Claims

1. A copolymer of a polyamine that has two or more amino groups, and a polyanhydride that has two or more anhydride groups; wherein the polyamine comprises a polyaminopolyolefin; wherein the copolymer has the structure of Formula A:

$$R^5\text{-}(\text{-X—Y-})_n\text{X—}R^6 \qquad (A)$$

wherein:

each X is independently alkylene, cycloalkylene, arylene, heteroarylene, heterocyclylene, or a divalent polymer group, provided that at least one of the X groups is a divalent polyolefin group;

each Y is independently a moiety containing two groups, each of which is independently amido or imido;

R^5 and R^6 are each independently amino, amido, or imido; and

n is an integer ranging from about 1 to about 100.

2. The copolymer of claim 1, wherein the polyamine is a polyaminopolymer or polyaminopolyisobutylene.

3. The copolymer of claim 1, wherein the polyaminopolyolefin is a quasi-living polyaminopolyolefin or quasi-living polyaminopolyisobutylene.

4. The copolymer of claim 1, wherein the polyaminopolyolefin has the structure of Formula I:

$$R^x\text{-}[\text{-}R^b\text{-L-Z—}(CR^1R^2)_m\text{NH}_2]_r \qquad (I)$$

wherein:

each L is independently a bond, alkylene, alkenylene, cycloalkylene, arylene, heteroarylene, or heterocyclylene;

each Z is independently a bond, —O—, —S—, —NR^z—, —C(O)—, —C(O)NR^z—, —OC(O)NR^z—, —NR^zC(O)NR^z—, or —NR^zC(NR^z)NR^z—; where each R^Z is independently hydrogen or alkyl;

each R^b is independently a divalent oligoolefin group;

R^x is an initiator residue of functionality r;

each R^1 and R^2 is independently hydrogen, hydroxy, or alkyl;

each m is independently an integer ranging from about 0 to about 20; and

r is an integer ranging from about 2 to about 8;

wherein the alkyl, alkylene, alkenylene, cycloalkylene, arylene, heteroarylene, and heterocyclylene are each independently and optionally substituted.

5. The copolymer of claim 4, wherein each L is independently a bond, C_{6-14} arylene, or 5-membered heteroarylene, wherein the arylene and heteroarylene are each independently and optionally substituted.

6. The copolymer of claim 4, wherein each L is independently a bond, phenylene, or pyrrolene, wherein the phenylene and pyrrolene are each independently and optionally substituted.

7. The copolymer of claim 4, wherein each L is 1,4-phenylene, optionally substituted.

8. The copolymer of claim 4, wherein Z is a bond, —O—, or —S—.

9. The copolymer of claim 4, wherein each R^1 is hydrogen or each R^2 is hydrogen.

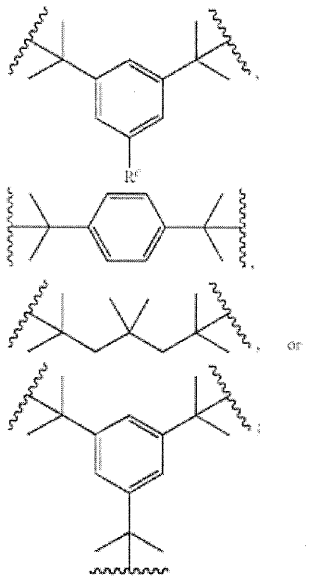
10. The copolymer of claim 4, wherein m is an integer of 0, 1, 2, 3, 4, 6, or 11.

11. The copolymer of claim 4, wherein R^b is a divalent oligoisobutylene group.

12. The copolymer of claim 4, wherein R^b is a divalent oligoisobutylene group of —$[CH_2—C(CH_3)_2]_p$—, wherein p is an integer ranging from about 2 to about 10,000.

13. The copolymer of claim 12, wherein p is an integer from about 5 to about 100.

14. The copolymer of claim 4, wherein R^x is an initiator residue of:



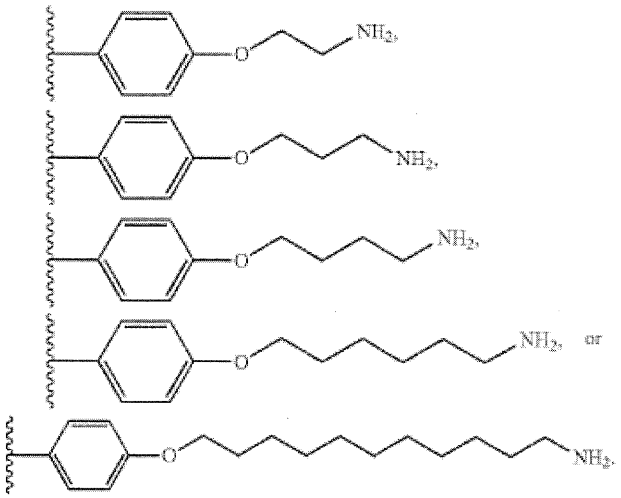
wherein R^c is hydrogen or alkyl, wherein the alkyl is optionally substituted.

15. The copolymer of claim 14, wherein R^c is hydrogen or t-butyl.

16. The copolymer of claim 4, wherein r is an integer of 2, 3, or 4.

17. The copolymer of claim 4, wherein r is 2.

18. The copolymer of claim 4, wherein the moiety -L-Z—$(CR^1R^2)_mNH_2$ is each independently:

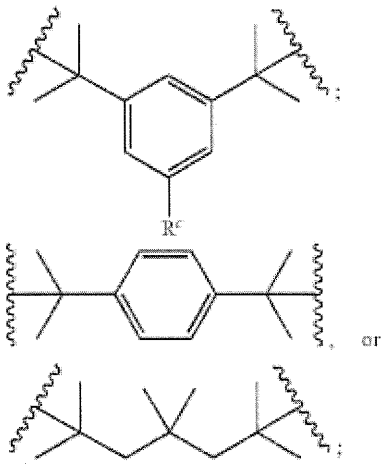


19. The copolymer of claim 4, wherein:

each L-Z is independently phenyleneoxy, pyrrolene, or —S—;

each R^b is independently a divalent oligoisobutylene group of —[CH_2—$C(CH_3)_2]_p$—, wherein p is an integer ranging from about 5 to about 100;

R^x is an initiator residue of:



wherein R^c is hydrogen or t-butyl;

each R^1 and R^2 is hydrogen;

each m is independently an integer ranging from about 2 to about 12; and

r is an integer of 2;

wherein the phenylene and pyrrolene are each independently and optionally substituted.

20. The copolymer of claim 1, wherein the polyanhydride is a dianhydride.

21. The copolymer of claim 20, wherein the dianhydride is an aryl dianhydride, optionally substituted.

22. The copolymer of claim 20, wherein the dianhydride is pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4′-(4,4′-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3′,4,4′-tetracarboxylic dianhydride, or a mixture thereof.

23. The copolymer of claim 2, wherein the polyaminopolymer is a polyaminopolyolefin.

24. The copolymer of claim 1, wherein the polyamine further comprises a polyetheramine.

25. The copolymer of claim 24, wherein the polyetheramine is a polyaminopoly(propylene oxide) or polyetherdiamine.

26. The copolymer of claim 24, wherein the polyetheramine is a polyetherdiamine of Formula XI-1:

(XI-1)



wherein x is an integer ranging from about 2 to about 100.

27. The copolymer of claim 26, wherein x is an integer of about 6, about 33, or about 68.

28. The copolymer of claim 1, wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, and pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4′-(4,4′-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3′,4,4′-tetracarboxylic dianhydride, or a mixture thereof.

29. The copolymer of claim 1, wherein the copolymer is a copolymer selected from:

a copolymer of a quasi-living diaminopolyisobutylene and pyromellitic dianhydride;

a copolymer of a quasi-living diaminopolyisobutylene and 1,4,5,8-naphthalenetetracarboxylic dianhydride;

a copolymer of a quasi-living diaminopolyisobutylene and 4,4′-(4,4′-isopropylidenediphenoxy)bis(phthalic anhydride); and

a copolymer of a quasi-living diaminopolyisobutylene and benzophenone-3,3',4,4'-tetracarboxylic dianhydride.

30. The copolymer of claim 1, wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, polyetherdiamine, and pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3',4,4'-tetracarboxylic dianhydride, or a mixture thereof.

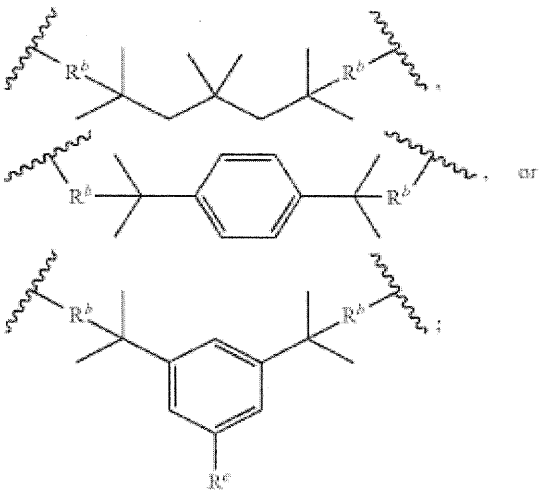
31. The copolymer of claim 1, wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, polyetherdiamine, 1,4,5,8-naphthalenetetracarboxylic dianhydride, and benzophenone-3,3',4,4'-tetracarboxylic dianhydride.

32. The copolymer of claim 1, wherein the copolymer has a weight average molecular weight ranging from about 1,000 to about 50,000.

33. The copolymer of claim 1, wherein the copolymer has a polydispersity index of no greater than about 5.

34. The copolymer of claim 1, wherein each X is independently a divalent polyolefin group.

35. The copolymer of claim 1, wherein each X is independently



wherein each R^b is independently a divalent oligoolefin group and R^c is hydrogen or alkyl, optionally substituted.

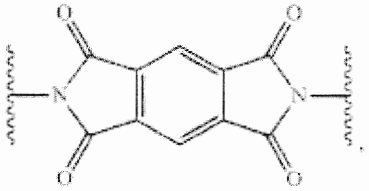
36. The copolymer of claim 35, wherein R^b is a divalent oligoisobutylene group.

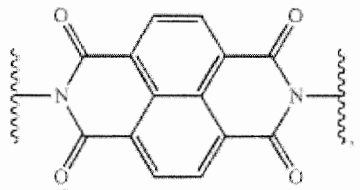
37. The copolymer of claim 35, wherein R^b is a divalent oligoisobutylene group of —$[CH_2—C(CH_3)_2]_p$—, wherein p is an integer from about 5 to about 100.

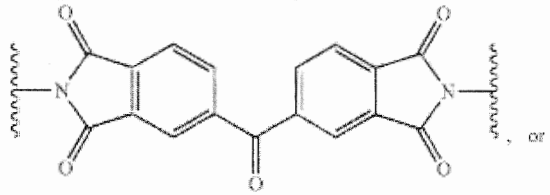
38. The copolymer of claim 35, wherein R^c is hydrogen or t-butyl.

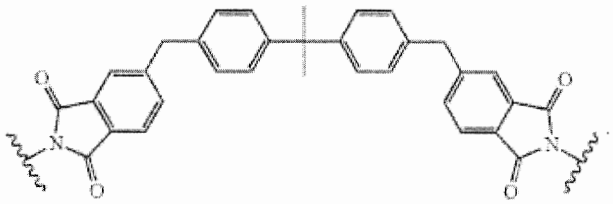
39. The copolymer of claim 1, wherein each Y is independently a divalent aryl group containing two imido groups.

40. The copolymer of claim 39, wherein each Y is independently







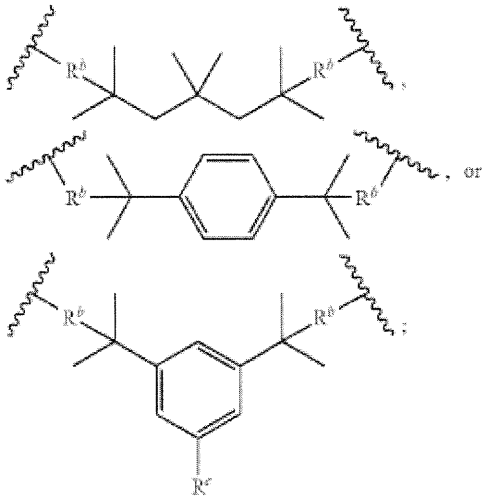


41. The copolymer of claim 1, wherein R^5 is amino, imido, or phthalimido.

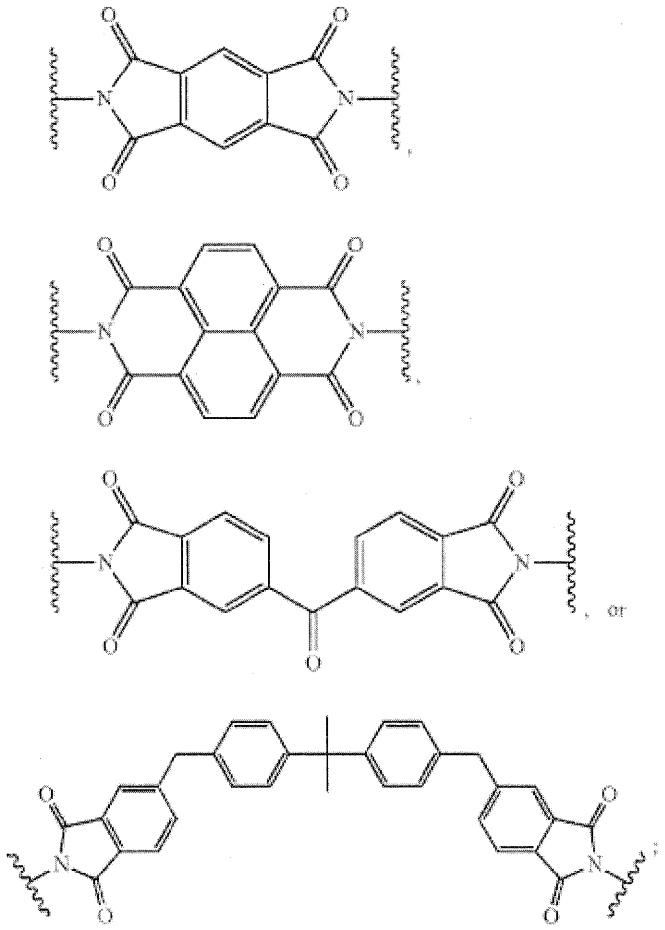
42. The copolymer of claim 1, wherein R^6 is amino, imido, or phthalimido.

43. The copolymer of claim 1, wherein n is an integer ranging from about 1 to about 10.

44. The copolymer of claim 34, wherein each X is independently:



wherein a divalent oligoisobutylene group of —[CH_2—$C(CH_3)_2$]$_p$—, wherein p is an integer from about 5 to about 100; and R^c is hydrogen or t-butyl;
each Y is independently



R^5 and R^6 are each independently —NH_2 or phthalimido; and n is an integer ranging from about 1 to about 10.

45. The copolymer of claim 1, wherein the copolymer has a number average molecular weight ranging from about 1,000 to about 50,000.

46. The copolymer of claim 1, wherein the copolymer has a polydispersity index of no greater than about 5.

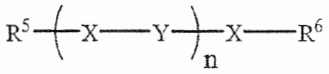
47. The copolymer of claim 1, wherein the copolymer is formed by reacting the polyamine with the polyanhydride.

48. A lubricating oil composition comprising an oil of lubricating viscosity and the copolymer of claim 1.

49. A concentrate comprising from about 20 to 60 wt. % of the copolymer of claim 1 and from about 80 to about 40 wt. % of an organic diluent.

Claims

1. A copolymer of a polyamine that has two or more amino groups, and a polyanhydride that has two or more anhydride groups; wherein the polyamine comprises a polyaminopolyolefin; wherein the copolymer has the structure of Formula A:



(A)

wherein:

each X is independently alkylene, cycloalkylene, arylene, heteroarylene, heterocyclylene, or a divalent polymer group, provided that at least one of the X groups is a divalent polyolefin group;

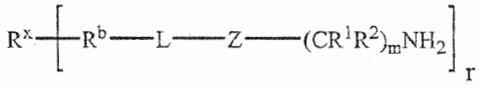
each Y is independently a moiety containing two groups, each of which is independently amido or imido;

R^5 and R^6 are each independently amino, amido, or imido; and

n is an integer ranging from 1 to 100.

2. The copolymer of claim 1, wherein the polyamine is a polyaminopolymer or polyaminopolyisobutylene; optionally wherein the polyaminopolyolefin is a quasi-living polyaminopolyolefin or quasi-living polyaminopolyisobutylene.

3. The copolymer of claim 1 or 2, wherein the polyaminopolyolefin has the structure of Formula I:



(I)

wherein:

each L is independently a bond, alkylene, alkenylene, cycloalkylene, arylene, heteroarylene, or heterocyclylene;

each Z is independently a bond, -0-, -S-, -NR -, -C(O)-, -C(0)NR^z- -OC(0)NR^z- -NR^zC(0)NR^z- or -NR^ZC(NR^Z)NR^Z-; where each R^z is independently hydrogen or alkyl; each R^b is independently a divalent oligoolefin group;

R^x is an initiator residue of functionality r;

each R^1 and R^2 are independently hydrogen, hydroxy, or alkyl;

each m is independently an integer ranging from about 0 to about 20; and

r is an integer ranging from about 2 to about 8;

wherein the alkyl, alkylene, alkenylene, cycloalkylene, arylene, heteroarylene, and heterocyclylene are each independently and optionally substituted.

4. The copolymer of claim 3,

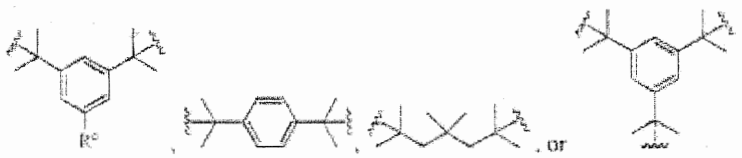
wherein each L is independently a bond, C_{6-14} arylene, or 5-membered heteroarylene, wherein the arylene and heteroarylene are each independently and optionally substituted; or wherein each L is independently a bond, phenylene, or pyrrolene, wherein the phenylene and pyrrolene are each independently and optionally substituted; optionally wherein each L is 1,4-phenylene, optionally substituted; and/or wherein Z is a bond, -0-, or -S-; and/or

wherein each R^1 is hydrogen or each R^2 is hydrogen; and/or

wherein m is an integer of 0, 1, 2, 3, 4, 6, or 11; and/or

wherein R^b is a divalent oligoisobutylene group; or wherein R^b is a divalent oligoisobutylene group of -$[CH_2$-$C(CH_3)_2]_p$-, wherein p is an integer ranging from about 2 to about 10,000, or ranging from about 5 to about 100; and/or

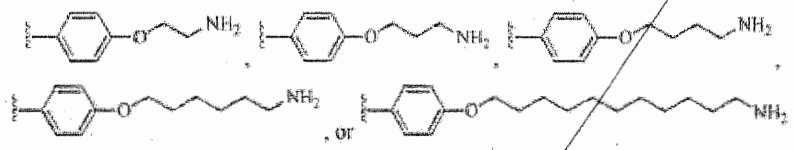
wherein R^x is an initiator residue of:



wherein R^c is hydrogen or alkyl, wherein the alkyl is optionally substituted; or wherein R^c is hydrogen or *t*-butyl; and/or

wherein r is an integer of 2, 3, or 4; or wherein r is 2.

5. The copolymer of claim 3, wherein the moiety $-L-Z-(CR^1R^2)_mNH_2$ is each independently:

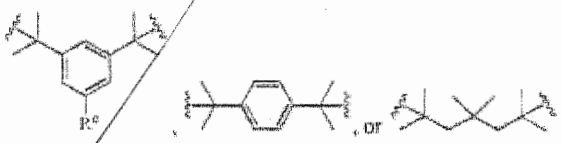


6. The copolymer of claim 3, wherein:

each L-Z is independently phenyleneoxy, pyrrolene, or -S-;

each R^b is independently a divalent oligoisobutylene group of $-[CH_2-C(CH_3)_2]_P-$ wherein p is an integer ranging from about 5 to about 100;

R^x is an initiator residue of:



wherein R^c is hydrogen or *t*-butyl;

each R^1 and R^2 are hydrogen;

each m is independently an integer ranging from about 2 to about 12; and

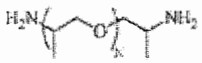
r is an integer of 2;

wherein the phenylene and pyrrolene are each independently and optionally substituted.

7. The copolymer of claim 1, wherein the polyanhydride is a dianhydride;

optionally wherein the dianhydride is an aryl dianhydride, optionally substituted; or wherein the dianhydride is pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3',4,4'-tetracarboxylic dianhydride, or a mixture thereof.

8. The copolymer of claim 1, wherein the polyamine further comprises a polyetheramine; optionally wherein the polyetheramine is a polyaminopoly(propylene oxide) or polyetherdiamine; or wherein the polyetheramine is a polyetherdiamine of Formula XI-1:



(XI-1)

wherein x is an integer ranging from about 2 to about 100, or wherein x is an integer of about 6, about 33, or about 68.

9. The copolymer of claim 1, wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, and pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3',4,4'-tetracarboxylic dianhydride, or a mixture thereof.

10. The copolymer of claim 1, wherein the copolymer is a copolymer selected from: a copolymer of a quasi-living diaminopolyisobutylene and pyromellitic dianhydride;

a copolymer of a quasi-living diaminopolyisobutylene and 1,4,5,8-naphthalenetetracarboxylic dianhydride;

a copolymer of a quasi-living diaminopolyisobutylene and 4,4'-(4,4'-isopropylidenediphenoxy)bis(phthalic anhydride); and

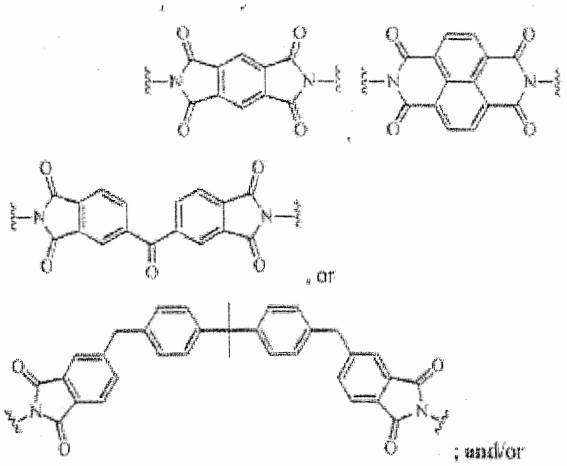
a copolymer of a quasi-living diaminopolyisobutylene and benzophenone-3,3',4,4'-tetracarboxylic dianhydride.

11. The copolymer of claim 1 , wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, polyetherdiamine, and pyromellitic dianhydride, 1,4,5,8-naphthalenetetracarboxylic dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)bis(phthalic anhydride), benzophenone-3,3',4,4'-tetracarboxylic dianhydride, or a mixture thereof; or wherein the copolymer is a copolymer of a quasi-living diaminopolyisobutylene, polyetherdiamine, 1,4,5,8-naphthalenetetracarboxylic dianhydride, and benzophenone- 3,3',4,4'-tetracarboxylic dianhydride.

12. The copolymer of claim 1, wherein each X is independently a divalent polyolefin group; or wherein each X is independently



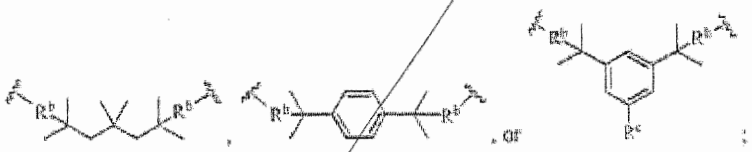
wherein each R^b is independently a divalent oligoolefin group and R^c is hydrogen or alkyl, optionally substituted; optionally wherein R^b is a divalent oligoisobutylene group; or wherein R^b is a divalent oligoisobutylene group of $-[CH_2-C(CH_3)_2]_P-$, wherein p is an integer from about 5 to about 100; and/or wherein R^c is hydrogen or ?-butyl; and/or wherein each Y is independently a divalent aryl group containing two imido groups; or wherein each Y is independently



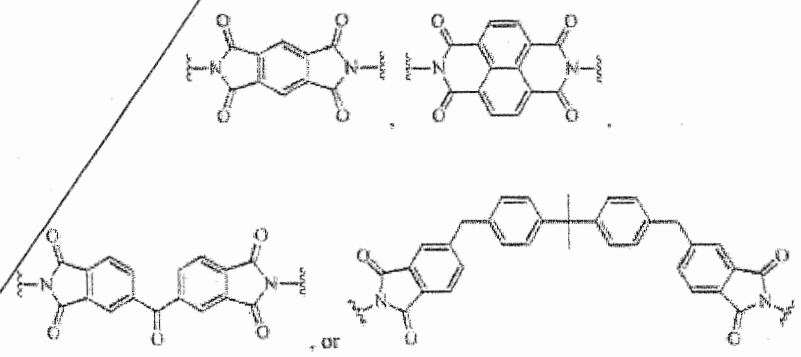
wherein R^5 is amino, imido, or phthalimido; and/or wherein R^6 is amino, imido, or phthalimido; and/or wherein n is an integer ranging from about 1 to about 10.

13. The copolymer of claim 1, wherein

each X is independently:



wherein each R^b is independently a divalent oligoisobutylene group of $-[CH_2-C(CH_3)_2]_p-$, wherein p is an integer from about 5 to about 100; and R^c is hydrogen or *t*-butyl; each Y is independently



R^5 and R^6 are each independently $-NH_2$ or phthalimido; and

n is an integer ranging from about 1 to about 10.

14. The copolymer of any of claims 1 to 13, wherein the copolymer has a weight average molecular weight ranging from about 1,000 to about 50,000; and/or wherein the copolymer has a polydispersity index of no greater than about 5.

15. The copolymer of any of claims 1 to 14, wherein the copolymer is formed by reacting the polyamine with the polyanhydride.

16. A lubricating oil composition comprising an oil of lubricating viscosity and the copolymer of any of claims 1 to 15.

17. A concentrate comprising from about 20 to 60 wt.% of the copolymer of any of claims 1 to 15 and from about 80 to about 40 wt. % of an organic diluent.