Claims

1. Method for densifying a hygroscopic material, whereby the hygroscopic material is selected from plant materials, natural fiber materials, synthetic fiber materials, mineral wool, animal wool, skin-based materials, chitin-based materials, chitosan-based materials, protein-based materials, and/or the mixtures of such materials~~especially a natural hygroscopic material~~, in particular wood, comprising the steps of:

   a) providing the hygroscopic material to be densified;

   b) pre-conditioning of the hygroscopic material by adjusting the moisture content of the hygroscopic material to a value within a predefined moisture range, if required;

   c) simultaneously heating and pressing the hygroscopic material under predefined temperature and pressure conditions, whereby the moisture content of the hygroscopic material is kept constant;

   d) obtaining a densified material,

   whereby step c) comprises the following sub-steps:

   c1) the hygroscopic material is pre-heated to a first temperature at a first pressure and kept for a predefined first dwell time, whereby, preferably, the first pressure is equal to ambient pressure;

   whereby the first temperature is from 50 - 100°C, and the first pressure is from 0 to 2 MPa and the first dwell time is about 1 min – 10 hours, especially 5 – 60 min, in particular 20 min;

   c2) while keeping the first temperature, the pressure is raised to a second pressure, especially at a constant rate of pressure increase, and kept for a predefined second dwell time;

   whereby the second pressure is from 9 – 50 MPa, especially 9 – 11 MPa whereby the constant rate of pressure increase is about 0.5 – 2 MPa/min, especially 0.9 – 1.1 MPa/min and the second dwell time is about 1 – 45 min, especially 20 – 30 min;

c3) while keeping the second pressure, the temperature is increased to a second temperature, especially at a constant rate of temperature increase, and kept for a predefined third dwell time;

whereby the second temperature is from 100-220°C or 130 - 190°C, whereby the constant rate of temperature increase is about 0.5 – 10°C/min, and the third dwell time is about 1 - 120 min or 1 – 90 min;

c4) reducing the temperature to room temperature;

c5) reducing the pressure to ambient pressure.

2. Method according to claim 1, whereby the method comprises a further step b1) of gas-tight packaging of the pre-conditioned hygroscopic material in a gas-tight casing before step c).

~~3. Method according to any of claims 1 – 2, whereby the hygroscopic material to be densified is selected from plant materials, natural fiber materials, synthetic fiber materials, mineral wool, animal wool, skin-based materials, chitin-based materials, chitosan-based materials, protein-based materials, and/or the mixtures of such materials, e.g. grasses, algae, hemp fibers and/or egg shells.~~

~~4.~~3. Method according to claim ~~3~~1, whereby the hygroscopic material to be densified is selected from plant materials.

~~5.~~4. Method according to any one of claims 1 - ~~4~~3, whereby the hygroscopic material to be densified is selected from wood, especially lumber, in particular from solid wood and/or wood veneers.

~~6.~~5. Method according to any one of claims 1 – ~~5~~4, whereby the method is effected such that a density of the obtained densified material is 1.01 – 100, in particular 1.1 – 50, especially 1.5 – 20, preferably 2 – 16, for example 2 – 3, times the density of the hygroscopic material before the treatment.

~~7.~~6. Method according to any one of claims 1 – ~~6~~5, whereby a surface of the hygroscopic material to be densified is chemically treated before step b), especially by impregnation with natural polymers, synthetic polymers, natural resins, synthetic resins, waxes, sulfur, and/or molten metals.

~~8.~~7. Method according to any one of claims 1 – ~~7~~6, whereby in step b) the moisture content of the hygroscopic material to be densified is adjusted to 5 – 30%, especially 10 – 15%.

~~9. Method according to any of claims 1 – 8, whereby in step c) the pressure is increased to a value of 5 – 50 MPa, especially 9 – 11 MPa and/or the temperature is increased to a value 120 - 190°C or 130 - 190°C.~~

~~10. Method according to any of claims 1 – 9, whereby step c) comprises the following sub-steps:~~

~~c1) the hygroscopic material is pre-heated to a first temperature at a first pressure and kept for a predefined first dwell time, whereby, preferably, the first pressure is equal to ambient pressure;~~

~~c2) while keeping the first temperature, the pressure is raised to a second pressure, especially at a constant rate of pressure increase, and kept for a predefined second dwell time;~~

~~c3) while keeping the second pressure, the temperature is increased to a second temperature, especially at a constant rate of temperature increase, and kept for a predefined third dwell time;~~

~~c4) reducing the temperature to room temperature;~~

~~c5) reducing the pressure to ambient pressure.~~

~~11. Method according to claim 10, whereby:~~

~~- in step c1) the first temperature is from 50 - 100°C, and the first pressure is from 0 to 2 MPa and the first dwell time is about 1 min – 10 hours, especially 5 – 60 min, in particular 20 min.~~

~~- in step c2) the second pressure is from 5 – 50 MPa, especially 9 – 11 MPa whereby the constant rate of pressure increase is about 0.5 – 2 MPa/min, especially 0.9 – 1.1 MPa/min and the second dwell time is about 1 – 45 min, especially 20 – 30 min;~~

~~- in step c3) the second temperature is from 100-220°C or 130 - 190°C, whereby the constant rate of temperature increase is about 0.5 – 10°C/min, and the third dwell time is about 1 - 120 min or 1 – 90 min.~~

~~12.~~8. Method according to any one of claims 1 – ~~11~~7, whereby the method further comprises a step of customizing a surface structure and/or a surface texture of the hygroscopic material to be densified and/or of the densified material.

~~13.~~9. Method according to claim ~~12~~8, whereby the customization of the surface structure and/or of the surface texture is effected during step c), especially by embossing, e.g. by using a mechanical press with a textured and/or structured press ram and/or by using an embossing insert.

~~14.~~10. Method according to any one of claims ~~12~~ 8 – ~~13~~9, whereby the customization of the surface structure and/or of the surface texture is effected after step c), especially by engraving, e.g. laser engraving and/or CNC-engraving.

~~15.~~11. Method according to any one of claims ~~12~~ 8 – ~~14~~10, whereby the customization of the surface structure and/or of the surface texture comprises the step of applying a predefined design, pattern and/or picture onto the surface of the hygroscopic material to be densified and/or of the densified material.

~~16.~~12. Method according to any one of claims ~~12~~ 8 – ~~15~~11, whereby by the customization of the surface structure and/or of the surface texture an ultrahydrophobic surface is generated, in particular by micro- and/or nano-structuration, whereby, preferably, the surface has a contact angle with water under standard conditions of 150° or more.

~~17.~~13. Method according to any one of claims 1 – ~~16~~12, whereby the obtained densified material is a translucent material, in particular a translucent wood material.

~~18.~~14. Method according to any one of claims 1 – ~~17~~13, whereby in step a), the hygroscopic material to be densified, especially wood-based material, is provided in the form of a stack comprising at least two layers, whereby at least one layer, especially at least two, three, four, five or more layers, is/are made of hygroscopic material, and whereby all layers of the stack are densified together.

~~19. Method according to any of claim 18, whereby the at least one layer of hygroscopic material comprises plant-based material, animal-based material and/or wood-based~~

~~material, especially paper, plant and/or wood fibers, wood-chips, wood flour, cellulose, starch, lignin, wood bark, wood extractives, algae, chitin-based materials, chitosan-based materials, native wood, protein, coal, char, carbon black and/or active coal.~~

~~20.~~15. Method according to ~~any of~~ claim~~s~~ ~~18 – 19~~14, whereby the stack furthermore comprises at least one layer of:

(i) metals and/or metal alloys, e.g. comprising or consisting of Aluminum, Steel, Copper, Silver, Gold, and/or Titanium; and/or

(ii) polymeric materials, especially synthetic polymers and/or biopolymers, e.g. PLA, PET, PP, PE, PVC and/or proteins; and/or

(iii) inorganic materials, e.g. ceramics, glass, stone, clay, metal-organic frameworks (MOF), zeolites, coal, char, carbon black and/or active coal.

~~21.~~16. Method according to any one of claims ~~18~~ 14 – ~~20~~15, whereby the outermost layers in the stack are made from wood-based material, especially wood, preferably lumber, in particular solid wood and/or wood veneers.

~~22.~~17. Method according to any one of claims ~~18~~ 14 – ~~21~~16, whereby at least one of layers of the stack is treated with an adhesive, especially a synthetic, natural, fossil or bio-based adhesive, and/or at least one adhesive foil is arranged between the layers of the stack, such that all the layers of the stack are bonded together upon densification in order to produce a laminated structure.

~~23.~~18. Method according to any one of claims ~~18~~ 14 – ~~22~~17, whereby the stack comprises an electronic functionality, a magnetic functionality, and/or an optical label, especially an electrical wire, in particular an antenna and/or an electromagnetic coil.

~~24.~~19. Method according to claim ~~23~~18, whereby the electronic functionality, the magnetic functionality, and/or the optical label is arranged on a layer of cellulosic material, especially on a layer of paper.

~~25.~~20. Method according to any one of claims ~~18~~ 14 – ~~24~~19, whereby at least two layers of the stack are made of wood, whereby the layers are oriented with different wood grain directions.

~~26.~~21. Method according to any one of claims ~~18~~ 14 – ~~25~~20, whereby at least two layers of the stack, especially the outermost layers of the stack, are made of wood.

~~27.~~22. Method according to any one of claims ~~18~~ 14 – ~~26~~21, whereby during steps b) and c), the outermost layers of the stack are covered with a plastic foil and/or the stack is enclosed in a plastic foil.

~~28.~~23. Method according to any one of claims ~~18~~ 14 – ~~27~~22, whereby the stack comprises at least two layers of different hygroscopic materials, especially of wood and paper.

~~29.~~24. Method according to any one of claims ~~18~~ 14 – ~~28~~23, whereby the stack comprises at least three layers, whereby a thickness of the outermost layers of the at least three layers is larger than a thickness of the one or more layers located in between the outermost layers.

~~30.~~25. Method according to any one of claims ~~18~~ 14 – ~~29~~24, whereby a surface structure and/or a surface texture of at least one outermost layer of the at least two layers of the stack is customized during step c), especially by embossing, e.g. by using a mechanical press with a textured and/or structured press ram and/or by using an embossing insert.

~~31.~~26. Method according to any one of claims ~~18~~ 14 – ~~30~~25, whereby after step d), a recess and/or an engraving is produced at least in the outermost layer, whereby, preferably, the recess and/or the engraving is produced by laser-engraving and/or laser cutting.

~~32.~~27. Method according to claim ~~31~~26, whereby an electronic functionality, a magnetic functionality and/or an optical label is placed in the recess, for example by adhesively bonding.

~~33.~~28. Method according to claim ~~28~~27, whereby the electronic functionality is arranged such that it is in electrical contact with the other electrical functionality comprised in the stack, especially an electrical wire, in particular an antenna and/or an electromagnetic coil.

~~34.~~29. Method according to any one of claims ~~31~~ 26 – ~~33~~28, whereby the recess and/or the engraving is produced such that the layer lying directly under the outermost layer is exposed, whereby, in particular, the layer lying directly under the outermost layer is a layer with a color different than the color of the outermost layer, whereby, for example,

the outermost layer is a layer of densified wood and the layer lying directly under the outermost layer is a layer of metal and/or plastics.

~~35.~~30. Method for producing a laminated structure, especially a laminated wood structure, whereby the laminated structure is produced with the method according to any one of claims ~~18~~ 14 – ~~34~~29.

~~36.~~31. Method for producing a laminated structure, especially a laminated wood structure, whereby a layer of hygroscopic material or a stack as defined in any one of claims ~~18~~ 14 – ~~35~~ 30 is densified with the method according to any one of claims 1 – ~~34~~ 29 and laminated with at least one further layer, e.g. by adhesively bonding, whereby the at least one further layer is made of:

(i) another layer of hygroscopic material densified with the method according to any one of claims 1 – ~~34~~29; and/or

(ii) plant-based material, animal-based material and/or wood-based material, especially paper, plant and/or wood fibers, wood-chips, wood flour, cellulose, starch, lignin, wood bark, wood extractives, algae, chitin-based materials, chitosan-based materials, native wood, protein, coal, char, carbon black and/or active coal; and/or

(iii) metals and/or metal alloys, e.g. Aluminum, Steel, Copper, Silver, Gold, and/or Titanium; and/or

(iv) polymeric materials, especially synthetic polymers and/or biopolymers, e.g. PLA, PET, PP, PE, PVC and/or proteins; and/or

(v) inorganic materials, e.g. ceramics, glass, stone, clay, metal-organic frameworks (MOF), zeolites, coal, char, carbon black and/or active coal; or other porous or non-porous inorganic materials.

~~37.~~32. Method according to claim ~~36~~31, whereby before laminating, an electronic functionality and/or a magnetic functionality is placed in a recess of the layer of hygroscopic material or in the stack, such that upon lamination, the electronic functionality and/or the magnetic functionality is embedded within the laminated structure.

~~38.~~33. Method according to any one of claims ~~35~~ 30 – ~~37~~32, whereby the laminated structure comprises:

a) a backside made of a layer of a densified or non-densified wood veneer

b) a frontside made of a layer of a densified or non-densified wood veneer

c) optionally, one or more further layers of a densified or non-densified wood veneer, or any non-wood-based material, which are arranged between the backside layer and the frontside layer

d) an integrated circuit, a memory device, a tracking device, a sensing device, an antenna and/or an electromagnetic coil, preferably embedded in the card

e) optionally, a support layer, especially made of cellulosic material, e.g. paper, densified wood, and/or fleece, which is arranged between the backside and the frontside, for carrying one or more of the integrated circuit, the memory device, the tracking device, the sensing device, the antenna and/or the electromagnetic coil

whereby the layers are laminated and at least one of the layers of wood veneer, in particular the frontside and the backside layers, especially all of the layer of wood veneer, are made of densified wood veneer.

~~39.~~34. Method for producing a product comprising the steps of (i) densifying a hygroscopic material according to any one of claims 1 – ~~34~~ 29 and/or producing a laminated structure according to any one of claims ~~35~~ 30 – ~~38~~33, and (ii) manufacturing the product at least partly from the densified material and/or the laminated structure obtained in step (i), whereby the product is a musical instrument or a part of it, a furniture, a door, a door handle, a floor covering, a wall covering, a revetment, an automotive part, a covering for a ceiling, a sports equipment, a load-bearing element, a card, an electronic device, or a casing for an electronic device, e.g. a key fob, a data storage device, for example a USB stick, or a casing for a mobile phone.

~~40.~~35. Method according to claim ~~39~~34, whereby the product is a card, especially a payment card, a credit card, a debit card, an identity card, a member card and/or an access card.

41. Densified material, especially densified wood, in particular a densified solid wood and/or a densified wood veneer, obtainable or obtained by the method according to any of claims 1 – 34.

42. Densified material according to claim 41, whereby the densified material is a translucent material, in particular a translucent wood material.

43. Laminated structure, especially a laminated wood structure, comprising at least two laminated layers, whereby at least one, especially at least two, of the laminated layers are made of the densified material according to any of claims 41 – 42, preferably of a densified wood veneer, especially a translucent wood material, and/or the laminated structure is obtainable or obtained by the method according to any of claims 35 – 38.

44. Product comprising a densified material according to any of claims 41 – 42 or a laminated structure according to claim 43, whereby, preferably, the product is a musical instrument or a part of it, a furniture, a door, a door handle, a floor covering, a wall covering, a revetment, an automotive part, a covering for a ceiling, a sports equipment, a load-bearing element, a card, an electronic device, or a casing for an electronic device, e.g. a key fob, a data storage device, for example a USB stick, or a casing for a mobile phone.

45. Product according to claim 44, comprising an electronic functionality, a magnetic functionality, and/or an optical label, especially comprised within the product and/or placed on a surface of the product.

46. Product according to any of claims 44 – 45 comprising an identification tag and/or a security tag, especially comprised within the product and/or placed on a surface of the product.

47. Card, especially with electronic functionality, comprising at least one layer of a densified wood veneer according to claim 41 or 42, whereby, preferably, the card is a payment card, a credit card, a debit card, an identity card, a member card and/or an access card.

48. Card according to claim 47 whereby a back side and a front side of the card each are made of a layer of a wood veneer, especially a densified wood veneer according to claim 41 or 42.

49. Card according to any of claims 47 – 48, whereby, with respect to the overall weight of the card, the card consist to an extent of at least 50 wt.%, in particular at least 75 wt.%, especially at least 90 wt.%, of wooden material, especially of densified wood according to claim 41 or 42.

50. Card according to any of claims 47 – 49 having a size of 80 – 100 mm × 50 – 70 mm × 0.5 – 1.5 mm, in particular a size of 85.5 mm × 54 mm × 0.8 mm.

51. Card according to any of claims 47 – 50 comprising at least two layers of laminated wood veneers, whereby, preferably, both of the at least two layers of wood veneers are densified wood veneers according to claim 41 or 42, whereby each of the layers of wood veneer has a thickness of 0.1 – 0.3 mm.

52. Card according to claim 51, whereby at least two of the at least two layers of laminated wood veneers are oriented with different wood grain directions.

53. Card according to any of claims 47 – 52, whereby the card comprises an integrated circuit, memory device, tracking device, sensing device, antenna and/or electromagnetic coil, especially embedded within the card and/or placed on a surface of the card.

54. Card according to claim 53, whereby the integrated circuit, the memory device, the tracking device, the sensing device and/or the electromagnetic coil, if present, are placed in a recess of the at least one layer of densified wood veneer.

55. Card according to any of claims 53 – 54, whereby at a card surface, a pattern of metal contacts for establishing an electrical connection to the integrated circuit, memory device, tracking device, sensing device, antenna and/or electromagnetic coil is arranged.

56. Card according to any of claim 41 – 55, whereby a card surface comprises an engraving, especially in the form of a logo, letters and/or numbers, whereby, preferably, the engraving is coated with a color that is different from the color of the surrounding area.

57. Card according any of claim 41 – 56, comprising:

f) a backside made of a layer of a densified or non-densified wood veneer

g) a frontside made of a layer of a densified or non-densified wood veneer

h) optionally, one or more further layers of a densified or non-densified wood veneer, or any non-wood-based material, which are arranged between the backside layer and the frontside layer

i) an integrated circuit, a memory device, a tracking device, a sensing device, an antenna and/or an electromagnetic coil, preferably embedded in the card

j) optionally, a support layer, especially made of cellulosic material, e.g. paper, densified wood and/or fleece, which is arranged between the backside and the frontside, for carrying one or more of the integrated circuit, the memory device, the tracking device, the sensing device, the antenna and/or the electromagnetic coil

whereby the layers are laminated and at least one of the layers of wood veneer, in particular the frontside and the backside layers, especially all of the layer of wood veneer, are made of densified wood veneer according to claim 42 or 43.