wherein:

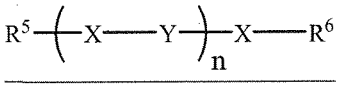
each X is independently alkylene, cycloalkylene, arylene, heteroarylene, heterocyclylene, or a divalent polymer group, provided that at least one of the X groups is a divalent polyolefin group;

each Y is independently a divalent moiety containing two imido groups;

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

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

[0013a] In one embodiment, there is provided 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; R5 and R6 are each independently amino, amido, or imido; and n is an integer ranging from 1 to 100.

[0014] Provided herein is a copolymer formed from the reaction of a polyamine with a polyanhydride, wherein the polyamine comprises a polyaminopolyolefin.

[0015] Provided herein is a copolymer formed from the reaction of a polyaminopolymer with a polyanhydride, wherein the polyaminopolymer comprises a polyaminopolyolefin.

[0016] Provided herein is a method for preparing a copolymer, comprising the step of reacting a polyamine with a polyanhydride, wherein the polyamine comprises a polyaminopolyolefin.

[0017] Provided herein is a method for preparing a copolymer, comprising the step of reacting a polyaminopolymer with a polyanhydride, wherein the polyaminopolymer comprises a polyaminopolyolefin.

[0018] Provided herein is a method for preparing a copolymer, comprising the step of reacting a polyamine with a polyanhydride in a solvent at an elevated temperature, wherein the polyamine comprises a polyaminopolyolefin. In one embodiment, the reacting step is performed in the presence of an end-capping reagent to form an end-capped copolymer.

[0019] Provided herein is a method for preparing a copolymer, comprising the step of reacting a polyaminopolymer with a polyanhydride in a solvent at an elevated temperature, wherein the polyaminopolymer comprises a polyaminopolyolefin. In one embodiment, the reacting step is performed in the presence of an end-capping reagent to form an end-capped copolymer.

[0020] Provided herein is a lubricant oil composition that comprises an oil of lubricating viscosity and a copolymer of a polyamine and polyanhydride, wherein the polyamine comprises a polyaminopolyolefin.

WHAT IS CLAIMED:

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.

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:

$$R^x\left[R^b-L-Z-(CR^1R^2)_mNH_2\right]_r$$

(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 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

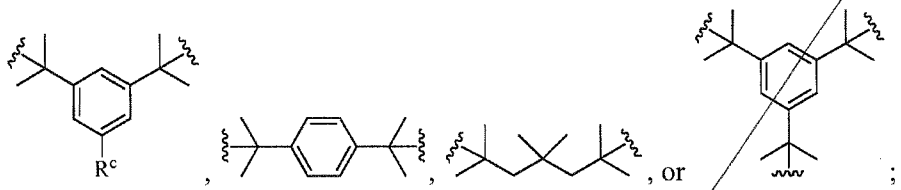
wherein Z is a bond, –O–, or –S–; and/or

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:

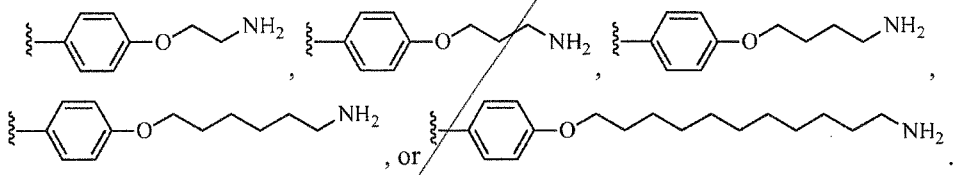


wherein R^c is hydrogen or alkyl, wherein the alkyl is optionally substituted; or

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:

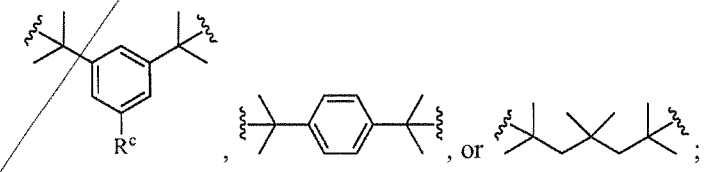


6. The copolymer of claim 3, wherein:

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

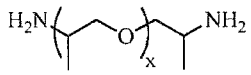
r is an integer of 2;

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;

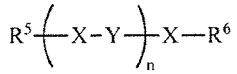
a copolymer of a quasi-living diaminopolyisobutylene and 1,4,5,8-naphthalenetetracarboxylic dianhydride;

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, having 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;

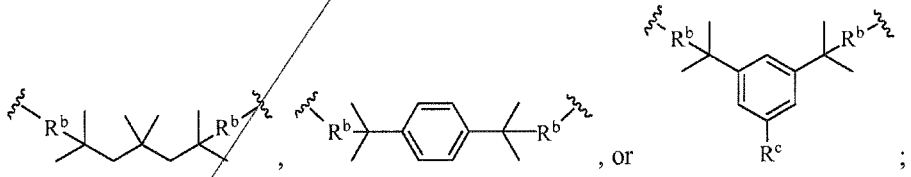
each Y is independently a moiety containing two groups, each of which is independently amido or imido;

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

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

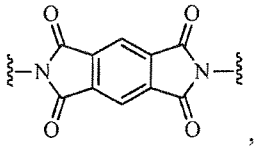
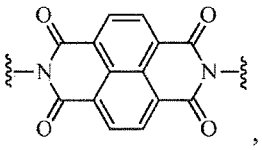
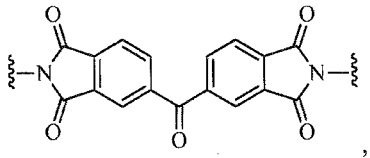
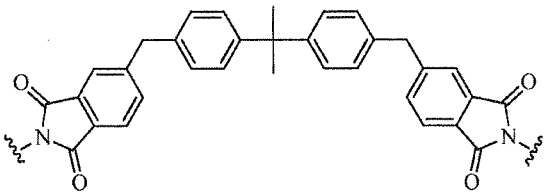
13. The copolymer of claim 12,

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 *t*-butyl; and/or

wherein each Y is independently a divalent aryl group containing two imido groups; or wherein each Y is independently


,

,

, or

; and/or

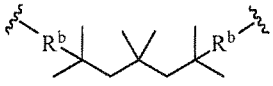
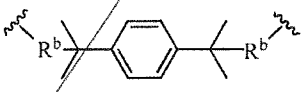
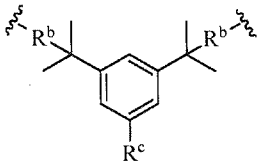
wherein R^5 is amino, imido, or phthalimido; and/or

wherein R^6 is amino, imido, or phthalimido; and/or

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

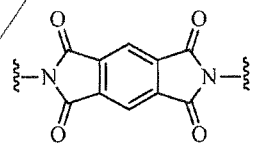
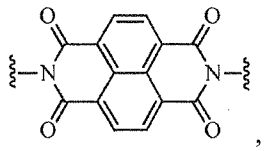
14. The copolymer of claim 12, wherein

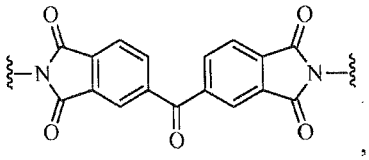
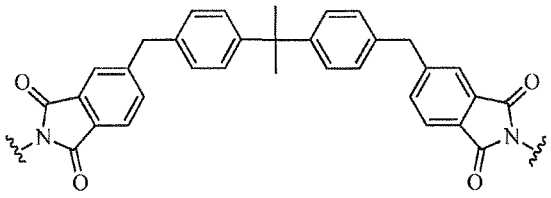
each X is independently:


,

, or

;

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


,

,


, or 
;

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

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

15. The copolymer of any of claims 1 to 14, 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.

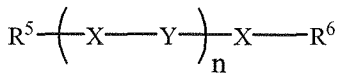
16. The copolymer of any of claims 1 to 15, wherein the copolymer is formed by reacting the polyamine with the polyanhydride.

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

18. A concentrate comprising from about 20 to 60 wt.% of the copolymer of any of claims 1 to 16 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;

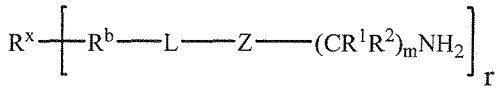
each Y is independently a moiety containing two groups, each of which is independently amido or imido;

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,

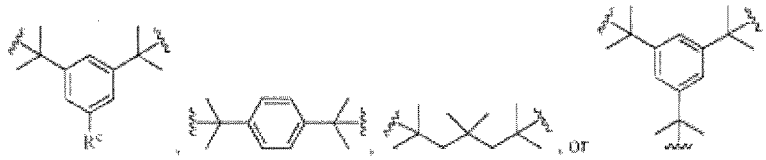
wherein each L is independently a bond, C_{6-14} arylene, or 5-membered heteroarylene, wherein the arylene and heteroarylene are each independently and optionally substituted; or wherein each L is independently a bond, phenylene, or pyrrolene, wherein the phenylene and pyrrolene are each independently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

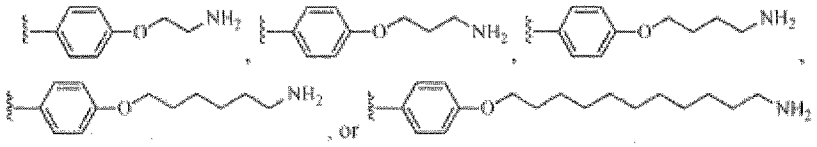
wherein R^x is an initiator residue of:



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:

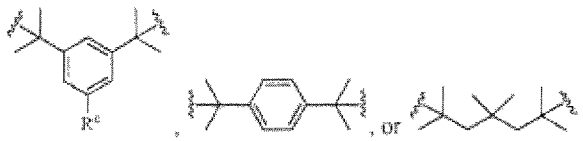


6. The copolymer of claim 3, wherein:

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

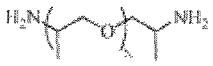
r is an integer of 2;

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;

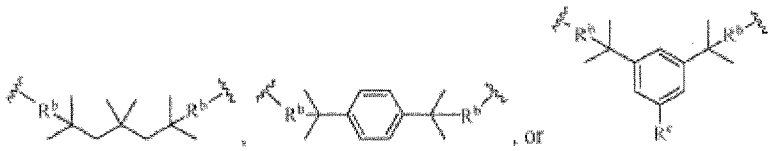
a copolymer of a quasi-living diaminopolyisobutylene and 1,4,5,8-naphthalenetetracarboxylic dianhydride;

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

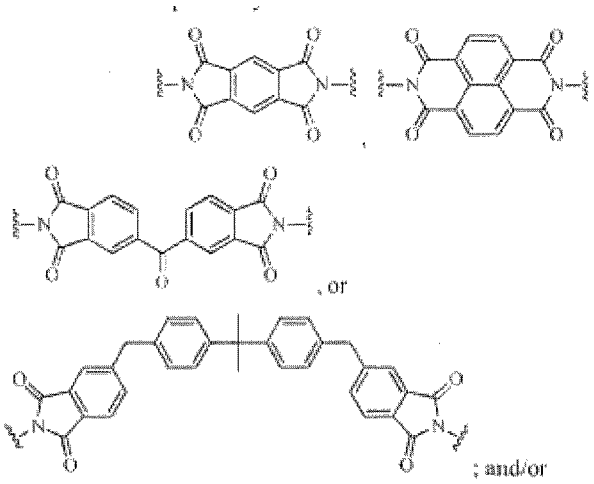
a copolymer of a quasi-living diaminopolyisobutylene and benzophenone-3,3',4,4'-tetracarboxylic dianhydride.

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



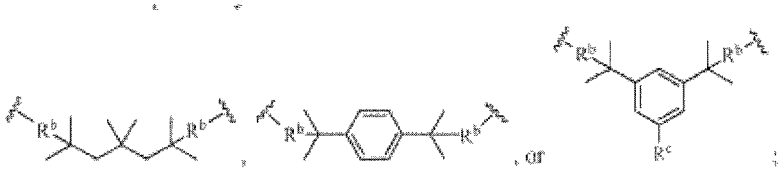
wherein each R^b is independently a divalent oligoolefin group and R^c is hydrogen or alkyl, optionally substituted; optionally wherein R^b is a divalent oligoisobutylene group; or wherein R^b is a divalent oligoisobutylene group of $-[CH_2-C(CH_3)_2]_P-$, wherein p is an integer from about 5 to about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



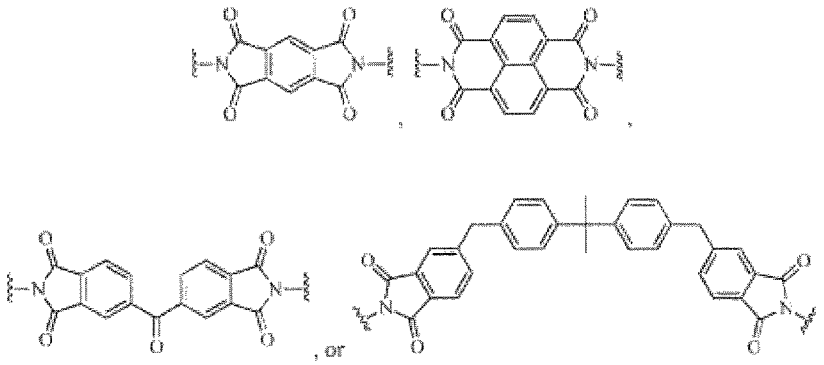
wherein R^5 is amino, imido, or phthalimido; and/or wherein R^6 is amino, imido, or phthalimido; and/or wherein n is an integer ranging from about 1 to about 10.

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.