignified cellulose-based material;

the subjecting to one or more chemical treatments of (a) is such that a hemicellulose content in the naturally-occurring cellulose-based material is reduced by between 0.1% and 99%, inclusive, to produce the piece of partially-delignified cellulose-based material; or

any combination of the above.

15. The method of either claim 1 or claim 4, wherein:

the naturally-occurring cellulose-based material is a hardwood, and an amount of lignin in the piece of partially-delignified wood after (a) is at least 10 wt%;

the naturally-occurring cellulose-based material is a softwood, and an amount of lignin in the piece of partially-delignified wood after (a) is at least 12.5 wt%; or

the naturally-occurring cellulose-based material is a bamboo, and an amount of lignin in the piece of partially-delignified bamboo after (a) is at least 13 wt%.

16. The method of claim 1, wherein for each lumen of the second cellulose-based longitudinal cells, a cross-sectional size thereof after the drying of (b) is less than a cross-sectional size thereof in the naturally-occurring cellulose-based material prior to (a).

17. The method of claim 4, wherein the further drying of (d) comprises exposing the piece of partially-delignified cellulose-based material to an air or gas flow, exposing the piece of partially-delignified cellulose-based material to a stagnant volume of air or gas, exposing the piece of partially-delignified cellulose-based material to room temperature, heating the piece of partially-delignified cellulose-based material to a temperature above room temperature, or any combination thereof.

18. The method of claim 4, further comprising, after (d):

assembling the rigid monolithic piece of partially-delignified cellulose-based material with one or more other rigid monolithic pieces of partially-delignified cellulose-based material;

assembling the rigid monolithic piece of partially-delignified cellulose-based material with one or more other pieces of cellulose-based material;

assembling the rigid monolithic piece of partially-delignified cellulose-based material with one or more other pieces of a non-cellulose-based material to form a composite structure; or

any combination of the above.

19. The method of either claim 1 or claim 4, wherein:

at least one of the one or more chemical treatments comprises treatment with sodium hydroxide (NaOH), lithium hydroxide (LiOH), potassium hydroxide (KOH), sodium sulfite (Na_2SO_3), sodium sulfate (Na_2SO_4), sodium sulfide (Na_2S), Na_nS wherein n is an integer, urea (CH_4N_2O), sodium bisulfite ($NaHSO_3$), sulfur dioxide (SO_2), anthraquinone ($C_{14}H_8O_2$), methanol (CH_3OH), ethanol (C_2H_5OH), butanol (C_4H_9OH), formic acid (CH_2O_2), hydrogen peroxide (H_2O_2), acetic acid (CH_3COOH), butyric acid ($C_4H_8O_2$), peroxyformic acid (CH_2O_3), peroxyacetic acid ($C_2H_4O_3$), ammonia (NH_3), tosylic acid (p-TsOH), sodium hypochlorite (NaClO), sodium chlorite ($NaClO_2$), chlorine dioxide (ClO_2), chorine (Cl_2), or any combination of the above.

20. The method of claim 4, wherein, after (d):

the non-planar three-dimensional configuration comprises an undulating configuration formed by multiple folds or bends therein, the undulating configuration having a repeating pattern with at least one peak and at least one trough;

the method further comprises coupling the rigid monolithic piece of the partially-delignified cellulose-based material to first and second support plates to form a structural material having a honeycomb configuration;

the folds or bends in the undulating configuration are about respective axes parallel to a first direction; and

the support plates are disposed on opposite sides of the rigid monolithic piece of the partially-delignified cellulose-based material with respect to the first direction so as to sandwich the rigid monolithic piece of the partially-delignified cellulose-based material therebetween.

21. The method of claim 4, wherein the forming of (c) and the further drying of (d) are performed at a same time.

22. The method of claim 4, wherein the further drying of (d) comprises using a hot press to dry and densify the piece of partially-delignified cellulose-based material.

23. A structure formed by the method of any one of claims 1-15 and 21-27.