CLAIMS

1. A method of forming a polyimide aerogel, the method comprising:

providing an aqueous solution of a polyamic acid salt, the polyamic acid salt comprising a polyamic acid including carboxylic acid groups, wherein the carboxylic acid groups are associated with an alkali metal cation and are present as carboxylate anions, wherein providing the aqueous solution of the polyamic acid salt comprises: providing a polyamic acid; adding the polyamic acid to water to form an aqueous suspension of the polyamic acid; and adding an alkali metal hydroxide to the aqueous suspension of the polyamic acid to form the aqueous solution of the polyamic acid salt;

imidizing the polyamic acid salt to form a polyimide gel; and

drying the polyimide gel to form the polyimide aerogel.

2. The method of claim 1, wherein the alkali metal hydroxide is lithium hydroxide, sodium hydroxide, or potassium hydroxide.

3. The method of claim 1, wherein the polyamic acid comprises a tetracarboxylic acid selected from the group consisting of benzene-1,2,4,5-tetracarboxylic acid, [1,1'-biphenyl]-3,3',4,4'-tetracarboxylic acid, 4,4'-oxydiphthalic acid, 4,4'-sulfonyldiphthalic acid, 4,4'-carbonyldiphthalic acid, 4,4'-(propane-2,2-diyl)diphthalic acid, 4,4'-(perfluoropropane-2,2-diyl)diphthalic acid, naphthalene-1,4,5,8-tetracarboxylic acid, 4-(2-(4-(3,4-dicarboxyphenoxy)phenyl)propan-2-yl)phthalic acid, perylene tetracarboxylic acid, and combinations thereof.

4. The method of claim 1, wherein the polyamic acid comprises a C2-C6 alkylene diamine, wherein one or more carbon atoms of the C2-C6 alkylene are optionally substituted with one or more alkyl groups.

5. The method of claim 1, wherein the polyamic acid comprises 1,3-phenylenediamine, 1,4-phenylenediamine, 4,4'-methylenedianiline, 4,4'-diaminodiphenyl ether, or a combination thereof.

6. The method of claim 1, wherein the polyimide gel is in monolithic form, and wherein imidizing the polyamic acid salt comprises adding a dehydrating agent to the aqueous solution of the polyamic acid salt to form a gelation mixture, the method further comprising pouring the gelation mixture into a mold and allowing the gelation mixture to gel.

7. The method of claim 1, wherein the polyimide gel is in monolithic form, and wherein imidizing the polyamic acid salt is performed thermally, the method further comprising:

adding delta-gluconolactone to the aqueous solution of the polyamic acid salt to form a gelation mixture;

pouring the gelation mixture into a mold and allowing the gelation mixture to gel;

washing the resulting polyamic acid gel with water; and

thermally imidizing the polyamic acid gel to form the polyimide gel, the thermally imidizing comprising exposing the polyamic acid gel to microwave frequency irradiation.

8. The method of claim 1, wherein the polyimide gel is in bead form, and wherein imidizing the polyamic acid salt comprises adding a dehydrating agent to the aqueous solution of the polyamic acid salt to form a gelation mixture;

the method further comprising adding the gelation mixture to a solution of a water-soluble acid in water to form the polyimide gel beads, wherein adding comprises dripping the gelation mixture into the solution of the water soluble acid in water, spraying the gelation mixture under pressure through one or more nozzles into the solution of the water-soluble acid in water using pressure; or electrospraying the gelation mixture into the solution of the water soluble acid in water.

9. The method of claim 1, wherein the polyimide gel is in bead form, and wherein imidizing the polyamic acid salt comprises adding a dehydrating agent to the aqueous solution of the polyamic acid salt to form a gelation mixture;

the method further comprising adding the gelation mixture to a water-immiscible solvent, optionally comprising an acid, wherein adding comprises dripping the gelation mixture into the water-immiscible solvent, spraying the gelation mixture under pressure through one or more nozzles into the water-immiscible solvent using pressure; or electrospraying the gelation mixture into the water-immiscible solvent.

10. The method of claim 9, wherein the method comprises electrospraying the gelation mixture through one or more needles at a voltage in a range from 5 to 60 kV.

11. The method of claim 1, wherein the polyimide gel is in bead form, and wherein imidizing the polyamic acid salt comprises adding a dehydrating agent to the aqueous solution of the polyamic acid salt to form a gelation mixture, the method further comprising combining the gelation mixture with a water-immiscible solvent comprising a surfactant; and mixing the resulting mixture under high-shear conditions.

12. The method of claim 1, wherein the polyimide gel is in bead form, and wherein imidizing the polyamic acid salt comprises chemical imidization, the method comprising:

combining the aqueous solution of the polyamic acid salt with a water-immiscible solvent comprising a surfactant;

mixing the resulting mixture under high-shear conditions to form a quasi-stable emulsion; and

adding a dehydrating agent to the quasi-stable emulsion.

13. The method of claim 1, wherein providing an aqueous solution of a polyamic acid salt comprises:

dissolving a water-soluble diamine in water to form an aqueous diamine solution;

adding a non-nucleophilic amine to the aqueous diamine solution;

adding a tetracarboxylic acid dianhydride to the aqueous diamine solution; and

stirring the resulting solution for a period of time in a range from about 1 hour to about 24 hours at a temperature in a range from 15 to 60°C.

14. The method of claim 1, wherein providing an aqueous solution of a polyamic acid salt comprises:

dissolving a water-soluble diamine in water to form an aqueous diamine solution;

adding a tetracarboxylic acid dianhydride to the aqueous diamine solution;

stirring the resulting suspension for a period of time in a range from about 1 hour to about 24 hours at a temperature in a range from 15 to 60°C;

adding a non-nucleophilic amine to the aqueous diamine solution; and

stirring the resulting suspension for a period of time in a range from about 1 hour to about 24 hours at a temperature in a range from 15 to 60°C.

15. The method of claim 1, wherein providing an aqueous solution of a polyamic acid salt comprises:

adding to water, simultaneously or in rapid succession, a water-soluble diamine, a tetracarboxylic acid dianhydride, and a non-nucleophilic amine; and

stirring the resulting mixture for a period of time in a range from about 1 hour to about 24 hours at a temperature in a range from 15 to 60°C.

16. A method of forming a polyamic acid aerogel, the method comprising:

providing an aqueous solution of a polyamic acid salt;

acidifying the polyamic acid salt solution to form a polyamic acid gel; and

drying the polyamic acid gel to form the polyamic acid aerogel.

17. A method of forming a polyimide aerogel in a bead form, the method comprising:

providing an aqueous solution of a polyamic acid salt, the polyamic acid salt comprising a polyamic acid including carboxylic acid groups, wherein the carboxylic acid groups are associated with a cationic species and greater than 95% of the carboxylic acid groups are present as carboxylate anions;

imidizing the polyamic acid salt to form a polyimide gel, wherein the imidizing comprises adding a dehydrating agent to the aqueous solution of the polyamic acid salt to form a gelation mixture;

adding the gelation mixture to a water-immiscible solvent, wherein adding comprises dripping the gelation mixture into the water-immiscible solvent, spraying the gelation mixture under pressure through one or more nozzles into the water-immiscible solvent using pressure, or electrospraying the gelation mixture into the water-immiscible solvent; and

drying the polyamic acid gel to form the polyamic acid aerogel.

18. The method of any one of claims 1, 16, or 17, further comprising converting the polyimide aerogel to an isomorphic carbon aerogel, the converting comprising pyrolyzing the polyimide aerogel under inert atmosphere at a temperature of at least 650°C.

19. The method of any one of claims 1, 16, or 17, further comprising adding an electroactive material to the aqueous solution of the polyamic acid salt.

20. The method of any one of claims 1, 16, or 17, wherein the polyimide gel contains residual water in an amount greater than 75% by volume.