CLAIMS

1. A sound absorption material, comprising:

a porous structure, comprising:

a hybrid composite of a first triboelectric material having a first charge affinity and a second triboelectric material having a second charge affinity, wherein the first charge affinity is greater than the second charge affinity, wherein a sound absorption coefficient of the hybrid composite as measured according to an ASTM E1050-19 procedure utilizing a standard acoustic tube (Bruel & Kjaer) with a sample thickness of 25 millimetres (mm) and diameter of 100 mm is greater than 50% at frequencies higher than between 550 Hertz (Hz) and 570 Hz in an audible range.

2. The sound absorption material of claim 1, wherein a difference between the first and second charge affinities is between 10 nano-Coulomb per Joule (nC/J) and 250 nC/J.

3. The sound absorption material of claim 2, wherein the difference between the first and second charge affinities is between 200 nC/J and 250 nC/J.

4. The sound absorption material of any one of claims 1 to 3, wherein the first triboelectric material has a positive charge affinity and the second triboelectric material has a negative charge affinity.

5. The sound absorption material of any one of claims 1 to 4, wherein at least one of the first and second triboelectric materials is a piezoelectric material.

6. The sound absorption material of claim 5, wherein the piezoelectric material is selected from a group consisting of a polyvinylidene fluoride (PVDF) homopolymer, a PVDF-based copolymer, poly(vinylidene fluoride trifluoroethylene), a poly(vinylidene fluoride-hexafluoropropylene) copolymer, poly(vinylidene fluoride-trifluoroethylene-chlorofluoroethylene) terpolymer, and poly(L-lactide) (PLLA).

7. The sound absorption material of claim 5 or 6, wherein a concentration of the piezoelectric material in the hybrid composite is between 1 percentage by mass (wt %) and 25 wt % of the hybrid composite.

8. The sound absorption material of any one of claims 1 to 7, wherein the first triboelectric material is selected from a group consisting of polymethyl methacrylate (PMMA), poly(L-lactide) (PLLA), polycarbonate (PC), polyurethane (PU), poly[imino(1,6-dioxohexamethylene) iminohexamethylene], cotton, and glass wool.

9. The sound absorption material of any one of claims 1 to 8, wherein the second triboelectric material is selected from a group consisting of polyimide (PI), polystyrene (PS), polypropylene (PP), polyethylene (PE), polyacrylonitrile (PAN), polyvinylpyrrolidone (PVP), polyvinyl chloride (PVC), and polyvinylidene fluoride (PVDF).

10. The sound absorption material of any one of claims 1 to 9, wherein the first and second triboelectric materials are a triboelectric pair selected from a group consisting of PVDF-glass wool, PVDF-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVDF-PE, PVDF-PP, PVDF-PLLA, PVDF-PMMA, PVC-glass wool, PVC-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVC-PU, PVC-PE, PVC-PP, PVC-PLLA, PVC-PMMA, PVA-glass wool, PVA-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVA-PU, PVA-PE, PVA-PP, PVA-PLLA, PVA-PMMA, PAN-glass wool, PAN-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PAN-PU, PAN-PE, PAN-PP, PAN-PLLA, PAN-PMMA, PS-glass wool, PS-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PS-PU, PS-PE, PS-PP, PS-PLLA, PS-PMMA, PC-glass wool, PC-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PC-PU, PC-PE, PC-PP, PC-PLLA, PC-PMMA, PI-glass wool, PI-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PI-PU, PI-PE, PI-PP, PI-PLLA, PI-PMMA, glass wool-PP, and poly[imino(1,6-dioxohexamethylene) iminohexamethylene]-PP.

11. The sound absorption material of any one of claims 1 to 10, wherein the hybrid composite further comprises an electrically conductive material providing an electrically conductive network within the porous structure.

12. The sound absorption material of claim 11, wherein the electrically conductive material is one or more selected from a group consisting of single-walled carbon nanotubes (SWCNTs), multi-walled carbon nanotubes (MWCNTs), graphene, carbon black, silver nanowires and metal particles.

13. The sound absorption material of claim 11 or 12, wherein a concentration of the electrically conductive material in the hybrid composite is at or above a percolation threshold.

14. The absorption material of claim 13, wherein the concentration of the electrically conductive material in the hybrid composite is between 3 percentage by mass (wt %) and 9 wt % of the first and second triboelectric materials.

15. The sound absorption material of any one of claims 1 to 14, wherein the sound absorption coefficient of the hybrid composite as measured according to the ASTM E1050-19 procedure utilizing the standard acoustic tube (Bruel & Kjaer) with the sample thickness of 25 millimetres (mm) and diameter of 100 mm is greater than 90% at frequencies higher than 1 kiloHertz (kHz) in the audible range.

16. The sound absorption material of any one of claims 1 to 15, wherein a concentration of one of the first and second triboelectric materials in the hybrid composite is between 1 wt % and 25 wt% of the hybrid composite.

17. A method of fabricating a sound absorption material, comprising:

preparing a first precursor solution or suspension of one of a first triboelectric material and a second triboelectric material; and

forming a porous structure by using the first precursor solution or suspension in one of a templating technique with a second precursor solution or suspension of the other one of the first and second triboelectric material, an immersion technique with the other one of the first and second triboelectric materials, and an electrospinning technique with the other one of the first and second triboelectric materials, wherein the porous structure comprises:

a hybrid composite of the first triboelectric material having a first charge affinity and the second triboelectric material having a second charge affinity,

wherein the first charge affinity is greater than the second charge affinity, wherein a sound absorption coefficient of the hybrid composite as measured according to an ASTM E1050-19 procedure utilizing a standard acoustic tube (Bruel & Kjaer) with a sample thickness of 25 millimetres (mm) and diameter of 100 mm is greater than 50% at frequencies higher than between 550 Hertz (Hz) and 570 Hz in an audible range.

18. The method of fabricating a sound absorption material of claim 17, wherein a difference between the first and second charge affinities is between 10 nano-Coulomb per Joule (nC/J) and 250 nC/J.

19. The method of fabricating a sound absorption material of claim 18, wherein the difference between the first and second charge affinities is between 200 nC/J and 250 nC/J.

20. The method of fabricating a sound absorption material of any one of claims 17 to 19, wherein the first triboelectric material has a positive charge affinity and the second triboelectric material has a negative charge affinity.

21. The method of fabricating a sound absorption material of any one of claims 17 to 20, wherein at least one of the first and second triboelectric materials is a piezoelectric material.

22. The method of fabricating a sound absorption material of claim 21, wherein the piezoelectric material is selected from a group consisting of a polyvinylidene fluoride (PVDF) homopolymer, a PVDF-based copolymer, poly(vinylidene fluoride trifluoroethylene), a poly(vinylidene fluoride-hexafluoropropylene) copolymer, poly(vinylidene fluoride-trifluoroethylene-chlorofluoroethylene) terpolymer, and poly(L-lactide) (PLLA).

23. The method of fabricating a sound absorption material of any one of claims 17 to 22, wherein the first triboelectric material is selected from a group consisting of polymethyl methacrylate (PMMA), poly(L-lactide) (PLLA), polycarbonate (PC),

polyurethane (PU), poly[imino(1,6-dioxohexamethylene) iminohexamethylene], cotton, and glass wool.

24. The method of fabricating a sound absorption material of any one of claims 17 to 23, wherein the second triboelectric material is selected from a group consisting of polyimide (PI), polystyrene (PS), polypropylene (PP), polyethylene (PE), polyacrylonitrile (PAN), polyvinylpyrrolidone (PVP), polyvinyl chloride (PVC), and polyvinylidene fluoride (PVDF).

25. The method of fabricating a sound absorption material of any one of claims 17 to 24, wherein the first and second triboelectric materials are a triboelectric pair selected from a group consisting of PVDF-glass wool, PVDF-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVDF-PE, PVDF-PP, PVDF-PLLA, PVDF-PMMA, PVC-glass wool, PVC-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVC-PU, PVC-PE, PVC-PP, PVC-PLLA, PVC-PMMA, PVA-glass wool, PVA-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PVA-PU, PVA-PE, PVA-PP, PVA-PLLA, PVA-PMMA, PAN-glass wool, PAN-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PAN-PU, PAN-PE, PAN-PP, PAN-PLLA, PAN-PMMA, PS-glass wool, PS-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PS-PU, PS-PE, PS-PP, PS-PLLA, PS-PMMA, PC-glass wool, PC-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PC-PU, PC-PE, PC-PP, PC-PLLA, PC-PMMA, PI-glass wool, PI-poly[imino(1,6-dioxohexamethylene) iminohexamethylene], PI-PU, PI-PE, PI-PP, PI-PLLA, PI-PMMA, glass wool-PP, and poly[imino(1,6-dioxohexamethylene) iminohexamethylene]-PP.

26. The method of fabricating a sound absorption material of any one of claims 17 to 25, further comprising adding an electrically conductive material to the first precursor solution or suspension, the electrically conductive material providing an electrically conductive network within the porous structure.

27. The method of fabricating a sound absorption material of claim 26, wherein the electrically conductive material is one or more selected from a group consisting of single-walled carbon nanotubes (SWCNTs), multi-walled carbon nanotubes (MWCNTs), graphene, carbon black, silver nanowires and metal particles.

28. The method of fabricating a sound absorption material of any one of claims 17 to 27, wherein the step of forming the porous structure using the first precursor solution or suspension in the templating technique with a second precursor solution or suspension of the other one of the first and second triboelectric material comprises:

preparing the second precursor solution or suspension of the other one of the first triboelectric material and the second triboelectric material;

mixing the first precursor solution or suspension and the second precursor solution or suspension to form a first mixture;

mixing a porogen into the first mixture to form a second mixture;

performing a moulding operation using the second mixture to produce the hybrid composite; and

dissolving the porogen to obtain the porous structure.

29. The method of fabricating a sound absorption material of claim 28, wherein a mass ratio of the second triboelectric material to the porogen is between 8:92 and 10:90.

30. The method of fabricating a sound absorption material of claim 28 or 29, wherein the porogen is a salt or a sugar.

31. The method of fabricating a sound absorption material of any one of claims 17 to 27, wherein the step of forming the porous structure using the first precursor solution or suspension in the immersion technique with the other one of the first and second triboelectric materials comprises:

immersing the first triboelectric material in the first precursor solution or suspension, wherein the first precursor solution or suspension is of the second triboelectric material.

32. The method of fabricating a sound absorption material of any one of claims 17 to 27, wherein the step of forming the porous structure using the first precursor solution or suspension in the electrospinning technique with the other one of the first and second triboelectric materials comprises:

electrospinning the first precursor solution or suspension to generate a plurality of first electrospun fibres; and

depositing the first electrospun fibres through an electric field onto the other one of the first and second triboelectric materials to cover a plurality of surfaces of the other one of the first and second triboelectric materials, the first electrospun fibres diffusing into a plurality of pores of the other one of the first and second triboelectric materials.

33. The method of fabricating a sound absorption material of claim 32, wherein the first precursor solution or suspension is of the second triboelectric material and the first electrospun fibres are deposited onto the first triboelectric material.

34. The method of fabricating a sound absorption material of any one of claims 17 to 27, wherein the step of forming the porous structure using the first precursor solution or suspension in the electrospinning technique with the other one of the first and second triboelectric materials comprises:

preparing the second precursor solution or suspension of the other one of the first triboelectric material and the second triboelectric material;

electrospinning the first precursor solution or suspension to generate a plurality of first electrospun fibres;

electrospinning the second precursor solution or suspension to generate a plurality of second electrospun fibres; and

depositing the first and second electrospun fibres through an electric field onto a substrate to produce the hybrid composite.