the super-capacitor when stressed either mechanically or thermally. The ion conductivities of these thermoplastic-IL are anisotropic (e.g., higher conductivity measured lateral to the polymer chains). The leaching of IL out of the electrolyte film causes the electrolyte ion conductivity to degrade overtime. Furthermore, due to similar polar nature of the ionic liquid and the polar polymer matrix, the mobility of the ionic liquid molecules would be hindered. This is due to attractive transient ion-dipole interaction between IL and polar groups of the polymer matrix resulting in a poor electrical conductivity when a potential is applied. Thus, the development of a super-capacitor system with both superior ion conductivity and mechanical property is an area of opportunity worthy of detailed investigation.

Accordingly, there is a need for a composite material for super-capacitor that ameliorates one or more disadvantages mentioned above.

Summary

There is provided a composition comprising at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte, wherein the at least one epoxy precursor comprises at least three glycidyl groups per molecule.

In one aspect, there is provided a composition comprising at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte, wherein the at least one epoxy precursor comprises at least three glycidyl groups per molecule, wherein the at least one cross-linker is selected from triethylenetetramine or tetraethylenepentamine, and wherein the at least one chain extender comprises at least three ethoxy groups, propyloxy groups, or a combination thereof.

There is provided a method of forming a composite material, comprising the steps of:

(a) mixing at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte to form a composition; and

(b) curing the composition of step (a) in a silicone to form the composite material.

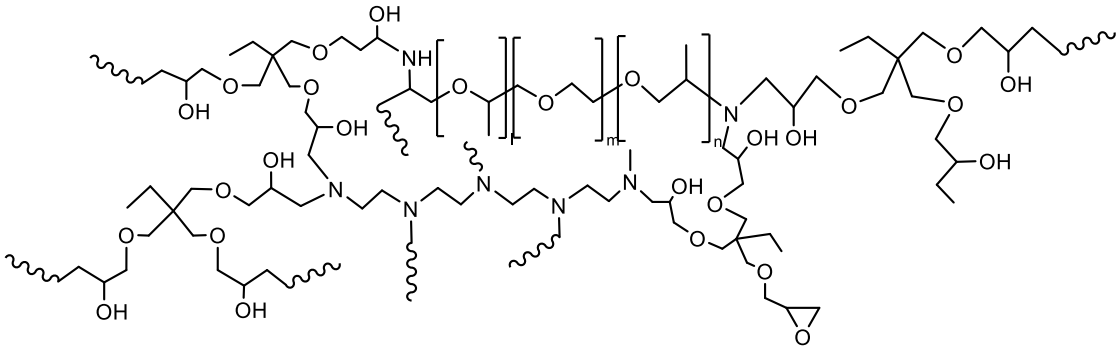
In another aspect, there is provided a method of forming a composite material, comprising the steps of:

(a) mixing at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte to form a composition; and

(b) curing the composition of step (a) to form the composite material,

wherein the at least one epoxy precursor comprises at least three glycidyl groups per molecule, wherein the at least one cross-linker is selected from triethylenetetramine or tetraethylenepentamine, and wherein the at least one chain extender comprises at least three ethoxy groups, propyloxy groups, or a combination thereof.

In another aspect, there is provided a composite material having a polymeric network comprising a plurality of moieties, each moiety independently having a formula of:



wherein:

each wavy bond represents a site of cross linking to another moiety;

l is an integer in the range of 2 to 4;

m is an integer in the range of 6 to 39; and

Claims

1. A composition comprising at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte, wherein the at least one epoxy precursor comprises at least three glycidyl groups per molecule, wherein the at least one cross-linker is selected from triethylenetetramine or tetraethylenepentamine, and wherein the at least one chain extender comprises at least three ethoxy groups, propyloxy groups, or a combination thereof.

2. The composition of claim 1, wherein the at least one epoxy precursor is selected from pentaerythritol tetraglycidyl ether or trimethylolpropane triglycidyl ether.

3. The composition of claim 1 or 2, wherein the at least one chain extender is selected from O,O'-bis(2-aminopropyl) polypropylene glycol-block-polyethylene glycol-block-polypropylene glycol, poly(propylene glycol) bis(2-aminopropyl ether), poly(propylene glycol) bis(2-aminopropyl ether) or 4,7,10-trioxatridecane-1,13-diamine.

4. The composition of any one of claims 1 to 3, which further comprises a catalyst selected from 2,4,6-tris(dimethylaminomethyl)phenol or a BF_3-amine complex.

5. The composition of any one of claims 1 to 4, wherein the electrolyte is non-aqueous, and comprises at least one ionic liquid.

6. The composition of claim 5, wherein the at least one ionic liquid is selected from 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide, 1-ethyl-3-methylimidazolium trifluoromethanesulfonate, 1-butyl-3-methylimidazolium tetrafluoroborate or 1-ethyl-3-methylimidazolium tetrafluoroborate.

7. The composition of claim 5 or 6, wherein the at least one ionic liquid has a weight percentage of 30 weight% to 50 weight% based on the total weight of the composition.

8. The composition of any one of claims 1 to 7, which comprises epoxy functional groups and amino functional groups at a total molar ratio in the range of 1 to 3.8.

9. The composition of any one of claims 1 to 8, wherein the at least one cross-linker and the at least one chain extender have a molar ratio in the range of 0.5 to 3.2.

10. The composition of any one of claims 4 to 9, wherein:
(a) the at least one epoxy precursor is trimethylolpropane triglycidyl ether;
(b) the at least one cross-linker is tetraethylenepentamine;
(c) the at least one chain extender is O,O'-bis(2-aminopropyl) polypropylene glycol-block-polyethylene glycol-block-polypropylene glycol; and
(d) the catalyst is 2,4,6-tris(dimethylaminomethyl)phenol.

11. A method of forming a composite material, comprising the steps of:
(a) mixing at least one epoxy precursor, at least one cross-linker, at least one chain extender, and an electrolyte to form a composition; and
(b) curing the composition of step (a) to form the composite material,

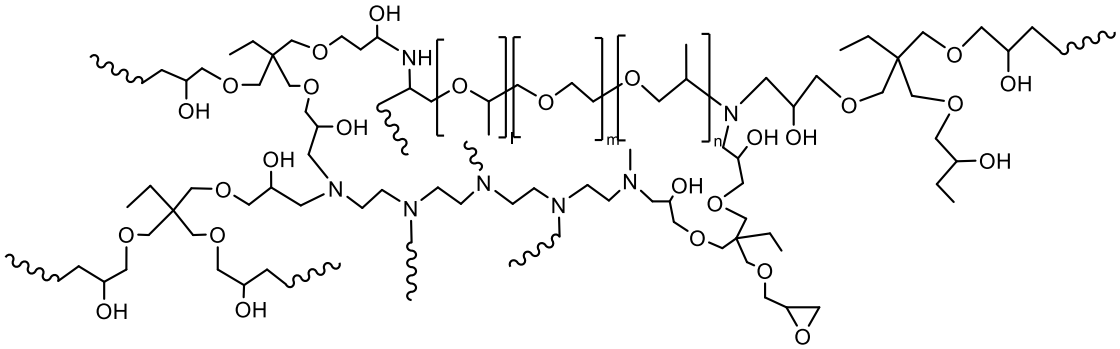
wherein the at least one epoxy precursor comprises at least three glycidyl groups per molecule, wherein the at least one cross-linker is selected from triethylenetetramine or tetraethylenepentamine, and wherein the at least one chain extender comprises at least three ethoxy groups, propyloxy groups, or a combination thereof.

12. The method of claim 11, wherein the mixing step (a) is undertaken in a one-pot system.

13. The method of claim 11 or 12, wherein the curing step (b) is undertaken at a temperature in the range of 60 °C to 90 °C.

14. The method of any one of claims 11 to 13, wherein the curing step (b) is undertaken for a duration in the range of 2 hours to 8 hours.

15. A composite material having a polymeric network comprising a plurality of moieties, each moiety independently having a formula of:



wherein: each wavy bond represents a site of cross linking to another moiety;
l is an integer in the range of 2 to 4;
m is an integer in the range of 6 to 39; and
n is an integer in the range of 2 to 4.

16. The composite material of claim 15, which is in the form of a free-standing film.

17. The composite material of claim 15 or 16, which has an ion conductivity of more than 10^{-4} S/cm.

18. The composite material of any one of claims 15 to 17, which has a storage modulus of more than 7 MPa.

19. A capacitor comprising the composite material of any one of claims 15 to 18.