

CLAIMS

1. A method of producing a porous composite material for sound absorption, comprising:
- 5 preparing a mixture of mechano-electrical conversion elements and electro-thermal conversion elements in an organic solvent;
- mixing the mixture of the mechano-electrical conversion elements and the electro-thermal conversion elements in the organic solvent with an aqueous solvent to precipitate a piezoelectric hybrid filler material;
- 10 mixing the piezoelectric hybrid filler material with a precursor; and
- performing a foaming operation with the precursor to produce the porous composite material.
2. The method of claim 1, wherein the step of preparing the mixture of the
- 15 mechano-electrical conversion elements and the electro-thermal conversion elements in the organic solvent comprises:
- dissolving the mechano-electrical conversion elements in the organic solvent;
- and
- dispersing the electro-thermal conversion elements in the organic solvent.
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3. The method of claim 1 or 2, wherein the mechano-electrical conversion elements comprise one of a piezoelectric polymer and a polymeric electret.
4. The method of claim 3, wherein the piezoelectric polymer is selected from a
- 25 group consisting of polyvinylidene fluoride (PVDF), poly(vinylidene fluoride-trifluoroethylene) (PVDF-TrFE) and poly(vinylidene fluoride-hexafluoropropylene) (PVDF-HFP).
5. The method of claim 3, wherein the polymeric electret is selected from a group
- 30 consisting of polyimide, polypropylene, polyethylene terephthalate (PET), polytetrafluoroethylene, polymethylmethacrylate, and ethylene vinyl acetate cyclic olefin copolymers.

6. The method of any one of the preceding claims, wherein the electro-thermal conversion elements comprise one of electrically conductive elements and dielectric lossy elements.
- 5 7. The method of claim 6, wherein the electrically conductive elements are selected from a group consisting of single-walled carbon nanotubes (SWCNT), multi-walled carbon nanotubes (MWCNT), graphene and carbon black.
8. The method of claim 6, wherein the dielectric lossy elements are selected from
10 a group consisting of aluminium nitrate nonahydrate, aluminium chloride hexahydrate ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$), tetra-n-butylammonium chloride and ammonium acetate.
9. The method of claim 8, wherein the piezoelectric hybrid filler material comprises
15 between about 10 percent by mass (wt%) and about 50 wt% of the dielectric lossy elements.
10. The method of any one of the preceding claims, wherein the foaming operation comprises one of a physical foam extrusion process, a chemical foam extrusion process and a chemical foam expanding process.
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11. The method of any one of the preceding claims, wherein the step of mixing the piezoelectric hybrid filler material with the precursor comprises:
mixing between about 1% by mass and about 10% by mass of the piezoelectric hybrid filler material and between about 90% by mass and about 98% by mass of the
25 precursor, wherein the precursor is a thermoplastic polymer.
12. The method of claim 11, further comprising mixing between about 1% by mass and about 10% by mass of a foaming agent with the piezoelectric hybrid filler material and the precursor.
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13. The method of claim 11 or 12, wherein the thermoplastic polymer is selected from a group consisting of poly(methyl methacrylate) (PMMA), polyamide (PA), polycarbonate (PC), polyester (PES), polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyurethane (PU), polyvinyl chloride

(PVC), polyvinylidene chloride (PVDC), poly(lactic acid) (PLA), polybenzimidazole (PBI), polyoxymethylene (POM), polyether ether ketone(PEEK), polyetherimide (PEI), polyphenylene oxide (PPO), polyphenylene sulfide (PPS), polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE) and acrylonitrile butadiene styrene (ABS).

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14. The method of any one of claims 1-10, wherein the step of mixing the piezoelectric hybrid filler material with the precursor comprises:

mixing between about 1 part and about 10 parts of the piezoelectric hybrid filler material with between about 50 parts and about 100 parts of the precursor and
 10 between about 1 part and about 2.5 parts of fire-retardant agent to form a set of reagents.

15. The method of claim 14, wherein the step of performing the foaming operation comprises:

15 reacting the set of reagents with about 25 parts of the precursor.

16. The method of claim 14 or 15, wherein the precursor comprises one of polyurethane (PU), silicone and latex.

20 17. A porous composite material for sound absorption, comprising:

a porous polymer matrix; and

a piezoelectric hybrid filler dispersed in the porous polymer matrix, wherein the piezoelectric hybrid filler comprises mechano-electrical conversion elements and electro-thermal conversion elements.

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18. The porous composite material of claim 17, wherein the porous polymer matrix comprises one of polyurethane (PU), silicone, latex and a thermoplastic polymer.

19. The porous composite material of claim 18, wherein the thermoplastic polymer
 30 is selected from a group consisting of poly(methyl methacrylate) (PMMA), polyamide (PA), polycarbonate (PC), polyester (PES), polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyurethane (PU), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), poly(lactic acid) (PLA), polybenzimidazole (PBI), polyoxymethylene (POM), polyether ether ketone(PEEK),

polyetherimide (PEI), polyphenylene oxide (PPO), polyphenylene sulfide (PPS), polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE) and acrylonitrile butadiene styrene (ABS).

5 20. The porous composite material of any one of claims 17 to 19, wherein the mechano-electrical conversion elements comprise one of a piezoelectric polymer and a polymeric electret.

21. The porous composite material of claim 20, wherein the piezoelectric polymer is
10 selected from a group consisting of polyvinylidene fluoride (PVDF), poly(vinylidene fluoride-trifluoroethylene) (PVDF-TrFE) and poly(vinylidene fluoride-hexafluoropropylene) (PVDF-HFP).

22. The porous composite material of claim 20, wherein the polymeric electret is
15 selected from a group consisting of polyimide, polypropylene, polyethylene terephthalate (PET), polytetrafluoroethylene, polymethylmethacrylate, and ethylene vinyl acetate cyclic olefin copolymers.

23. The porous composite material of any one of claims 17 to 19, wherein the
20 electro-thermal conversion elements comprise one of electrically conductive elements and dielectric lossy elements.

24. The porous composite material of claim 23, wherein the electrically conductive elements are selected from a group consisting of single-walled carbon nanotubes
25 (SWCNT), multi-walled carbon nanotubes (MWCNT), graphene and carbon black.

25. The porous composite material of claim 23, wherein the dielectric lossy elements are selected from a group consisting of aluminium nitrate nonahydrate, aluminium chloride hexahydrate ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$), tetra-n-butylammonium chloride and
30 ammonium acetate.

26. The porous composite material of claim 25, wherein the piezoelectric hybrid filler comprises between about 10 percent by mass (wt%) and about 50 wt% of the dielectric lossy elements.