

FUNCTIONAL POLYAMIDES

[0001] The disclosed technology relates to functional polyamides which may be used to form high-molecular-weight polymers with desirable polyamide properties.

5 [0002] Polyamides with desirable properties, and which impart desirable properties to polymers made using the polyamides, have been disclosed, for example in WO 2014/126739 A1, entitled "Telechelic N-Alkylated Polyamide Polymers and Copolymers", include a significant proportion of tertiary amide linkages. Subsequent development of the technology disclosed in WO 2014/126739 A1 has found that it may be difficult to obtain a
10 high number of tertiary amide linkages in polyamides, depending on reaction conditions and other factors. When tertiary amide linkages are not maximized, there will likely be a number of secondary amide linkages. Secondary amide linkages may sometimes form intermolecular hydrogen bonds (that is, hydrogen bonds with other molecules), which may undesirably increase the viscosity of the polyamide and reduce its usefulness in reactions to
15 create polymers from the polyamide, by undesirably increasing the effective molecular weight of the polyamide. It has been found that secondary amide linkages may be incorporated into a molecule of the polyamide such that an intramolecular hydrogen bond is formed preferentially over an intermolecular hydrogen bond, which may at least partially prevent undesirable increases in the viscosity of the polyamide. While tertiary amide
20 linkages are desirable for their beneficial properties, as described in WO 2014/126739 A1, when it is not possible to create a polyamide with all (or mostly all) tertiary amide linkages, it is more desirable to create secondary amide linkages which will form intramolecular hydrogen bonds, as compared to those which would form intermolecular hydrogen bonds.

[0003] The disclosed technology, therefore, solves the problem of inadvertent increases
25 in effective molecular weight, and thereby viscosity, in a polyamide, by incorporating into the polyamide tertiary amide linkages and/or secondary amide linkages which will form intramolecular hydrogen bonds.

[0004] The subject matter disclosed herein provides a functional polyamide comprising monomeric units selected from at least one of lactams, aminocarboxylic acids,
30 aminoalcohols, polycarboxylic acids, or polyamines, wherein: (a) the monomeric units have an average of greater than two functional groups per monomeric unit; (b) the functional groups of the monomeric units comprise at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups; (c) at least a portion of the functional groups of the monomeric units react together to form linkages between the monomeric units,

forming molecules of the functional polyamide; (d) at least 30 percent of the linkages between the monomeric units are amide linkages; (e) at least 50 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group; and (f) the functional polyamide has a theoretical functionality of greater than two, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0005] The following embodiments of the present subject matter are contemplated:

[0006] 1. A functional polyamide comprising monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, wherein: (a) the monomeric units have an average of greater than two functional groups per monomeric unit; (b) the functional groups of the monomeric units comprise at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups; (c) at least a portion of the functional groups of the monomeric units react together to form linkages between the monomeric units, forming molecules of the functional polyamide; (d) at least 30 percent of the linkages between the monomeric units are amide linkages; (e) at least 50 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group; and (f) the functional polyamide has a theoretical functionality of greater than two, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0007] 2. The functional polyamide of embodiment 1, wherein at least 50 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

[0008] 3. The functional polyamide of either embodiment 1 or embodiment 2, wherein at least 60 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

[0009] 4. The functional polyamide of any one of embodiments 1 to 3, wherein at least 70 weight percent of the monomeric units of the functional polyamide are derived from

monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

5 [0010] 5. The functional polyamide of any one of embodiments 1 to 4, wherein at least 75 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

10 [0011] 6. The functional polyamide of any one of embodiments 1 to 5, wherein at least 80 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

15 [0012] 7. The functional polyamide of any one of embodiments 1 to 6, wherein at least 85 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

20 [0013] 8. The functional polyamide of any one of embodiments 1 to 7, wherein at least 90 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

25 [0014] 9. The functional polyamide of any one of embodiments 1 to 8, wherein at least 95 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

30 [0015] 10. The functional polyamide of any one of embodiments 1 to 9, wherein at least 99 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.

- 5 [0016] 11. The functional polyamide of any one of embodiments 1 to 10, wherein substantially all of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.
- [0017] 12. The functional polyamide of any one of embodiments 1 to 11, wherein the monomeric units have an average of from greater than 2 to 20 functional groups per monomeric unit.
- 10 [0018] 13. The functional polyamide of any one of embodiments 1 to 12, wherein the monomeric units have an average of from greater than 2 to 10 functional groups per monomeric unit.
- [0019] 14. The functional polyamide of any one of embodiments 1 to 13, wherein the monomeric units have an average of from greater than 2 to 5 functional groups per monomeric unit.
- 15 [0020] 15. The functional polyamide of any one of embodiments 1 to 14, wherein the monomeric units have an average of at least 3 functional groups per monomeric unit.
- [0021] 16. The functional polyamide of any one of embodiments 1 to 15, wherein the monomeric units have an average of from 3 to 20 functional groups per monomeric unit.
- [0022] 17. The functional polyamide of any one of embodiments 1 to 16, wherein the monomeric units have an average of from 3 to 10 functional groups per monomeric unit.
- 20 [0023] 18. The functional polyamide of any one of embodiments 1 to 17, wherein the monomeric units have an average of from 3 to 5 functional groups per monomeric unit.
- [0024] 19. The functional polyamide of any one of embodiments 1 to 18, wherein at least 50 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.
- 25 [0025] 20. The functional polyamide of any one of embodiments 1 to 19, wherein at least 60 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.
- 30 [0026] 21. The functional polyamide of any one of embodiments 1 to 20, wherein at least 70 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

[0027] 22. The functional polyamide of any one of embodiments 1 to 21, wherein at least 75 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

5 [0028] 23. The functional polyamide of any one of embodiments 1 to 22, wherein at least 80 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

[0029] 24. The functional polyamide of any one of embodiments 1 to 23, wherein at
10 least 85 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

[0030] 25. The functional polyamide of any one of embodiments 1 to 24, wherein at
15 least 90 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

[0031] 26. The functional polyamide of any one of embodiments 1 to 25, wherein at least 40 percent of the linkages between the monomeric units are amide linkages.

[0032] 27. The functional polyamide of any one of embodiments 1 to 26, wherein at
20 least 50 percent of the linkages between the monomeric units are amide linkages.

[0033] 28. The functional polyamide of any one of embodiments 1 to 27, wherein at least 60 percent of the linkages between the monomeric units are amide linkages.

[0034] 29. The functional polyamide of any one of embodiments 1 to 28, wherein at least 70 percent of the linkages between the monomeric units are amide linkages.

25 [0035] 30. The functional polyamide of any one of embodiments 1 to 29, wherein at least 75 percent of the linkages between the monomeric units are amide linkages.

[0036] 31. The functional polyamide of any one of embodiments 1 to 30, wherein at least 80 percent of the linkages between the monomeric units are amide linkages.

[0037] 32. The functional polyamide of any one of embodiments 1 to 31, wherein at
30 least 85 percent of the linkages between the monomeric units are amide linkages.

[0038] 33. The functional polyamide of any one of embodiments 1 to 32, wherein at least 90 percent of the linkages between the monomeric units are amide linkages.

[0039] 34. The functional polyamide of any one of embodiments 1 to 33, wherein at least 95 percent of the linkages between the monomeric units are amide linkages.

[0040] 35. The functional polyamide of any one of embodiments 1 to 34, wherein at least 55 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

5 [0041] 36. The functional polyamide of any one of embodiments 1 to 35, wherein at least 60 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0042] 37. The functional polyamide of any one of embodiments 1 to 36, wherein at
10 least 65 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0043] 38. The functional polyamide of any one of embodiments 1 to 37, wherein at
15 least 70 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0044] 39. The functional polyamide of any one of embodiments 1 to 38, wherein at
20 least 75 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0045] 40. The functional polyamide of any one of embodiments 1 to 39, wherein at
least 80 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

25 [0046] 41. The functional polyamide of any one of embodiments 1 to 40, wherein at least 85 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0047] 42. The functional polyamide of any one of embodiments 1 to 41, wherein at
30 least 90 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0048] 43. The functional polyamide of any one of embodiments 1 to 42, wherein the functional polyamide has a theoretical functionality of 3 or more.

[0049] 44. The functional polyamide of any one of embodiments 1 to 43, wherein the functional polyamide has a theoretical functionality of from greater than 2 to 30.

[0050] 45. The functional polyamide of any one of embodiments 1 to 44, wherein the functional polyamide has a theoretical functionality of from greater than 2 to 10.

5 [0051] 46. The functional polyamide of any one of embodiments 1 to 45, wherein the functional polyamide has a theoretical functionality of from 3 to 5.

[0052] 47. The functional polyamide of any one of embodiments 1 to 46, wherein the functionality in at least 75 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional,
10 or hydroxyl-functional.

[0053] 48. The functional polyamide of any one of embodiments 1 to 47, wherein the functionality in at least 80 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

15 [0054] 49. The functional polyamide of any one of embodiments 1 to 48, wherein the functionality in at least 85 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0055] 50. The functional polyamide of any one of embodiments 1 to 49, wherein the
20 functionality in at least 90 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0056] 51. The functional polyamide of any one of embodiments 1 to 50, wherein the
25 functionality in at least 95 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0057] 52. The functional polyamide of any one of embodiments 1 to 51, wherein the
30 functionality in at least 96 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0058] 53. The functional polyamide of any one of embodiments 1 to 52, wherein the functionality in at least 97 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0059] 54. The functional polyamide of any one of embodiments 1 to 53, wherein the functionality in at least 98 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

5 [0060] 55. The functional polyamide of any one of embodiments 1 to 54, wherein the functionality in at least 99 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

10 [0061] 56. The functional polyamide of any one of embodiments 1 to 55, wherein the functionality in substantially all molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0062] 57. The functional polyamide of any one of embodiments 1 to 56, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is hydroxyl-functional.

[0063] 58. The functional polyamide of any one of embodiments 1 to 57, wherein the functionality in at least 75 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

20 [0064] 59. The functional polyamide of any one of embodiments 1 to 58, wherein the functionality in at least 80 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0065] 60. The functional polyamide of any one of embodiments 1 to 59, wherein the functionality in at least 85 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

25 [0066] 61. The functional polyamide of any one of embodiments 1 to 60, wherein the functionality in at least 90 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

30 [0067] 62. The functional polyamide of any one of embodiments 1 to 61, wherein the functionality in at least 95 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0068] 63. The functional polyamide of any one of embodiments 1 to 62, wherein the functionality in at least 96 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0069] 64. The functional polyamide of any one of embodiments 1 to 63, wherein the functionality in at least 97 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

5 [0070] 65. The functional polyamide of any one of embodiments 1 to 64, wherein the functionality in at least 98 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0071] 66. The functional polyamide of any one of embodiments 1 to 65, wherein the functionality in at least 99 mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

10 [0072] 67. The functional polyamide of any one of embodiments 1 to 66, wherein the functionality in substantially all molecules of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0073] 68. The functional polyamide of any one of embodiments 1 to 67, wherein the functional polyamide has a number average molecular weight of from 200 to 10,000 g/mole.

15 [0074] 69. The functional polyamide of any one of embodiments 1 to 68, wherein the functional polyamide has a number average molecular weight of from 200 to 8,000 g/mole.

[0075] 70. The functional polyamide of any one of embodiments 1 to 69, wherein the functional polyamide has a number average molecular weight of from 200 to 6,000 g/mole.

20 [0076] 71. The functional polyamide of any one of embodiments 1 to 70, wherein the functional polyamide has a number average molecular weight of from 200 to 4,000 g/mole.

[0077] 72. The functional polyamide of any one of embodiments 1 to 71, wherein the functional polyamide has a number average molecular weight of from 300 to 10,000 g/mole.

[0078] 73. The functional polyamide of any one of embodiments 1 to 72, wherein the functional polyamide has a number average molecular weight of from 300 to 8,000 g/mole.

25 [0079] 74. The functional polyamide of any one of embodiments 1 to 73, wherein the functional polyamide has a number average molecular weight of from 300 to 6,000 g/mole.

[0080] 75. The functional polyamide of any one of embodiments 1 to 74, wherein the functional polyamide has a number average molecular weight of from 300 to 4,000 g/mole.

30 [0081] 76. The functional polyamide of any one of embodiments 1 to 75, wherein the functional polyamide has a number average molecular weight of from 400 to 10,000 g/mole.

[0082] 77. The functional polyamide of any one of embodiments 1 to 76, wherein the functional polyamide has a number average molecular weight of from 400 to 8,000 g/mole.

[0083] 78. The functional polyamide of any one of embodiments 1 to 77, wherein the functional polyamide has a number average molecular weight of from 400 to 6,000 g/mole.

[0084] 79. The functional polyamide of any one of embodiments 1 to 78, wherein the functional polyamide has a number average molecular weight of from 400 to 4,000 g/mole.

[0085] 80. The functional polyamide of any one of embodiments 1 to 79, wherein the functional polyamide has a number average molecular weight of from 500 to 10,000 g/mole.

5 [0086] 81. The functional polyamide of any one of embodiments 1 to 80, wherein the functional polyamide has a number average molecular weight of from 500 to 8,000 g/mole.

[0087] 82. The functional polyamide of any one of embodiments 1 to 81, wherein the functional polyamide has a number average molecular weight of from 500 to 6,000 g/mole.

10 [0088] 83. The functional polyamide of any one of embodiments 1 to 82, wherein the functional polyamide has a number average molecular weight of from 500 to 4,000 g/mole.

[0089] 84. The functional polyamide of any one of embodiments 1 to 83, wherein the functional polyamide has a viscosity of less than 100,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

15 [0090] 85. The functional polyamide of any one of embodiments 1 to 84, wherein the functional polyamide has a viscosity of less than 80,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

20 [0091] 86. The functional polyamide of any one of embodiments 1 to 85, wherein the functional polyamide has a viscosity of less than 60,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

25 [0092] 87. The functional polyamide of any one of embodiments 1 to 86, wherein the functional polyamide has a viscosity of less than 50,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

30 [0093] 88. The functional polyamide of any one of embodiments 1 to 87, wherein the functional polyamide has a viscosity of less than 40,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

[0094] 89. The functional polyamide of any one of embodiments 1 to 88, wherein the functional polyamide has a viscosity of less than 30,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

[0095] 90. The functional polyamide of any one of embodiments 1 to 89, wherein the functional polyamide has a viscosity of less than 20,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

5 [0096] 91. The functional polyamide of any one of embodiments 1 to 90, wherein the functional polyamide has a viscosity of less than 10,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

[0097] Various features and embodiments of the present subject matter will be described
10 below by way of non-limiting illustration.

[0098] The amount of each chemical component described herein is presented exclusive of any solvent or diluent oil, which may be customarily present in the commercial material, that is, on an active chemical basis, unless otherwise indicated. Unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial
15 grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade.

[0099] As used herein, the term “hydrocarbyl” refers to a group having a carbon atom directly attached to the remainder of the molecule, where the group includes at least carbon and hydrogen atoms. If the hydrocarbyl group comprises more than one carbon atom, then
20 those carbons need not necessarily be linked to each other. For example, at least two of the carbons may be linked via a suitable element or group. In various embodiments, the term “hydrocarbyl” refers to a group having a carbon atom directly attached to the remainder of the molecule, where the group consists of carbon, hydrogen, optionally one or more heteroatoms provided the heteroatoms do not alter the predominantly hydrocarbon nature
25 of the substituent. The heteroatom may link at least two of the carbons in the hydrocarbyl group, and optionally no more than two non-hydrocarbon substituents. Suitable heteroatoms will be apparent to those skilled in the art and include, for instance, sulphur, nitrogen, oxygen, phosphorus and silicon. Where the hydrocarbyl contains heteroatoms, optionally, no more than two heteroatoms will be present for every ten carbon atoms in the hydrocarbyl
30 group. Suitable non-hydrocarbon substituents will also be apparent to those skilled in the art and include, for instance, halo, hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulphony.

[0100] Examples of hydrocarbyls within the context of the present technology therefore include: (i) hydrocarbon groups selected from aliphatic (e.g. alkyl or alkenyl), alicyclic (e.g.

cycloalkyl, cycloalkenyl, cycloalkadienyl), and aromatic groups; (ii) substituted hydrocarbon groups, selected from hydrocarbon groups defined in (i) substituted with no more than two non-hydrocarbon substituents and/or one or more hydrocarbon substituents, the non-hydrocarbon substituents being selected from the group consisting of halo, hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulphoxy; and/or (iii) hetero-containing hydrocarbon groups, selected from hydrocarbon groups defined in (i) containing one or more heteroatom in the ring or chain, provided that the group has no more than two heteroatoms present for every ten carbon atoms in the group, the heteroatoms being selected from sulphur, nitrogen, oxygen, phosphorus and silicon. The hetero-containing hydrocarbon groups may be substituted with no more than two non-hydrocarbon substituents and/or one or more hydrocarbon substituents. In certain embodiments, the term “hydrocarbyl” refers to a group having a carbon atom directly attached to the remainder of the molecule, where the group consists of carbon and hydrogen atoms.

[0101] It is known that some of the materials described herein may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) may migrate to other acidic or anionic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present subject matter in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included within the scope of the present subject matter; the present subject matter encompasses the composition prepared by admixing the components described herein.

[0102] As used herein, the indefinite article “a”/“an” is intended to mean one or more than one. As used herein, the phrase “at least one” means one or more than one of the following terms. Thus, “a”/“an” and “at least one” may be used interchangeably. For example “at least one of A, B or C” means that just one of A, B or C may be included, and any mixture of two or more of A, B and C may be included, in alternative embodiments.

[0103] As used herein, the transitional term “comprising,” which is synonymous with “including,” “containing,” or “characterized by,” is inclusive or open-ended and does not exclude additional, un-recited elements or method steps. However, in each recitation of “comprising” herein, it is intended that the term also encompass, as alternative embodiments, the phrases “consisting essentially of” and “consisting of,” where “consisting of” excludes any element or step not specified and “consisting essentially of” permits the

inclusion of additional un-recited elements or steps that do not materially affect the essential or basic and novel characteristics of the composition or method under consideration.

[0104] Provided is a functional polyamide comprising monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, wherein: (a) the monomeric units have an average of greater than two functional groups per monomeric unit; (b) the functional groups of the monomeric units comprise at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups; (c) at least a portion of the functional groups of the monomeric units react together to form linkages between the monomeric units, forming molecules of the functional polyamide; (d) at least 30 percent of the linkages between the monomeric units are amide linkages; (e) at least 50 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group; and (f) the functional polyamide has a theoretical functionality of greater than two, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

[0105] As used herein, the term “functional”, in the context of a polyamide or monomeric unit, means a group on a molecule which will react with other groups; in the context of the polyamide, for example, a functional group on the polyamide will be capable of reacting with a group on another oligomer/macromonomer when forming a polymer based on the polyamide; in the context of a monomeric unit, for example, a functional group on a monomeric unit will be capable of reacting with other monomeric units to form the polyamide, and some functional groups on monomeric units may remain to create the functional groups on the polyamide (or the functional groups on the polyamide may result from other groups during reaction of the monomeric groups to form the polyamide).

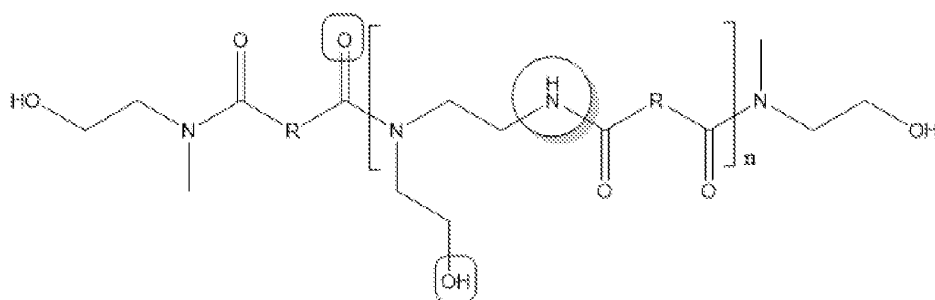
[0106] In the context of the terms “polyamide”, “polycarboxylic acid”, “polyamine”, the prefix “poly” means “more than one”.

[0107] The functional polyamide is described as comprising monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines. In this context, the term “polyamide” requires that a monomer with a functional group based on a nitrogen atom reacts with a monomer with a functional group based on an atom other than nitrogen. As such, while only one of the listed types of monomeric units is strictly required by this description, it is included in the definition of the

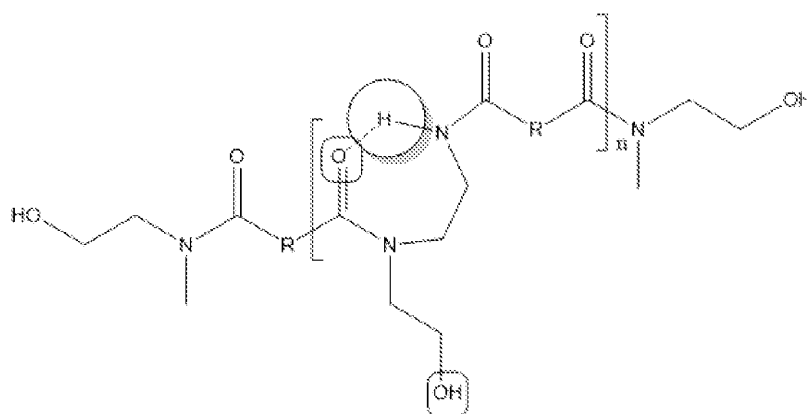
term “polyamide” that at least two monomeric units be reacted together to form the polyamide (one with a functional group including a nitrogen atom reacting with one with a functional groups including an atom other than nitrogen), and that there be at least two amide groups present in the polyamide.

- 5 [0108] Among the monomeric units specifically described herein, lactams are a somewhat special case, in that they may not be considered to have functional groups until they are ring-opened to be reacted into a polyamide. As such, for purposes of the present disclosure, it is considered that lactams include functional groups based on their structure after they are ring-opened to react with other monomeric units. Those of ordinary skill in
 10 the relevant art understand that lactams are used in reactions such as this, and that they ring-open before or during reaction with other monomeric units.

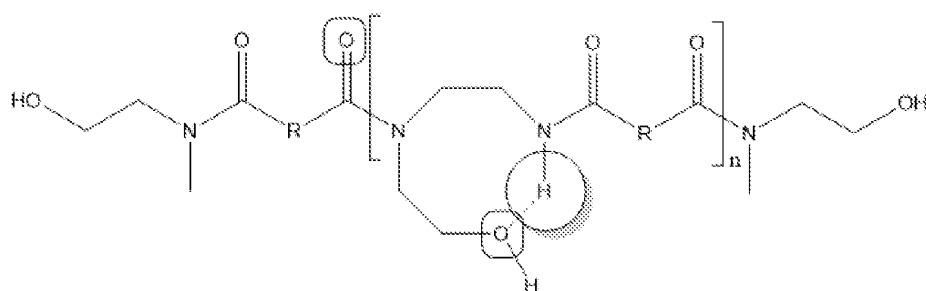
- [0109] In order to illustrate, in a non-limiting fashion, what is meant by intramolecular hydrogen bonds in the context of the present subject matter, the following illustrative chemical formulae may be considered. Formula 1 includes circled locations where
 15 intramolecular hydrogen bonds may form, and Formulas 2 and 3 show equilibrium states of Formula 1 including the intramolecular hydrogen bonds.



(1)

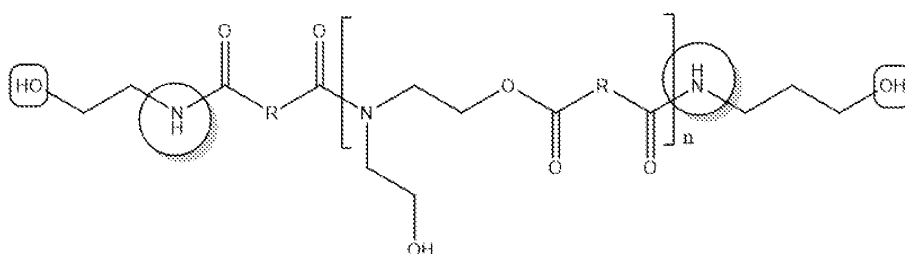


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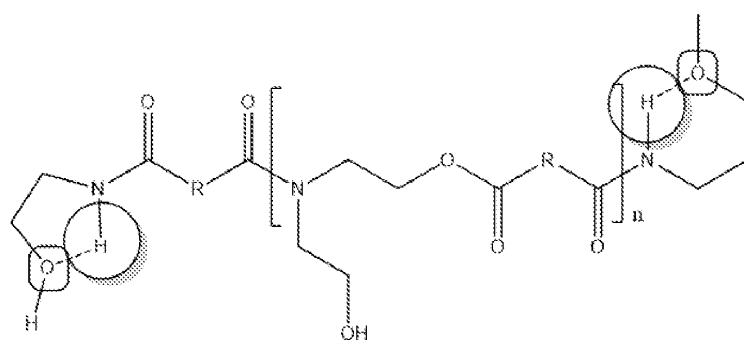


(3)

[0110] Similarly, Formula 4 includes circled locations where intramolecular hydrogen bonds may form, and Formula 5 shows an equilibrium state of Formula 4 including the intramolecular hydrogen bonds.



(4)



(5)

[0111] In the various permutations of the present subject matter, there are many possibilities of where intramolecular hydrogen bonds could form. A general guideline is that an intramolecular hydrogen bond may form at sites like those shown in Formulae 1 through 5, when the sites are within roughly 5 to 8 atoms of one another; this allows for enough proximity that the intramolecular hydrogen bond will form somewhat readily, and in preference to forming an intermolecular hydrogen bond. With this guidance, a person of ordinary skill in the relevant art would understand how to determine whether intramolecular hydrogen bonds may form in a specific embodiment of the present subject matter.

[0112] In certain embodiments, at least 50 (such as at least 55, at least 60, at least 65, at least 70, at least 75, at least 80, at least 85, at least 90, at least 95, at least 96, at least 97, at least 98, or at least 99) weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide. In certain embodiments, substantially all of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide. In certain embodiments, from 50 to substantially all (such as from 50 to 99, from 50 to 98, from 50 to 97, from 50 to 96, from 50 to 95, from 50 to 90, from 50 to 85, from 50 to 80, from 50 to 75, from 50 to 70, from 50 to 65, from 50 to 60, from 50 to 55, from 55 to substantially all, from 55 to 99, from 55 to 98, from 55 to 97, from 55 to 96, from 55 to 95, from 55 to 90, from 55 to 85, from 55 to 80, from 55 to 75, from 55 to 70, from 55 to 65, from 55 to 60, from 60 to substantially all, from 60 to 99, from 60 to 98, from 60 to 97, from 60 to 96, from 60 to 95, from 60 to 90, from 60 to 85, from 60 to 80, from 60 to 75, from 60 to 70, from 60 to 65, from 65 to substantially all, from 65 to 99, from 65 to 98, from 65 to 97, from 65 to 96, from 65 to 95, from 65 to 90, from 65 to 85, from 65 to 80, from 65 to 75, from 65 to 70, from 70 to substantially all, from 70 to 99, from 70 to 98, from 70 to 97, from 70 to 96, from 70 to 95, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75 to substantially all, from 75 to 99, from 75 to 98, from 75 to 97, from 75 to 96, from 75 to 95, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to substantially all, from 80 to 99, from 80 to 98, from 80 to 97, from 80 to 96, from 80 to 95, from 80 to 90, from 80 to 85, from 85 to substantially all, from 85 to 99, from 85 to 98, from 85 to 97, from 85 to 96, from 85 to 95, from 85 to 90, from 90 to substantially all, from 90 to 99, from 90 to 98, from 90 to 97, from 90 to 96, from 90 to 95, from 95 to substantially all, from 95 to 99, from 95 to 98, from 95 to 97, from 95 to 96, from 96 to substantially all, from 96 to 99, from 96 to 98, from 96 to 97, from 97 to substantially all, from 97 to 99, from 97 to 98, from 98 to substantially all, from 98 to 99, or from 99 to substantially all) of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide. Those of ordinary skill in the relevant art understand that commercially-available monomeric units which would be suitable for use herein generally include impurities; such impurities are not considered when referring to “the total weight of

the functional polyamide”. Further, when creating the polyamide, small amounts of other materials may be used, which may end up reacting into the polyamide at very low levels, and these also are not considered when referring to “the total weight of the functional polyamide”. This also bears on the term “substantially all”, which, in this context, would mean that impurities and small amounts of other additives may be present, but that monomeric units other than those listed are not intentionally added.

[0113] In certain embodiments, the monomeric units have an average of greater than two functional groups per monomeric unit. In certain embodiments, the monomeric units have at least three functional groups per monomeric unit. In certain embodiments, the monomeric units have from 2 to 20 (such as from 2 to 19, from 2 to 18, from 2 to 17, from 2 to 16, from 2 to 15, from 2 to 14, from 2 to 13, from 2 to 12, from 2 to 11, from 2 to 10, from 2 to 9, from 2 to 8, from 2 to 7, from 2 to 6, from 2 to 5, from 2 to 4, from 2 to 3, from 3 to 20, from 3 to 19, from 3 to 18, from 3 to 17, from 3 to 16, from 3 to 15, from 3 to 14, from 3 to 13, from 3 to 12, from 3 to 11, from 3 to 10, from 3 to 9, from 3 to 8, from 3 to 7, from 3 to 6, from 3 to 5, from 3 to 4, from 4 to 20, from 4 to 19, from 4 to 18, from 4 to 17, from 4 to 16, from 4 to 15, from 4 to 14, from 4 to 13, from 4 to 12, from 4 to 11, from 4 to 10, from 4 to 9, from 4 to 8, from 4 to 7, from 4 to 6, from 4 to 5, from 5 to 20, from 5 to 19, from 5 to 18, from 5 to 17, from 5 to 16, from 5 to 15, from 5 to 14, from 5 to 13, from 5 to 12, from 5 to 11, from 5 to 10, from 5 to 9, from 5 to 8, from 5 to 7, from 5 to 6, from 6 to 20, from 6 to 19, from 6 to 18, from 6 to 17, from 6 to 16, from 6 to 15, from 6 to 14, from 6 to 13, from 6 to 12, from 6 to 11, from 6 to 10, from 6 to 9, from 6 to 8, from 6 to 7, from 7 to 20, from 7 to 19, from 7 to 18, from 7 to 17, from 7 to 16, from 7 to 15, from 7 to 14, from 7 to 13, from 7 to 12, from 7 to 11, from 7 to 10, from 7 to 9, from 7 to 8, from 8 to 20, from 8 to 19, from 8 to 18, from 8 to 17, from 8 to 16, from 8 to 15, from 8 to 14, from 8 to 13, from 8 to 12, from 8 to 11, from 8 to 10, from 8 to 9, from 9 to 20, from 9 to 19, from 9 to 18, from 9 to 17, from 9 to 16, from 9 to 15, from 9 to 14, from 9 to 13, from 9 to 12, from 9 to 11, from 9 to 10, from 10 to 20, from 10 to 19, from 10 to 18, from 10 to 17, from 10 to 16, from 10 to 15, from 10 to 14, from 10 to 13, from 10 to 12, from 10 to 11, from 11 to 20, from 11 to 19, from 11 to 18, from 11 to 17, from 11 to 16, from 11 to 15, from 11 to 14, from 11 to 13, from 11 to 12, from 12 to 20, from 12 to 19, from 12 to 18, from 12 to 17, from 12 to 16, from 12 to 15, from 12 to 14, from 12 to 13, from 13 to 20, from 13 to 19, from 13 to 18, from 13 to 17, from 13 to 16, from 13 to 15, from 13 to 14, from 14 to 20, from 14 to 19, from 14 to 18, from 14 to 17, from 14 to 16, from 14 to 15, from 15 to 20, from 15 to 19, from 15 to 18, from 15 to 17, from 15 to 16, from 16 to

20, from 16 to 19, from 16 to 18, from 16 to 17, from 17 to 20, from 17 to 19, from 17 to 18, from 18 to 20, from 18 to 19, or from 19 to 20) functional groups per monomeric unit.

[0114] In certain embodiments, at least 50 (such as at least 55, at least 60, at least 65, at least 70, at least 75, at least 80, at least 85, or at least 90) percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups. In certain embodiments, from 50 to 90 (such as from 50 to 85, from 50 to 80, from 50 to 75, from 50 to 70, from 50 to 65, from 50 to 60, from 50 to 55, from 55 to 90, from 55 to 85, from 55 to 80, from 55 to 75, from 55 to 70, from 55 to 65, from 55 to 60, from 60 to 90, from 60 to 85, from 60 to 80, from 60 to 75, from 60 to 70, from 60 to 65, from 65 to 90, from 65 to 85, from 65 to 80, from 65 to 75, from 65 to 70, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to 90, from 80 to 85, or from 85 to 90) percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

[0115] In certain embodiments, at least 30 (such as at least 35, at least 40, at least 45, at least 50, at least 55, at least 60, at least 65, at least 70, at least 75, at least 80, at least 85, at least 90, or at least 95) percent of the linkages between the monomeric units are amide linkages. In certain embodiments, from 30 to 95 (such as from 30 to 90, from 30 to 85, from 30 to 80, from 30 to 75, from 30 to 70, from 30 to 65, from 30 to 60, from 30 to 55, from 30 to 50, from 30 to 45, from 30 to 40, from 30 to 35, from 35 to 95, from 35 to 90, from 35 to 85, from 35 to 80, from 35 to 75, from 35 to 70, from 35 to 65, from 35 to 60, from 35 to 55, from 35 to 50, from 35 to 45, from 35 to 40, from 40 to 95, from 40 to 90, from 40 to 85, from 40 to 80, from 40 to 75, from 40 to 70, from 40 to 65, from 40 to 60, from 40 to 55, from 40 to 50, from 40 to 45, from 45 to 95, from 45 to 90, from 45 to 85, from 45 to 80, from 45 to 75, from 45 to 70, from 45 to 65, from 45 to 60, from 45 to 55, from 45 to 50, from 50 to 95, from 50 to 90, from 50 to 85, from 50 to 80, from 50 to 75, from 50 to 70, from 50 to 65, from 50 to 60, from 50 to 55, from 55 to 95, from 55 to 90, from 55 to 85, from 55 to 80, from 55 to 75, from 55 to 70, from 55 to 65, from 55 to 60, from 60 to 95, from 60 to 90, from 60 to 85, from 60 to 80, from 60 to 75, from 60 to 70, from 60 to 65, from 65 to 95, from 65 to 90, from 65 to 85, from 65 to 80, from 65 to 75, from 65 to 70, from 70 to 95, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75 to 95, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to 95, from 80 to 90, from 80 to 85, from 85 to 95, from 85 to 90, or from 90 to 95) percent of the linkages between the monomeric units are amide linkages.

[0116] In certain embodiments, at least 50 (such as at least 55, at least 60, at least 65, at least 70, at least 75, at least 80, at least 85, or at least 90) percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group. In certain embodiments, from 50 to 90 (such as from 50 to 85, from 50 to 80, from 50 to 75, from 50 to 70, from 50 to 65, from 50 to 60, from 50 to 55, from 55 to 90, from 55 to 85, from 55 to 80, from 55 to 75, from 55 to 70, from 55 to 65, from 55 to 60, from 60 to 90, from 60 to 85, from 60 to 80, from 60 to 75, from 60 to 70, from 60 to 65, from 65 to 90, from 65 to 85, from 65 to 80, from 65 to 75, from 65 to 70, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to 90, from 80 to 85, or from 85 to 90) percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

[0117] In certain embodiments, the functional polyamide has a theoretical functionality of greater than two (such as 3 or more, or 4 or more). In certain embodiments, the functional polyamide has a theoretical functionality of from greater than 2 to 30 (such as from greater than 2 to 25, from greater than 2 to 20, from greater than 2 to 15, from greater than 2 to 10, from greater than 2 to 9, from greater than 2 to 8, from greater than 2 to 7, from greater than 2 to 6, from greater than 2 to 5, from 3 to 30, from 3 to 25, from 3 to 20, from 3 to 15, from 3 to 10, from 3 to 9, from 3 to 8, from 3 to 7, from 3 to 6, from 3 to 5, from 4 to 30, from 4 to 25, from 4 to 20, from 4 to 15, from 4 to 10, from 4 to 9, from 4 to 8, from 4 to 7, from 4 to 6, or from 4 to 5). It has been found that polyamides with just two functionalities may not completely react with other oligomers/macromonomers to form cured polymers. Thus, a polyamide with greater than two functionalities may improve curing over polyamides with just two functionalities, and thereby provide better properties to the resulting cured polymer.

[0118] In certain embodiments, the functionality is at least 70 (such as at least 75, at least 80, at least 85, at least 90, at least 95, at least 96, at least 97, at least 98, or at least 99, or 100) mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional. In certain embodiments, the functionality in substantially all molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional. In certain embodiments, the functionality is from 70 to 100 (such as from 70 to 99, from 70 to 98, from 70 to 97, from 70 to 96, from 70 to 95, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75

to 100, from 75 to 99, from 75 to 98, from 75 to 97, from 75 to 96, from 75 to 95, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to 100, from 80 to 99, from 80 to 98, from 80 to 97, from 80 to 96, from 80 to 95, from 80 to 90, from 80 to 85, from 85 to 100, from 85 to 99, from 85 to 98, from 85 to 97, from 85 to 96, from 85 to 95, from 85 to 90, from 90 to 100, from 90 to 99, from 90 to 98, from 90 to 97, from 90 to 96, from 90 to 95, from 95 to 100, from 95 to 99, from 95 to 98, from 95 to 97, from 95 to 96, from 96 to 100, from 96 to 99, from 96 to 98, from 96 to 97, from 97 to 100, from 97 to 99, from 97 to 98, from 98 to 100, from 98 to 99, or from 99 to 100) mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional. In certain embodiments, the functionality in from 70 (such as from 75, from 80, from 85, from 90, from 95, from 96, from 97, from 98, or from 99) mole percent of molecules, to substantially all molecules, of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional. When stating that the functionality of a molecule of the polyamide is of the same functional type, what is meant that each functional group on the polyamide is of the same type; when stating that a certain mole percentage of molecules have functionality of the same type, what is meant is that each individual molecule includes functionalities which are all the same type, but it is possible that each individual molecule could have a different functionality from another molecule. For example, if 35 mole percent of molecules of the polyamide have hydroxyl-functionality, and 35 mole percent of molecules of the polyamide have amino-functionality, 70 mole percent of molecules of the functional polyamide would be of the same functional type. That being said, it is also contemplated that the functionality of all molecules of the polyamide would be of the same functional type, for example 70 mole percent could be hydroxyl-functional.

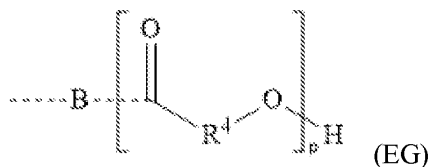
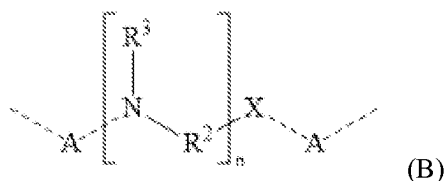
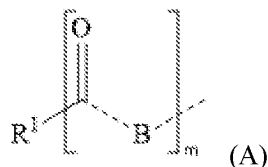
[0119] In certain embodiments, the functionality in at least 70 (such as at least 75, at least 80, at least 85, at least 90, at least 95, at least 96, at least 97, at least 98, or at least 99, or 100) mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional. In certain embodiments, the functionality in substantially all molecules of the functional polyamide is of the same functional type and is hydroxyl-functional. In certain embodiments, the functionality in from 70 to 100 (such as from 70 to 99, from 70 to 98, from 70 to 97, from 70 to 96, from 70 to 95, from 70 to 90, from 70 to 85, from 70 to 80, from 70 to 75, from 75 to 100, from 75 to 99, from 75 to 98, from 75 to 97, from 75 to 96, from 75 to 95, from 75 to 90, from 75 to 85, from 75 to 80, from 80 to 100, from 80 to 99, from 80 to 98, from 80 to 97, from 80 to 96, from 80 to 95, from 80 to

90, from 80 to 85, from 85 to 100, from 85 to 99, from 85 to 98, from 85 to 97, from 85 to 96, from 85 to 95, from 85 to 90, from 90 to 100, from 90 to 99, from 90 to 98, from 90 to 97, from 90 to 96, from 90 to 95, from 95 to 100, from 95 to 99, from 95 to 98, from 95 to 97, from 95 to 96, from 96 to 100, from 96 to 99, from 96 to 98, from 96 to 97, from 97 to 100, from 97 to 99, from 97 to 98, from 98 to 100, from 98 to 99, or from 99 to 100) mole percent of molecules of the functional polyamide is of the same functional type and is hydroxyl-functional. In certain embodiments, the functionality in from 70 (such as from 75, from 80, from 85, from 90, from 95, from 96, from 97, from 98, or from 99) mole percent of molecules, to substantially all molecules, of the functional polyamide is of the same functional type and is hydroxyl-functional.

[0120] In certain embodiments, the functional polyamide has a number average molecular weight of from 200 (such as from 300, from 400, from 500, from 600, from 700, from 800, from 900, or from 1,000) to 10,000 (such as to 9,000, to 8,000, to 7,000, to 6,000, to 5,000, to 4,000, to 3,000, or to 2,000) g/mole. Number average molecular weights described herein may be measured using gel permeation chromatography (GPC) using a Waters GPC 2000 equipped with a refractive index detector and Waters Empower® data acquisition and analysis software. Samples were run against polystyrene calibration standards. The columns are polystyrene (PLgel, 5 micron, available from Agilent/Polymer Laboratories, Inc.). For the mobile phase, individual samples are dissolved in tetrahydrofuran and filtered with PTFE filters before they are injected into the GPC port. Waters GPC 2000 Operating Conditions: Injector, Column, and Pump/Solvent compartment temperatures, 40° C; Autosampler Control: Run time, 40 minutes; Injection volume, 300 microliter; Pump, System pressure, ~90 bars (maximum pressure limit, 270 bars; minimum pressure limit, 0 psi); Flow rate, 1.0 ml/minute; Differential Refractometer, Sensitivity, -16; Scale factor: 6.

[0121] In certain embodiments, the functional polyamide has a viscosity of less than 100,000 (such as less than 90,000, less than 80,000, less than 70,000, less than 60,000, less than 50,000, less than 40,000, less than 30,000, less than 20,000, or less than 10,000) cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm. In general, room temperature is considered to be about 20 to about 25 °C, and within that range, it is expected that these viscosity measurements would not significantly vary. However, in certain embodiments, room temperature may mean any one temperature within the range of from about 20 to about 25 °C.

[0122] In certain embodiments, the functional polyamide has an acid fragment (A) as follows, connected to an amine fragment (B) as follows, which is terminated by an end group fragment (EG) as follows:



wherein, independently for each fragment and each instance of each variable in each fragment: R^1 is a 2- to 36-carbon hydrocarbyl group; B is where the (A) fragment or the (EG) fragment connects to the (B) fragment; m is an integer of from 1 to 3; A is where the (A) fragment connects to the (B) fragment; R^2 is a 2- to 36-carbon hydrocarbyl group; R^3 is H, a 1- to 12-carbon hydrocarbyl group, $\text{R}^5\text{-O-H}$, or $\text{R}^5\text{-O-(A)}$ (wherein R^5 is a 2- to 36-carbon hydrocarbyl group, and (A) is where an (A) fragment connects to the (B) fragment via the $\text{R}^5\text{-O}$ linkage); n is an integer of from 1 to 4; X is O or NR^3 ; R^4 is a 3- to 7-carbon hydrocarbyl group; and p is 0 or an integer of from 1 to 5.

[0123] In certain embodiments, fragment (A) represents a hydrocarbyl group with from 1 to 3 carboxyl-derived groups as functionalities anywhere on the hydrocarbyl group, as opposed to a hydrocarbyl group with 1 to 3 repeating carboxyl-derived groups. In certain embodiments, the “X” in fragment (B) could be OH to provide a functional group for the polyamide, rather than joining to another (A) fragment.

[0124] The embodiment depicted by end group segment (EG), above, represents a hydroxyl-functional end group for the polyamide. Similar embodiments including other end groups are possible as set forth herein.

[0125] With regard to the number of each of segments (A), (B), and (EG), any permutations are possible which would result in a polyamide as described herein. In certain embodiments, the hydroxyl number of the resulting polyamide is from 3 to 400 mg KOH/g.

[0126] The percent of tertiary amide linkages of the total number of amide linkages may be calculated using the following equation:

$$\text{Tertiary amide linkage \%} = \frac{\sum_{i=1}^n (w_{tertN,i} \times n_i)}{\sum_{i=1}^n (w_{totalN,i} \times n_i)} \times 100$$

5 where n is the number of monomers, the index i refers to a certain monomer, w_{tertN} is the average number nitrogen atoms in a monomer that form or are part of tertiary amide linkages in the polymerizations, (note: end-group forming amines do not form amide groups during the polymerizations and their amounts are excluded from w_{tertN}), w_{totalN} is the average number nitrogen atoms in a monomer that form or are part of tertiary amide linkages in the
10 polymerizations (note: the end-group forming amines do not form amide groups during the polymerizations and their amounts are excluded from w_{totalN}), and n_i is the number of moles of the monomer with the index i .

[0127] The percent of amide linkages of the total number of all heteroatom containing linkages (connecting hydrocarbon linkages) may be calculated using the following equation:

$$15 \quad \text{Amide linkage \%} = \frac{\sum_{i=1}^n (w_{totalN,i} \times n_i)}{\sum_{i=1}^n (w_{totalS,i} \times n_i)} \times 100$$

where w_{totalS} is the sum of the average number of heteroatom containing linkages (connecting hydrocarbon linkages) in a monomer and the number of heteroatom containing linkages (connecting hydrocarbon linkages) forming from that monomer by the reaction with a carboxylic acid bearing monomer during the polyamide polymerizations.
20 “Hydrocarbon linkages” are just the hydrocarbon portion of each repeat unit formed from continuous carbon to carbon bonds (i.e. without heteroatoms such as nitrogen or oxygen) in a repeat unit. This hydrocarbon portion would be the ethylene or propylene portion of ethylene oxide or propylene oxide; the undecyl group of dodecylactam, the ethylene group of ethylenediamine, and the $(CH_2)_4$ (or butylene) group of adipic acid.

25 [0128] The percent of secondary amide linkages capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group (“Linkage %”) may be calculated using the following equation:

$$\text{Linkage \%} = \frac{\sum_{i=1}^n (w_{intraN,i} \times n_i)}{\sum_{i=1}^n (w_{totalN,i} \times n_i)} \times 100$$

30 where $w_{intraN,i}$ refers to the weight fraction of an amide group capable of forming intramolecular hydrogen bonds due to the presence of carbonyl, alcohol or amine

groups in the vicinity of that amide group. Intramolecular hydrogen bonds can form when the distance of a hydrogen connected to the nitrogen atom of a secondary amide group is 4 to 7, or most optimally 4 to 5 bonds away from an atom carrying lone electron pairs that are capable of forming strong intramolecular hydrogen bonds with the said hydrogen atom due to the stabilizing effect of 5 or 8, or most optimally 5 to 6 membered rings. The atom carrying the lone electron pair is preferably an alcohol or carbonyl type of oxygen or an amine type of nitrogen and the spacer between said hydrogen atom and the atom carrying the lone electron pair is preferably hydrocarbon.

[0129] Uses of the polyamides described herein are described in WO 2014/126739 A1, which also described methods of making the polyamides.

[0130] The subject matter disclosed herein may be better understood with reference to the following examples, which are set forth merely to further illustrate the subject matter disclosed herein. The illustrative examples should not be construed as limiting the subject matter in any manner.

[0131] Examples 1 through 8 were prepare according to the following descriptions, with amounts of each component (in grams) being shown in Table 1.

Table 1

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8
Hydrogenated dimer acid	1605.4	394.2	617.1	929.6	757.9	2790.8	856.6	1089.9
N-methylethanolamine	210.8					269.6		
Hydroxyethylethylenediamine	292.2					339.8		
Caprolactone	1281.2	631.3	494.1	186.1	379.3			
Bis(hexamethylene)triamine		297.9						
Diethanolamine			227.6	171.4	209.6		263.2	201
Piperazine				70.2				82.3
Maleic anhydride								9.4
Heat stabilizer*	0.96	1.44	0.23	1.36	1.11	0.56	1.67	1.59
Methylamylketone						799.4	351.2	288.2

*The heat stabilizer was BRUGGOLEN® H10, from L. Brüggemann GmbH & Co. KG, Heilbronn, Germany.

5 **[0132]** Example 1: Hydrogenated dimer acid, N-(2-hydroxyethyl)ethylenediamine, N-methylethanolamine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 150 °C, and held at 500 mbar for 48 h. Caprolactone was charged and reacted at 160 °C for 3h, then at 180 °C for 8 h at atmospheric pressure. The pressure was reduced to 4 mbar for 1 h, then
10 the batch was cooled to 50 °C. The product is a clear viscous liquid at 50 °C.

15 **[0133]** Example 2: Bis(hexamethylene)triamine, Hydrogenated dimer acid and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was repeatedly vacuumed and filled with nitrogen at 50 °C, then the temperature was increased to 180 °C at 50 mbar pressure and the charge was reacted for 24 h. The
15 pressure was reduced to 4 mbar for 1 h then the batch was cooled to 50 °C. The product is a clear viscous liquid at 50 °C.

20 **[0134]** Example 3: Hydrogenated dimer acid, diethanolamine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 100 °C under 50 mbar pressure and held for 20 h. Then, deoxygenated caprolactone was added to the reactor and the polyol was reacted at 140 °C for 8 h with a nitrogen blanket at atmospheric pressure. The batch was cooled to 50 °C, the product is a clear viscous liquid at 50 °C.

25 **[0135]** Example 4: Hydrogenated dimer acid, piperazine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was

flushed with nitrogen, heated to 180 °C for 1h, the pressure was reduced to 50 mbar and held for two hours. The temperature was lowered to 80 °C and the reactor pressure was changed to atmospheric using nitrogen. Diethanolamine was charged and the reactor was heated to 130 °C and held at 30 mbar pressure for 16 h. The reactor was flushed with nitrogen, then caprolactone was deoxygenated via nitrogen sparge and was charged to the reactor and reacted for 16 h. The batch was cooled to 50 °C, the product is a clear viscous liquid at 50 °C.

[0136] Example 5: Hydrogenated dimer acid, diethanolamine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 130 °C under 50 mbar pressure and held for 20 h. Then deoxygenated caprolactone was added to the reactor and the polyol was reacted at 150 °C for 12 h at atmospheric pressure under nitrogen atmosphere. The batch was cooled to 50 °C, the product is a clear viscous liquid at 50 °C.

[0137] Example 6: Hydrogenated dimer acid, N-(2-hydroxyethyl)ethylenediamine, N-methylethanolamine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 150 °C and held for 6 h at atmospheric pressure, then at 500 mbar for 24 h and then reduced to 40 mbar for 1 h. The reactor was filled with nitrogen and cooled to 50 °C. Methyl amyl ketone was charged and mixed for 1 h at 50 °C. The batch was then cooled to room temperature. The product is a clear viscous liquid at room temperature.

[0138] Example 7: Hydrogenated dimer acid, diethanolamine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 130 °C under 50 mbar pressure and held for 20 h. Then the reactor was filled with nitrogen and the batch was cooled to 50 °C. Methyl amyl ketone was charged and mixed for 1 h at 50 °C. The batch was then cooled to room temperature. The product is a clear viscous liquid at room temperature.

[0139] Example 8: Hydrogenated dimer acid, piperazine and heat stabilizer were charged to a reactor equipped with a column (Vigreux) and a condenser. The reactor was flushed with nitrogen, heated to 180 °C for 1 h, then the pressure was reduced to 50 mbar and was held for two hours. The temperature was lowered to 80 °C, and the reactor pressure was changed to atmospheric using nitrogen. Diethanolamine was charged and the reactor was heated to 130 °C and held at 30 mbar pressure for 16 h. The reactor was filled with nitrogen, then caprolactone was deoxygenated using nitrogen sparge and charged to the reactor. The caprolactone was reacted for 16 h. The batch was cooled to 50 °C, methyl amyl

ketone and maleic anhydride were charged and mixed for 1 h. The batch was then cooled to room temperature. The product is a clear viscous liquid at room temperature.

[0140] Examples 1 through 8 were tested for various physical properties, with results shown in Table 2.

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Table 2

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8
Amine # (mgKOH/g)	10.3	32.8	6.84	10.3	8.3	20.5	22.5	22.7
Brookfield viscosity (cP)	2310	23500	49000	185000	344000	18200	17500	38500
Temp. for viscosity (°C)	RT	50	RT	50	50	RT	RT	RT
Solid % for viscosity	100	100	100	100	100	80.5	78.5	79
Color (Gardner)		4	11	2	4	0	0	0
OH # (mgKOH/g)	104.8	80.8	127.24	117.2	104.05	86	128.7	95.2
Mn (GPC) (g/mol)	1339	2133	2258	1822	3645	2933	2941	2165
Theoretical functionality	3.0	4.0	4.0	4.0	5.0	3.7	4.5	4.2

[0141] Amine number, expressed in mgKOH/g, was determined by titrating an isopropanol solution of the sample with 1N HCl solution in water using bromophenol blue indicator. Brookfield viscosity (cP) was determined using a DV-E Brookfield viscometer (using a circular spindle at 5 or 10 rpm), at the temperature and % solids noted in Table 2. Color was determined using the Gardner color scale. OH number (mgKOH/g) was tested according to ASTM D4274 or ASTM E1899. Molecular weight (Mn, g/mol) was determined using an Agilent Plgel 5u, 2x Mixed C column set in THF mobile phase at 1 mL/min flow rate with a Waters 2414 RI Detector at 40 °C. Theoretical functionality was calculated by the following equation:

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$$F = (\sum n_{OH} + \sum n_{NH}) / (\sum (n_{Amines} + n_{Aminoalcohols} - n_{Acids}))$$

where n_{OH} are moles of hydroxyl groups, n_{NH} are moles of amine groups, n_{Amines} are moles of amine-type monomers, $n_{Aminoalcohols}$ are moles of aminoalcohol-type monomers, and n_{Acids} are moles of diacid- and anhydride-type monomers, which are calculated from the weight charges and the corresponding molecular weights of the monomers used in each Example.

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[0142] Except in the Examples, or where otherwise explicitly indicated or required by context, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word “about”. As used herein, the term “about” means that a value of a given quantity is within $\pm 20\%$ of the stated value. In other embodiments, the value is within $\pm 15\%$ of the stated value. In other embodiments, the value is within $\pm 10\%$ of the stated

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value. In other embodiments, the value is within $\pm 5\%$ of the stated value. In other
embodiments, the value is within $\pm 2.5\%$ of the stated value. In other embodiments, the
value is within $\pm 1\%$ of the stated value. In other embodiments, the value is within a range
of the explicitly-described value which would be understood by those of ordinary skill,
5 based on the disclosures provided herein, to perform substantially similarly to compositions
including the literal amounts described herein.

[0143] It is to be understood that the upper and lower amount, range, and ratio limits set
forth herein may be independently combined, and that any amount within a disclosed range
is contemplated to provide a minimum or maximum of a narrower range in alternative
10 embodiments (with the proviso, of course, that the minimum amount of a range must be
lower than the maximum amount of the same range). Similarly, the ranges and amounts for
each element of the subject matter disclosed herein may be used together with ranges or
amounts for any of the other elements.

[0144] While certain representative embodiments and details have been shown for the
15 purpose of illustrating the subject matter disclosed herein, it will be apparent to those skilled
in this art that various changes and modifications may be made therein without departing
from the scope of the subject matter. In this regard, the scope of the invention is to be
limited only by the following claims.

What is claimed is:

1. A functional polyamide comprising monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, wherein:
 - 5 a. the monomeric units have an average of greater than two functional groups per monomeric unit;
 - b. the functional groups of the monomeric units comprise at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups;
 - c. at least a portion of the functional groups of the monomeric units react together to
10 form linkages between the monomeric units, forming molecules of the functional polyamide;
 - d. at least 30 percent of the linkages between the monomeric units are amide linkages;
 - e. at least 50 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages capable of individually forming an intramolecular hydrogen bond
15 with a carbonyl group or an ether group; and
 - f. the functional polyamide has a theoretical functionality of greater than two, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is of the same functional type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.
- 20 2. The functional polyamide of claim 1, wherein at least 50 weight percent of the monomeric units of the functional polyamide are derived from monomeric units selected from at least one of lactams, aminocarboxylic acids, aminoalcohols, polycarboxylic acids, or polyamines, based on the total weight of the functional polyamide.
3. The functional polyamide of either claim 1 or claim 2, wherein the monomeric units
25 have an average of from greater than 2 to 20 functional groups per monomeric unit.
4. The functional polyamide of any one of claims 1 to 3, wherein the monomeric units have an average of at least 3 functional groups per monomeric unit.
5. The functional polyamide of any one of claims 1 to 4, wherein the monomeric units have an average of from 3 to 20 functional groups per monomeric unit.
- 30 6. The functional polyamide of any one of claims 1 to 5, wherein at least 50 percent of the functional groups of the monomeric units are selected from at least one of primary amine groups, secondary amine groups, carboxyl groups, or hydroxyl groups.

7. The functional polyamide of any one of claims 1 to 6, wherein at least 40 percent of the linkages between the monomeric units are amide linkages.

8. The functional polyamide of any one of claims 1 to 7, wherein at least 55 percent of the amide linkages are: (i) tertiary amide linkages; and/or (ii) secondary amide linkages
5 capable of individually forming an intramolecular hydrogen bond with a carbonyl group or an ether group.

9. The functional polyamide of any one of claims 1 to 8, wherein the functional polyamide has a theoretical functionality of 3 or more.

10. The functional polyamide of any one of claims 1 to 9, wherein the functional
10 polyamide has a theoretical functionality of from greater than 2 to 30.

11. The functional polyamide of any one of claims 1 to 10, wherein the functional polyamide has a theoretical functionality of from 3 to 5.

12. The functional polyamide of any one of claims 1 to 11, wherein the functionality in at least 75 mole percent of molecules of the functional polyamide is of the same functional
15 type, selected from at least one of amino-functional, carboxyl-functional, or hydroxyl-functional.

13. The functional polyamide of any one of claims 1 to 12, wherein the functionality in at least 70 mole percent of molecules of the functional polyamide is hydroxyl-functional.

14. The functional polyamide of any one of claims 1 to 13, wherein the functional
20 polyamide has a number average molecular weight of from 200 to 10,000 g/mole.

15. The functional polyamide of any one of claims 1 to 14, wherein the functional polyamide has a viscosity of less than 100,000 cps measured in methyl amyl ketone solvent at 85% solids at room temperature, as measured by a Brookfield circular disk viscometer with the circular disk spinning at 5 rpm.

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